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Environmental Studies No. 75

Synopsis of Research Conducted under the 1997/98 Northern Contaminants Program

Canada

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Northern Affairs Program

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The views, conclusions and recommendations expressed herein are those of the authors and not necessarily those of the Department.

FOREWORD

This report summarizes the results of research and monitoring studies on contaminants in northern Canada. These studies were conducted under the auspices of the Northern Contaminants Program.

The projects cover all aspects of the northern contaminants issues, including sources and transport; contamination of marine, freshwater and terrestrial ecosystems; human exposure through diet and related health implications; communication and education of northern residents; and international initiatives addressing the global aspect of the problem.

These projects were evaluated by the Technical and Science Managers Committees on Contaminants in Northern Ecosystems and Native Diets to ensure that they supported the overall Northern Contaminants Program objectives.

A list of addresses for the project leaders is given in Appendix I.

PRÉFACE

Ce rapport résume les résultats de recherches portant sur les contaminants et d'études sur la surveillance des contaminants dans le Nord canadien. Ces études ont été menées dans le cadre du Programme de lutte contre les contaminants dans le Nord.

Ces projets représentent tous les aspects du problème des contaminants, incluant les sources et le transport, la contamination des écosystemes aquatiques (eaux douces et eaux salées) et terrestres, l'exposition de l'organisme humain en raison de son régime alimentaire et ses effets sur la santé, la communication avec les résidants du Nord et leur éducation, et les initiatives internationales abordant l'aspect global du problème.

Les comités de gestionnaires techniques et scientifiques sur les contaminants dans les écosystèmes du Nord et dans les régimes alimentaires des Autochtones ont examiné ces projets afin de s'assurer qu'ils répondent à l'ensemble des objectifs du programme Action sur les contaminants.

Vous trouverez à l'appendice 1 une liste des gestionnaires de projet.

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III HUMAN HEALTH

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INTRODUCTION

The Northern Contaminants Program (NCP) was initiated in 1991 in response to results of cooperative studies undertaken in the mid- to late-1980s by a number of federal departments on the issue of contaminants in the Arctic. The studies indicated that there was wide distribution in the Arctic ecosystem of a spectrum of substances, many of which had no Canadian or Arctic sources, but which were, nevertheless, reaching unexpectedly high levels in Arctic biota. The three main contaminant groups of concern are heavy metals, radionuclides, and persistent organic pollutants (mainly organochlorines). These findings were of concern, particularly because of the potential human health implications arising from the dependence of many northern Native Peoples on traditionally harvested foods and their position as high trophic level consumers. The Program's key objective is "to reduce and, wherever possible, eliminate contaminants in traditionally harvested foods while providing information that assists informed decision-making by individuals and communities in their food use".

The NCP is directed by a management committee, which is chaired by Indian and Northern Affairs Canada, and which includes representatives from the five northern Aboriginal organizations (Council for Yukon First Nations, Dene Nation, Métis Nation, Inuit Tapirisat Canada and the Inuit Circumpolar Conference), the Yukon and Northwest Territorial governments, and four federal departments (Environment Canada, Fisheries and Oceans Canada, Health Canada and Indian and Northern Affairs Canada).

The strategic action plan for the NCP is based on an ecosystem approach, focussing on four main categories: i) Human Health; ii) Ecosystem Uptake and Effects; iii) Sources, Pathways, and Fate; iv) Education and Communication. Initiatives to promote international control of contaminants are supported by the scientific research. Since 1991, the NCP has provided approximately $36 million for research, in addition to supporting the McGill Centre for Indigenous Peoples Nutrition and Environment (CINE), and participation of Aboriginal organizations. The NCP Aboriginal partner organizations lead communications activities.

In 1997, the NCP completed an assessment of its first phase (1991/92-1996/97), entitled *Canadian Arctic Contaminants Assessment Report*. This report was accompanied by a community reference manual, entitled *Highlights of the Canadian Arctic Contaminants Assessment Report*. Research during the first phase of the NCP enabled us to establish a number of important points: 1) the majority of contaminants detected in the biotic and abiotic environment of the Arctic are derived from sources outside the Arctic and outside Canada; 2) the atmosphere plays a major role in the transport of contaminants to the north; and, 3) measurable and often significant levels of a number of contaminants occur in a wide range of important traditionally harvested food species, as well as in other ecosystem components.

The next phase of the NCP will focus on developing effective community dialogue and carrying out more research on human health. In addition, emphasis will be placed on reducing source inputs of contaminants through working towards international agreements on emissions controls.

Due to the transboundary nature of the issue of contaminants in the Arctic food chain, Canada is pursuing international initiatives for control of these substances, with the scientific evidence generated by the NCP providing substantiation for our concerns and calls for action. The main fora in which Canada plays a leadership role, and to which data generated by the NCP provide a strong contribution are: the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP); the United Nations Economic Commission for Europe's (UN ECE) Protocols on Persistent Organic Pollutants and Heavy Metals; and the United Nations Environment Programme's (UNEP) global initiative to negotiate a legally binding instrument on POPs.

This report provides a summary of the research and activities funded by the Northern Contaminants Program in 1997/98. This was an interim year between phases one and two of the NCP, funded solely by Indian and Northern Affairs Canada. Long-term Program funding was procured in January 1998 to continue the program for a five-year period (1998/99–2002/03).

I SOURCES, PATHWAYS AND FATE OF CONTAMINANTS

NORTHERN CONTAMINANTS AIR MONITORING: A KEY ELEMENT OF NORTHERN CONTAMINANT PATHWAYS STUDIES

Project Leader: L. Barrie, Atmospheric Environment Service

Project Team: T. Bidleman (AES); B. Billick (FWI); K. Brice (AES); D. Dougherty (CP); P. Fellin (CP); B. Grift (FWI); C. Halsall (U. Lancaster); L. Lockhart (FWI); D. Muir (DOE); D. Toom-Sauntry (AES); G. Stern (FWI),

OBJECTIVES

1. to measure and understand the occurrence and trends of selected organochlorines (OCs) and polycyclic organic hydrocarbons (PAHs) in the Arctic atmosphere.

2. to provide insight into contaminant pathways (i.e. sources, transport, transformation and removal processes).

3. to enable validation of models of toxics in the northern environment with atmospheric observations.

4. to maintain an archive of organic extracts of arctic air samples for retrospective investigation for "contaminants of the future"(e.g. new generation pesticides, degradation products of pesticides currently not recognized as contaminants or contaminants that were undetectable previously by less modern analytical methods etc.).

5. to operate a major long term trends measurement station for AMAP at Alert NWT (operation since 1992) in parallel with a western Russian arctic station funded by External Affairs Canada.

REPORT

Since January 1992, measurements of persistent organic pollutants including herbicides, pesticides, synthetic industrial compounds and polycyclic aromatic hydrocarbons (PAHs) have been made on a weekly basis in the Canadian and Russian Arctic (Figure 1).

METHODOLOGY

A hi-volume air sampler placed at: Alert, NWT (82.5 N, 62.3W); Tagish, Yukon (60.3 N, 134.2 W); C. Dorset, Baffin Island and at the mouth of the Lena River on Dunai Island in Russia- was used to collect particulate and gaseous fractions of these airborne pollutants on filters and foam plugs. They were subsequently extracted in organic solvents and analysed at the Fresh Water Institute for more than 80 organochlorines and for 20 PAHs by gas chromatographic techniques. The sampling schedule is shown in Table 1.

Quality controlled data sets for the northern contaminants air monitoring program now extend into 1996, allowing for a detailed look at temporal trends occurring in the arctic atmosphere. To examine contaminant behaviour over annual cycles will give greater understanding to the behaviour of the compound(s) in question and also allow the effects of seasonal temperature fluctuations, long range transport or even periods of pesticide usage to be examined.

ACCOMPLISHMENTS

Assessments

A major part of our effort can be seen in contributions to the major assessment by the Northern Contaminants Program* and to various chapters of the AMAP assessment report.

*L. Barrie, R. Macdonald, T. Bidleman, M. Diamond, D. Gregor, R. Semkin, W. Strachan, M. Alaee, S. Backus, M. Bewers, C. Halsall, C. Gobeil, J. Hoff, A. Li, L. Lockhart, D. Mackay, D. Muir, J. Pudykiewicz, K. Reimer, J. Smith, G. Stern, W. Schroeder, R. Wagemann, F. Wania, M. Yunker. 1997, Sources, Occurrence And Pathways, Chapter 2, p. 25–182, in Shearer, R. (Ed), *Canadian Arctic Contaminants Assessment Report*, Indian and Northern Affairs Canada, Ottawa, 460 pp.

This assessment document has contributed substantially to Canada's policy on international controls on persistent organic pollutants. It will be submitted to *Sci. of the Tot. Environ.* as a follow-up to an earlier review paper.

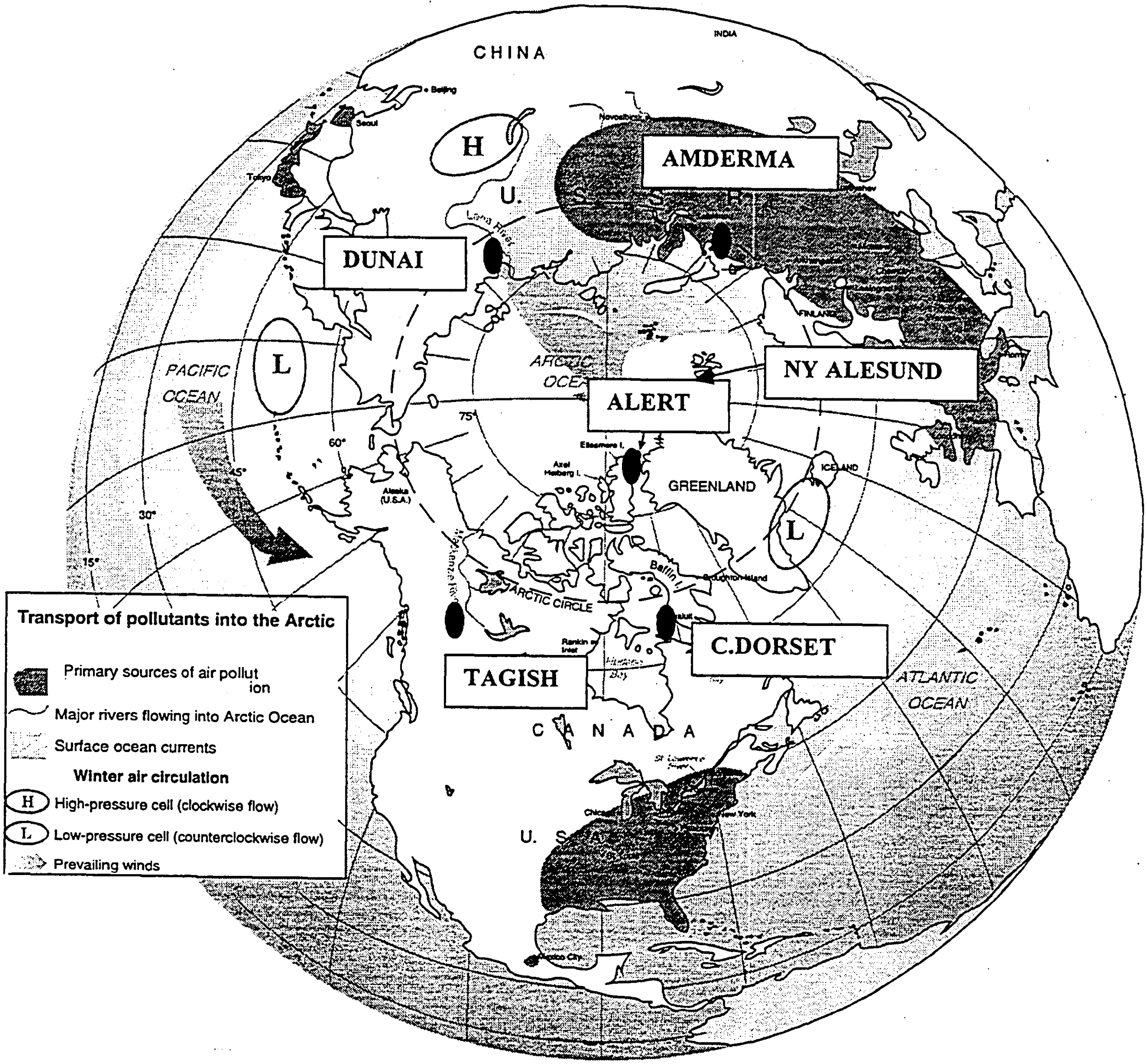

Figure 1. Locations of Northern Contaminant Program's air monitoring stations (black ovals) Ny Ålesund is operated by the Norwegians.

Table 1. The sampling schedule past, present and future for northern contaminants air measurements.

SITE	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
ALERT	|<-->|						|<------------------------>|			
TAGISH	|<------------------------------------->|									
DUNAY I.		|<--------------------------->|								
C. DORSET			|<----------------------------->|							
W. RUSSIA							|<----------------------->|			

Publications

The foundation of the above assessments has been the numerous publications documenting the measurement program and highlighting some of the exciting new discoveries that a continuous set of observations of this sort inevitably leads to if sufficient effort is made to analyse and interpret the data:

1. Barrie, L. A., T. Bidleman, D. Dougherty, P. Fellin, N. Grift, D. Muir, B. Rosenberg, G. Stern and D. Toom, 1993, Atmospheric toxaphene in the high Arctic, *Chemosphere,* 27, 2037-2046.
2. Fellin, P., L. Barrie, D. Dougherty, D. Muir, N. Grift, L. Lockhart and B. Billeck, 1993, Air monitoring at Alert: results for 1992 for organochlorines and PAHs Proc. In Symp. "Ecological Effects of Arctic Airborne Contaminants", October 4-8, Reykjavik, Iceland, Eds. Christie and Martin, USA CRREL Rep. 93-23.
3. Fellin, P. *et al.* Technical and Operating Manual for The Canadian Arctic Air Toxics Network, Concord Environment Report, J3034.
4. Bailey, R., L. Barrie, D. Dougherty, P. Fellin, B. Grift, D. Muir, and D. Toom, 1994, Preliminary measurements of PCCs in air at Tagish Yukon, Proceedings of the Yukon Contaminants Committee Workshop, Feb 1994, Whitehorse Yukon.
5. Fellin, P., D. Friel, and D. Dougherty, Technical and Operating Manual for The Canadian Arctic Air Toxics Network, Concord Environment Report, J3034
6. Bidleman, T.F., L.M. Jantunen, R.L. Falconer, and L.A. Barrie, 1995, *Geophys. Res. Lett.* 22, 219-222.
7. Fellin, P., L.A. Barrie, D. Dougherty, D. Toom, D. Muir, B. Grift, L. Lockhart, and B. Billeck, 1996, Air monitoring in the Arctic: Selected results for organochlorine and PAH compounds for 1992, *Envir. Toxicol. & Chemistry*, 15, 253-261.
8. Barrie, L.A., 1996, Occurrence and trends of pollution in the Arctic troposphere, in "Chemical Exchange Between the Atmosphere and Polar Snow", eds. Wolff and Bales, NATO ASI Series I: Global Environmental Change, 43, 93-130.
9. Stern, G.A., C.J. Halsall, L.A. Barrie, D.C.G. Muir, P. Fellin, B. Rosenberg, F. Ya. Rovinsky, E. Ya. Kononov and B. Pastuhov, 1997, Polychlorinated biphenyls in arctic air, 1. Temporal and spatial trends: 1992-1994. *Envir. Sci. Techn.,* 31, 3619-3628.
10. Halsall, C.J., L.A. Barrie, P. Fellin, D.C.G. Muir, B.N. Billeck, L. Lockhart, F. Ya Rovinsky, E. Ya. Kononov, and B. Pastuhov. 1997, Spatial and temporal variation of polycyclic aromatic hydrocarbons in the Arctic atmosphere, *Envir. Sci. Techn.,* 31, 3593-3599.
11. Halsall, C.J. R. Bailey, G.A. Stern, L.A. Barrie, P. Fellin, D.C.G. Muir, F. Ya. Rovinsky, E. Ya. Kononov, and B. Pastuhov, 1997, Organohalogen pesticides in the arctic atmosphere, *Environmental Pollution,* submitted.
12. Harner, T., H. Kylin, T.F. Bidleman, C, Halsall, W.M.J. Strachan, L.A. Barrie, and P. Fellin, 1998, Polychlorinated napthalenes and coplanar biphenyls in arctic air, *Envir. Sci. & Tech.*, in press.
13. Bailey, R., L.A. Barrie, C. J. Halsall, P. Fellin, G. A Stern, C.G. Muir, B. Rosenberg., 1998, Evidence of the importance of long-range atmospheric transport of organochlorines to Tagish, Yukon, Canada, *Envir. Sci and Tech.,* to be submitted autumn 1998.

Presentations

Another important aspect of research is the communication of results in technical as well as public fora. This effort has been well represented as indicated by the following list which highlights a few of these.

1. Fellin, P., L. Barrie, D. Dougherty, D. Muir, N. Grift, L. Lockhart and B. Billeck, 1993, Air monitoring at Alert: results for 1992 for organochlorines and PAHs, poster presentation at Symp. On "Ecological Effects of Arctic Airborne Contaminants", October 4-8, Reykjavik, Iceland, Eds. Christie and Martin, USA CRREL Rep. 93-23.
2. Barrie, L., Atmospheric toxaphene measurements

in the Canadian Arctic, February 1993, Toxaphene Workshop hosted by Bidleman and Muir.
3. Barrie, L., Contaminants monitoring in the Arctic, October, 1993, Atmospheric Environment Service seminar, Downsview.
4. Barrie, L., Arctic contaminants pathways occurrence and effects, October 1993. Invited Seminar, Dept. of Chemical Engineering, University of Toronto.
5. Barrie, L., Contaminants monitoring in the Arctic, November 1993, Winnipeg, AES Northern Contaminants Workshop.
6. Bailey, R., Toxaphene and air pathways to Tagish, January 1993, Yukon Contaminants Workshop, Whitehorse.
7. Barrie, L, Contaminants monitoring in the Arctic, November 1995, Winnipeg, Northern Contaminants Workshop.
8. Barrie, L, Contaminants monitoring in the Arctic, January 1996, Calgary, Northern Contaminants Workshop.
9. Barrie, L and C. Halsall, Contaminants monitoring in the Arctic, January 1997, Victoria, Calgary, Northern Contaminants Workshop.
10. Halsall, C. *et al.* paper and three posters at January 1998, Calgary, Northern Contaminants Workshop.
11. L. Barrie, Invited lecture on Is Air Pollution Changing The Northern Environment? Trent University, series on "The Arctic Environment Landscape Under Pressure, a public forum.

RESULTS: SELECTED HIGHLIGHTS

Polycyclic Aromatic Hydrocarbons

Two years of total PAH observations at three locations (Figure 2) show a strong seasonality with widespread elevated concentrations in the winter months of December, January and February. At Alert in 1993 there are indications of local contamination due to demolition of buildings by burning . At Tagish in 1993 the summer per peaks are related to forest fires in the Yukon and northern B.C.

Annual mean concentrations in 1993 of selected organochlorine compounds are displayed in Figure 2. Included are levels reported from a Norwegian study at Ny Ålesund (Figure 1). Spatially, the annual concentrations at the various sites do not show

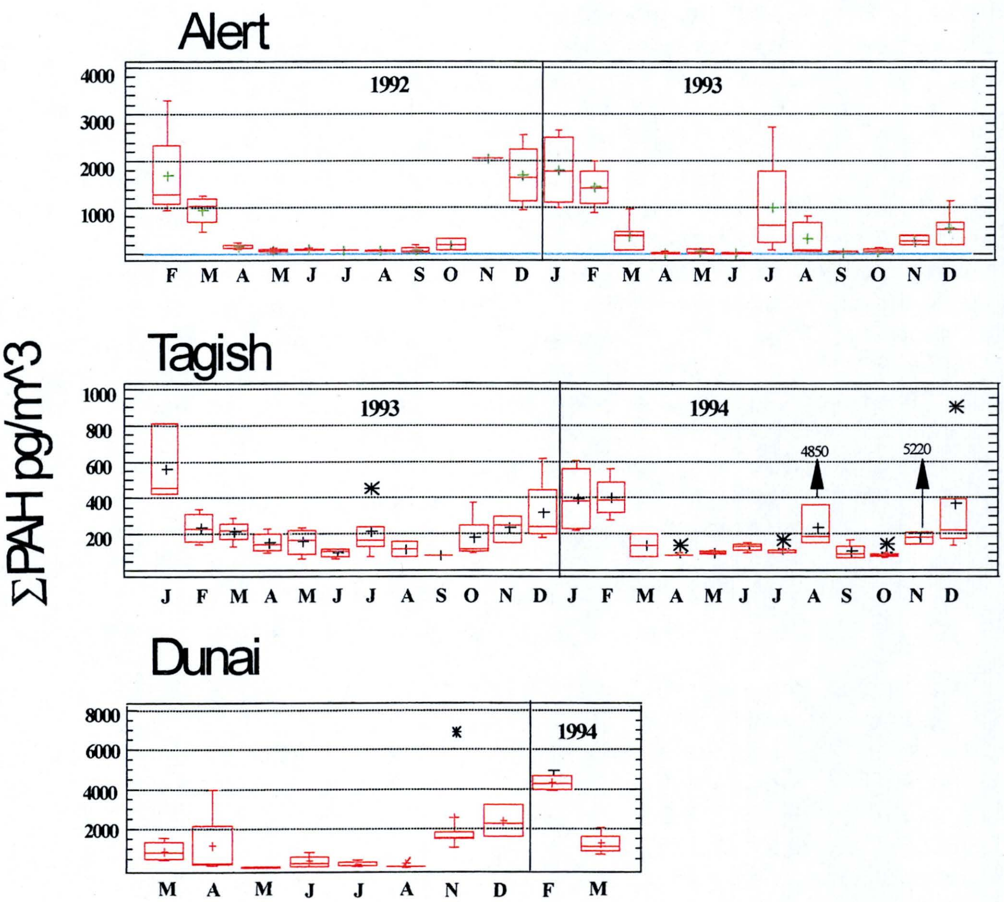

Figure 2. Observed time series of total PAH in the Arctic at selected northern contaminant sites (Halsall *et al.* 1998).

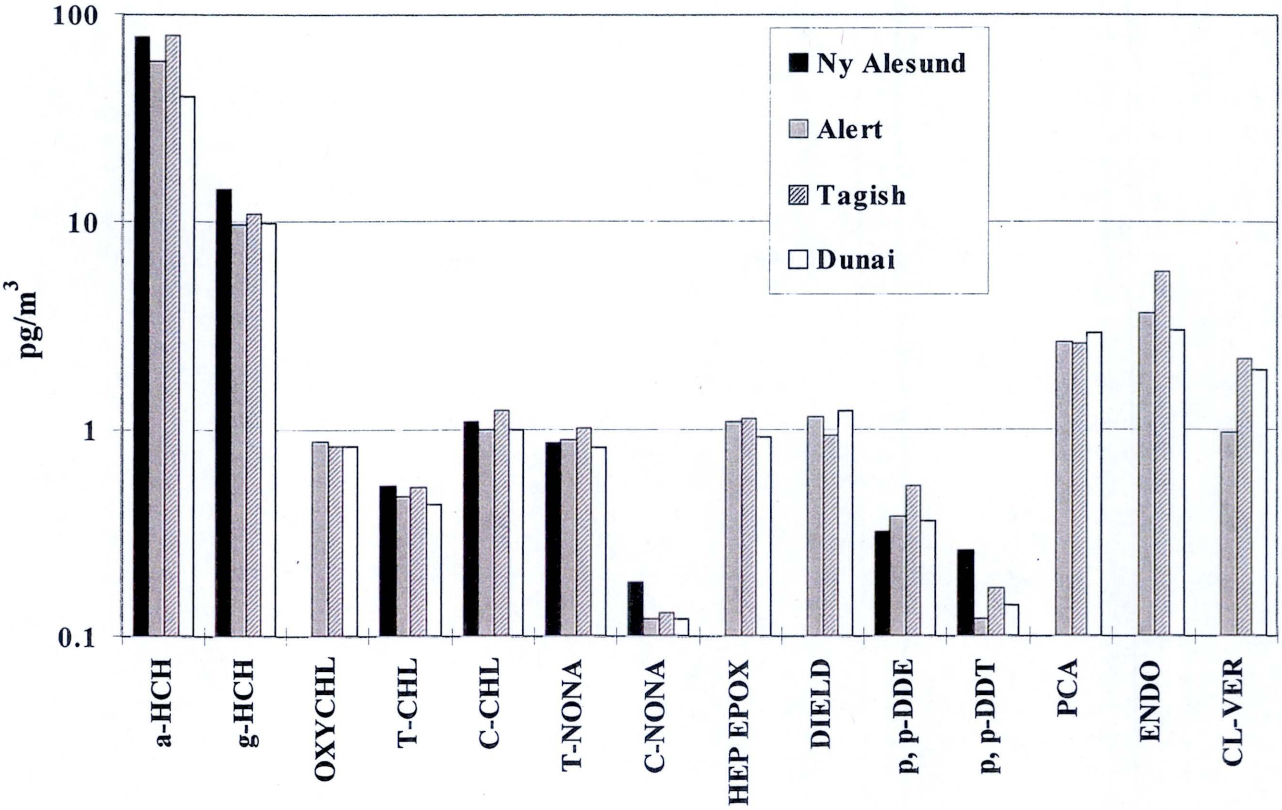

Figure 3. Mean annual (1993) organochlorine concentrations (filter + PUF) (pg/m³). The Norwegian data are from the study of Oehme *et al.* (1996).

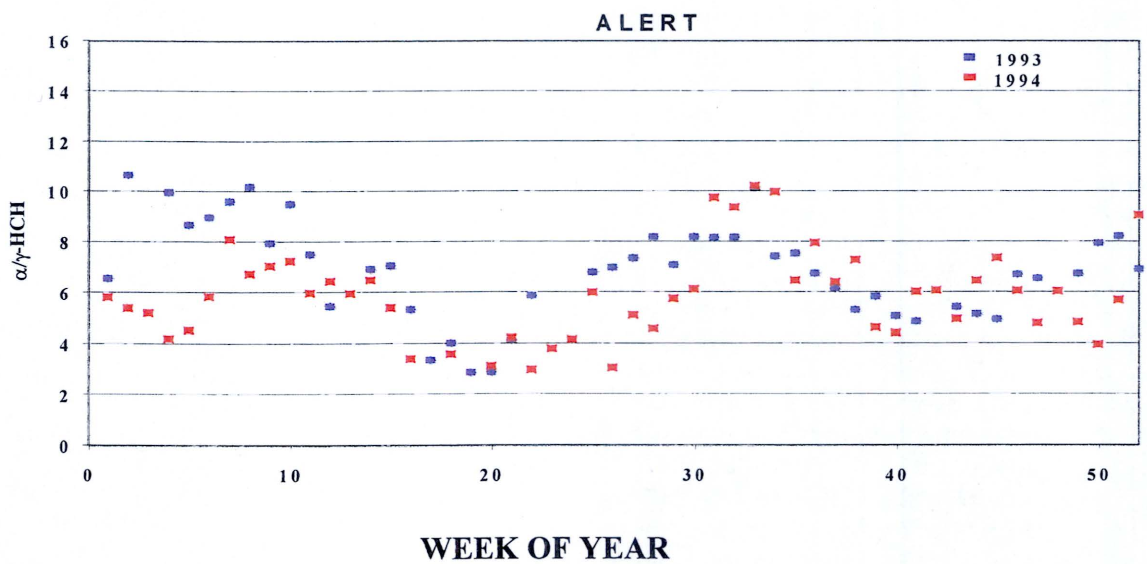

Figure 4. Ratios of α-HCH to γ-HCH in weekly air samples for the combined samples years of 1993/94 at Alert. The lower the ratio, the greater the fraction of current use HCH (Halsall et al. 1998).

remarkable differences, indicating a degree of uniformity in contamination of the arctic atmosphere. Note, however, that the y-axis is a log scale, significant variations can be seen in the levels of the chloro-veratroles, these being metabolites of chlorinated catechols released in bleached kraft mill effluent (Brownlee *et al.* 1993). Higher levels of the chloro-veratroles in the Tagish atmosphere may be indicative of the wood pulp industry located in northwestern Canada.

In order of abundance, the chlordanes, endosulfan and pentachloroanisole (PCA) displayed mean annual concentrations typically below 10 pg/m^3, while levels of *p,p*-DDT and *p,p*-DDE were observed at much lower concentrations, with annual mean concentrations <1 pg/m^3. Similarly, levels of methoxychlor and trifluralin, the latter being a widely used fluorinated herbicide (Key *et al.* 1997), were found at extremely low levels, usually in the sub-picogram range and often on or below the limits of detection. However, for trifluralin, a concentration of 3 pg/m^3 was observed at Tagish during the sample week of Dec 1–8, 1994 indicating an episodic input probably associated with a long range transport (LRT) event.

Pesticide ratios

Ratios of α-HCH to γ-HCH which are typically around 1 in northern Europe are >6 at Alert. Levels of α-HCH were consistently higher than γ-HCH in the arctic atmosphere due to: a) the photo-transformation of γ-HCH to α-HCH (Oehme and Mano 1984, Hargrave *et al.* 1988), indicative of the remoteness of the arctic, and b) the past/present use of technical-HCH, which comprises ~70% α-HCH (Li *et al.* 1996, Haugen *et al.* in press). During April, May and early June, however, the ratio of α-HCH to γ-HCH declined in the high Arctic (Alert) from a winter ratio of >8. Figure 4 shows the annual trend for the combined sample years of 1993 and 1994 for both Alert and Tagish. A spring decline is clearly evident at Alert, however at Tagish the pattern is not as well defined. This may reflect the influence that the European region has on the high Arctic, where usage of lindane is approximately an order of magnitude higher than in Canada and the US (Li *et al.* 1996). Secondly, an increase of the ratio during the warmer months at Alert, may be the result of decreased ice cover over the Arctic Ocean, whereby re-volatilization of previously deposited HCH may influence the overlying atmosphere. Differential air-sea transfer rates between α- and γ-HCH may favour this observed increase in the ratio during the summer. The water/air fugacity (f_w/f_a) ratio for α-HCH has been calculated to be significantly greater than that of γ-HCH in the Bering and Chukchi seas (Jantunen and Bidleman, 1995. A similar summer increase in the ratio was also observed in the atmosphere of Ny Ålesund (Oehme *et al.* 1996).

REFERENCES (NOT LISTED ABOVE)

Brownlee, B.G.; G.A. MacInnis, and L.R. Noton. (1993) Chlorinated anisoles and veratroles in a Canadian river receiving bleached kraft pulp mill effluent. Identification, distribution and olfactory evaluation. *Environmental Science and Technology* 27, 2450-2455.

Haugen, J-E., F. Wania, N. Ritter, and M. Schlabach. Hexachlorocyclohexanes in air and precipitation. Temporal variation, source allocation, temperature dependence and vapour scavenging. *Environmental Science and Technology* (in press).

Hargrave, B.T.; L.A. Barrie, T.F. Bidleman, and H.E. Welch. (1997) Seasonality in exchange of organochlorines between arctic air and seawater. *Environmental Science and Technology* 31, 3258-3266.

Jantunen, L.M. and T.F. Bidleman. (1995) Reversal of the air-water gas exchange direction of hexachlorocyclohexanes in the Bering and Chukchi Seas: 1993 versus 1988. *Environmental Science and Technology* 29, 1081-1089.

Li, Y-F., A. McMillan, and M.T. Scholtz. (1996) Global HCH usage with 1° x 1° longitude/latitude resolution. *Environmental Science and Technology* 30, 3525-3533.

Oehme, M.; J-E. Haugen, and M. Schlabach. (1996) Seasonal changes and relations between levels of organochlorines in arctic ambient air: First results of an all-year-round monitoring program at Ny-Alesund, Svalbard, Norway *Environmental Science and Techology* 30, 2294-2304.

Oehme, M. and S. Mano. (1984) The long-range transport of organic pollutants to the Arctic. *Fresenius Zeitschrift fur Analytische Chemie* 319, 141-146.

CYCLING OF OCS THROUGH AIR-WATER-BIOTA COMPARTMENTS IN THE CANADIAN ARCHIPELAGO

Project Leader: T.F. Bidleman, Atmospheric Environment Service, ARQP

Project Team: T. Harner, L. Jantunen, K. Wiberg, C. Halsall, L. Barrie (AES); H. Kylin (Swedish University of Agricultural Sciences); W. Strachan (National Water Research Institute)

OBJECTIVES

1. Plan activities for an integrated study of the Canadian Archipelago.
2. Complete analytical work for air and water samples from the eastern Arctic, 1996.
3. Complete determination of Henry's law constants for toxaphene.
4. Complete synthesis and publication of results from NCP Phase I.
5. Begin a study of coplanar PCBs and polychloronaphthalenes (PCNs) in arctic air.

DESCRIPTION

During the "Ideas Workshop" in Yellowknife (Nov. 1996) and the ensuing Results Workshop in Sydney (Jan. 1997), discussions were held to determine the future direction of research in NCP II. It became clear that future projects would need to be more integrated than in the past and would require development of central themes involving a multi-investigator approach. One suggested theme was an investigation of the physical, chemical and biological relationships that control key contaminants in the Canadian Archipelago.

Additional time was needed to complete ongoing work from NCP Phase I and prepare the results for publication. These studies included analysis of samples from the 1996 Oden expedition to the Barents Sea and eastern Arctic Ocean and finalizing the details of Henry's law constant determinations for toxaphene.

Funding was received at mid-year to begin a new project on "new" chemicals in arctic air. The chemicals are so designated because they are currently used as pesticides or industrial compounds, or because they have not been sought for in air samples. Two substances were selected, coplanar PCBs and polychlorinated naphthalenes (PCNs). Both include compounds that have dioxin-like activity.

ACTIVITIES IN 1997/98

Archipelago Workshop

A workshop on the "Archipelago Project" was held in Iqaluit, July 25–28, 1997, co-chaired by Terry Bidleman (AES), Robie Macdonald (Institute of Ocean Sciences) and Violet Ford (Inuit Circumpolar Conference) and a report (Meakin *et al.* 1997) has been distributed to all participants. The workshop included 34 participants from government, university and aboriginal organizations (32 from Canada, one from the U.S. and one from Sweden) and two rapporteurs. The workshop began with overviews presented on contaminant transport in the Archipelago, food chain accumulation, and the role of tradition ecological knowledge (TEK) in community involvement and the scientific process. Discussions of data gaps, research needs and ideas for the Archipelago Project followed. Key recommendations of the workshop were:

- A community-based workshop should be held in Resolute Bay to initiate a working partnership between the communities and scientists regarding the Archipelago Project. Specific objectives of the workshop would be to establish a co-management approach between communities and scientists, develop communication strategies, develop further the knowledge and capacity of communities regarding the issue of contaminants in the Archipelago region and aid scientists in understanding how TEK can complement, direct and impact areas of research.

- The Archipelago Project should be structured as an integrated study with the following components:

  a) A "vertical" study is proposed for the Resolute Bay area, which considers contaminant input from the atmosphere and ocean and transfer through abiotic and biotic compartments. Essential components of this study are investigating the behaviour of the system during the critical period of peak runoff and productivity around mid-summer, and developing physical and biological models to describe the exchange and trophic transfer processes and to predict future trends in contaminant levels of country foods.

  b) A "horizontal" study is proposed in which representative Archipelago locations are selected for monitoring spatial and temporal trends in contaminants. It was felt that this component of the study should "piggy-back" on the CINE Five-Year Food Survey wherever feasible.

- Searches should be made for a broader range of contaminants in the Arctic environment to include "new generation" pesticides and industrial com-pounds which are not being monitored at present. This effort supports international control objectives regarding persistent chemicals.

- The Archipelago Project should establish linkages with other proposed projects such as the Northwater Polynya Program (NOW), Joint Ocean Ice Study (JOIS), Surface Heat Budget of the Arctic Ocean (SHEBA) and the Swedish expedition Tundra-99.

Other Activities

Analysis of air and water samples from the Oden cruise was completed for HCHs. Air samples from this cruise and archived samples from atmospheric monitoring stations at Alert and Dunai Island were analysed for coplanar PCBs and PCNs. Papers based on these studies were presented at the Dioxin-98 meeting in Stockholm (Harner *et al.* 1998a,b) and details of the sampling and analytical methodology are given therein. A manuscript which summarizes the spatial trends of OC pesticides in water from the western Arctic Ocean, based on the 1994 Arctic Oceans Section (AOS) cruise, was recently accepted for publication (Jantunen and Bidleman 1998a). Final results for the Henry's law constants for toxaphene and HCHs have been obtained and are being prepared for publication.

In collaboration with Ross Norstrom and Rob Letcher, we have investigated the occurrence of pesticide enantiomers and PCB methyl sulfone atropisomers in Arctic biota. Details are given in a Dioxin-98 abstract (Wiberg *et al.* 1998a) and a publication (Wiberg *et al.* 1998b).

RESULTS

PCNs and Coplanar PCBs in Arctic Air

A total of 34 air samples was collected on a cruise of the eastern Arctic Ocean (Figure 1) using a high volume train consisting of a glass fiber filter (GFF) followed by two polyurethane foam plugs (PUF). At Alert and Dunai, weekly samples were collected which represented an air volume of about 11400 m^3. For this study, we were able to obtain a limited set of archived weekly PUF and GFF extracts representing approximately 2500 m^3 (Alert) and 3000 m^3 (Dunai) air. Samples were extracted with organic solvents and subjected to cleanup and fractionation steps to isolate the coplanar PCBs and PCNs from the multi-ortho PCBs and chlorinated pesticides. Prior to extraction, PUF plugs were fortified with a surrogate mixture containing $^{13}C_{12}$-labelled coplanar PCBs. Recoveries of these surrogates were used to correct for losses of the coplanars during sample workup. To correct for PCN and mono-/multi-ortho PCB losses, four clean PUFs were spiked with Halowax 1014 (a commercial mixture of 2-Cl to 8-Cl PCNs) and a PCB mixture containing 56 congeners. PCNs were quantified against Halowax 1014 by GC - negative ion mass spectrometry (GC-NIMS), using individual response factors for congeners or congener pairs based on their percentages in the Halowax mixture. Multi-ortho PCBs in Oden-96 samples were quantified using a Hewlett Packard GC equipped with an electron capture detector (GC-ECD) against a mixture of 56 individual congeners. Coplanars in Oden, Dunai and Alert samples were quantified by GC-NIMS. Analytical details are presented by Harner and Bidleman (1997, 1998) and Harner *et al.* (1998a).

Concentrations of ΣPCNs (pg/m^3) averaged 40 (n=2) for the Barents Sea, 11.6 ± 3.2 (n=10) for the eastern Arctic, and 7.1 (n=2) for the Norwegian Sea. Values at the land-based monitoring stations were: Alert = 3.5 ± 2.7 (n=5) and Dunai Island = 0.84 ± 0.47 (n=3) (pg/m^3). ΣPCNs from the eastern Arctic Ocean and the land-based stations are approximately an order of magnitude lower than levels found in Chicago during the winter (68 pg m^{-3}) (Harner and Bidleman 1997). The arctic samples have a homologue mass distribution dominated by the lighter (3 and 4-Cl) congeners (Figure 1). This may be due to preferential volatilization of the lighter PCN congeners, i.e. global fractionation, or to different source signatures.

Concentrations of ΣPCBs (~86 congeners) at Alert and Dunai during May - August were taken from Stern *et al.* (1997), and measured in this work for Oden-96 samples (~25 congeners). Adjustment for the different number of congeners quantified was made when comparing results. Mean concentrations of ΣPCBs in the Barents

Sea (126 pg/m^3) were ~3.5 times greater than those found at Alert (38 pg/m^3) and Dunai (30 pg/m^3) during the warm months in 1993-1994, while levels in the eastern Arctic Ocean (Oden-96, 37 pg/m^3) were in good agreement. Average concentrations of coplanar PCBs (fg/m^3) were: Barents Sea = 347 (PCB 77) and 5.0 (PCB 126), eastern Arctic Ocean = 51 (PCB 77) and 1.3 (PCB 126), Alert = 12 (PCB 77) and 2.4 (PCB 126), and Dunai = 32 (PCB 77) and 2.5 (PCB 126). The proportion of coplanar PCBs to ΣPCBs in air samples was within the range reported for Aroclor and Clophen commercial mixtures.

TCDD toxic equivalents (TEQs) for coplanar PCB 77 and 126, mono-ortho congeners 105, 114, 118 and 156, and PCNs 63, 66/67, 69, and 73 were calculated by multiplying the air concentrations of the particular compounds by their toxic equivalent factor (TEFs). The relative TEQ contributions for non- and mono-ortho PCBs and dioxin-like PCNs are summarized in Figure 2. In most cases the highest TEQ contribution is attributed to the coplanar PCBs, mostly congener 126. The PCNs also make an important contribution - accounting for 13-67% of the TEQ at the Arctic sites and ~30% in Chicago.

Concentrations and Gas Exchange of HCHs in the Eastern Arctic Ocean

Air and water samples were collected aboard the Swedish icebreaker Oden during July–September, 1996 (Figure 3). Air samples of ~600 m^3 were drawn over 24 h through a glass fibre filter followed by a PUF trap. Water samples were collected with a submersible pump lowered ~3 m below the water into 20-L stainless steel cans. HCHs were extracted by pressurizing the cans and filtering the water through 47-mm diameter glass fibre filters followed by 200-mg Isolute Env+ cartridges. Samples were fortified with α-HCH-d$_6$ as a recovery surrogate. After extraction and cleanup, HCHs and the enantiomers of α-HCH were determined by capillary GC - NIMS. Further details of sample cleanup and analytical methods are given by Harner *et al.* (1998b).

Blanks for Env+ cartridges (n=3) and PUF plugs (n=6) showed no detectable HCHs, and therefore no blank correction was applied. The estimated instrumental detection limit was 0.2 pg, the lowest quantity of HCHs injected which gave a 2:1 signal/noise ratio. Recovery checks were done using undeuterated HCHs to supplement the α-HCH-d$_6$ surrogate experiments. Average recoveries (± s.d.) for water samples were: α-HCH = 64 ± 13% (n = 5), γ-HCH = 54 ± 8% (n = 5), α-HCH-d$_6$ = 77 ± 20% (n = 40). Recoveries from PUF plugs were: α-HCH = 67 ± 8% (n = 4), γ-HCH = 84 ± 6% (n = 4), α-HCH-d$_6$ = 102 ± 18% (n = 32).

Concentrations of α-HCH in air ranged from 11-68 pg/m^3 (mean = 37 pg/m^3). Li *et al.* (1998) noted that α-HCH in arctic air has declined in response to restrictions of technical HCH usage in Asian countries over the last decade. Mean values observed in recent years were 77 pg/m^3 at Spitsbergen in 1993 (Oehme *et al.* 1996), 60 pg/m^3 at Alert (NWT Canada) in 1993-94 (Halsall *et al.* 1998), 81 pg/m^3 on a trans-arctic cruise in the summer of 1994 (Jantunen and Bidleman 1996) and 47 pg/m^3 at Lista, southern Norway in 1995 (Haugen *et al.* 1998). The latter authors noted that α-HCH at Lista has shown a downward trend of 10 pg/m^3 per year since 1991. Levels of γ-HCH in eastern arctic air are more variable due to episodic transport of lindane from Europe which becomes superimposed on a background of γ-HCH from technical HCH usage (Haugen *et al.* 1998, Oehme *et al.* 1996). On the Oden cruise, γ-HCH ranged from 6-68 pg/m^3 and averaged 17 pg/m^3.

The range and (mean) concentrations of HCHs in surface water were 350-1630 (910) pg/L α-HCH and 120-400 (270) pg/L γ-HCH. These agreed well with measurements by Strachan *et al.* (1998) on the Oden-96 cruise, who collected and analysed their samples independently, and also with values reported by Gaul (1992) for a 1985 survey of the Norwegian Sea. Both HCHs increased with latitude between 74° - 88°N (r^2=0.58 and 0.69 for α- and γ-HCH, respectively). A single station at 69°N near Norway showed elevated levels and was an outlier. Vertical profiles at four stations indicated that concentrations at 600-1000 m were ~50% of surface values for α-HCH and ~75% for γ-HCH. Concentrations of HCHs in eastern Arctic waters are lower than those in the Bering-Chukchi seas (Jantunen and Bidleman 1995) and the western Arctic Ocean (Jantunen and Bidleman 1996, 1998, Macdonald *et al.* 1997).

Estimates of gas exchange were made in four zones of similar latitudes and concentrations of HCHs in surface water (Figure 2). Mean concentrations of 37 pg/m^3 α-HCH and 17 pg/m^3 γ-HCH in air were assumed to be representative of the entire cruise region. Fluxes were calculated using the two-film model with fugacity definitions (Jantunen and Bidleman 1995, 1996) and the Henry's law constants for artificial seawater as a function of temperature (Kucklick *et al.* 1991). An average wind speed of 5 m/s was assumed, corresponding to an air-side mass transfer coefficient (k_g) of 0.005 m/s and D_{aw} (86400 k_g/RT) = 0.19 mol/m^2 d Pa for T_w = 272 K. Table 1 summarizes the data, water/air fugacity ratios (f_w/f_a) and fluxes to a unit area of open water. Fugacity ratios of α-HCH ranged from 0.80-1.26, close to air-water equilibrium. Net deposition of γ-HCH was indicated by fugacity ratios of 0.29-0.47. By comparison, α-HCH is outgassing from the western Arctic Ocean and the Bering-Chukchi seas, and γ-HCH is close to equilibrium (Jantunen and Bidleman 1995, 1996).

The enantiomer ratios (ER = (+)/(-)α-HCH) in surface water ranged from 0.72–0.94 and averaged 0.87±0.06 (n=21), indicating selective degradation of (+) α-HCH. Mean ERs (± s.d.) in the zones identified in Figure 1 and Table 1 were: A = 0.91 (0.01), B = 0.83 (0.03), C = 0.89 (0.04), D = 0.83 (0.09). The same metabolic preference and similar ERs were found in the western Arctic Ocean, but (-)α-HCH was depleted in the Bering and Chukchi seas, which are derived from Pacific water (Jantunen and Bidleman 1996, 1998). Enantioselective breakdown of (+)α-HCH was greater in subsurface water, with ERs ~0.2–0.3 at 250–1000 m, agreeing with results from the western Arctic Ocean (Jantunen and Bidleman 1996, 1998). The range of ERs in air samples was 0.87–1.00, with a mean of 0.95±0.03 (n=16). This suggests that the air sampled from the ship contained a mixture of non-racemic α-HCH from volatilization and racemic α-HCH transported from continental regions.

Other Results

In collaboration with Ross Norstrom and Rob Letcher, we have investigated the occurrence of pesticide enantiomers and PCB methyl sulfone atropisomers in arctic biota. Details are given in a Dioxin-98 abstract (Wiberg *et al.* 1998a) and a publication (Wiberg *et al.* 1998b).

The enantiomer ratios (ERs) of α-HCH, cis- and trans-chlordane and other components of technical chlordane (MC4, MC5, MC6) were close to seawater values in pooled samples of arctic cod, collected at Resolute Bay. This suggests little or no selective metabolism in the transfer of these organochlorines from water to cod. Selective metabolism of α-HCH increased in the food chain, in the order: ringed seal blubber < ringed seal liver < polar bear fat < polar bear liver. Chlordane components also showed evidence of selective metabolism in the food chain, although the relationships did not appear as simple as for α-HCH. Non-racemic residues of the metabolites oxychlordane and heptachlor-*exo*-epoxide were found in ringed seal and polar bear tissues. Apparent biomagnification factors (BMFs) of these organochlorines differed for the two enantiomers, showing the importance of selective metabolism in governing residues in higher animals.

A method was developed for separating and determining the two atropisomers (enantiomers) of several PCB methyl sulfones, using gas chromatography on chiral-phase capillary columns and two types of mass spectrometry, low-resolution NIMS with a quadrupole instrument and electron impact MS/MS using an ion trap instrument. The method was applied to samples of ringed seal blubber and polar bear liver. Evidence for selective formation of one atropisomer was found for the methyl sulfones of PCBs 91, 132 and 149.

Table 1. Gas Exchange of HCHs in the Eastern Arctic Ocean.

	Temp., K		C_w, ng/m³			H, Pa m³/mol		f_w/f_a		Flux[b], ng/m² d	
Latitude[a]	T_w	T_a	α-HCH	γ-HCH	Stations	α-HCH	γ-HCH	α-HCH	γ-HCH	α-HCH	γ-HCH
73 - 79 A	278	275	405 ± 53	138 ± 24	3	0.159	0.091	0.80	0.32	–3.1	–5.1
80 - 87 B	272	275	736 ± 123	208 ± 38	4	0.092	0.055	0.84	0.29	–2.5	–5.3
85 - 88 C	272	270	1030 ± 272	327 ± 41	9	0.092	0.055	1.19	0.47	2.9	–3.9
82 - 87 D	271	268	1180 ± 288	280 ± 73	4	0.084	0.051	1.26	0.37	3.9	–4.6

[a] See Figure 3.

[b] Positive = volatilization, negative = deposition.

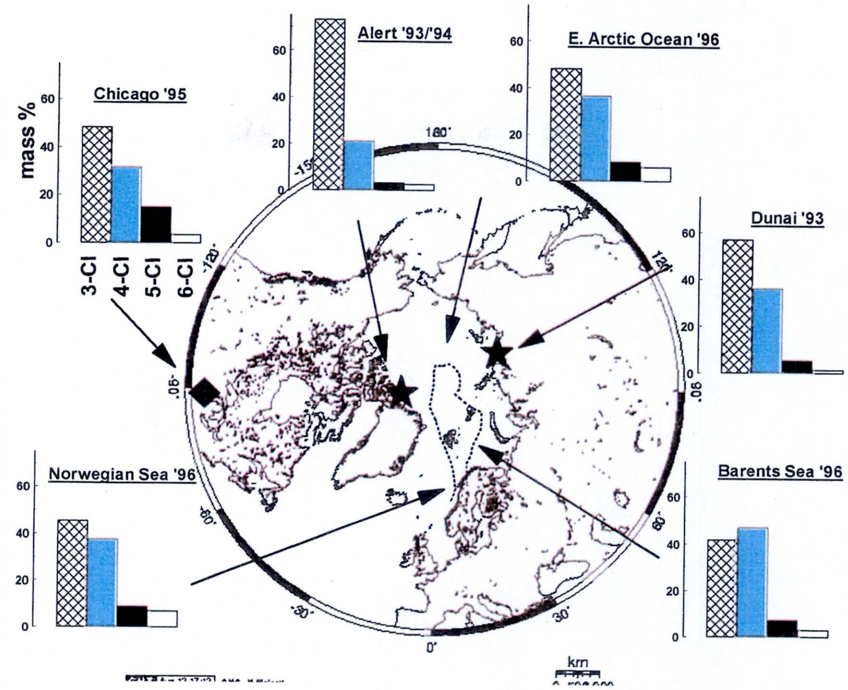

Figure 1. Map showing cruise track and PCN homolog profiles at the sampling locations.

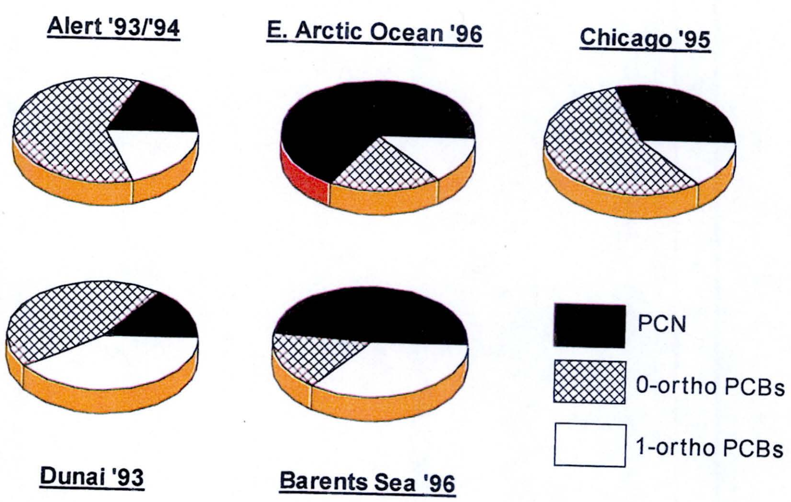

Figure 2. Percent TEQ contributions of PCNs, mono-ortho and coplanar PCBs in arctic and urban air.

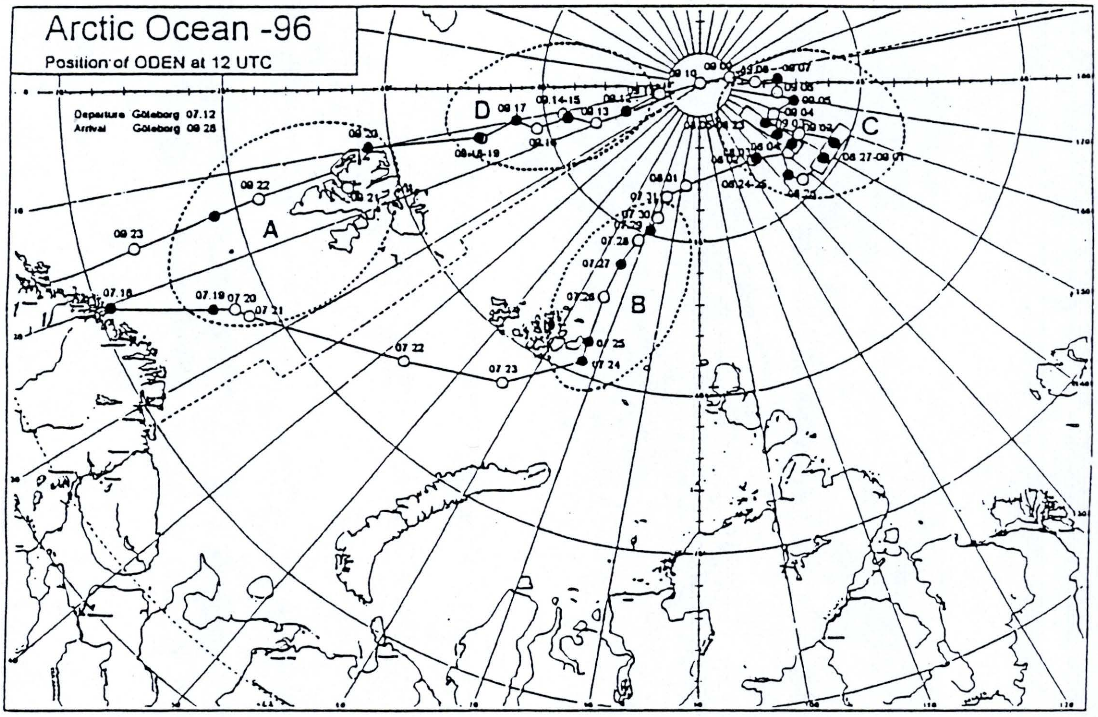

Figure 3. Cruise track of the Oden. Black circles indicate stations where water samples were collected for HCHs. Dotted circles show groupings of stations for gas exchange estimates.

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CONTAMINANT FATE AND TRANSPORT IN ARCTIC WATERSHEDS AND LAKES

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OBJECTIVES

1. to understand, quantitatively and qualitatively, the fate and transport of inorganic and organic contaminants in arctic and subarctic lakes, including those compartments that act as long-term a nd transient sinks, the response time of aquatic systems to changes in loadings, and key factors controlling contaminant fate.

2. to investigate the rate and factors controlling the enantioselective degradation of α-HCH in arctic watersheds, in the context of processes affecting overall chemical fate.

3. to understand factors leading to the bioaccumulation of contaminants in arctic freshwater biota.

DESCRIPTION

Watersheds and lakes are the intermediaries through which atmospherically deposited contaminants are transferred to freshwater and marine biota, some of which are important components of traditional diets. Our research has investigated understanding, qualitatively and quantitatively, the fate of contaminants in lakes and secondarily, within watersheds, as well as the main processes controlling chemical fate. The ultimate objective of the research is to improve our ability to predict contaminant fate in arctic lakes and aquatic biota, thereby allowing us to link the atmospheric deposition of contaminants with concentrations in biota.

The research began with developing a simple and general model of contaminant fate in arctic and subarctic lakes that we applied to several systems, notably Amituk Lake as part of the Amituk Lake project (e.g., Freitas *et al.* 1997, Diamond 1994), nearby Char Lake (Freitas 1994, Freitas *et al.* 1997), and lakes of the southern Yukon River basin (Diamond *et al.* 1996, Kawai 1995). As part of the Amituk Lake project, we developed a simple model of contaminant movement through an aquatic food chain and applied it to the simple trophic structures of Amituk and Char Lakes (Laposa *et al.* In prep). From this work we concluded that arctic and subarctic lakes act as conduits for contaminants by exporting from 80 to 99% of loadings. These exported loadings then move to the arctic ocean that serves as the main sink. Despite low contaminant loadings to lakes, fish such as arctic char can achieve high concentrations due to their longevity and slow growth, and because they are an important lipid/organic carbon pool in the entire aquatic system.

The reasons for high export rates lie in the hydrology of arctic lakes whereby most meltwater with attendant particles and chemicals, pass through the lake without mixing with the water column, and the fraction of chemical that does mix with the lake remains in the water column due to minimal particle scavenging in these nutrient poor waters.

We have also been examining the enantioselective degradation of α-HCH which is the most abundant organochlorine in arctic waters. Following the work of Falconer *et al.* (1995a,b), we have found that (+)α-HCH degrades in preference to the (-) enantiomer, resulting in enantiomer ratios (ER) substantially less than 1.0, which is the value found in mixed air masses and snow. By means of field and, more recently, laboratory studies, we have been examining rates of enantioselective degradation and factors affecting the rate (Diamond 1997).

ACTIVITIES IN 1997/98

Lake Modelling

1. We continued to develop the unsteady-state version of whole lake model. The model will estimate year-to-year changes in lake water and sediment concentrations in response to changes in loadings

and air concentrations. The model is being applied to Amituk Lake, for the years 1992, 1993 and 1994. The model may also be applied to Char Lake which is limnologically well characterized and for which we have limited organochlorine data.

2. The food chain model has been developed and is currently undergoing testing.

Enantioselective Degradation of α-HCH

1. To explore the rate and factors effecting the rate of enantioselective degradation, P. Helm (1) analysed 1994 Amituk Lake, stream and sediment extracts archived by Ray Semkin (NWRI); (2) sampled the streams of, and within the lakes Amituk, Char and mesotrophic Meretta nearby Resolute Bay in July 1997 and 1998; and (3) used a mass balance approach to estimate the relative importance of within watershed versus within lake degradation. Water and sediment extracts have been and are being analysed for total α-HCH and enantiomer concentrations. Water samples were also taken for nutrient analysis.

2. In July 1998, a series of controlled experiments was run in microcosms at Polar Continental Shelf in Resolute Bay, to test for those factors related to the rate of enantioselective degradation. The experiments consisted of spiking 4 L sediment-water systems with low levels of racemic α-HCH and sampling after about two weeks to determine the magnitude of degradation. Among the factors manipulated were sediment type and nutrient levels. α-HCH extracts from these experiments will be analysed this fall.

RESULTS

Enantioselective Degradation of α-HCH

The range of ER values for streams of the Amituk watershed spanned from 1.01 in snow, indicative of a racemic, non-degraded mixture, to 0.95-0.8 during peak flow, to as low as 0.36 in meltwater entering Amituk Lake late in the snowmelt season (Figure 1). The decline in ER values was coincident with increasing temperature, as noted by Falconer *et al.* (1995a,b). For Gorge and Cave Creeks, ER values were positively related to stream discharge and negatively related to indicators of low flow conditions and streambed weathering (e.g., concentrations of Ca^{+2} and Mg^{+2}, alkalinity, conductivity) (Table 1). These results suggest that contact with substrates, in which are found the microbial communities responsible for degradation, may be at least as important in controlling degradation rates as water temperature. Differences in ER trends in Mud Creek may be due to basin topography that may minimize the contribution of subsurface flow due to minimal snow accumulation and early snowmelt.

To further investigate this hypothesis concerning the importance of substrates, streams differing in substrate type and biological productivity were sampled in summer 1997. The streams entering Char Lake are similar to those of Amituk, and showed parallel trends of decreasing ER values with increasing temperature and indicators of streambed weathering (Helm *et al.* In prep.). However, the two inlet streams of Meretta Lake provided insight into the role of substrate productivity. Inlet 1, which receives nutrient inputs from an upstream sewage lagoon and has a lower discharge rate than Inlet 2, had ER values ranging from 0.42 to 0.54, compared with Inlet 2 which is similar to streams of Char and Amituk Lake and had ER values of 0.73 to 0.81 (Figure 2). These results suggest that enantioselective degradation is promoted (not surprisingly) by chemical contact with biologically productive matrices.

To substantiate this result, ER values were measured at the inlet, mid-point and outlet of a wetland nearby Resolute. ER values decreased from 0.85 in the inflow to 0.63 in the outflow less than 500 m downstream. The degradation of almost 20% of the (+) α-HCH enantiomer ER over a relatively short space and time scales, strongly supports the notion that enantioselective degradation is a function of contact with biologically productive substrates and can occur rapidly.

From these results we conclude that stream hydrology is the main abiotic factor controlling the enantioselective degradation of α-HCH through the influence of chemical-substrate contact time, and that the presence of a productive microbial community, necessarily supported by adequate nutrient concentrations, is an essential biotic factor controlling this process.

We next investigated the enantioselective degradation of α-HCH within Amituk, Char and Meretta Lakes. We will focus on results for Amituk Lake that are most detailed (Figure 4). ER values at 3 m depth (maximum lake ice thickness was 2.2 m) reflect hydrological events occurring in the lake. ER values quickly increased to 0.9, coincident with peak flows, and then declined to 0.76 in mid-July at overturn, which is similar to that measured at greater depths in the lake. ER values at 20 and 40 m depths increased slightly over the summer from 0.73 and 0.66, respectively, in early June, to about 0.75 at overturn. ER values in the outflow (not shown) were virtually identical to those at 3 m.

The pattern of ER values in the lake again indicate hydrological control over chemical fate: as our model

Table 1. Correlation coeficients (r^2 values) between α-HCH enantiomer ratios and physical and chemical characteristics of streams entering Amituk Lake.

Creek	α-HCH Conc.	Discharge	Temp.	Mg^{2+}	Ca^{2+}	Alkalinity	Conductivity	DOC	SS	$N\text{-}NO_3$	$N\text{-}NH_4$
Mud	0	(-) 0.06	(+) 0.43	(+) 0.31	(+) 0.24	(+) 0.20	(+) 0.20	(+) 0.38	0	(-) 0.12	(-) 0.11
Gorge	(+) 0.61	(+) 0.35	(-) 0.67*	(-) 0.84*	(-) 0.51	(-) 0.80*	(-) 0.73*	(+) 0.22	(+) 0.32	(-) 0.41	(+) 0.03
Cave	(+) 0.69*	(+) 0.97*	(-) 0.52	(-) 0.36	(-) 0.69*	(-) 0.63	(-) 0.54	(+) 0.67*	0	(+) 0.14	(-) 0.21

DOC - dissolved organic carbon
SS - suspended sediment
$N\text{-}NO_3$ - nitrate nitrogen
$N\text{-}NH_4$ - ammonia nitrogen
TP - total phosphorous

(-) - negative correlation
(+) - positive correlation
* - significant at $p < 0.05$\

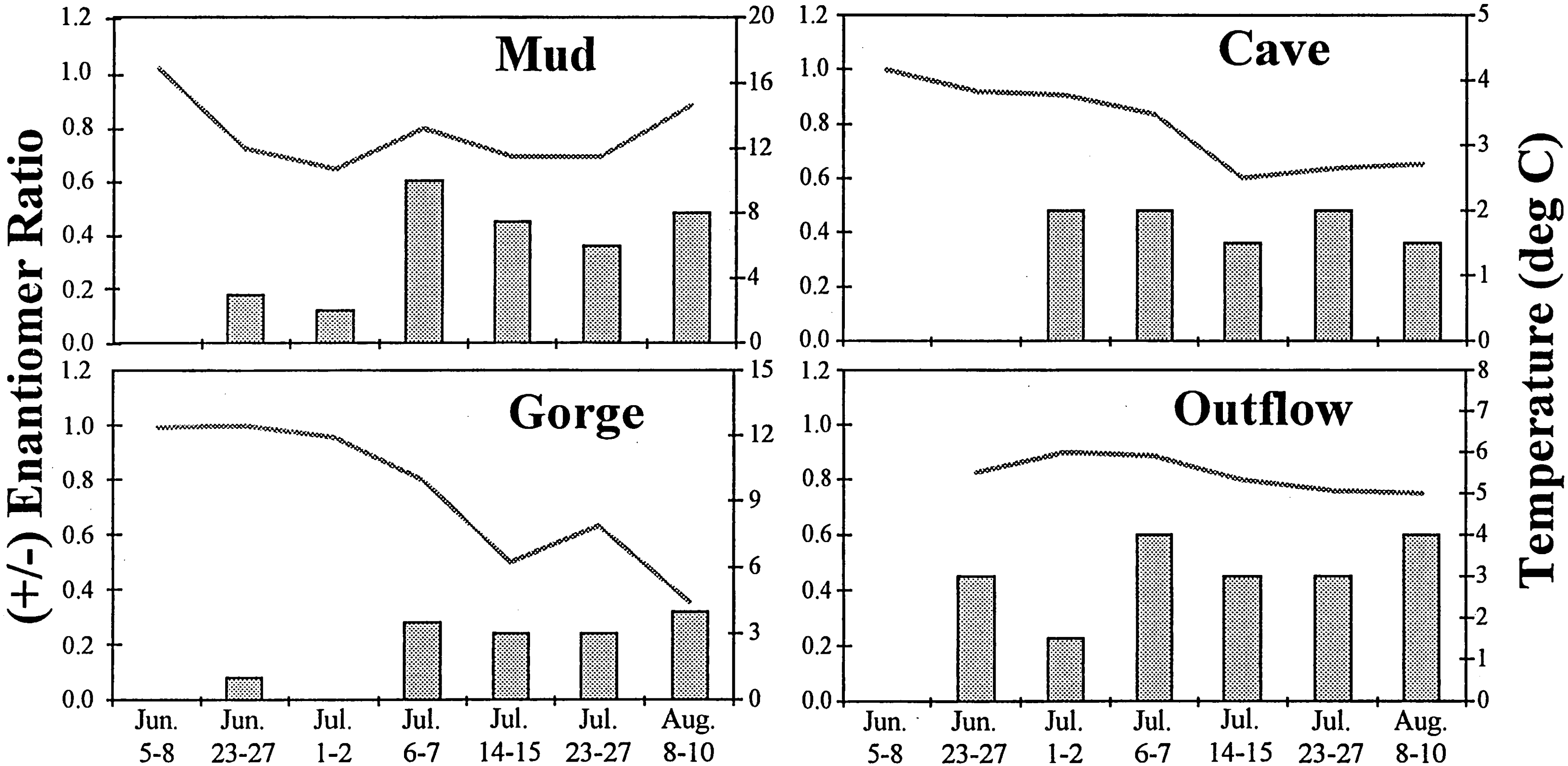


Figure 1. α-HCH enantiomer ratios (lines) and stream temperatures (bars) by sampling date for the Amituk Lake basin (1994 data).

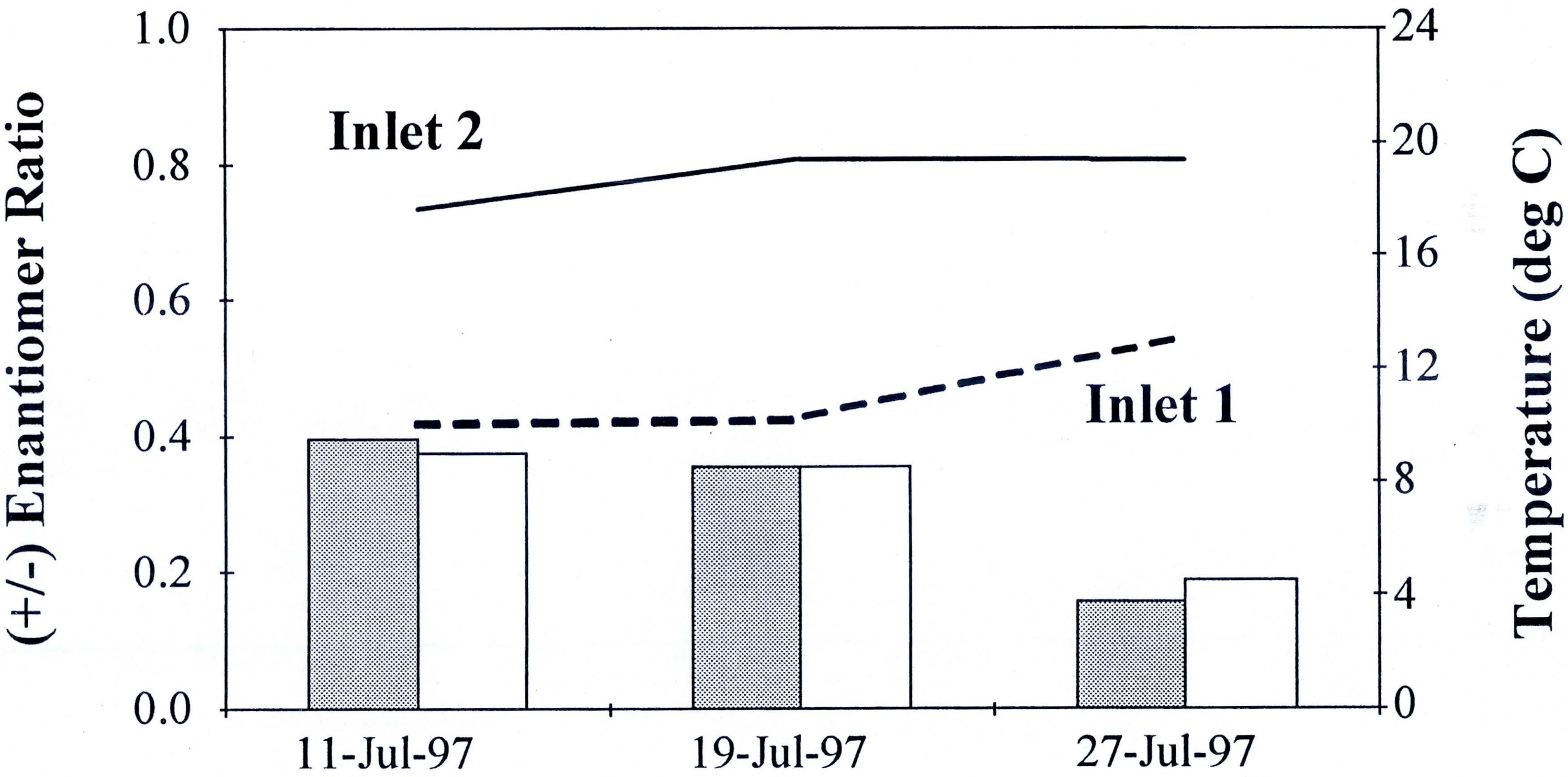
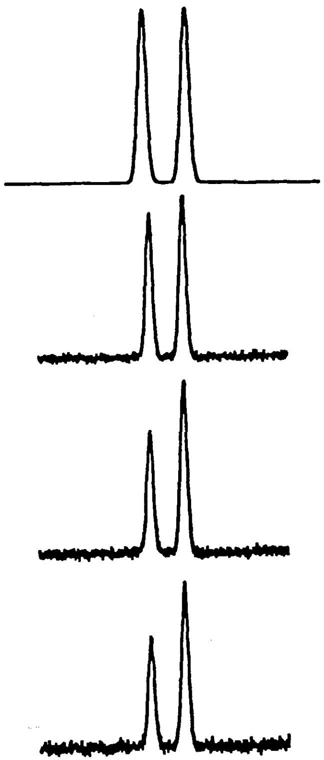


Figure 2. α-HCH enantiomer ratios and temperatures for Inlet 1 (dashed line and white bars, respectively) and Inlet 2 (solid line and gray bars, respectively) for samples from Meretta Lake basin (1997 data).



Sample	Enantiomer Ratio	Temp.
Standard	0.98	
Inlet	0.85	10 °C
Mid	0.69	11.25 °C
Outlet	0.63	11.75 °C

Figure 3. α-HCH chromatograms, enantiomer ratios and water temperatures within a wetland near Resolute Bay. The chromatograms of (+)α-HCH depict the progression of degradation through the wetland.

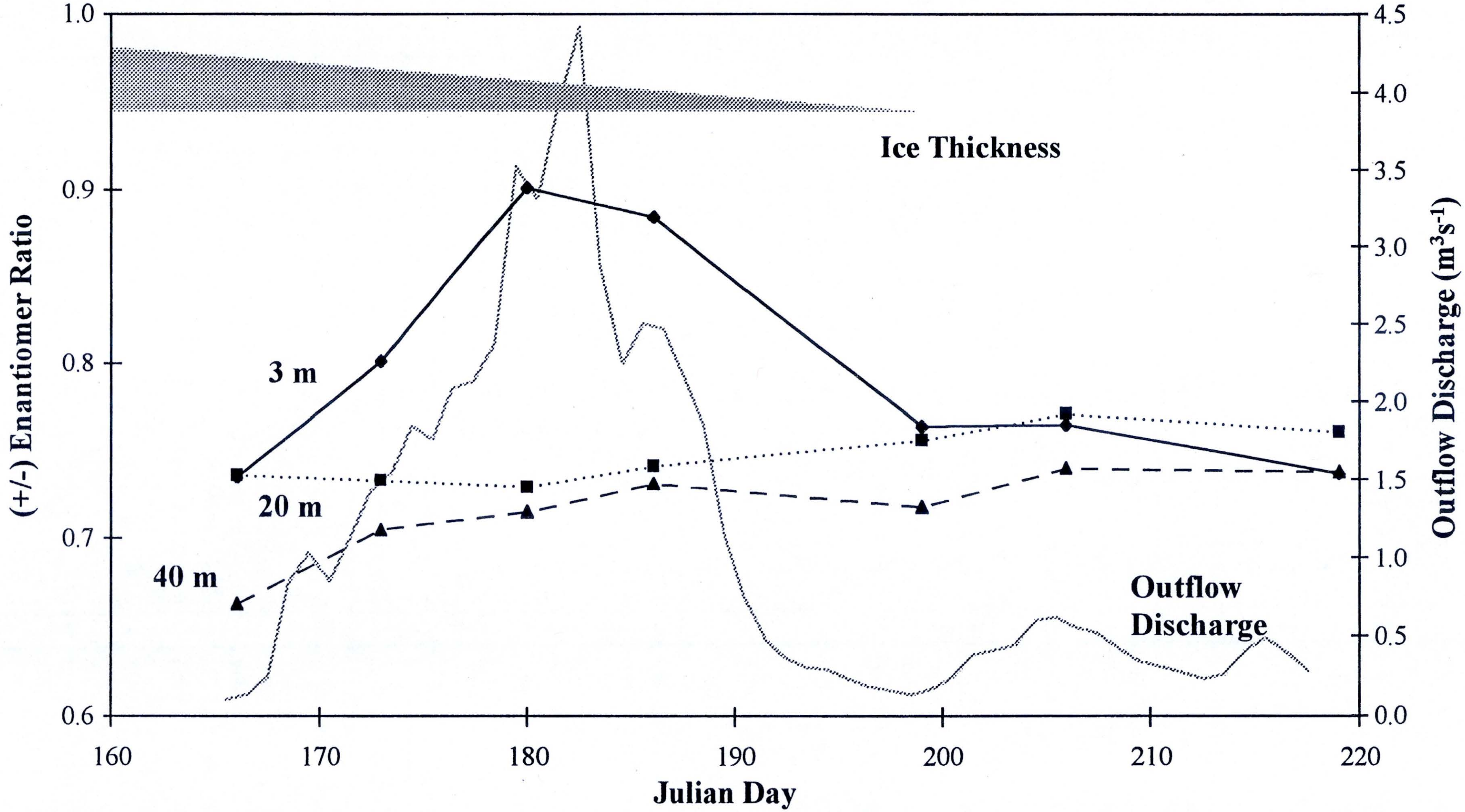


Figure 4. α-HCH enanotiomer ratios at three depths in Amituk Lake, stream discharge and approximate ice thickness (1994 data).

results have shown: most chemicals pass through the lake without mixing with the water column due to temperature-induced density gradients. Thus, the ER values at 3 m reflect that of the inflowing streams and not the deeper water column. The lower ER values at depth before ice-off suggest that enantioselective degradation is occurring in the lake over winter where the water is in close contact with sediments due to lake bathymetry and limited mixing under the ice.

Finally, we used the ER values to determine the relative importance of in-stream and in-lake degradation. Although ER values declined throughout snowmelt in the streams, the greatest loadings to the lakes occurred when ER values were relatively high. For Amituk Lake, a mass budget indicated that approximately 6% of the α-HCH was enantiomerically degraded prior to entering Amituk Lake, with the greatest mass being degraded at high flows when ER values were greater than 0.8. Less than one third of the total mass was degraded under low flow (and ER) conditions. A simple mass budget calculation for the lake indicated that about 7% of α-HCH exported from Amituk was enantiomerically degraded. This percentage is slightly greater than the estimated 6% enantiomerically degraded in the inflow streams and is likely within the margin of error of the measurements. Thus, the results suggest that most degradation is occurring within the streams feeding the lake, and conversely, minimal degradation occurs within the lake. The accuracy of this comparison is being improved by using the whole lake model that accounts for variable mixing of the inflow with the water column as the melt proceeds.

DISCUSSION/CONCLUSIONS

Enantioselective degradation of α-HCH occurs as a cometabolic process with microbes using other, more "palatable" carbon sources for nutrients and α-HCH being degraded incidentally in the process. Degradation is promoted by close contact of the chemical with biologically productive substrates when stream flow is low and water temperatures are highest. Degradation appears to be greatest within streams, and less so within small lakes with relatively short water retention times. However, within lake observations tend to substantiate the work of Alaee *et al.* (1997) that showed that degradation is positively related to lake residence time in a series of large lakes in the Yukon. Generally, these results point to the importance of watershed and lake hydrology for controlling the magnitude of this biological degradation process, as well as overall chemical fate.

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BIOMAGNIFICATION OF PERSISTENT ORGANIC CONTAMINANTS IN GREAT SLAVE LAKE

Project Leader: M. S. Evans, National Hydrology Research Institute, Saskatoon, SK

Project Team: D. Muir, National Water Research Institute, Burlington, ON; W. L. Lockhart, Freshwater Institute, Winnipeg, MB

OBJECTIVES

1. To investigate the role of the Slave River as a source of persistent organic contaminants to Great Slave Lake.
2. To investigate factors affecting organic contaminant contamination in fish important in community diets, including considerations of food web biomagnification and the influence of the Slave River.
3. To respond to community concerns regarding contaminants in the environment.

DESCRIPTION

This project is based on the investigation of the influence of the Slave River on the contaminant loading to and biomagnification within Great Slave Lake. The study began in 1993 with a preliminary lake survey in the Resolution Bay-Slave River delta area and with fish collections being made at Lutsel K'e and Fort Resolution, primarily by community members. The last field samples to be collected were in the Resolution Bay area in 1996. Water, sediments, and fish were collected during these studies. Most of the funding support for this several year study was provided by the Northern Contaminants Program of the Department of Indian Affairs and Northern Development (DIAND) in Ottawa, DIAND-Yellowknife, and the Northern River Basins Study. The National Hydrology Research Institute (Saskatoon) of Environment Canada provided funding and other support as did the Freshwater Institute (Winnipeg) of Fisheries and Oceans. Fort Resolution, with NCP-funding, provided support to some of the 1996 studies. Fort Resolution studies focused on concerns related to the decommissioned Pine Point mine.

ACTIVITIES IN 1997/1998

Funding support in 1997/1998 was modest ($11K). Funds were used to support workshop presentations and to work towards completion of two reports based on research conducted on behalf of the community of Fort Resolution. Specifically, the following were accomplished:

- A broad overview of research studies on Great Slave Lake was given at the June 1-5, 1997 Arctic Monitoring and Assessment Program International Symposium in Tromso Norway (Evans *et al.* 1997). NHRI supported the majority of the costs associated with attendance at this symposium.
- Three presentations on research studies conducted on Great Slave Lake were given at the Upper Mackenzie Basin Planning Workshop held in Yellowknife, NWT, August 18-20 (Evans 1997 a, b, c). Immediately following these presentations, similar presentations were given in Fort Resolution. These presentations were at the invitation of Maurice Boucher, Manager, Environmental Working Committee, Fort Resolution. A similar series of presentations were given at the Ataitcho Territory Regional Contaminants Workshop, held in Yellowknife, March 31-April 1. This workshop was sponsored by the Dene Nation Lands and Environment Department.

The remaining effort was directed towards competing reports based on two studies conducted on behalf of Fort Resolution. The larger report was based on community concerns related to the decommissioned Pine Point mine (Evans *et al.* 1998a). The second report investigated organic contaminant and metal concentrations in selected tissues of predatory fish (Evans *et al.* 1998b). This report is near completion.

RESULTS

Our studies have determined the following:

- The Slave River is a significant source of organochlorine, PAHs, PCDDs, and PCDFs to the West Basin of Great Slave Lake. Most deposition occurs in the Slave River delta and the region offshore of the delta.
- Organic contaminants tend to occur in higher concentrations in surficial sediments in the West Basin, particularly offshore of the Slave River, than in the East Arm where the Slave River influence is weaker.

- Although organic contaminant concentrations tend to be higher in the West Basin than the East Arm, biota collected offshore of Lutsel K'e (East Arm) tend to have higher concentrations of PCBs and toxaphene than the same animals collected in the vicinity of Fort Resolution. We hypothesize that, because of the heavy sediment load carried by the Slave River, organic contaminants are less bioavailable to biota in the West Basin than in the East Arm.
- Organic contaminants such as PCBs and toxaphene occur in highest concentrations in coldwater predatory fish such as lake trout and burbot. Burbot appears to be an atypical fish with relatively high concentrations of organochlorine contaminants in its liver but low concentrations in its muscle.
- There was no evidence that the decommissioned Pine Point Pine had or continues to measurably contaminate the Resolution Bay area with metals. Metal concentrations in water and sediment are similar to those observed in the Slave River, the primary source of metals and waters to the Resolution Bay area. Metal concentrations in fish are similar to those observed in other regions of Great Slave Lake and to reference lakes.

EXPECTED COMPLETION DATE

With the near completion of outstanding reports, effort will now focus in preparing scientific publications based on the 1993–1996 research programs on Great Slave Lake. In addition, new research support is being sought to continue to address scientific issues raised during this first phase of studies investigating the influence of the Slave River on contaminant loading to and biomagnification within Great Slave Lake. One newly-funded study, supported by Petroleum, Energy, Research and Development (PERD), will investigate the potential environmental consequences of increased tar sands development at Fort McMurray to the Peace-Athabasca-Slave River systems, including lakes such as the delta lakes, Lake Athabasca, and Great Slave Lake. Two proposals have been submitted to the Northern River Ecosystem Initiative (the successor of NRBS) to continue studies on Great Slave Lake with new research effort on the Slave River delta.

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MACKENZIE BASIN INTEGRATED STUDY: DEVELOPMENT AND PLANNING PHASE

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Project Team: D. Muir and W.M.J. Strachan, National Water Research Institute, Burlington, ON; W.L. Lockhart and G. Stern, Freshwater Institute, Winnipeg, MB; C. Mills, Department of Indian and Northern Affairs, Yellowknife, NT; S. Papik, Dene Nation, Yellowknife, NT

OBJECTIVES

This study builds on research conducted in the Mackenzie River Basin under NCP-I. During this five-year program, baseline data were obtained on contaminant concentrations in aquatic and terrestrial biota inhabiting the Mackenzie River Basin, time trends in contaminant inputs, and pathways and sinks. Highlights of these studies are reported in Jensen *et al.* (1997). Our study was designed to continue that research effort by developing a new, multi-year investigation of contaminants in the Mackenzie River Basin. The long-term term objectives of the Integrated Mackenzie Basin Study are as follows:

1. Further investigate how contaminants enter, move through, and are lost from the Mackenzie Basin ecosystem. Of particular concern is the contamination of country foods.
2. Based on community interests and country food usage, develop site-specific studies to investigate issues of greatest concern. The geographic focus of the study is the upper Mackenzie Basin.
3. Provide educational and training opportunities to local communities through a variety of mechanisms, e.g., participation in research studies, community visits, and training in specific issues.
4. Further develop educational opportunities through universities and colleges (formal courses, internships, research projects for credit).
5. As part of the overall integrated study, develop long-term monitoring programs at selected sites and for selected compounds. The framework for such monitoring is to be based on community concerns and could be modeled on other such programs, e.g., the long-term monitoring programs for the Great Lakes.
6. Consider long-range (atmospheric, Peace-Athabasca-Slave-Liard Mackenzie River system) and local (natural and anthropogenic sources) of contaminants.

DESCRIPTION

This project is based on the intent to develop an integrated, multi-disciplinary study of contaminants in the Mackenzie Basin. The overall objective of studies under NCP II is to reduce and wherever possible eliminate contaminants in traditionally harvested foods. Studies must also be designed to provide information that assists in the informed decision-making by individuals and communities in their food use. Ideally, the results of these studies will be used to develop strategies to minimize and/or eliminate the contamination of this ecosystem, with a focus on country foods. Studies should be based on community involvement and will provide education and training opportunities. In the first year of the Mackenzie Basin Integrated Study, effort was addressed towards developing the framework of a multi-year, multi-partner, integrated study of the contaminants in the upper Mackenzie Basin. A workshop approach was used.

ACTIVITIES IN 1997/1998

A planning workshop was developed to synthesize existing knowledge, identify knowledge gaps, and present local concerns regarding contaminants in country foods in the Upper Mackenzie Basin. The workshop was held in Yellowknife over August 18–20, 1997. Equal representation was sought from the research/management and local communities.

Bill Carpenter visited several communities along the upper Mackzenie River (including Wrigley, Norman Wells, Tulita, Deline, and Fort Good Hope) to inform them of the workshop and invite them to send delegates to speak on behalf of community concerns. All communities were interested in the workshop and most were able to send delegates.

In the months following the August workshop, various team members worked towards further developing the

Mackenzie River Basin Study. Effort initially focussed on Great Bear Lake in the Sahtu region. In October, M. Evans visited Deline and gave a presentation before the Sahtu Renewable Resources Board. Visits also were made to Fort Good Hope and with the Renewable Resources Council in Norman Wells. Two proposals were submitted to the SRRB.

In January, M. Evans attended a community-organized Lower Mackenzie Basin Community Planning Workshop; this workshop was held in Tulita and focussed on concerns to Tulita, Norman Wells, Norman Wells, and Deline.

In March, M. Evans attended a community-organized Akaitcho Territory Regional Contaminant Workshop. This workshop, held in Yellowknife, focused on issues of concern to residents of Yellowknife, Fort Resolution, and Lutsel K'e, all along the Great Slave Lake shoreline.

RESULTS

Two Mackenzie Basin Planning Workshops were supported by NCP II. The first, the focus of this report, was held in August in Yellowknife. Following a day of presentations, work groups were formed to identify contaminants and issues of concern, including priorities. The workshop was highly informative and many issues of concern were raised regarding contaminants in various organisms and regions within the Mackenzie River Basin. However, the workshop was unable to establish priorities. Highlights of the workshop were prepared as a report (Evans and Carpenter 1997).

The second workshop was organized by the representatives from the Sahtu and was held in January in Tulita. During this second workshop, Great Bear Lake was identified as a priority concern for the aquatic realm and caribou and moose for the terrestrial realm.

In February, various proposals were submitted to NCP II to investigate issues of concern in the Mackenzie River Basin. These studies focused on widespread concerns with elevated mercury levels in predatory fish in some lakes in the Mackenzie River Basin, various concerns regarding Great Bear Lake; and concerns related to caribou and moose in the Sahtu Region.

EXPECTED COMPLETION DATE

The Yellowknife Workshop was very successful enabling community members and researchers to meet one another and to become better informed of community concerns and scientific understandings. Various partnerships were strengthened and others established. The planning phase for the upper Mackenzie Basin Integrated Study has been completed and a variety of proposals have been submitted to address the diverse issues in this region. Thus, as such, no integrated study has been developed although future effort could be addressed towards integrating the ongoing studies through the exchange of information, etc. Possible mechanisms of exchange are suggested in Evans and Carpenter (1997).

In retrospect, given the large number of communities and territories in the Mackenzie Basin and the variety of concerns, it was highly unlikely that the August workshop would result in the recommendation for an integrated site-specific study in some region of the basin. All community studies which were suggested were of value and require some level of investigation. Projects which were submitted in February 1998 were a first step towards these endeavors. As previously noted, partnerships were established and it is believed that various researchers and communities can and will work together in the continuing years to develop further support and funding for these important activities.

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SOURCES AND SINKS OF ORGANOCHLORINES IN THE ARCTIC MARINE FOOD WEB

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Project Team: G.A. Phillips, (Habitat Ecology Section, Marine Environmental Sciences Division, DFO, Bedford Institute of Oceanography, Maritimes Region); H. Welch (DFO, Central & Arctic Region); L. Barrie, T. Bidleman (DOE, Atmospheric Environment Service, Downsview)

OBJECTIVES

1. to quantify the long-range atmospheric and marine transport of organic contaminants and their incorporation into lower trophic level organisms of the marine food web in the Arctic Ocean.
2. to provide baseline measurements of major semi-volatile organic (chlorinated pesticides, PCBs) in the Canadian high Arctic Ocean environment by sampling seawater (dissolved and particulate phases), plankton, benthos and fish.
3. to assess the relative importance of atmospheric versus oceanic input of these contaminants to Arctic Ocean biota by seasonal measurements.
4. to evaluate the seasonal bioconcentration of these compounds for comparison with data from more southern latitude oceans sites to assess input of organochlorines to food web organisms utilized as food by northern populations.

DESCRIPTION

Organochlorines (OCs) extracted from sea-water, epontic ice algae, marine planktonic and benthic fauna and fish collected seasonally in the Barrow Strait/ Resolute Bay area in 1993 provide a unique data set for calculation of total body burden and mass transfer rates in various organisms. New information on stable isotope (C^{14} and N^{15}) content in organisms previously analysed for OCs allow objective classification of organisms into separate tropic groups. The study allows calculations of mass balance transfer rates of OCs from air to seawater and from seawater to lower trophic level biota in the Arctic Ocean and Barrow Strait-Resolute Bay area on a seasonal basis. Monthly measurements of OCs in air collected at Alert during 1993 (L. Barrie) have been compared with surface seawater concentrations measured in Barrow Strait to allow calculation of seasonal air-to-water exchanges between the atmosphere and surface ocean within the Canadian archipelago. Henry's Law coefficients were used to calculate fugacity ratios to calculate air-water fluxes. Calculated rates of deposition and volatilization can now be compare to data for bioaccumulation in lower trophic level organisms to model seasonal changes in the rates of entry of different OCs into the marine food web.

Organochlorines, such as PCBs, DDT, chlordane and toxaphene, are present in diets of northern populations due to global redistribution processes. OCs enter the arctic marine food web from atmospheric, riverine and ocean sources and they are concentrated in lipid-rich tissues of lower trophic level marine invertebrates. Biomagnification occurs through the food web leading to marine fish and mammals due to predator/prey links that transfer and accumulate these contaminants in successive trophic levels. Previous studies have provided a large data base for marine mammals, but the dynamics of bioaccumulation in lower trophic level organisms was poorly understood. New information on the seasonal dynamics of air-to-sea OC exchange can also now be incorporated into models of bioaccumulation by lower trophic level organisms. Since this is the point of entry of OC contaminants into the food web leading to man, it is important to understand how seasonal changes in bioaccumulation factors are linked to atmospheric forcing. The transfer rates can be expected to vary due to differences in atmospheric and seawater concentrations, marine food web productivity, organism feeding and growth rates and lipid metabolism.

ACTIVITIES IN 1997/98

Collaboration with L. Barrie, T. Bidleman and H. Welch has continued to complete a seasonal description of transfer of volatile OCs between the atmosphere, surface seawater and lower trophic level organisms within a region of the Canadian archipelago. Henry's Law constants were used to calculate the degree of over- or under-saturation in surface seawater relative to levels measured in air. The combination of data from Alert and Barrow Strait/Resolute Bay areas during 1993 provides the first study to estimate annual air-sea fluxes for OCs in any arctic environment. Calculations were published in a primary paper in Environmental Science and Technology.

Biomagnification factors between amphipods and arctic cod were re-examined by analysing additional frozen amphipods remaining from the 1993 seasonal study. Concentrations measured in previously analysed samples were confirmed. Increases in body lipid content during the mid-summer to fall period dilute the body burden of OCs in tissues of fish and invertebrates.

The SCICEX-96 mission by the US Navy (Arctic Submarine Laboratory, Nuclear Underwater Warfare Center, San Diego) using the nuclear submarine USS Pogy completed between September and November 1996 provided samples (n=31) of the large scavening amphipod *Eurythenes gryllus* from stations (3600–3700 m depth) in the Canada Basin. Amphipods were analysed during 1997 for OCs for comparison with previous observations for this species collected from the Alpha Ridge area during the CESAR project (April–May 1983). Levels of PCBs and toxaphene in lipids of *Eurythenes gryllus* (>10 ppm) are the highest observed in any arctic invertebrate (equivalent to concentrations in blubber of polar bear and walrus) presumably due to biomagnification from their food supply. *Eurythenes* is a useful sentinel organisms for monitoring spatial and temporal trends of OC levels in the arctic marine food web. The US Navy will repeat this type of sample collection during June–July 1998 which if successful will provide additional samples of amphipods for OC determinations.

New data was obtained during 1997/98 for stable isotopes (C^{13} and N^{15}) in lower trophic level organisms collected in 1993 and 1996 that were previously analysed for OCs. This allows more accurate calculation of biomagnification factors between potential predator-prey linkages. The results will be incorporated into a primary paper summarizing seasonal changes in biomagnification factors for OCs within lower tropic levels of the marine food web in Barrow Strait.

Data entry into a relational database (Alpha Four) summarizing analytical results for OCs measured in air, snow, ice, seawater, epontic particles, under-ice biota, plankton, benthic crustaceans and fish collected from Canadian Ice Island off Ellef Ringnes Island (1986–1990) and in Barrow Strait (1993) was completed. The information was used to provide data for a summary table for OCs in arctic marine biota in a chapter of the 1997 Canadian Arctic Contaminant Assessment Report. The database allows evaluation of the importance of regional and temporal variations in OC concentrations in lower trophic levels arctic marine biota from areas of high and low productivity by comparing results from Barrow Strait with those collected in more offshore areas outside of the arctic archipelago.

A paper was presented (Hargrave 1997) at the Arctic Archipelago Project Workshop held in Iqualuit, NWT, July 24–27, 1997.

RESULTS

The use of Henry's Law constants to calculate the degree of over- or under-saturation of OCs in surface Proceedings and Recommendations of relative to levels measured in air during 1993 (Hargrave *et al.* 1997) showed that decreases in atmospheric concentrations in the Northern Hemisphere during the last decade have resulted in Arctic Ocean surface layer water that is now supersaturated for HCHs, HCB and dieldrin. Other compounds (toxaphene, cis- and trans-chlordane and endosulphan-I) are undersaturated with net air-to-sea deposition. Out-gassing of HCHs, HCB and dieldrin during the ice-free period could have lowered surface layer inventories by 4 to 20%. In contrast, net deposition of toxaphene, chlordanes and endosulphan-I during the open water period was equivalent to 50 to >100% of the surface layer inventory. Air-sea fluxes of OCs were influenced by the combined effects of changes in vapor pressure.

The database for all OC measurements on all sample types collected from the Canadian Ice Island (1986–89) and in Barrow Strait (1993 annual study) has been completed and results summarized for modelling biomagnification factors between trophic levels. Collaboration/data sharing was initiated with Dr. B. Hickie (Trent University) during 1997 to further model development to assess factors that influence food web biomagnification.

DISCUSSION/CONCLUSIONS

Seasonality of contaminant input and loss of OCs to the Arctic Ocean must be considered in modelling the dynamics of transfer of these contaminants between physical and biological arctic marine ecosystem components. Air-sea gas exchange and water mass advection are two critical processes affecting the concentration of OCs in the surface layer of the Arctic

Ocean. Potential removal of OCs on sedimenting particles was calculated to be less important in controlling surface layer concentrations (Hargrave *et al.* 1997). Other exchange processes such as precipitation and dry particle deposition contribute additional sources of OCs with the partitioning between gas and solid phases dependent on physical/chemical properties of specific OC compounds. Substances such as HCHs with high vapor pressure and low particle affinity tend to remain in the atmosphere rather than become associated with settling particulate matter.

The majority of HCH in the Arctic Ocean exists in dissolved form in the upper 50 to 100 m surface layer. Lower air concentrations in HCHs during the past decade have resulted in an out-gassing to the atmosphere which along with advective transport of surface water may lead to a slow decrease in oceanic concentrations over the next decade. At present the Arctic Ocean is a source rather than a sink for HCHs. Toxaphene, chordanes and endosulphan-I, on the other hand, were being transferred from the atmosphere to the ocean during the seasonal study in 1993 with the most rapid deposition occurring during the ice-free period (July–September). This coincides with the time of maximum biological productivity by both ice algae and phytoplankton in the water column. The maximum rate of entry of OCs into lower trophic level organisms occurs during these summer months. Continuing work using stable isotopes to normalize OC concentrations on the basis of defined trophic levels is underway.

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QUANTIFYING THE ATMOSPHERIC DELIVERY OF ORGANIC CONTAMINANTS INTO THE HIGH ARCTIC MARINE ECOSYSTEM AS INFLUENCED BY SNOW AND ICE

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Project Team: D. Mackay (Environmental and Resource Studies, Trent U., Peterborough, ON); R. Semkin (National Water Research Institute, Burlington, ON); C.Q. Jia (U. of Toronto)

OBJECTIVES

1. The main objective of the project was to provide the quantitative knowledge on snow and ice-related contaminant transport processes necessary for planning, conducting and integrating the joint study on contaminant pathways and ecosystem uptake in the Canadian Arctic Archipelago.
2. Sub-objectives are:
   - to extend the available data base on specific snow surface area to include samples of snow, sea ice and glaciers from the Canadian Arctic Archipelago
   - to develop quantitative models of contaminant fate in metamorphosing snow and glacier ice, and evaluate these with field data gained during phase 1 of the NCP
   - to provide expressions for describing snow-related processes in multimedia models of contaminant fate
   - to contribute to the planning of snow/ice-related sampling and measurements during the field part of the Canadian Arctic Archipelago Project
   - to model the post depositional behaviour of contaminants in snow packs
   - to extend the available data base on interfacial partitioning of non-polar organic chemicals to include less volatile chemicals

DESCRIPTION

It is acknowledged that snow can be a significant vector for transport of contaminants from the atmosphere to the terrestrial and marine environments. This is in part because of the efficiency of snow for scavenging aerosol particles, but also because the relatively large interfacial area effectively sorbs and scavenges gaseous contaminant, especially at low temperatures. A key question is the post depositional behaviour of these contaminants. Whether they evaporate or leach into the melt water has profound implications for subsequent human exposure. This project seeks to measure the parameters necessary to describe quantitatively snow scavenging and post-depositional snow pack processes, model these phenomena and thus help establish the significance of snow-related contaminant fate processes.

ACTIVITIES IN 1997/98

Development of a more sensitive method for measuring the specific surface area of snow

A paper on measuring the specific surface area (SSA) of snow using the nitrogen adsorption technique has been published this year (Hoff *et al.* 1998). Two short articles describing our work have appeared in Science News (1998, v. 153, p. 88) and Weatherwise (May–June, 1998, pp. 11–12) as a result of this paper. Because it was learned that the nitrogen adsorption method is able to measure the SSA of freshly precipitated snow, but not metamorphosed snow, a more sensitive method has been developed. Initial experiments with frontal gas chromatography using normal alkanes at low concentration showed promise. Eventually, it was realized that a more polar adsorbate, ethyl acetate, would give better sensitivity because of its higher interfacial partition coefficient K_{ia}. This new method was employed to measure the surface area of snow sampled near Lake Louise, Alberta, indicating that the new method is sensitive enough to measure the SSA of metamorphed snow.

Modelling organic contaminant fate in snow pack

Using and modifying a one-layer snow pack model described by Wania (1997) we simulated field data gained during the Amituk lake studies within the NCP, namely we tried to reproduce and thus explain the measured (1) volatilization loss of organic contaminants from a repeatedly sampled shallow snow pack and (2) meltwater hydrographs of several chemicals in the creeks draining into Amituk Lake. Some results are presented below and in more detail in a submitted paper (Wania *et al.* 1998b).

During the year a second mass balance model was assembled and tested in a preliminary fashion. The model was set up to treat the ageing and melting of a multi-layer snow pack. It is thus similar in principle to the model published by Wania (1997), but instead of treating the snow pack as being vertically mixed it allows for differences in concentration vertically. It is likely that the surface snow experiences more rapid evaporation than the underlying snow because of its closer proximity to the atmosphere. Partitioning in the pack is assumed to occur between water, air, the ice interface and aerosol particles. As a result of running the model we have become convinced that its failure to treat contaminant loss during snow accumulation in the early and mid winter is a major weakness. As a result we have modified and expanded the model to treat the entire snow pack "life-cycle" from initial snowfall to complete melt. Essentially the user will start with a snow free surface then specify periodic snowfalls, aging, melting, rainfall, temperature and atmospheric concentrations. The model will then compute behavior during the specified period then stop and request input for the next period. This "discrete dynamic" modelling approach will permit the user to assemble a complete mass balance over the winter and spring and test various scenarios of snow accumulation. This approach will enable the user to "validate" the model by comparing measured and computed concentrations at various times and depths. The model code is being written in QBasic and it is planned for completion in late 1998.

Modelling the scavenging of organic contaminants by snow

A conceptual model of snow scavenging was developed and presented at the AMAP conference in June 1997 (Hoff *et al.* 1997). Using that approach and averaged data published in the CACAR report we have started analysing atmospheric and snowfall concentrations generated in phase 1 of the NCP with the aim of deriving scavenging ratios. Preliminary results of this exercise were presented at the Archipelago Workshop in July 1997. In a meeting with C. Halsall from AES and W. Strachan from CCIW the possibility of a more thorough analysis of the existing NCP data was discussed and it was concluded that it should be feasible to estimate scavenging ratios for both Alert, N.W.T. and Tagish, YT.

Other work

Our ideas on the role of snow and ice in the environmental behaviour of non-polar organic contaminants were summarized in an extensive review paper, which was accepted for publication (Wania *et al.* 1998a). Further, a literature review of physical chemical data for mercury (Hg) species in water and air was conducted. On the basis of these data, speculative calculations of adsorption at the air-ice interface have been made, and hypotheses have been formed which can be tested by measurements. There are no data for adsorption of Hg vapor on ice, but it is possible to use the theory of adsorption of organic vapors on ice to estimate the K_{ia} values.

RESULTS

Development of a more sensitive method for measuring the specific surface area of snow

The apparatus for measuring snow surface area by frontal chromatography consists of a glass column containing a sample of snow, which is immersed in a low temperature bath. The inside surface of the glass column is coated with ice to minimize adsorption on the container surface. The organic vapor is introduced into the column by means of a gas switching valve, and the signal of the flame ionization detector is logged on a computer by means of an external data acquisition module. Figure 1A gives examples of breakthrough curves (BTC) obtained with this method. The areas under the transformed BTCs, shown in Figure 1B, are proportional to the elution volumes, i.e. the volume of carrier gas required to elute the organic vapor from the snow column. Elution volumes were calculated from both (adsorption and desorption) limbs of the BTCs for three BTCs obtained at each measurement time. The coefficient of variation for the elution volumes was about 3%. The elution volumes decrease with time. The volume that is due to adsorption of ethyl acetate on the snow surface was obtained by correcting the elution volume for the pore space volume in the snow column. It was found that adsorption on the container surface was minimal and could be ignored. The SSA was obtained by dividing the volume of ethyl acetate vapor adsorbed per gram of snow by an estimated value of K_{ia} for ethyl acetate (0.027 cm). The K_{ia} value for 25°C (Hoff *et al.* 1993), was adjusted for temperature using eq. 13 from Hoff *et al.* (1995) and assuming that the enthalpy of adsorption is equal to that for partitioning between air and water (Kiekbusch and King 1979).

Figure 2 shows the decrease in SSA with time for two freshly precipitated snow samples aged at –4°C. The initial SSAs are near the low end of the range of values determined for fresh snow using the nitrogen adsorption technique (0.05 to 0.5 m^2/g). These data were fit to an empirical model proposed by Jellinek and Ibrahim (1967) for quantifying the rate of SSA decrease for artificial ice powders. A half-life τ of 46 h was obtained for the SSA

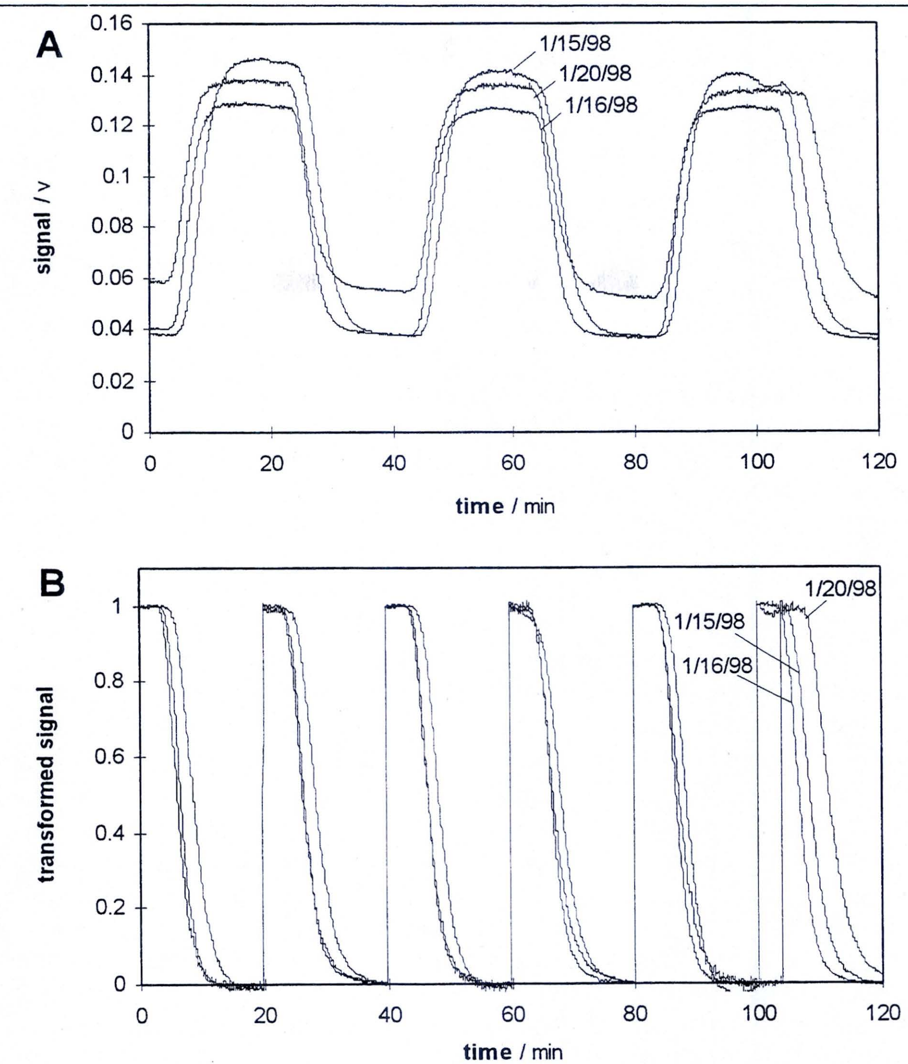

Figure 1. Frontal chromatography breakthrough curves (BTCs) for a sample of fresh snow held at –4°C for 0, 21 and 112 hours. The BTCs were measured at –1°C. The lower figure shows the transformed BTCs, from which the elution volumes were calculated.

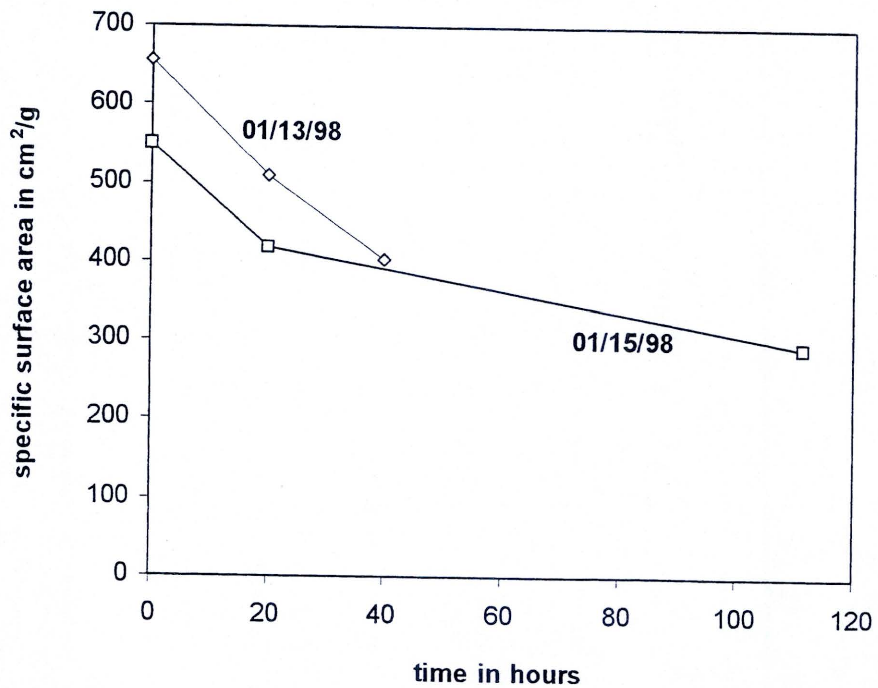

Figure 2. Decrease in specific snow surface area with time for two freshly precipitated snow samples aged at –4°C measured with a frontal chromatographic method.

of fresh snow. This is consistent with Wania's (1997) assumption that the SSA of snow decreases by a factor of 10 during the first 10 days of settling at –5°C, which translates to a τ value of 33 h. Jellinek and Ibrahim obtained much smaller (values for artificial ice powder produced by spraying a mist of water into liquid nitrogen. Their (values ranged from 0.5 h at –8°C to 50 h at –30°C. The initial SSA of the ice powder was very large, 5 to 12 m^2/g. The particle size (equivalent spherical diameter) of the ice powder is approximately a hundredth that for the snow crystals. Keyser and Leu (1993) studied similar ice powder produced by condensing water vapor into liquid nitrogen. Their ice powder had a SSA in the order of 10^2 m^2/g. Such large SSA can only be due to internal porosity. One would expect the half-life for SSA to depend on particle size and geometry. One would therefore expect the half-life for snow to be considerably larger than that for such an artificial ice powder produced at liquid nitrogen temperature, and this is consistent with our observations. These are the first measurements of the rate of decrease of SSA for natural snow, to our knowledge. They are of crucial importance for modelling the behavior of contaminants in snow packs, and they may also be useful for modelling slope stability, heat conduction and other important snow pack properties.

In late February, the well-ripened snow pack at Bow Lake, near Lake Louise, Alberta was sampled by Jules Blais and Derek Muir and sent to Waterloo by air freight in a large cooler which contained a block of dry ice. Upon receipt the cooler was kept in a walk-in freezer at –10°C, until the SSAs were determined by the frontal chromatography method described above. Because the snow was already metamorphosed, artifacts from shipping and storage were not expected to be large. The SSA values obtained for the open and forested Bow Lake sampling sites are 0.0104 and 0.0089 m^2/g, respectively. Although there is uncertainty in these values arising from the K_{ia} value used to calculate SSA, they are thought to be reasonable for snow which has been subjected to low temperature gradient metamorphism. Scanning electron microscope images for this type of snow (Wergin *et al.* 1996) show that the sharp angles characterizing the crystalline features of the snow crystals are lost, and the snow grains are appreciably sintered.

Modelling organic contaminant fate in snow pack

When reporting the concentrations of several organochlorine chemicals in the water of a small creek during the short but intense snow melting period in the Amituk Lake region, Semkin (1996) suggested that "because the ground was still frozen at the onset of snowmelt and the infiltration of meltwater into the subsurface appeared to be negligible, the initial water flowing in the stream channels reflected the physico-chemical processes operate in the ablating snow pack". The relatively water-soluble pesticides α– and γ-HCH and endosulfan showed a profile with high concentrations in the initial meltwater and steadily decreasing levels afterwards. Neither PCBs nor DDT showed this behaviour (Figure 4).

Table 1. Conditions for the model simulation of melt water concentrations in Gorge Creek, Cornwallis Island in June 1993.

length of snow ageing	30 days (Julian day 170 to 200)
snow pack temperature	assumed constant at 0 °C
melt water loss	determined by recorded instantaneous water flow as described in Fig. 4, normalized to an initial SWE of 0.204 m^2/m^3
snow depth	decreasing from 0.47 m to 0 m at a rate determined by melt water loss
snow gravity	constant at 0.433 g/m^3
snow surface area	constant at 0.1 or 0.5 m^2/g
particle content	initially 0.1 mg/L, constant mass throughout melting
MTC air boundary layer	5 m/h
snow pack burden at start	141.3 ng/m^2 α-HCH, 52.2 ng/m^2 γ-HCH, 39.6 ng/m^2 Endosulfan, 4.6 ng/m^2 DDT, and 128.6 ng/m^2 PCBs

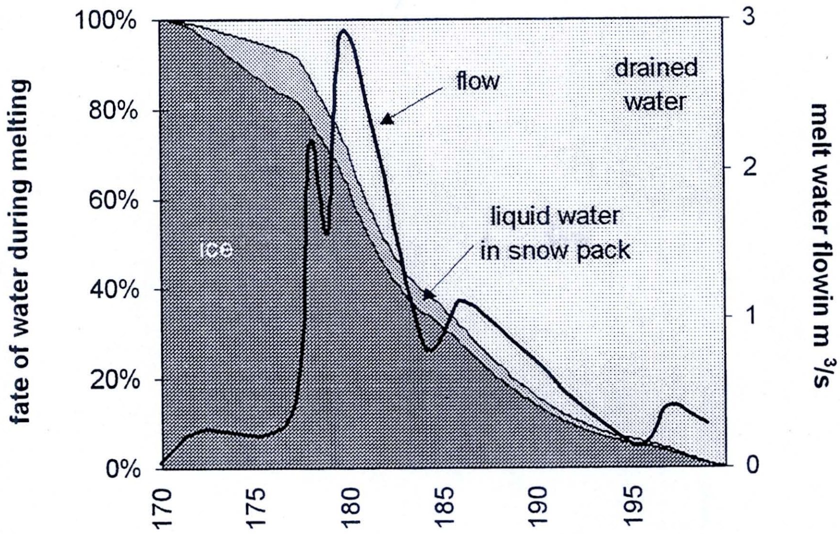

Figure 3. Assumed fate of the water originally present in the snow pack (i.e. fraction of water which is present as ice or liquid water within the snow pack, or which has been drained away at any point in time). The instantaneous flow was determined in the field (Semkin 1996).

The one layer snow pack model (Wania 1997) was employed to simulate the time course of melt water concentrations. Table 1 lists the simulation conditions, and Figure 3 shows the input parameters describing the water balance of the snow pack during melting. Snow surface area was assumed to be either 0.1 or 0.5 m^2/g. The reported average snow pack burden in the Amituk Lake area in ng/m^2 in June 1993 (Table 3.12 in Barrie *et al.* 1997) was used as a starting condition. Three alternative methods were employed to estimate the interfacial partition coefficients K_{ia}.

A: estimation of K_{ia} and its temperature dependence according to Hoff *et al.* (1993).

B: K_{ia} according to Valsaraj *et al.* (1993), temperature dependence according to Hoff *et al.* (1993).

C: K_{ia} and temperature dependence according to Goss (1994).

The results shown in Figure 4 are very dependent on the choice of K_{ia} estimation method. Not one method gives results for all five chemicals, which agree well with the observations. Rather, method A gave best agreement with the measurements for α- and γ-HCH, method C gave result closest to observations for endosulfan, and method B performed best for DDT and PCBs. The calculation also reveals the immense influence of specific snow surface area. For example, a five-fold decrease in the selected surface area results in a doubling of the calculated initial melt water concentrations of α- and γ-HCH.

The calculations did not indicate the existence of a threshold value for K_{ia} below which a chemical would preferentially elute with the first melt water fractions. Endosulfan with a ln K_{ia} of –5.2 (method C) shows first flush behaviour, whereas PCB-52 with a ln K_{ia} of –3.2 (method B) does not. The difference between the two chemicals is that despite their similar solubilities in water, endosulfan has a much smaller octanol-water partition coefficient. Obviously, log K_{OW} and ln K_{ia} control jointly whether a chemical is retained in the snow pack upon melting by being sorbed to the remaining ice surfaces and to particles.

Modelling the scavenging of organic contaminants by snow

A model of snow scavenging with temperature and sub-cooled liquid vapor pressure as the main determinants predicted gaseous scavenging ratios W_g which range from 10^3 to 10^6 for the relevant contaminants and conditions (Hoff *et al.* 1997). An analysis of mass transfer rates suggests that equilibrium is reached during falling except for large (1 cm diameter) snow flakes, which are not typical in the high Arctic. It was concluded that deposition by falling snow is probably the main atmospheric removal mechanism in the Arctic terrestrial environment.

In a preliminary analysis of snow scavenging ratios W_T in Tagish and Alert, the measured ratios agree reasonably well with the predicted ones (Figure 5). W_T was calculated as the weighted average of W_g and W_p, where W_p was assumed to be $4 \cdot 10^5$. The fact that the measured W_Ts are generally smaller may be due to the fat that (1) the snow collector did not adequately preserve the snow samples, and/or (2) the calculated W_Ts are based on the assumption that snow falls

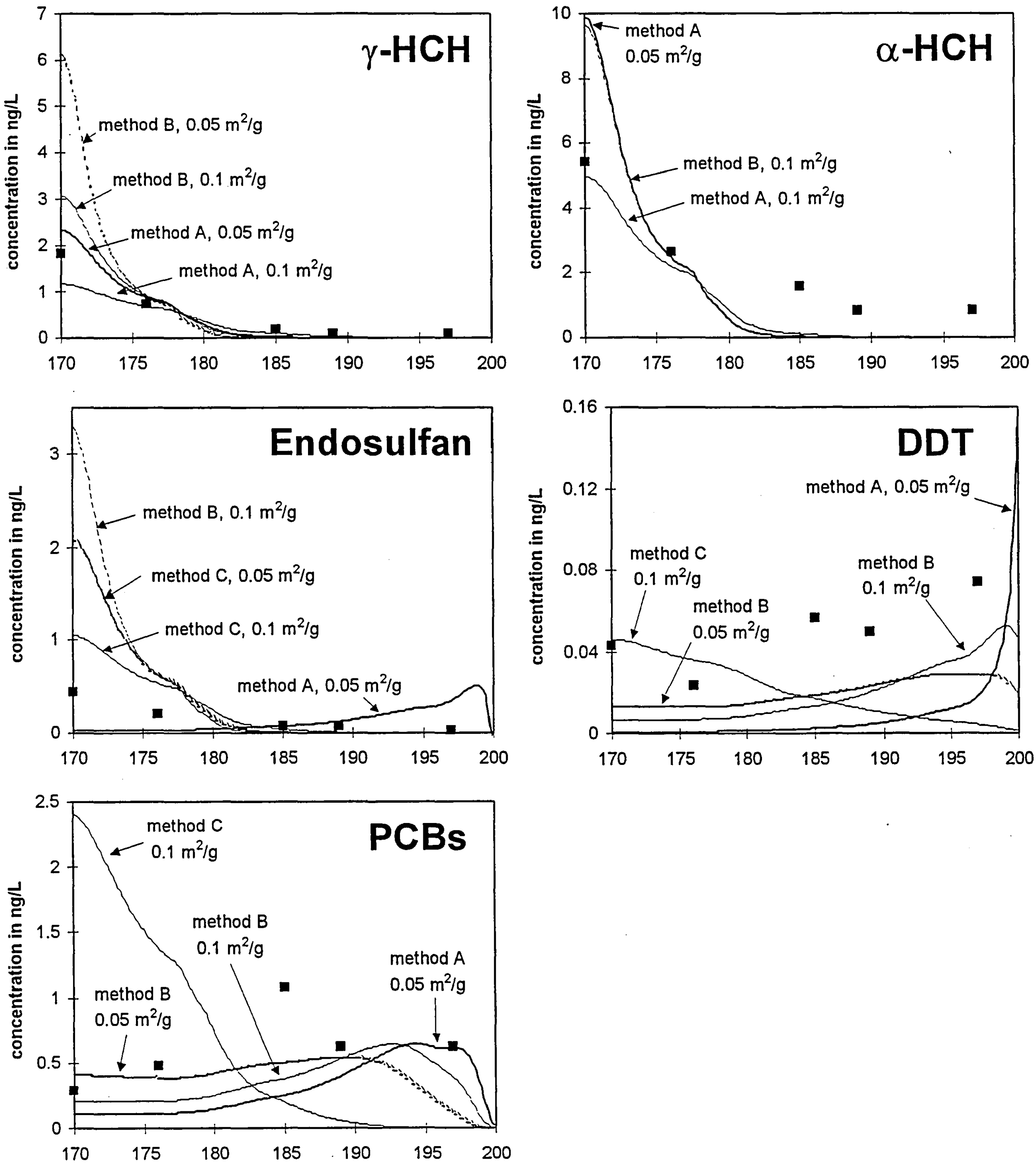

Figure 4. Measured and simulated concentrations of several organochlorine chemicals in water from Gorge Creek during the snow melt period 1993 on Cornwallis Island, Canadian Arctic.

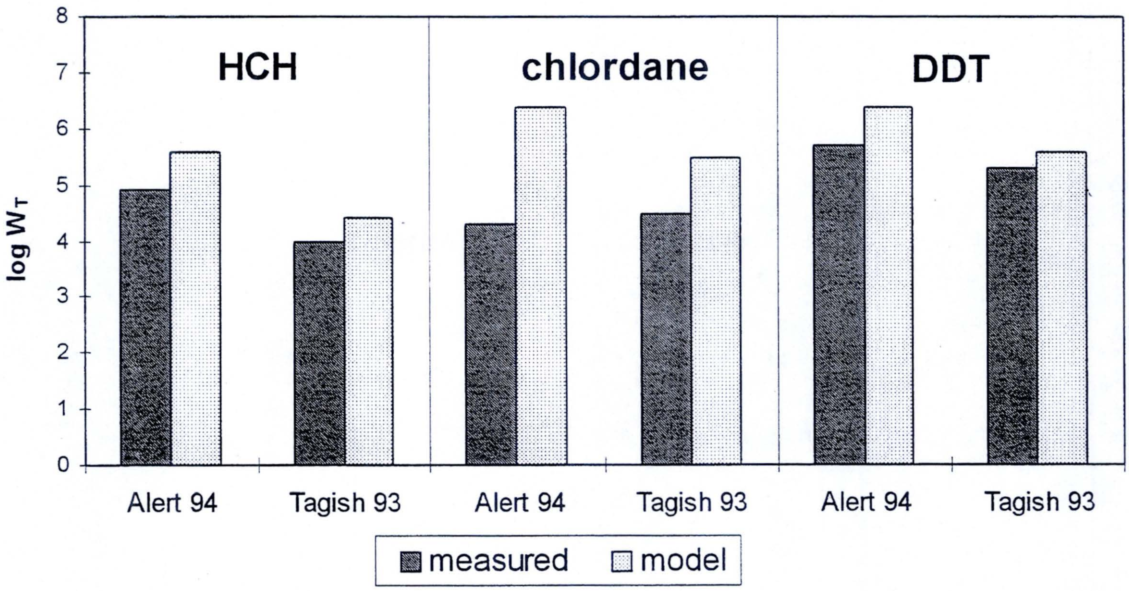

Figure 5. Measured and modelled total snow scavenging ratios for three organochlorine pesticides in Tagish, Y.T. and Alert, N.W.T.

continuously rather than sporadically. The calculations indicate that atmospheric concentrations can be significantly depleted during discrete snow fall events. Carefully designed field experiments are thus required to test scavenging hypotheses.

DISCUSSION/CONCLUSIONS

The available evidence is compelling that snow is a major vector for the transport of organic contaminants between the lower troposphere and the ground. It is clear that snow is more effective in scavenging airborne non-polar organic substances than rain. Adsorption to the ice surface is a major mechanism of scavenging organic vapors. The specific surface area of ice crystals and the air-ice partition coefficient are the two key parameters in this process. Snow is also an efficient scavenger of aerosols and thus aerosol-bound organic compounds. Snow pack metamorphosis is expected to play a key role in determining the post-depositional behaviour of non-polar organic substances.

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INTRODUCTION TO PROPOSED FORMAT FOR THE DEVELOPMENT OF ENVIRONMENTAL SAMPLING PROTOCOLS FOR THE NORTHERN CONTAMINANTS PROGRAMS

Project Leader: W. Hu, JP Ztech Company, March, 1998

INTRODUCTION

In the past several years, activities of the Northern Contaminant Program's QA/QC program have been largely limited to the performance of laboratory analysis. Although the importance of accurate and representative sampling was recognized in the past, a quality assurance program for sampling procedures was not pursued due to constraint in resources and the timing. As the result, sampling quality, and hence the overall data quality, of the NCP measurement data can not be adequately assessed.

Accurate and representative sampling is important to achieve high quality data. It is important to take actions on quality assurance measures for sampling procedures while maintaining a good QA/QC program for the laboratory analysis. Only then will the overall data quality be assured.

In a discussion paper prepared by Dr. Jiping Zhu for the Department of Indian Affairs and Northern Development and distributed at the NCP Annual Workshop 1996/97 in Victoria, B.C., we proposed the concept of developing an "NCP Manual for Sample Collection and Handling" that would include each sampling protocol employed within the scope of the NCP.

Sampling protocols are written descriptions of the detailed procedures to be followed in the collection, packaging, labelling, preservation, transport, storage and documentation of the samples. A sampling protocol serves two purposes: It provides a written instruction to be followed during sampling, and it keeps the information on the history of a sample upon which analytical data are generated. However, sampling procedures are only briefly mentioned in the published scientific papers without sufficient information for evaluation on the quality of the sampling process.

The proposed Manual will ensure that details of sampling procedures are clearly written for each project, and any deviations from the sampling protocols are properly documented. Sufficient information in the Manual will be available for the interpretation of the data generated for the NCP.

The matrices of environmental samples studied within the scope of NCP can be categorized into six major groups. They are (1) air samples, (2) water samples including surface water, deep water, and precipitation, (3) solid samples including sediments, soil and solid wastes, (4) botanical samples including land plants and underwater plants, (5) biological samples such as fish, land animals and marine mammals, and (6) samples from humans such as blood, breast milk and urine. Each group requires specific methods to collect and handle the samples.

Developing sampling methods specific to a given matrix requires extensive knowledge and experience of the individuals who are working in that particular area. It is the responsibility of these individuals to develop and implement protocols for environmental samples. The following proposed format for an Environmental Sampling Protocol is intended to help researchers and scientists develop the protocols in a format so that the protocols can be integrated into the NCP Manual. By working with the individuals who are conducting research project for the NCP, we hope to produce a sampling manual that is specific to the NCP can eventually be published as a supplementary documents to the final results of NCP.

PROPOSED FORMAT FOR THE DEVELOPMENT OF ENVIRONMENTAL SAMPLING PROTOCOLS FOR THE NORTHERN CONTAMINANTS PROGRAMS

1. Title of the sampling method

The title should reflect the *subject* (for example, sediments), *source* (river bed), and *target analyte* (PAHs).

2. Authors

Name and affiliation of the person(s) preparing the sampling method should be listed.

3. Key Words

Six words that best describing the sampling method should be selected for index purpose.

4. Application of the method

Each project funded by NCP has a project number as well as a project title. The title(s) and project number(s) for which the method applies should be provided in this section. This will provide the link between analytical data and the sampling method for the users, and hence will enable the users of the analytical data to judge the sample quality of a particular project.

5. Summary of the sampling method

Summary of the method provides a quick understanding of the method in sample collection, transportation and storage. Summary should be limited to within 300 words.

6. Sampling objective(s)

Sampling objective is governed by the project objective, which has been defined in the project proposal submitted for NCP funding. Once the project objective is defined, the sampling objective(s) should include: (1) type of the sampling project and (2) (data quality objective (DQO)).

Sampling type can be divided into exploratory (surveillance) or monitoring (assessment) sampling. Exploratory sampling is designed to provide preliminary information about the site or materials being analysed. This will determine the extent of contamination and help define the scope for the monitoring project. Monitoring sampling, on the other hand, is intended to provide more quantitative information on the variation in concentrations of a specific analyte or a set of analytes over a particular period of time or within a specific geographic area. DQO is the statement that defines the confidence required in drawing conclusions from the entire project data. It certainly depends on whether it is an exploratory or assessment project. The DQO determines the degree of total variability (uncertainties), and hence the sampling variability, that can be tolerated in the data. Furthermore, sampling frequency and sample numbers have to be consistent with the DQO.

7. Equipment

Describe all the instruments, tools, sampling devices, containers, reagents and shipping devices to be used during sample collection, transport and storage. If possible, list the models, sizes and vendors of all the equipment used.

Describe clearly the specifications such as detection limit, working capacity and accuracy of all the field instruments and tools such as such as flow meters, thermometers, samplers and pumps. These information are very important for the data end users to understand the quality of the samples.

8. Sampling procedures

Sample procedure should be written in such a way that it can be understood by field worker(s) and by the data end user(s). It includes, but is not limited to, the following aspects.

8.1 Preparation prior to sampling

Describe the preparation work of the sampling such as cleaning of equipment/tools and sample containers, and visit to the sampling site(s) including communication with local people if they are involved in the sampling. Any precautions needed for accurate and representative samples.

8.2 Sample Collection

Detailed procedures should be available in a clear, easy to follow format such as 8.2.1, 8.2.2, 8.2.3 *etc.* so that samples can be collected according the procedures with minimum deviation from the protocol.

8.3 Sample Handling in the Field

Describe sample handling procedures that are necessary in the field to preserve the samples, especially when collecting biological samples.

8.4 Transport of Samples to the Laboratory

Clearly indicate how to pack the samples carefully so they will not be broken during the transport, and required temperature during transport if samples have to be transported in a frozen status.

8.5 Sample Handling in the Laboratory

Describe the storage conditions for samples once they arrive in the laboratory. The samples should be kept in such a way that sample integrity is guaranteed until analysis. Procedures for sub-sampling in the laboratory may be needed if samples have to be sub-sampled before storage.

9. Quality assurance and quality control

Sampling protocols should contain written instructions for all sampling activities including observations at the sampling site, and field documentation of sampling techniques. In addition, the protocol should have the following aspects:

(a) Sampling protocols should have a statistically approved design so that collected samples are representative of the population or matrix being studied.

(b) Information on the qualifications of the field workers should be provided. The training may be provided to the field workers.

(c) Documentation of any procedures deviated from written protocols should be documented so that sample quality can be evaluated.

(d) Natural variation should be considered when estimate sample quality based on the following factors:
- Seasonal impact (winter, summer, weekend)
- Sampling time (high traffic time, daytime, night time)
- Site conditions (sun, wind, temperature, humidity, upstream, downstream)
- Biological variation (age, size, sex, health, behaviour)
- Sample homogeneity.

(e) Sampling variation due to limitations of the sampling techniques such as variation in equipment and its impact on sampling quality should also be estimated to evaluate the overall sample quality.

(f) Use of quality control samples can effectively assess the sample quality. Quality samples include blanks, replicates, and spiked samples. There are many types of quality control samples used in the field. A definition and use of various quality control samples are attached at the end of the proposed format.

(g) If possible sampling procedures should be tested against either through round robin programs or using a different sampling technique. Round robin samples are collected at the same site from the same matrix at the same time by using similar sampling techniques. All round robin samples may be analysed in a single laboratory or analysed in several laboratories. Depending on the number of participants, the mean values of the round robin may not be the reflection of the true values.

However, such results will at least provide information on the relative accuracy of the described sampling method compared to others with similar sampling methods. If the described sampling method has been tested in round robins, the results of the round robin and reference for more detailed information should be made available.

(h) If the described sampling procedure has been compared with a different sampling technique (for example, a different sample collection equipment). The results of such comparison and reference for more detailed information should be made available too.

10. Safety Measurement

Safety measures must always be considered in the development of any sampling plan. The safety issue is particularly important when sampling in a remote area or under harsh Arctic environment. Safety of field personnel is always the number one priority.

APPENDIX I: QUALITY CONTROL SAMPLES USED IN THE FIELD:

1. **Blanks:** defined as matrices that have negligible or unmeasurable amount of the substance of interest. Blanks commonly used for environmental sampling are field blank, trip blank, equipment blank and material blank.

- Field blank: samples of analyte-free media similar to the sample matrix. They are prepared in the laboratory, carried to the site and exposed to the sampling environmental at the site, and shipped back to the laboratory. Field blanks are used to measure incidental or accidental sample contamination during the whole sampling process.
- Trip blank (or transport blank): samples of analyte-free media taken from the laboratory to the sampling site and returned to the laboratory unopened. They are used to measure cross-contamination from the container and preservative during transport, field handling, and storage.
- Equipment blank (or rinsate blank): samples of analyte-free media that have been used to rinse the sampling equipment. They are used to measure contamination from use of equipment.
- Material blank: samples of construction materials such as pipes, pumps. They are used to measure contamination from use of these materials.

2. **Replicates:** duplicates; samples collected at the same site from the same matrix at the same time using the same sampling technique. Replicate samples provide information to assess the precision of a given sampling procedure.

3. **Spikes:** samples of the similar analyte-free media spiked with known amount of substance of interest. They are prepared in the laboratory and treated the same way as field blanks. Spiked samples are used to measure the sample integrity (stability of analyte, recoveries) during whole sampling process. It can also be used to assess the accuracy of a given sampling procedure.

GLOBAL EMISSIONS INVENTORIES: GLOBAL HEXACHLOROCYCLOHEXANE USE TRENDS AND THEIR IMPACT ON THE ARCTIC ATMOSPHERIC ENVIRONMENT

Project Leader: Y.-F. Li, Modelling & Integration Research Division, Atmospheric Environment Services (ARQI), Environment Canada

Project Team: T.F. Bidleman, and L. Barrie, Atmospheric Environment Services, Environment Canada

OBJECTIVES

1. to determine the sources of persistent organochlorine pesticide contaminants in the Arctic.
2. to increase the effectiveness of Canada's efforts in building global emissions inventories by integrating our work with that of the international community.
3. to contribute to the Northern Contaminants Program, the United Nations Economic Council of Europe's Task Force on Persistent Organic Pollutants and Heavy Metals; the UN ECE Expert Panel on Emissions; the Global Emissions Inventory Activity (GEIA) of the International Geosphere/Biosphere Program, and the United Nations Environment Programme (UNEP).

DESCRIPTION

Hexachlorocyclohexane (HCH) is an organochlorine insecticide that is available in two formulations: technical HCH which is dominated by the α-HCH and γ-HCH with traces of β-, δ-, and ε-HCH (Metcalf 1955) and lindane (> 90% γ-HCH). Because of low cost and high effectiveness, HCH was one of the most widely used insecticides in the world.

HCH compounds volatilize soon after application in source regions (Glotfelty *et al.* 1984), and migrate through the atmosphere to the polar regions (Gregor and Gummer 1989). Since the low Henry's law constants of HCHs favour partitioning from air into water (Kucklick *et al.* 1991), especially at low temperatures, HCHs condense into the lakes and oceans of northern ecosystems (McConnell *et al.* 1993, Hinckley *et al.* 1991). This is sometimes referred to as the "cold condensation" phenomenon (Wania, and Mackay 1993 1996). In fact, HCHs have been found to be the most abundant organic compounds in the arctic atmosphere and surface waters (Iwata *et al.* 1993, Hargrave *et al.* 1988, Bidleman *et al.* 1995). A compilation of measurements made between 1979–93 from stations in the Canadian and Norwegian arctic and from cruises in the Bering and Chukchi seas indicates that atmospheric concentrations of α-HCH have declined significantly (Bidleman *et al.* 1995, Jantunen and Bidleman 1995 1996). This decline was not linear but rather occurred in steps, decreasing after 1982 and again between 1990 and 1992. This work summarizes global usage of α-HCH from 1979 to 1994, and compares the usage trends with concentration of α-HCH in arctic air during the same time period. This will be helpful for us to understand the relationship between the global HCH use and the contamination by this insecticide in the Arctic. The work presented here was published, and most parts of this work are from this publication (Li *et al.* 1998a).

ACTIVITIES IN 1996/97

The following activities were undertaken in the past year:

1. A global HCH/Lindane usage database with 1° X 1° lat./long resolution for 1980 and 1990 without any interpolation has been compiled and the result was published (Li *et al.* 1996).
2. A number of fruitful collaborations with a host of scientists and agencies worldwide continued. In 1996/1997 Atmospheric Environment Service of Environment Canada and the Nanjing Institute of Environmental Science (NIES), one of three research institutes directly under the National Environmental Protection Agency of China, jointly implemented a project "the history, present, and future of the organochlorine pesticides use in China" with partial funding from UNEP. This is a successful practice, and some results of that work were either published (Li *et al.* 1998b) or submitted (Li *et al.* 1998c).

RESULTS

Global Usage of Technical HCH

Many countries, especially developed countries, banned technical HCH usage in 1970s (Voldner and Li 1995). In 1979 there were around 70 countries still using technical HCH, but half of these countries banned the product between 1979 to 1992 (Voldner and Li 1995). Since 1979 China, India and the former Soviet Union have been the top technical HCH consuming countries. In 1980, the annual consumption of technical HCH in these three countries accounted for more than 90% of the total technical HCH usage in the world.

China was the largest producer and user of technical HCH from the 1970s until April 1 1983, when China banned both production and usage of technical HCH (Chinese Ministry of Agriculture 1989). The total amount of technical HCH produced from 1952 to 1983 in China was around 4.5 million tonnes (Li *et al.* 1998b).

India is another country with large technical HCH consumption in both the agriculture and public health sectors. Maximum annual usage reached 57,000 t in the latter 1980s. On October 30,1990 the government of India banned technical HCH usage on vegetable, fruit, and oilseed crops and for preservation of grains, but continued to allow its use for public health protection (Parmar 1993) and on certain food crops (David *et al.* 1992) at around 20,000t annually. It was reported that the India Government has taken a decision to phase out a production of 30,000 tonnes of HCH per annum (Sugavanam and Kim 1996).

In the former Soviet Union, technical HCH was one of the most widely used insecticides from 1940s to 1980s (Kundiev and Kagan 1993). The most extended areas of the arable lands on the territory of the former Soviet Union were in Russia and Ukraine. The use of technical HCH was banned at the end of the 1980s for the major agricultural crops, however, use of remaining stockpiles was allowed even after 1991. (Kundiev *et al.* 1993).

Estimated technical HCH productions/usage for China, India and the former Soviet Union from 1979 to 1994 are depicted in Figure 1. The graph illustrates the heavy HCH usage in China compared with India and the former Soviet Union if assuming that the main part of technical HCH produced each year in China was used in the same year.

The Impact of Global HCH Usage on the Arctic Atmosphere

As α-HCH is the dominant isomer in the formulation of technical HCH, tracking the atmospheric concentration of this compound should directly reflect current use rates. In Figure 2, global use rates of technical HCH can be compared with historical measurements of α-HCH concentration (from June to November) in the atmosphere of arctic regions (Bidleman *et al.* 1995, Jantunen and Bidleman 1995 1996, Patton *et al.* 1989, Hargrave *et al.* 1988, Falconer *et al.* 1995, Oehme & Ottar 1984, Pacyna & Oehme 1988, Oehme 1991, Oehme *et al.* 1995, Tanabe & Tatsukawa 1980, Hinckley *et al.* 1991, Iwata *et al.* 1993). These air concentration data were measured from different stations in different years by several research groups. The variability for these data can be found in (Bidleman *et al.* 1995).

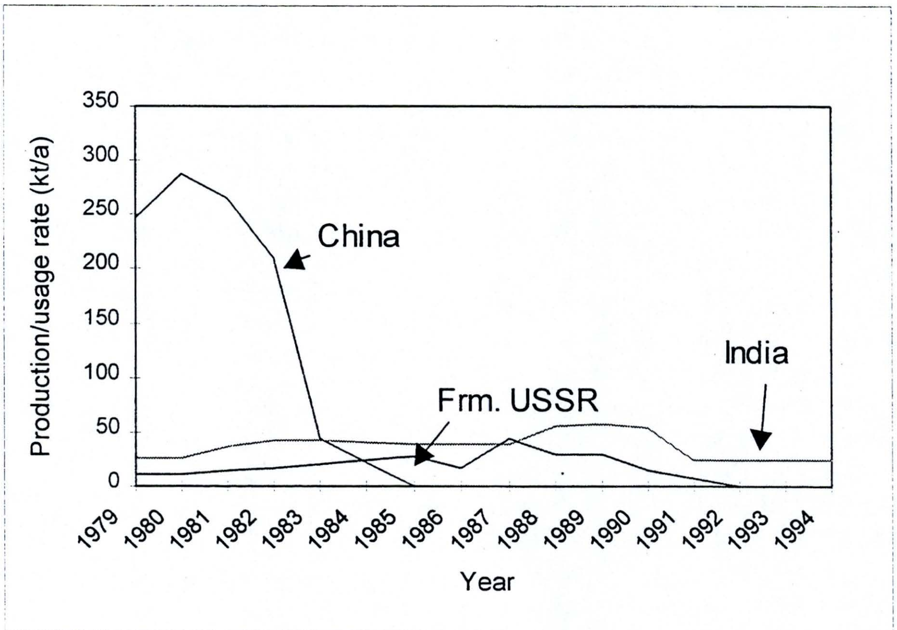

Figure 1. Technical HCH production for China, and usage for India, and the former Soviet Union from 1979 to 1994.

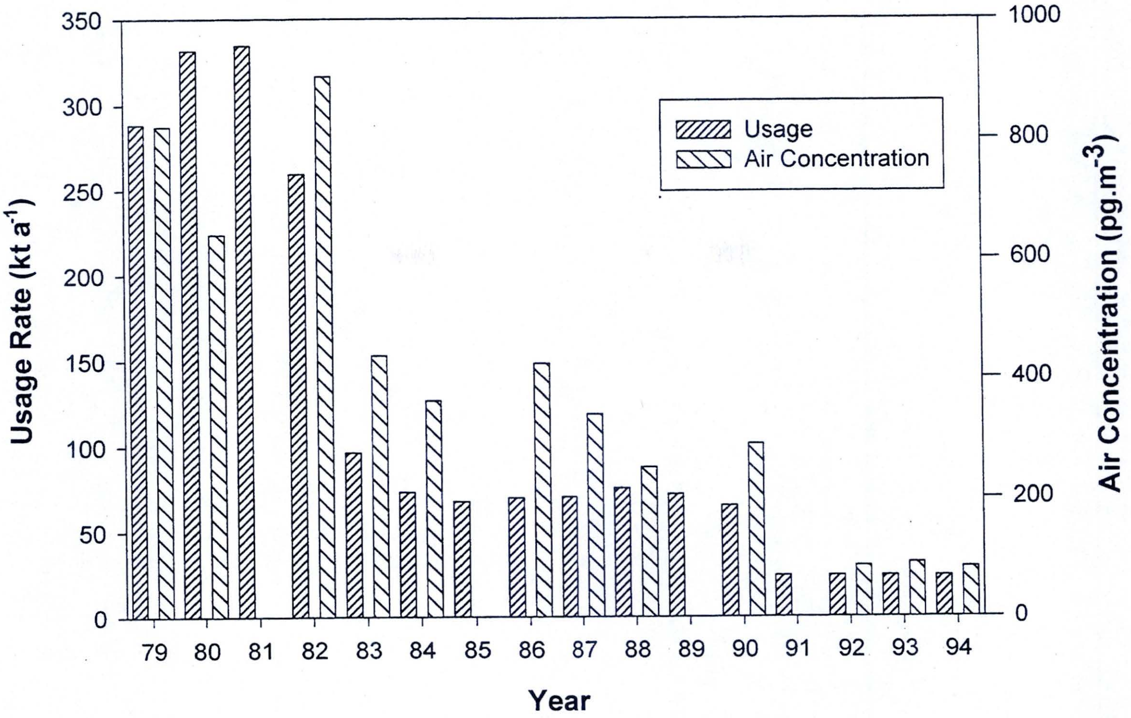

Figure 2. Long-term trends of global technical HCH usage and mean air concentrations of α-HCH in the arctic regions from 1979 to 1994.

Two significant drops of global technical HCH usage are identified in Figure 2. One started in 1983 when China banned the use of technical HCH, and another occurred around 1990 when India banned technical HCH usage in agriculture and the former Soviet Union banned the usage of technical HCH. Air concentrations of α-HCH appear to respond within a few years to changes of usage. The long-term trends also show two significant decreases, one between 1982 and 1983, and another between 1990 and 1992. The consistency between global technical HCH usage and air concentrations of α-HCH in arctic regions illustrates a relationship between usage and air concentrations on a global level.

DISCUSSION/CONCLUSIONS

The net direction of the air-sea gas flux is controlled by the dissolved and gaseous HCH concentrations in water and air, the Henry's law constant, and the air temperature. The drop in atmospheric α-HCH concentrations since 1991 in arctic regions has actually caused a shift in the direction of the airwater flux of α-HCH from deposition to volatilization (Jantunen and Bidleman 1995, Bidleman *et al.* 1995). Up until 1991, measurements of HCH airwater flux in the arctic as well as in other large, cold water bodies such as the Great Lakes and Lake Baikal, Russia resulted in an air-to-water flux direction for both α- and γ-HCH except for the warmest months of the year (Bidleman and McConnell 1995).

Atmospheric concentrations of α-HCH seem to be responding rapidly to reductions in global use rates. A continuation in the trend in declining air concentrations is expected as more and more countries phase out the use of this compound. However, as the air α-HCH concentration drops, the net direction of air-sea gas flux has been reversed since α-HCH concentrations in the arctic waters have remained relatively unchanged. Thus, soils and surface waters containing HCH will be a diffuse, nonpoint source to the atmosphere that will likely maintain detectable atmospheric concentrations for some time in the future.

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PAH CONCENTRATIONS AND DISTRIBUTIONS IN THE ARCTIC OCEAN

Project Leaders: R.W. Macdonald (IOS, Sidney, BC); W.L. Lockhart (FWI, Winnipeg, MB)

Project Team: M.B. Yunker, F.A. McLaughlin, B. Billeck, L.R. Snowdon, J.N. Smith, G. Ilyin.

OBJECTIVES

1. Establish the sources of PAHs in the basins by comparing the PAH profiles of shelf sediments and using multivariate statistical models to look for similarities.
2. Use the PAH pattern distributions to infer contaminant transport pathways and mechanisms within the Arctic Ocean.
3. Assess the relative contributions of natural *vs.* anthropogenic PAH sources.
4. Determine what risks PAHs pose in the Arctic marine environment.

DESCRIPTION

PAHs can induce biological effects, including tumors (cf. Yunker and Macdonald 1995). PAHs are also good tracers in that PAH patterns have the potential to provide definitive evidence of sediment transport pathways linking sources to sinks (areas of contaminant accumulation). Pathways, illuminated by the PAH patterns, will also be valid for other particle-reactive contaminants including radionuclides, some metals, and many of the higher molecular weight organochlorines such as PCBs. In this project it is intended to integrate two large data/sample sets assembled by IOS and FWI and thence to apply statistical multivariate techniques to examine sediment concentrations, sources, pathways and sinks for PAH (and related hydrocarbon biomarkers) for the Arctic Ocean.

ACTIVITIES IN 1997/98

The work was initiated after mid-year funding was approved (Sept. 1997). Samples have been collated and examined carefully for discrepancies. Multivariate statistical techniques have also been applied to aid in the process of sorting samples and compound groups.

RESULTS

Sample Suite

Samples collected under the NCP and other programs include sediment cores from AOS-94 (the Arctic Ocean Section), sediment cores from the Chukchi, East Siberian and Beaufort Seas (Larsen-93 and earlier NOGAP work), surface samples from the Laptev and outer Barents Seas (Polarstern Arctic-93), sediment cores from the Barents Sea (Geolog Fersman-92; see Figure 1). These samples have been taken from important source areas (Eurasian and North American shelves) and important depositional areas (ocean basins and the Canadian Archipelago).

Samples Analysed

PAH analyses for the samples collected under the NCP have been conducted principally by two laboratories (Axys Analytical Laboratory (Axys) and Freshwater Institute (FWI)). Axys has determined concentrations of parent (unsubstituted) and alkyl-substituted PAHs for 67 samples of suspended particulate matter and sediment box-core sections and 15 samples of ice, snow melt and seawater for samples from the 1993 and 1994 icebreaker cruises to the Arctic Ocean. n-Alkanes and hopane triterpanes (biomarkers of petroleum) have also been measured for most of the sediment samples. These samples build on PAH and alkane concentration data from the Beaufort and Barents Seas; to date the distributions of PAHs, alkanes and hopanes in arctic sediments have been comprehensively interpreted on a limited set of samples and published in the open literature (Yunker and Macdonald 1995, Yunker *et al.* 1991, 1993, 1994, 1995, 1996).

FWI has determined parent PAH concentrations and some alkylated PAHs in 28 samples of sediment from the Laptev and outer Barents Seas and two from off Axel Heiberg Island and have analysed all of the atmospheric samples from the Arctic air monitoring stations at Alert, Cape Dorsett, Tagish and Dunai. Results of the air monitoring program are in press (Halsall *et al.* 1997).

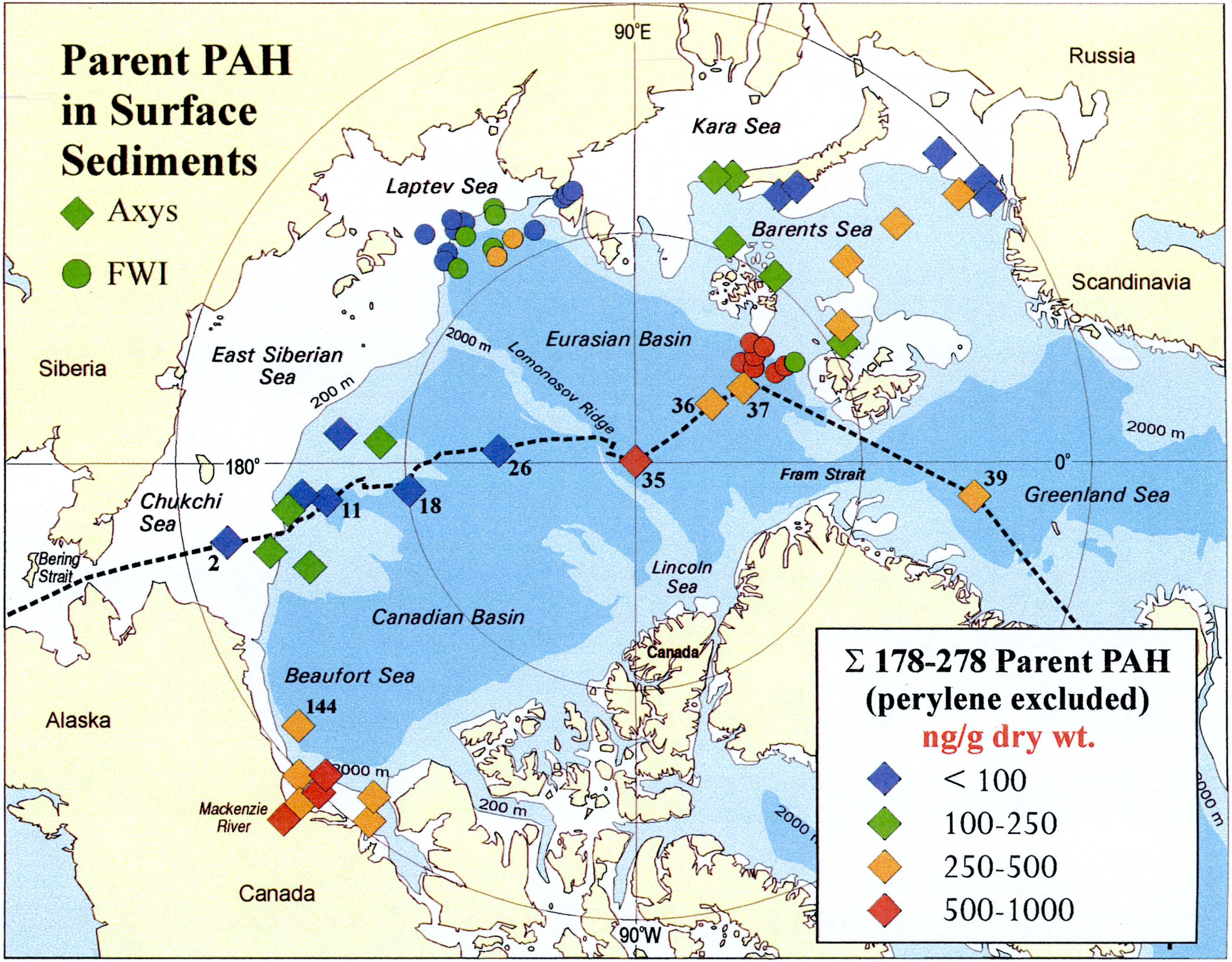

Figure 1. Sampling locations with Σ178-278 parent PAH concentrations in selected surface core sections.

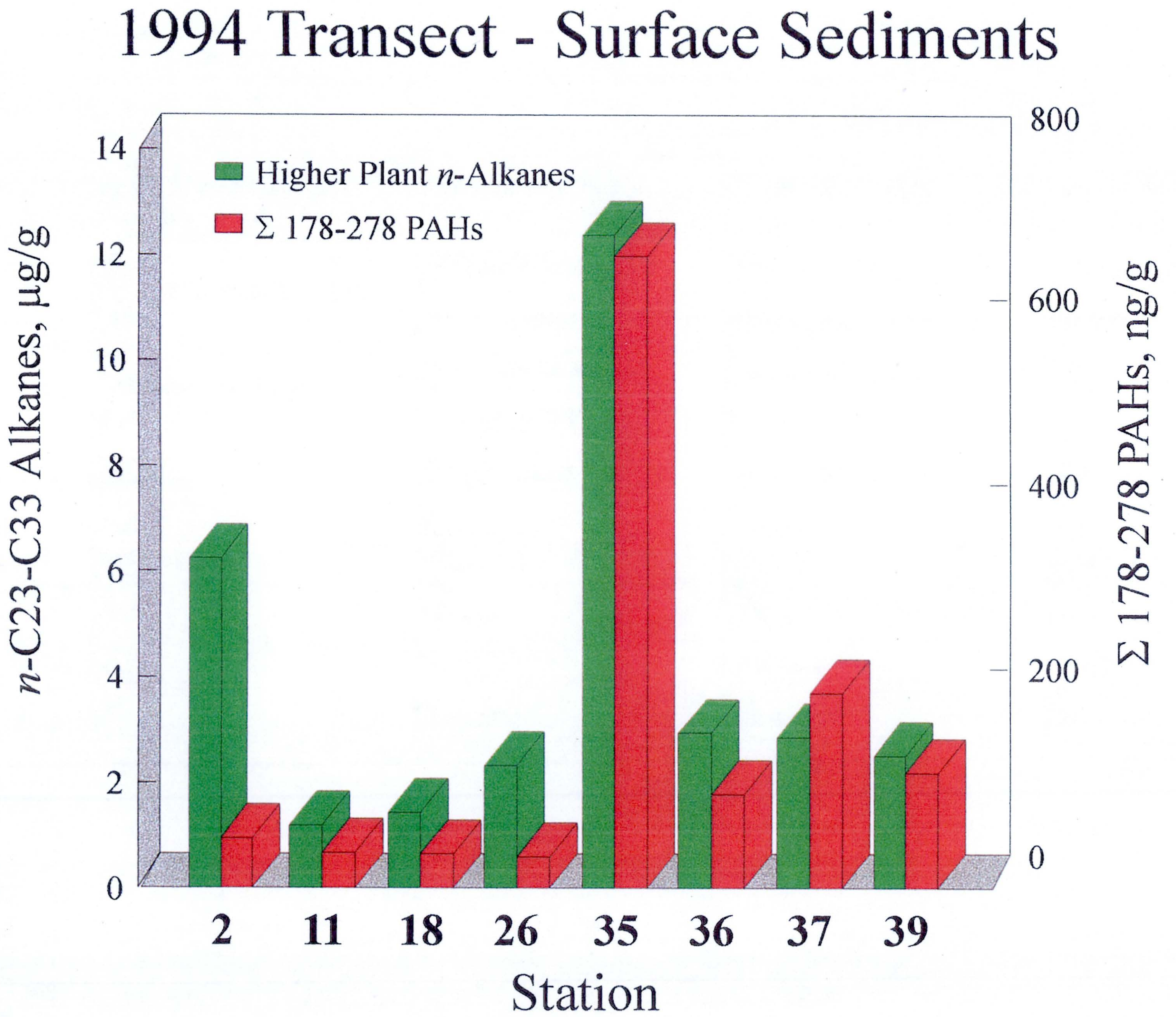

Figure 2. Surface concentrations of plant n-Alkanes and PAH from cores collected along the AOS-94 section. Note in particular the generally higher concentrations in the Eurasian Basin and especially at Station 35 under the Transpolar Drift.

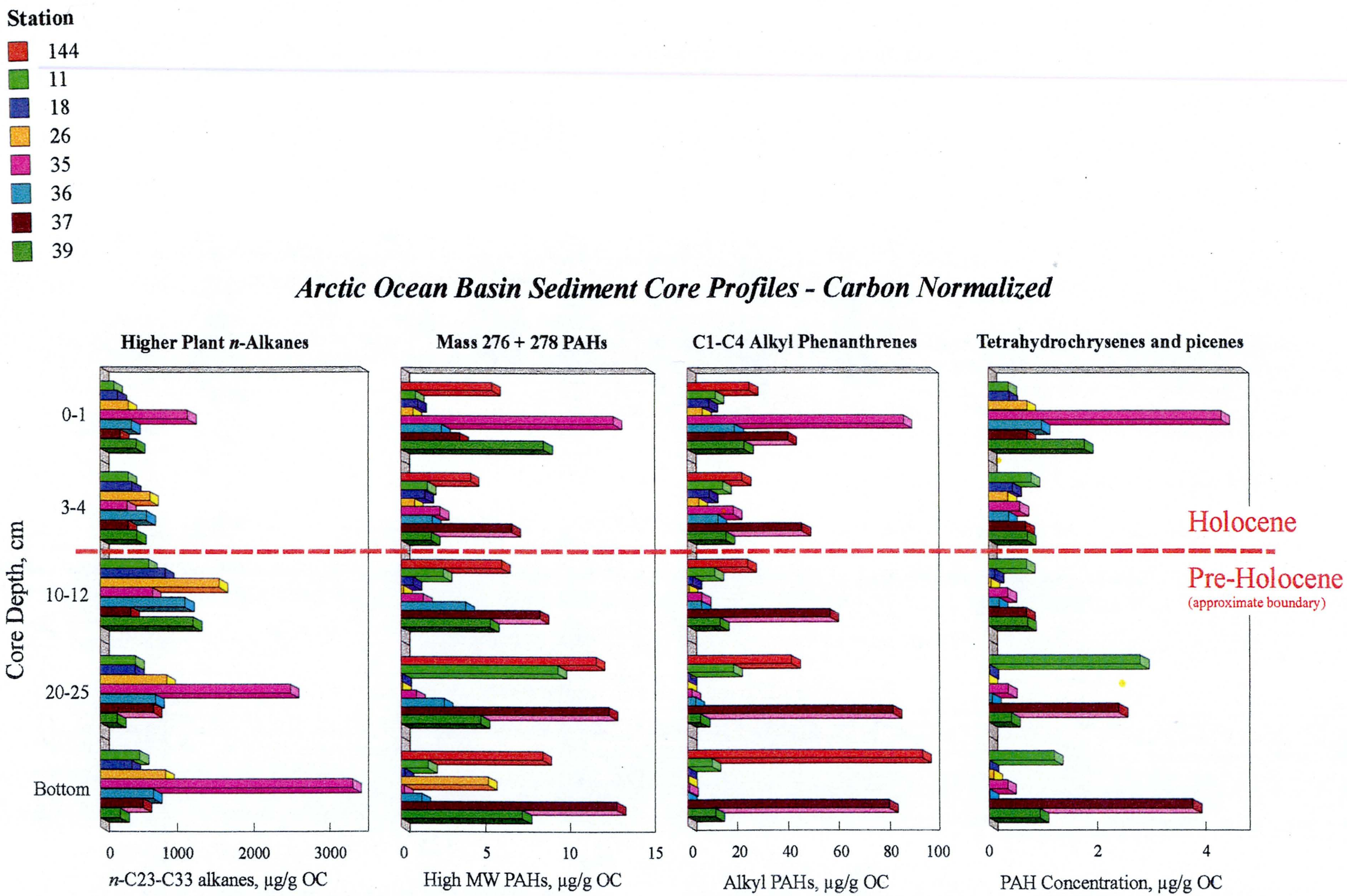

Figure 3. Core profiles from selected stations for higher plant alkanes, high molecular weight PAHs, alkyl PAHs and selected biomarker PAHs.

DISCUSSION/CONCLUSIONS

Comparison of the data from the Axys and FWI laboratories reveals uniform, high-quality analyses which can, therefore, be applied to questions of source and transport (i.e. objectives 2 and 3).

As shown in Figures 1 and 2, Arctic basin locations influenced by the Transpolar Drift (Eurasian Basin, Greenland Sea) have higher hydrocarbon concentrations, both PAH and alkane, than locations influenced by the Beaufort Gyre (Canadian Basin).

Both PAH profiles and the distribution of hopane biomarkers characteristic of Russian petroleum basins suggest that sediment from the eastern Russian shelves makes a greater contribution to the basins than sediment from the Chukchi and Beaufort Seas. Hence sediment from Russian shelves that is transported by the Transpolar Drift is primarily deposited in the Eurasian Basin.

Hydrocarbons such as the higher plant n-alkanes and the higher molecular weight (primarily combustion derived) PAHs that can be transported on both oceanic and atmospheric particulate are present at all basin stations in core intervals that correspond to both Holocene and Glacial eras (cf. Figure 3). In contrast, sediment-bound hydrocarbons such as the petroleum-derived alkyl naphthalenes and phenanthrenes or the higher plant-sourced tetrahydrochrysenes and picenes remain present in Glacial times at the basin margins (Stations 144, 11, 37) but are largely absent in the central basins (Stations 18, 26, 35, 36). A shift in parent PAH composition towards the less-stable or combustion PAHs is also observed in the pre-Holocene core sections of the basin samples.

Concentration profiles with depth in the basin cores imply a reduced transport of sediment to the central Arctic Ocean during Glacial times, but suggest that off-shelf transport was relatively unaffected by ice cover at the basin margins. Profiles also indicate that the atmospheric delivery of plant alkanes and combustion PAHs to the central Arctic basins apparently continued uninterrupted when ice rafting and the supply of presumably sediment-borne alkyl PAHs (both petroleum and higher plant) were curtailed. The hydrocarbon biomarkers very clearly provide insights into the transport of particulate material from Arctic shelves to basins over large spatial and temporal scales with obvious implications for transport of modern particle reactive contaminants.

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LONG-RANGE TRANSPORT OF CONTAMINANTS TO THE CANADA BASIN AND SELECTIVE WITHDRAWAL THROUGH THE CANADIAN ARCHIPELAGO

Project Leaders: R.W. Macdonald, F.A. McLaughlin, E.C. Carmack (IOS), G. Stern (FWI)

Project Team: M.C. O'Brien, D. Tuele, D. Sieberg, and D. Paton

OBJECTIVES

1. to understand the Arctic Ocean's role in contaminant transport and accumulation in the Canada Basin and the downstream selective withdrawal of these contaminants into the Canadian Archipelago. For 1997/98, the NCP funded us only to *collect* samples for organochlorine determination of water, particles and biota along the JOIS cruise track through the Canadian Archipelago (Leg 3) and to the SHEBA site (Leg 4) in the Canada Basin interior (Figure 1).

DESCRIPTION

Based on NCP results obtained over the last 5 years (Barrie *et al.* 1997), we observe the highest concentrations of HCHs in the Arctic Ocean within the Canada Basin interior. Indeed, it is almost certain that the surface waters of the Canada Basin contain the highest concentrations in the world oceans – concentrations which are 4–10 times higher than, for example, Pacific or Atlantic waters now entering the Arctic. By contrast, HCH concentrations in waters that can exchange with the atmosphere, such as those found in the source regions of Bering Strait and Fram Strait and in seasonally ice-free shelf regions, reflect the downturn in atmospheric concentrations. However, the high HCH concentrations found in the Canada Basin interior are the result of a combination of factors: An atmospheric HCH source function that peaked nearly twenty years ago, the slow renewal time of upper layer waters in the Canada Basin and the presence of a near-permanent ice cover (Macdonald *et al.* 1997). These high concentrations are found in the upper 200 m of the water column — the region most closely associated with biological activity. The Canada Basin time series station is unique and provides an opportunity to observe the ocean's response to atmospheric downturn in contaminant concentrations and thus estimate the residence time of this high HCH reservoir.

Sometime between 1989 and 1993, the location of the Atlantic-Pacific water mass boundary has changed from the Lomonosov Ridge to the Alpha-Mendeleyev Ridge (McLaughlin *et al.* 1996). This shift signals a displacement of the upper 200-300m of Pacific-origin waters from the Makarov Basin. The significance to Canada is that the most likely route for the exit of this water is through the Canadian Archipelago and, as discussed above, this water contains a potentially large inventory of contaminants.

The strength of our HCH contaminant sampling program is that it has been integrated with other broad science plans. This means that contaminant distributions can be *interpreted and modeled* within the full context of physical, chemical and biological processes, and of atmospheric and oceanic transport mechanisms. Clearly this approach is of far greater value for understanding the ocean's role in the persistence of globally transported contaminants than that of isolated sampling in time or space.

ACTIVITIES IN 1997/98

The JOIS mission was carried out as planned, with the collection of samples through the Canadian Archipelago as well as along a section in the Canada Basin en route to the SHEBA site. During Leg 3, 50 CTD and 25 geochemistry stations were occupied to provide data for examining the selective withdrawal of waters from the Canada Basin into the Archipelago as well as understanding water mass circulation and processes that occur within the Archipelago. The contaminant sampling included water column samples for HCH analysis at seven stations, box cores at six stations and arctic cod at one station zooplankton samples were also collected at selected stations along the transect to provide estimates of biomass.

During Leg 4, 15 CTD and geochemistry stations were occupied. Surface water samples for HCH analysis and zooplankton samples for organochlorine analysis were also collected at each station At the most northern station in the Canada Basin water column samples (16 depths) were collected for HCH analysis to provide a detailed profile for comparison to our time-series data.

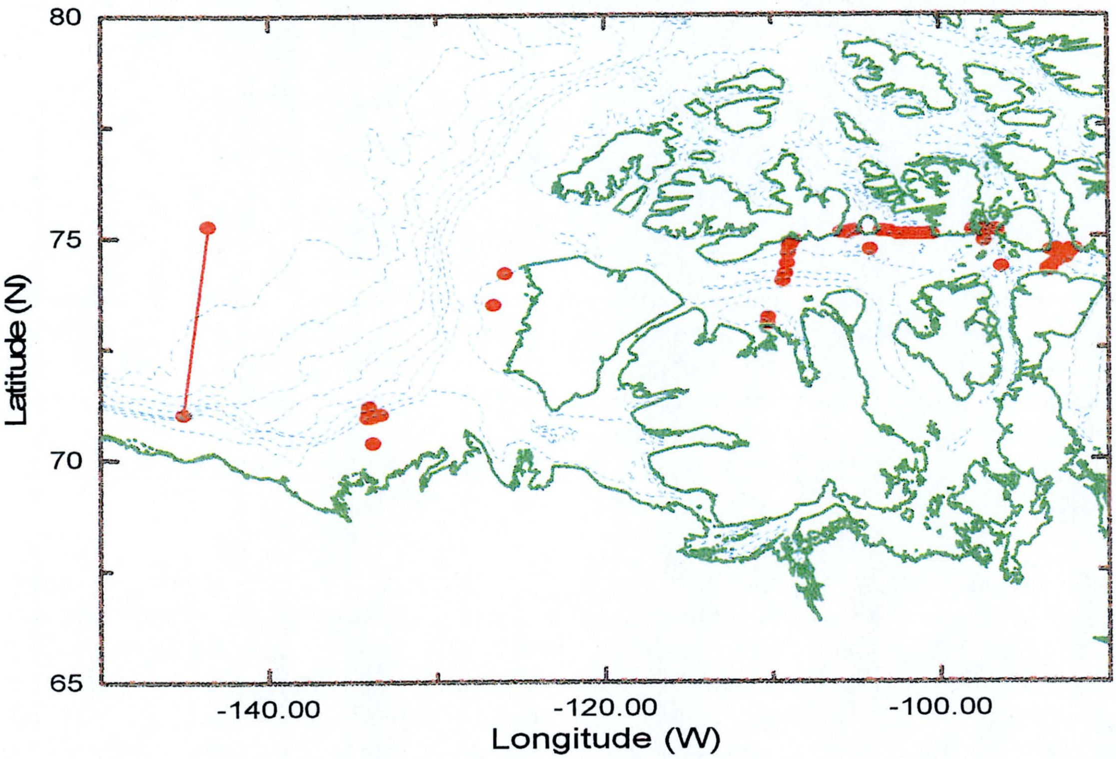

Figure 1. Cruise track of the Canadian Archipelago and Canada Basin transit.

RESULTS

Due to severely restricted funds, money was not allocated to *analyse* the samples in 1997/98. Accordingly, although we have started to compile the physical and chemical support data, we have no organochlorine data to submit at this time.

DISCUSSION/CONCLUSIONS

Funds have been approved in 1998/99 to analyse our archipelago sample set and these analyses will progress in this fiscal year.

Expected Project Completion Date: April 30, 1999.

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THE SEASONAL CYCLE OF ORGANOCHLORINE CONCENTRATIONS IN THE CANADIAN BASIN

Project Leaders: R.W. Macdonald, F.A. McLaughlin and E. Carmack (IOS); H. Welch, G. Stern (FWI)

Project Team: D. Paton, M. O'Brien, D. Tuele, D. Sieberg (IOS)

OBJECTIVES

1. to measure the intra-annual variability of contaminant transport and food-web accumulation in the Canada Basin in the Canada Basin from October, 1997 to October, 1998 from the drifting platform provided by CCGS *de Groselliers* and SHEBA.

DESCRIPTION

SHEBA (Surface Heat Budget of the Arctic) provides a unique window to examine the physical and biological processes that ultimately cause high contaminant concentrations in top predators of the Arctic Ocean. The interior Canada Basin provides a large mesocosm, known to be enriched in some contaminants, wherein we can observe how the ocean maintains contaminant burdens in the euphotic zone and how such contaminants transfer into ice and pelagic biota. Therefore, we are proposing to carry out a "vertical" food-chain study in a seasonal context (Figure 1). "Vertical" components will include the water and ice, particles, algae, zooplankton (sorted by trophic level) and fish. Samples collected during SHEBA will provide information about the relationship between seasonal ice formation and melt, seasonal atmospheric transport and water column organochlorine concentrations in the Canada Basin. For example, based on program results obtained over the last five years, during August–September the highest concentrations of HCHs in the Arctic Ocean are found in the Canada Basin interior and are believed to be the result of a combination of factors: An atmospheric HCH source function that peaked nearly twenty years ago, the slow renewal time of upper layer waters in the Canada Basin and the presence of a near-permanent ice cover (cf. Macdonald *et al.* 1997). The SHEBA program will expand our knowledge to incorporate the seasonal cycle. Furthermore, because the platform will remain within the Beaufort Gyre throughout the year, there will be opportunity to collect large volume samples using Infiltrex pumps and filters to yield valid data for other OCs of concern like PCBs, chlordane and toxaphene. Such data, which are almost impossible to collect from ships carrying out transects, were noticeably absent during recent assessments (cf. Barrie *et al.* 1997).

Under the U.S. National Science Foundation sponsored SHEBA program a full seasonal study will be made of physical and biological processes. DFO already has a large investment in SHEBA to perform some of these biological and physical studies (FWI, Welch; IOS, Carmack). Therefore, this proposal together with funded process studies provides an unparalleled opportunity to incorporate contaminants and learn how the physical and biological systems couple to produce contaminant entry into the food web. The seasonal influence of ice cover is expected to dominate at the SHEBA site (75°N 140°W) whereas advection is anticipated to be less important. Therefore, SHEBA will mimic a large mesocosm representative of the interior surface pool of the Beaufort Gyre. So far, there has been only one study of organochlorine intra-annual variability and, because of logistics, the site was in the Canadian Archipelago, a region of strong advection.

The strength of our contaminant sampling program is that it is integrated with other broad science plans in SHEBA. This means that contaminant distributions can be *interpreted and modelled* within the full context of physical, chemical and biological processes, and of atmospheric and oceanic transport mechanisms. Clearly this approach is of far greater value for interpretation and policy setting than that of isolated sampling in time or space.

ACTIVITIES IN 1997/98

In October, 1997, the CCGS *de Grosellier*s was set into the ice within the Beaufort Gyre of the Canada Basin and began the year-long drift experiment (Figure 2).

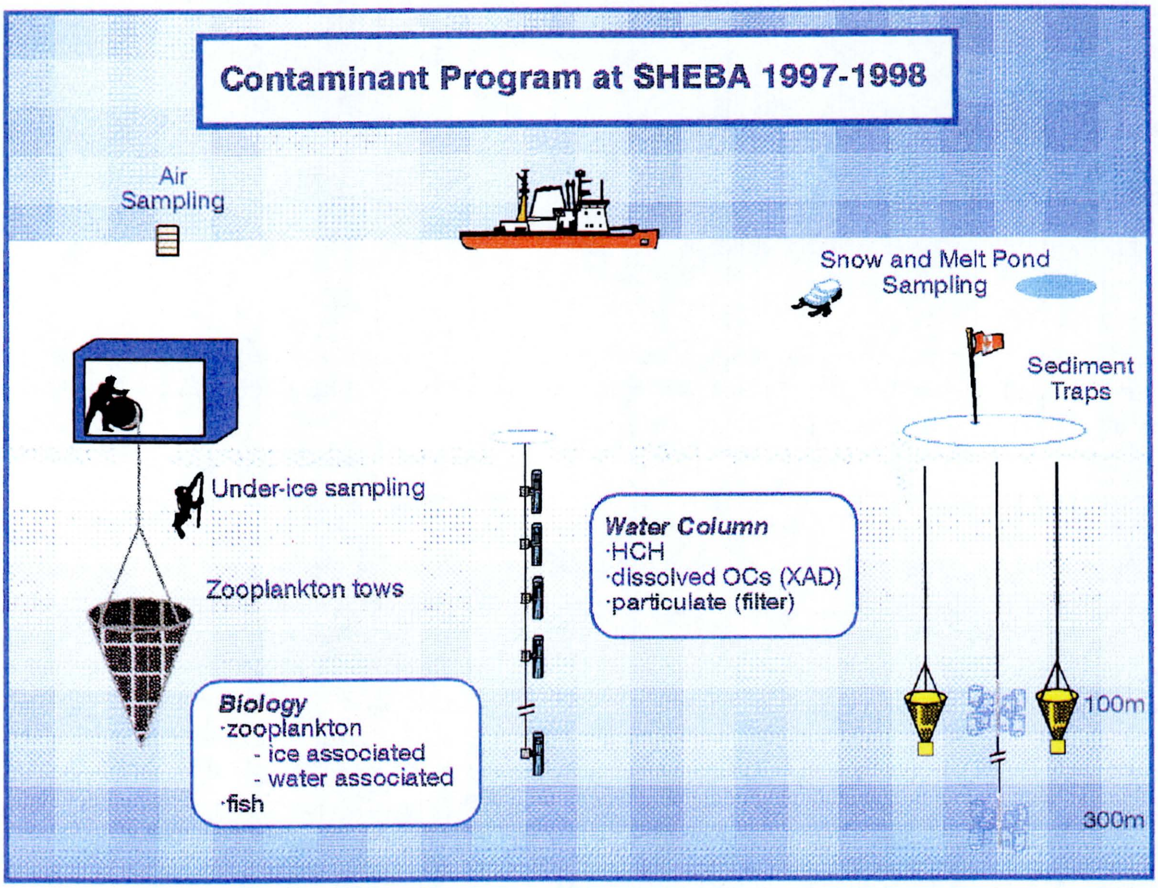

Figure 1. A schematic diagram of the SHEBA site and sampling structure.

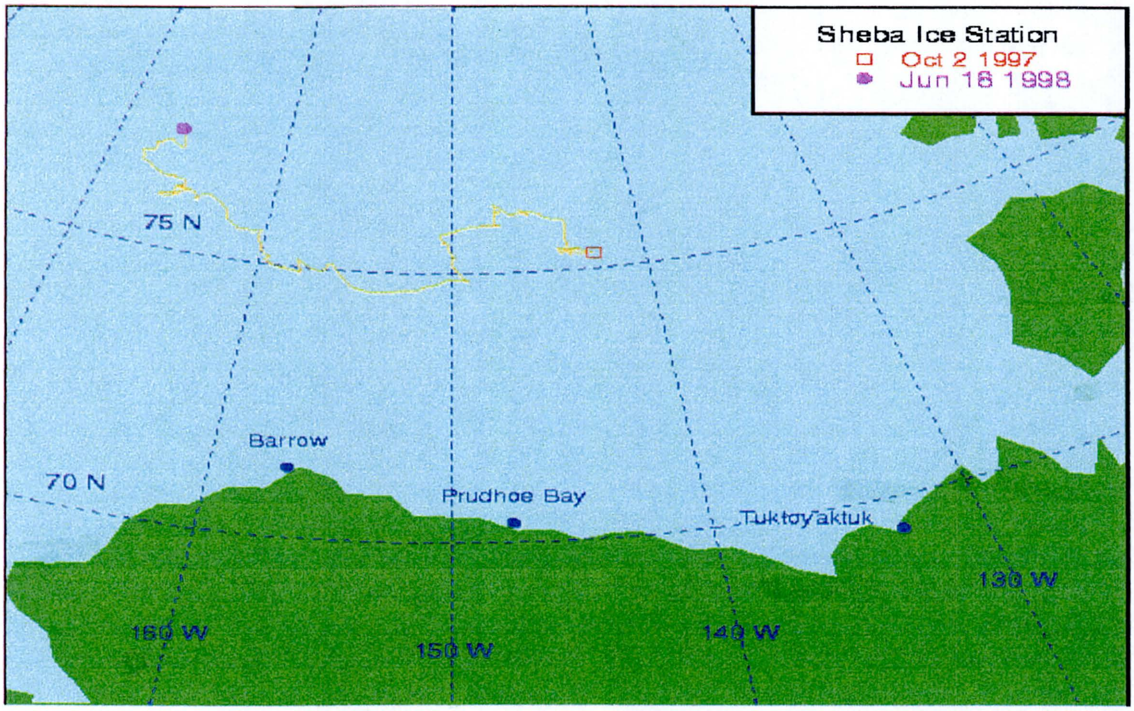

Figure 2. The SHEBA site and its drift trajectory in 1997.

Since that time, there has been a regular schedule of sampling for the various contaminants (Table 1) and for supporting physical and chemical parameters.

RESULTS

The year-long SHEBA program is still underway. Accordingly only samples collected during the first sampling period in November have been analysed and only toxaphene data are presented below. Although at this stage in the analysis it is too early to interpret these findings, some interesting patterns are apparent when comparing water, particulates and biota (Figure 3).

Analytical Methods

PCBs and OC pesticides were quantified by high resolution gas chromatography with electron capture detection (GC/ECD) using a 60 m x 0.25 mm i.d. DB5 column (0.25 um film thickness) and H_2 carrier gas. CHBs were analysed using high resolution gas chromatography electron capture negative ion high resolution mass spectrometry (HRGC/ECNI/HRMS) in the selected ion mode on a Kratos Concept mass spectrometer controlled using a Mach 3 data system. Analyses were performed at a resolving power of ~12000. Argon (UHP) was used as the moderating gas and perflurokerosene as the mass calibrant. Optimum sensitivity was obtained at a gas pressure of ~2×10^{-4} torr as measured by the source ion gauge. The electron energy was adjusted for maximum sensitivity (~180 eV), the accelerating voltage was 5.3 kV and the ion source temperature was 120°C. The SIM program and GC conditions used have been described previously (Donald *et al.* 1998). In addition to ΣCHB and the Cl_6 to Cl_9 homologue groups, four individual CHB congeners were quantified; T2 (Parlar 26, B8-1413), and T12 (Parlar 50, B9-1679), both of which are known for their persistence in marine mammals, and Hx-Sed (B6-923) and Hp-Sed (B7-1001), the two major end products found in sediments of toxaphene treated lakes (Miskimmin *et al.* 1995, Stern *et al.* 1996).

Results

All four of the individual congeners were present in all samples. ΣCHB concentrations in the biota range from 107.5 ng/g (wet wt.) in *Thermisto abyssorum* to 377.2 ng/g (wet wt.) in orange amphipods. On average, the sum of T2 and T12 corresponds to 12.8% of ΣCHB compared to 6.3% for total Hx- and Hp-Sed. Although the latter two congeners have the same staggered 2-*exo*, 3-*endo*, 5-*exo*,6-*endo* ring structure as T2 and T12, they do not have the same propensity for

Table 1. SHEBA sampling schedule (X represents collected samples).

Month	Air	Water column HCH, S. O-18 17 depths 4 L	Water column HCH O-18, S 10,50, 100,150m 4 L	Infiltrex Samplet profile: XAD 9 depths >400 L.	Large Volume Filter 10m + pyc >2000L	Zoopl. ice assoc.	Zoopl. water assoc.	Fish	Melt pools XAD, S, O-18
October		X						X	
November			X	X	X		X	X	
December			X		X			X	
January	X		X					X	
February	X		X	X	X		X	X	
March	X		X					X	
April	X	X		X	X	X	X	X	X
May	X		X						
June	X		X	X	X		X		
July			X						
August	X		X	X	X		X	X	
September			X				X		

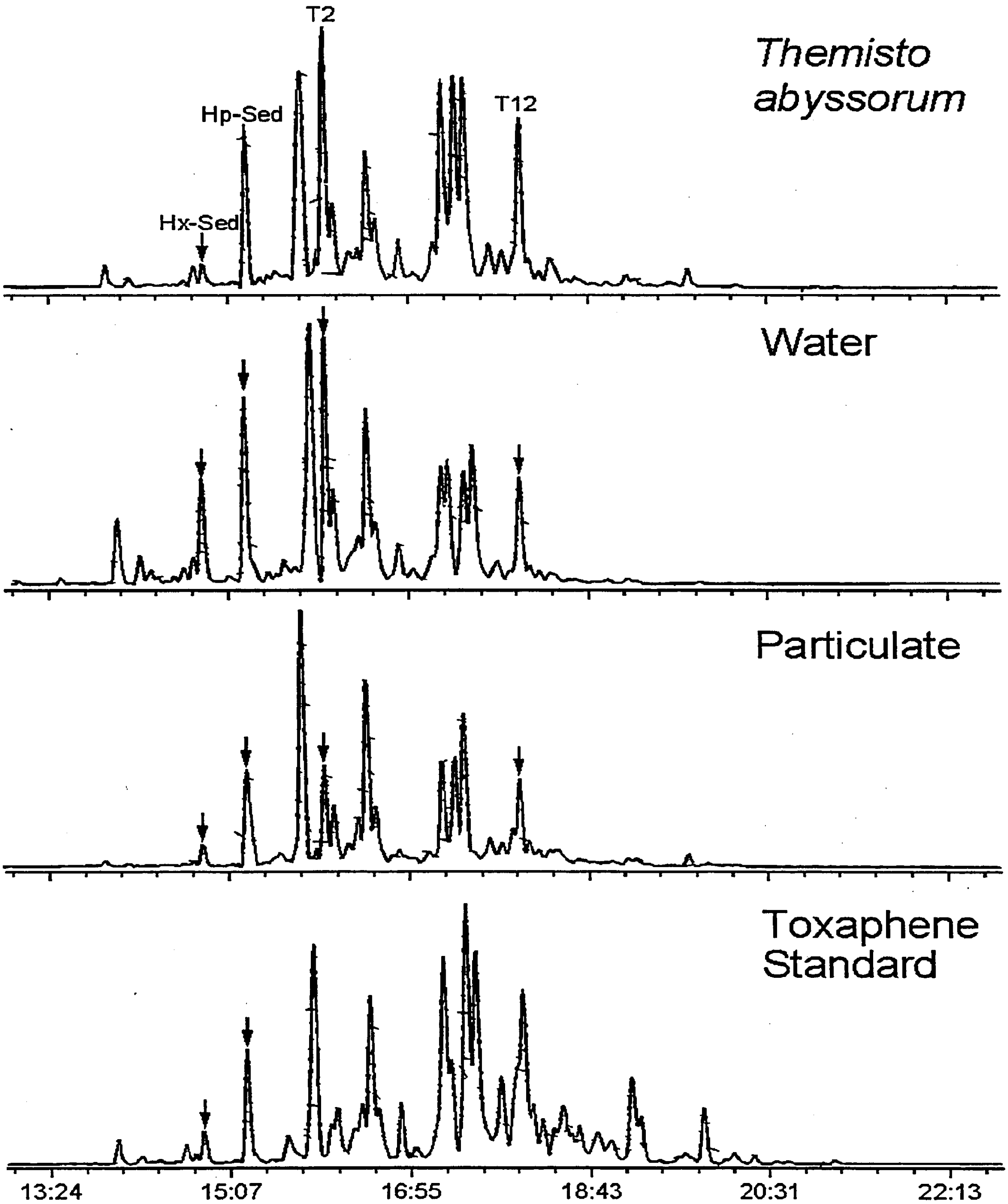

Figure 3. GC/ECNI/HRMS selected ion chromatograms of toxaphene (sum of Cl_6 to Cl_7 chlorobornanes) for selected marine biota, water and particulate samples and the technical mixture

Table 2. Concentrations of CHB homologue groups, of selected congeners, total CHBs (ΣCHB) and PCBs (ΣPCB) in arctic marine biota and water.

	%lipid	Cl-6	Cl-7	Cl-8	Cl-9	HxSed	HpSed	T2	T12	ΣCHB	ΣPCB
Biota, ng/g ww											
Shrimp	56.6	3.7	84.2	169.8	82.4	1.4	9.2	23.5	56.7	340.2	8067
Orange amphipods	nd	3.8	91.7	214.5	67.3	1.0	13.3	34.0	54.5	377.2	206.8
Gammarus wilkitzkii	4.6	1.7	45.6	65.6	11.5	0.5	5.6	7.9	8.9	124.4	115.8
Thermisto libellula	nd	8.1	166.8	174.8	21.8	4.0	26.9	10.5	18.5	371.5	92.4
Euchaeta	34.7	5.4	102.4	102.1	15.2	2.7	17.2	11.7	12.4	255.1	66.7
Thermisto abyssorum	37.1	3.2	41.7	54.4	8.2	0.8	5.7	3.4	5.6	107.5	74.4
Chaetognaths	14.3	2.9	50.3	63.4	9.1	1.4	8.2	5.8	7.0	125.6	53.5
Herbivores	33.9	11.5	65.6	58.7	7.9	2.2	8.7	4.8	3.6	143.6	15.5
Water (depth, M), pg/L											
30		4.6	20.1	10.2	0.6	2.1	3.9	0.7	0.4	35.4	136.7
170		12.5	66.1	33.0	5.6	5.4	12.5	3.2	4.7	117.2	240.5
200		22.1	135.7	83.7	6.7	9.5	19.7	6.1	5.2	248.2	259.7
250		39.3	253.9	196.6	23.9	20.0	39.6	9.4	19.6	513.6	714.9

nd = not determined

bioaccumulation. Recently Fisk *et al.* (1996) reported that Hp-Sed was more rapidly eliminated from salmonoids than either T2 or T12, and that it did not biomagnify in laboratory dietary accumulation studies. In the water samples, ΣCHB concentrations range from 35.4 to 513.4 pg/L. Contrary to what was observed in the biota, Hx- and Hp-Sed were present in higher concentrations than T2 and T12 (13.5 and 4.8% of ΣCHB, respectively). Both ΣCHB and ΣPCB were found to increase with water depth.

DISCUSSIONS/CONCLUSIONS

Technical toxaphene is thought to contain up to 300 different congeners, consisting mainly of penta- to decachlorobornanes and to a lesser extent camphadienes (Zhu *et al.* 1994). Toxaphene extracted from environmental samples gives chromatographic profiles that differ from the analytical standard; degradation of some of the congeners in the technical mixture occur by photodegradation during atmospheric transport and by biotransformation in water sediment and biota (cf. Loewen *et al.* 1998). Analysis of total toxaphene alone would give little insight into this complexity, however, a comparison of chlorobornane (CHB) congener patterns would by extremely useful with regard to understanding sources and transport/ bioaccumulation pathways.

Expected Project Completion Date: March 30, 2000.

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MERCURY IN AMBIENT AIR AT ALERT

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OBJECTIVES

1. to determine total gaseous mercury and particulate-phase mercury concentrations in ambient air at Alert, for the purpose of establishing:
   (i) baseline concentrations
   (ii) the temporal variability/trends of atmospheric mercury in the high Arctic, and;
   (iii) linkages to the elevated levels of mercury existing in the Arctic food chain.
2. to investigate atmospheric mercury vapour transformation processes, as well as mercury removal/depletion mechanisms, occurring at Alert (and probably elsewhere in the Arctic) after polar sunrise, which result in enhanced atmospheric input of mercury to Arctic ecosystems in the spring.

DESCRIPTION

Two landmark reports on contamination of the Arctic environment were published during 1997: The *Canadian Arctic Contaminants Assessment Report* (Jensen *et al.* 1997) and the Arctic Monitoring and Assessment Programme report on *Arctic Pollution Issues: A State of the Arctic Environment Report* (AMAP 1997). Both reports consider mercury as a priority heavy metal because of its environmental persistence, ecotoxicity, and ability to be bio-accumulated in the human food chain (in the form of methylmercury). As mercury exists in ambient air predominantly in the vapour phase (as Hg^{o}), is not very soluble in water, and is relatively inert chemically, it can be transported in the atmosphere over long distances from its emission sources to remote Arctic locations (Schroeder & Munthe 1998, Fitzgerald *et al.* 1998).

From other scientific studies (Slemr and Langer 1992, Mason *et al.* 1994, Fitzgerald 1995) it is known that, on a global scale, atmospheric mercury concentrations were increasing (at least between 1977 and the late 1980s) by about 0.6% to 1.5% per annum. More recent measurements (in the Bavarian Alps, and over the northern and southern Atlantic Ocean) reported by Slemr and Scheel (1998) point to a significant decline (about 7.5% per year, between March 1990 and May 1996) in atmospheric mercury levels on both regional (European) and global scales. Such a relatively large decrease in atmospheric mercury concentrations is not, however, consistent with published anthropogenic emission inventories (Nriagu & Pacyna 1988, Lindqvist 1991, Pirrone *et al.* 1996, Pacyna 1996, Porcella 1996, Pai & Niemi 1997).

Our atmospheric mercury measurements at Alert – a World Meteorological Organization Global Atmosphere Watch (WMO/GAW) Baseline Observatory – and the resulting time series, could (in a few years) help to resolve the apparent discrepancy described above. In the meantime, our continuing determinations of the concentrations of total gaseous mercury (TGM) and (occasionally) total particulate-phase mercury (TPM) in ambient air at Alert will supplement the meagre data set of atmospheric mercury concentrations in the Arctic (Schroeder *et al.* 1995). These measurement results will define, inter alias, the temporal variability of atmospheric mercury levels, both in the short term (daily, weekly, seasonally) as well as in the long term (annually, and longer), in order to understand and to be able to predict/model the atmospheric behaviour, pathways and temporal trends of this environmental contaminant in polar regions. At present, information on temporal (and spatial) trends in the high Arctic is virtually non-existent. This project is intended to address these information gaps.

ACTIVITIES IN 1997/98

In fiscal year 97/98 we continued our ground-level measurements of total gaseous mercury (TGM) concentrations in ambient air at Alert. As was the case

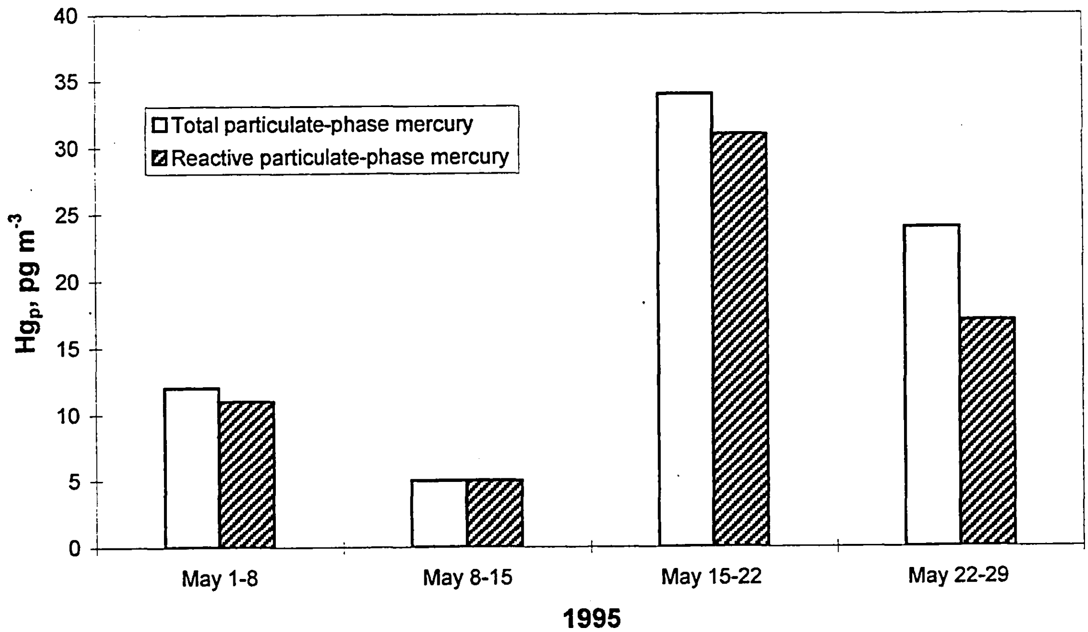

Figure 1. Particulate-phase mercury concentrations in ambient air at Alert during May 1995 (weekly integrated samples).

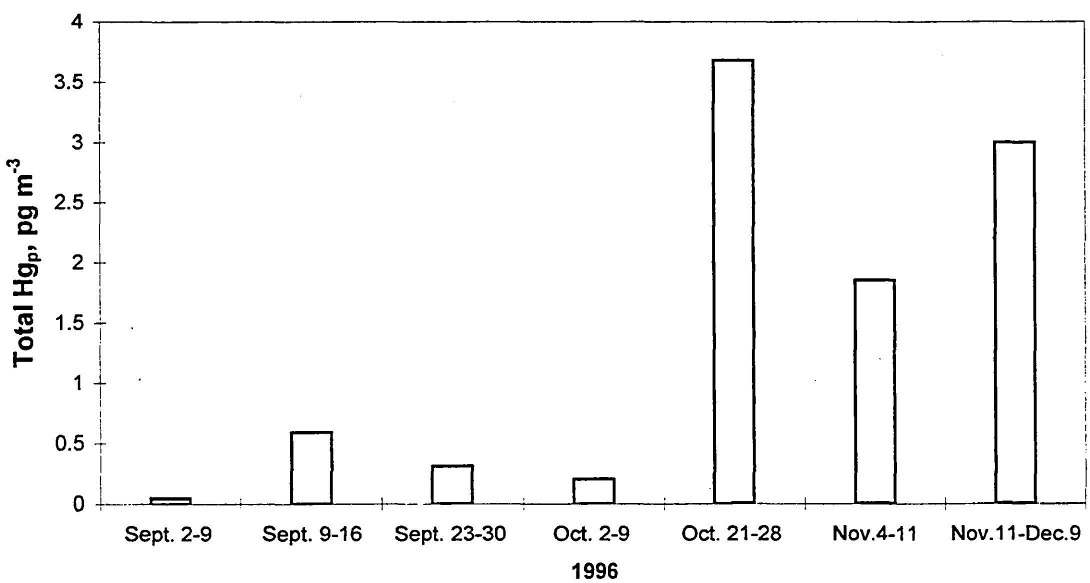

Figure 2. Total particulate-phase mercury concentrations in ambient air at Alert during autumn 1996.

in 1995 and 1996, we again recorded a dramatic increase in the variability of boundary layer TGM concentrations after polar sunrise during the spring of 1997 and lasting from about mid-March until mid-June. Through a series of judiciously planned and carefully executed experiments performed during March, April and May 1997, we obtained conclusive evidence that the depletion of atmospheric mercury vapour in the Arctic in springtime (following polar sunrise) is a real phenomenon, not a measurement artifact (Schroeder *et al.* 1998a).

During April and May of 1997, using a new method recently developed at AES (Lu *et al.* 1998), we also conducted concurrent measurements of TPM and TGM concentrations at Alert in order to obtain information on the conversion of elemental mercury vapour into particulate-phase mercury species as a result of springtime chemical transformation processes analogous to those resulting in Arctic tropospheric (boundary layer) ozone depletion in spring after polar sunrise.

RESULTS AND DISCUSSION

Particulate-Phase Mercury Concentrations in Ambient Air at Alert

Due to existing resource limitations, only intermittent determinations of particulate-phase mercury were made at Alert during the time period from May 1995 to May 1997. Accordingly, weekly-integrated filtered air samples were collected (in duplicate) at Alert and then sent to the University of Connecticut for chemical analysis in the ultra-trace mercury laboratory of W. Fitzgerald. The results obtained for 1995 and 1996 are shown in Figures 1 and 2, respectively. It is quite evident from these two charts that the springtime (1995) values for total particulate-phase mercury concentrations are generally an order of magnitude higher than the (1996) autumn values. This picture is consistent with our expectations of elevated TPM concentrations in the spring (after polar sunrise) due to conversion, by one or more as yet unknown chemical oxidation reactions, of Hg^{2+} vapour into Hg^{2+} species which are much less volatile (i.e. have lower vapour pressure) than the starting material (elemental mercury vapour) and are thus more likely to be associated with airborne particulate matter (Pearce 1997, Schroeder *et al.* 1998b, c & d).

Total particulate-phase mercury concentrations which were determined for atmospheric aerosol samples collected at Alert in April and May of 1997, using a sampling and analytical method recently developed at AES in Downsview (Lu *et al.* 1998), are summarized in Table 1. The values obtained range from below the detection limit of the method (2 picograms Hg per m^3 of air) to about 450 pg m^{-3}. Figure 3 shows these TPM results (this time expressed in units of ng m^{-3} to be consistent with the concentration units generally used for TGM) along with the TGM concentrations observed at Alert from early April to the latter part of May, 1997. This figure shows several occasions (samples collected on April 5, April 5–7 and April 29–May 6) on which TPM concentrations were elevated (>0.1 ng m^{-3}) when TGM concentrations were significantly depleted (i.e., <1 ng m^{-3}). The exception to this trend occurred for the 2 samples of TPM collected (in parallel) for the 7-day period from May 12 to May 19, during which an elevated TPM concentration might have been expected based on the concurrently recorded TGM values which were below 1 ng m^{-3} during most of that week. It is conceivable that the particulate-phase mercury produced from the conversion of (the "missing") Hg° vapour may have been deposited (i.e. "removed from the atmosphere") en route to Alert.

Enhancement of Atmospheric Mercury Input to the Arctic Ecosystem in Springtime

The results of our DIAND-sponsored research program at Alert indicate that frequent episodes of atmospheric mercury vapour depletion occur at Alert (and probably also at other polar coastal locations) in the spring following polar sunrise, at the same time as there are "low ozone events" in the Arctic troposphere (boundary layer), with both phenomena being amplified/modulated by the evolution/devolution of stable temperature inversions near the Earth's surface (Schroeder *et al.* 1997a & b, Schroeder *et al.* 1998 b, c & d). This situation leads to greatly enhanced deposition of mercury from the atmosphere to Arctic ecosystems since the long-lived form of mercury (viz., Hg°, which is estimated to have a mean global atmospheric residence time of about 6 to 24 months and is normally predominant in ambient air) is chemically transformed into one or more oxidized mercury (Hg^{2+}) species having mean atmospheric residence times under Arctic environmental/ meteorological conditions of several days or, at most, a few weeks.

On the basis of the high-temporal-resolution atmospheric mercury measurements we made at Alert during 1995 and 1996, we have estimated atmospheric mercury (particulate-phase) deposition fluxes, and the corresponding "loadings", to the Arctic environment in the springtime during those periods when we observed depletion of mercury vapour in the boundary layer of the troposphere. The experimental/environmental conditions and parameters, and the assumptions involved in these estimates of atmospheric mercury inputs into the Arctic ecosystem during the spring of 1995 and 1996 are summarized in Table 2.

Table 1. Total particulate-phase mercury (TPM) concentrations in ambient air at Alert from April 5 to May 19, 1997.

Sampling date	Sampling time hours	TPM pg m^{-3} (n[a])
April 5	11	119 (27 (3)
April 5–7	47	449 (91(2)
April 7–14	165	28 (17 (3)
April 17- 22	116	27 (0.4 (2)
April 29-May 6	183	148 (12 (2)
May 6–12	142	< 2[b] (2)
May 12–19	165	9.6 (0.6 (2)

[a] Number of determinations. When n = 3, the values after ± signs are standard deviations; when n=2, the values after ± signs are the difference from the mean.
[b] Limit of detection.

Table 2. Parameters and assumptions involved in the estimation of atmospheric mercury deposition in the Arctic during springtime.

PARAMETER/ASSUMPTION	1995	1996
Start of mercury depletion window	April 1[a] (JD 091)	March 1 (JD 061)
End of mercury depletion window	June 15 (JD 166)	June 9 (JD 161)
Duration of depletion window, days	75[a]	100[b]
Annual mean TGM concentration, ng/m^3	1.62	1.56
Number of days with TGM concentrations <annual mean	51	62
Number of days with TGM concentrations >annual mean	24	32
Mean TGM concentration for non-depletion periods	1.84	1.79
Mean TGM concentration for depletion periods	0.98	0.89
Mean concentration of Hg^{2+} produced during depletion periods	0.86	0.90
Dry deposition velocity for Hg^{2+}, cm/s m/day	0.1 86.4	0.1 86.4
Dry deposition flux of Hg^{2+} , ng/m2/day ng/m2/hour	74.3 3.10	77.8 3.24
Amount of mercury deposited in spring, µg/m^2 (= g/km^2)	3.79[a]	4.82
Area of Arctic Ocean = 13,218,146 km^2 Amount of mercury deposited on Arctic Ocean, tonnes	50.1	63.7
Amount of mercury deposited on Canadian Arctic (area of 3,407,120 km^2) [40o sector from northern tip of Ellesmere Island (83°N) to southern end of Hudson Bay (55°N)]	12.9	16.4

[a] No TGM concentration data available between March 15–31, 1995
[b] No TGM concentration data available for 6 days in this period

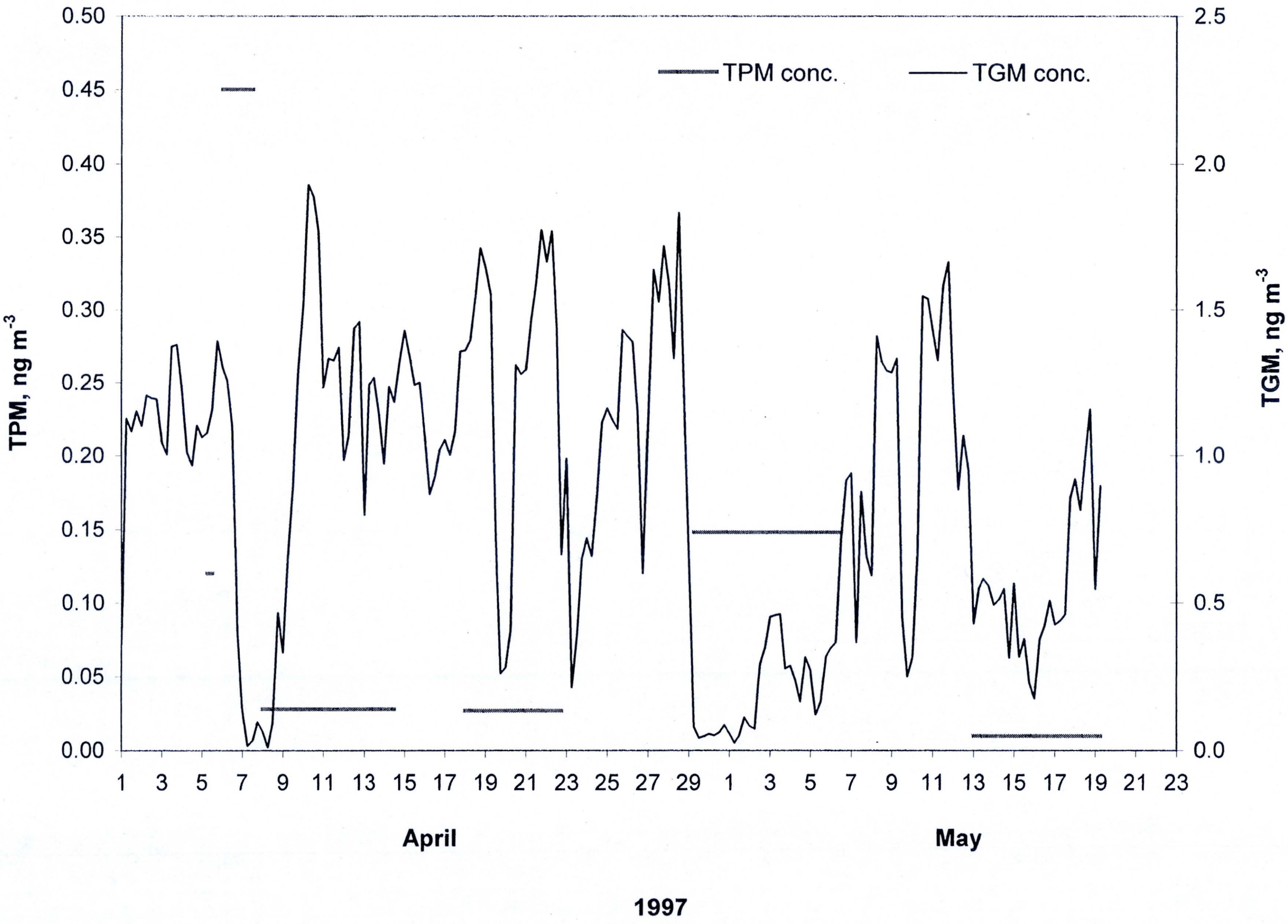

Figure 3. Results of concurrent measurements of total gaseous-phase mercury (TGM) and total particulate-phase mercury (TPM) concentrations in ambient air at Alert during April and May, 1997.

It is interesting to note that the dry (particle) deposition flux values in this table, viz., 3.1 and 3.2 $ng/m^2/h$, are very similar to the 1995 springtime dry deposition flux value of 2.5 + 0.5 $ng/m^2/h$ which we derived via a different estimation scenario (Schroeder *et al.* 1998c). If we take our estimated 1995 springtime atmospheric mercury loading value of 3.8 $\mu g/m^2$ and the snow depth of 54 cm reported for Alert by Welch *et al.* (1997) during their 1997 survey of mercury concentrations in snow collected over sea ice at 20 localities in the Canadian Arctic, we obtain a concentration of 20 ng Hg per litre of snow melt water. Compare this to the value of 22.3 ng Hg/L obtained by Welch and co-workers for a snow sample collected at Alert on June 6, 1997. Our 1996 particulate-phase mercury dry deposition loading estimate of 4.8 $\mu g/m^2$ would correspond to a snow (melt water) concentration of 25.4 ng/L. Thus, our mercury loading estimates result in snow (melt water) concentrations which bracket the value determined experimentally for the snow sample from Alert by Welch *et al.* in their 1997 Canadian Arctic snow survey.

Furthermore, using our springtime atmospheric mercury measurement results from Alert, we have also calculated the amounts of mercury deposited from the atmosphere to: (a) the surface of the Arctic Ocean (the smallest of the world's oceans), and; (b) a central (40°) sector of the Canadian Arctic (from the northern tip of Ellesmere Island to the southern end of Hudson Bay). For the spring of 1995, we calculate that 50 tonnes of mercury were deposited to the surface of the Arctic Ocean, an area of some 13 million square kilometers, and about 13 tonnes to the central sector of the Canadian Arctic (comprising an area of about 3.4 million km^2). In 1996, the corresponding amounts were 64 tonnes and 16 tonnes, respectively.

To put these atmospheric deposition estimates into perspective, it is helpful to compare them with reported estimates of annual *anthropogenic* mercury emissions for North America and for the world. Thus, Canadian anthropogenic mercury emissions for 1995 have been estimated at 12.7 tonnes (Deslauriers 1998), while those for the United States during 1994–1995 were inventoried at 143 tonnes (U.S. EPA 1997). Globally, Mason *et al.* (1994) assumed that anthropogenic mercury emissions totalled 4000 tonnes/year, somewhat lower than an earlier estimate by Fitzgerald (1986) of 5000-6000 tonnes/yr. A similar comparison with *natural* emissions of mercury into the atmosphere is not made here due to the large uncertainties attached to existing estimates of mercury emissions from natural sources on regional, continental and global scales. [For the reader's information, a Canadian government–university collaborative research project has been initiated for the purpose of providing the first national emission inventory of natural sources of mercury in Canada based on environmental flux measurement methodologies.]

Our discovery and recognition of this special polar (Arctic and, quite possibly, Antarctic) springtime environmental phenomenon, involving the heavy metal mercury, has profound implications for Arctic ecosystems and human health, since even remote polar regions can be significantly impacted by long-range atmospheric transport of mercury (and other persistent pollutants) emitted in industrialized as well as developing nations around the globe. Atmospheric mercury vapour oxidation, and the attendant depletion, after polar sunrise results in a toxic heavy metal shock being delivered to the Arctic ecosystem in the springtime just as biota are re-awakening after the long polar night and are getting ready for the ever-so-short Arctic summer season.

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MEASUREMENTS OF RADIOACTIVE CONTAMINANTS IN THE ARCTIC OCEAN

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Project Team: K. Ellis (BIO), R. McDonald (Institute of Ocean Sciences, DFO); L. Polyak (Byrd Polar Research Centre, Columbus, Ohio); G. Ivanov (Okeanogeologia, St. Petersburg, Russia); D. Matishov (Murmansk Marine Biological Institute, Murmansk, Russia); S. Dahle (Akvaplan Niva, Tromso, Norway)

OBJECTIVES

1. to determine source functions for radioactive contaminants in the Arctic Ocean associated with nuclear accidents, nuclear weapons tests and ocean dumping of radioactive wastes.

2. to identify the mechanisms governing radionuclide transport from anthropogenic sources through different environmental phases (sediments, seawater, biota) with special reference to the Russian marginal seas.

DESCRIPTION

Reports of the dumping of radioactive wastes on the Russian Continental Shelf have raised concerns regarding the transport of radioactive contaminants through the Arctic Ocean, their uptake in the food chain and the consequent radiological exposures of northern population groups. This project provides information on: (1) the magnitude of radioactive source terms in the arctic through site-specific measurements of radioactive contaminants on environmental samples collected within the vicinity of radioactivity sources (i.e. radioactive waste dumpsites, sunken submarines, nuclear weapons accident sites) in the Arctic Ocean, and, (2) fluxes of radioactivity and other contaminants (organics, metals) in the arctic marine environment through measurements of natural and artificial radionuclides in sediments, seawater and biota and the application of various models (ventilation, sediment biodiffusion, etc.) to estimate radionuclide transport fluxes. Radionuclides are also used as tracers to estimate inorganic and organic contaminant fluxes in collaborations with other investigators.

ACTIVITIES IN 1997/98

Arctic activities in 1997/98 included: (a) the collection of seawater samples during the CSS Louis S. St. Laurent cruise in Baffin Bay and the Canadian Archipelago in 1997, (b) the collection and analysis of seawater samples from the central Arctic Ocean in 1997 from the US Navy nuclear submarine, USS Archerfish, (c) the collection of seawater and sediment samples in Kola Bay and off Novaya Zemlya in the Barents Sea in 1997 in collaboration with Russian scientists (Okeangeologia, St. Petersburg), (d) radionuclide analyses of sediment, seawater and biota samples collected in 1995–97 in the Barents and Kara Seas in the Russian Arctic; (e) radionuclide analyses of sediment and seawater samples collected aboard the CSS Louis S. St. Laurent during the Arctic Ocean Section (AOS) cruise in 1994 and the Beaufort Sea cruise in 1995, and (f) publication of a series of papers and reports on these arctic activities and the presentation of these results at national and international meetings.

RESULTS

Cruise Activities

Several oceanographic sampling programs were carried out in 1997:

(1) Samples were collected for radionuclide analyses during the cruise of the CSS Louis S. St. Laurent in the Beaufort Sea, Baffin Bay and various locations in the Canadian Archipelago in collaboration with scientists from the Institute of Ocean Sciences (B.C.) and the University of Rhode Island (URI). One BIO scientist from the Bedford Institute of Oceanography accompanied the CSS Louis S. St. Laurent and collected seawater sample profiles in Baffin Bay and samples were collected by collaborators at other locations in the Archipelago. The purpose of this work is to determine radionuclide (^{137}Cs, ^{90}Sr, ^{129}I, $^{239,240}Pu$) distributions and their rates of transport through the Arctic Ocean. Large volume (50 1) seawater

samples were collected from a range of water depths and passed through filters and resins to extract particulate and dissolved radionuclides (eg. ^{137}Cs and $^{239,240}Pu$), while smaller 1 litre samples were collected for ^{129}I analyses (Smith and Ellis 1995). Four Challenger in-situ pumps were deployed, as on the 1994 AOS cruise, and used to process the large (> 300 1) volumes of seawater required to measure radionuclides such as ^{137}Cs and Ra isotopes at low levels in surface and deep waters.

(2) Seawater samples were collected for ^{137}Cs and ^{129}I analyses from the US Navy nuclear submarine, USS Archerfish during a 1997 cruise in the Central Arctic Ocean. Samples were collected through the hull of the submarine down to depths of 240 m. The primary focus of this work is to determine the extent to which radioactive contaminants from the Russian marginal seas and European Reprocessing Plants have been transported through the Arctic Ocean and into the Canada Basin and to evaluate any environmental impacts on the North American continental shelf.

(3) Collaborative cruises with other scientists in 1997/98 included work undertaken in the Kara and Barents Seas in association with scientists at Okeangeologica in St. Petersburg, Russian and Akvaplan Niva in Tromso, Norway. Seawater samples collected on these cruises will be analysed for ^{137}Cs and ^{129}I in order to determine input functions for these tracer isotopes into the Arctic Ocean.

Analytical Work

Central Arctic Ocean

More than 150 sediment and seawater samples collected during Canadian icebreaker cruises in the Arctic Ocean during 1994-96 (Ellis *et al.* 1995) were analysed in 1997-98. Measurements of ^{210}Pb, ^{137}Cs and $^{239,240}Pu$ conducted on sediment samples from box cores collected on slope/shelf regions of the Makarov, Canada and Eurasian Basins reveal elevated radionuclide levels in slope/shelf compared to deep basin sediment regimes owing to preferential scavenging in the former regions. Radionuclide sediment-depth profiles have been introduced into biodiffusion models to constrain sedimentation and bioturbation rates. ^{129}I and ^{137}Cs analyses of seawater samples from both the icebreaker and submarine cruises clearly delineate the plume of Sellafield and Cap La Hague contaminants being transported across the Arctic Ocean (Smith *et al.* 1998a). ^{129}I sections have been constructed for the Makarov Basin and the Beaufort Sea from the 1994 and 1995 CSS St. Laurent cruises. The 1994 results clearly show the "front' between Atlantic-origin water, labelled with reprocessing plant signals and Pacific-origin water distinguished mainly by fallout from nuclear weapons tests which is positioned over the Mendeleyev Ridge (Carmack *et al.* 1997). The 1995 icebreaker results from the Beaufort Sea show the presence of a boundary current aligned with the Canadian continental slope carrying elevated levels of reprocessing ^{129}I along the North American continental margin.

^{129}I and ^{137}Cs samples collected during the 1996 and 1997 US Navy nuclear submarine cruises aboard the USS Pogy and USS Archerfish, respectively were also analysed in 1997-98. The Pogy results have been used to construct an ^{129}I section for the Canada Basin which is the first chemical tracer section of any kind for this part of the Arctic Ocean (Smith *et al.* 1998b). These results reveal that, contrary to previous thought, the interior of the Canada Basin is relatively efficiently ventilated, probably by boundary current separation north of the Chukchi Plateau. These results also show the front between Pacific and Atlantic origin water along the Mendeleyev Ridge in considerable detail, in regions of the Arctic Ocean, not previously sampled.

Barents and Kara seas

Sediment samples collected during an Okeangeologia research cruise in Kola Bay, the site of numerous radioactive waste storage sites and the home of a large portion of the Russian military and civilian nuclear fleet, have been analysed for a wide range of radionuclides in 1997/98. Elevated levels of ^{60}Co and ^{137}Cs are clearly related to the operation of nuclear submarines and show that emissions from these vessels have resulted in radioactive contamination of the seabed. Radionuclide measurements have also been continued on samples collected in 1994–96 in the Barents and Kara Seas. Sediment and seawater samples collected from Chernaya Bay, Novaya Zemlya in collaboration with Russian scientists from Okeangeologia in St. Petersburg and the Murmansk Marine Biological Institute were analysed for ^{137}Cs, $^{239,240}Pu$, ^{60}Co and ^{210}Pb. Chernaya Bay is the site of at least two underwater nuclear weapons tests conducted by the former Soviet Union in the 1950s. Levels of $^{239,240}Pu$ in the sediments caused by fallout from these tests are among the highest recorded anywhere in the world and are equivalent to levels measured at the US nuclear test site in the Marshall Islands in the Pacific Ocean (Smith *et al.* 1995). The sediment-depth distributions of radioactivity have been modelled using ^{210}Pb profiles and a biodiffusion model in order to predict the rates of burial and potential release of radioactivity from these highly contaminated regimes. Measurements of radioactivity were also conducted on several species of sediment infauna in order to estimated rates of uptake of radioactivity into the food chain. Trace metal analyses of these sediment samples have also revealed unusually high levels of As which are clearly associated with the weapons tests.

In 1993, sediment and seawater samples were collected in the vicinity of a submerged vessel, identified using side-scan sonar in the Novaya Zemlya Trough in the Kara Sea, which is reported to have contained over 200 curies of radioactive wastes when it was scuttled in 1980. Radionuclide analyses on these samples indicate that there is negligible release of radioactivity from the dumpsite. Measurements of ^{129}I and ^{137}Cs in the water column proximal to the dumpsite indicate that these contaminants are derived from European reprocessing plants with smaller inputs coming from the Ob River. The analysis of seven sediment cores collected in 1993 in the Ob and Yenesey River estuaries was continued through 1995/1996. Elevated levels of ^{137}Cs and ^{60}Co in sediments at the mouth of the Yenesey River have also been traced to the Krasnoyarsk nuclear complex located several thousand kilometres upstream. This represents one of the few cases in which releases from upstream nuclear facilities in Russia have been shown to produce significant contamination in downstream estuaries.

DISCUSSION/CONCLUSIONS

Kara and Barents Sea

One of the major accomplishments of this program was the detection of elevated levels of plutonium in Chernaya Bay, Novaya Zemlya (Smith *et al.* 1998c), indicating that this fjord represents a potential source of radioactivity contamination to the Barents Sea and Arctic Ocean. Measurements of the distribution of $^{239,240}Pu$ and ^{241}Am with distance from Chernaya Bay into the Barents Sea reveal that approximately 25% of the plutonium originally produced in the weapons tests has been transported out of Chernaya Bay. to distances as great as 100 km from the test location. This indicates that Chernaya Bay could remain a significant source of radioactivity to the Arctic Ocean for many years in the future. Further, extremely elevated levels of plutonium measured in organisms from Chernaya Bay indicate that significant uptake is occurring into lower trophic levels. Future international monitoring of this location will be required to determine whether there will be significant long term biological or toxicological effects associated with the dissemination of radioactivity through the fjord.

Studies of radionuclide distributions in sediments and seawater in the vicinity of a radioactive waste dumpsite in the Novaya Zemlya Trough that was studied as part of the DIAND project indicate that there are only negligible, local releases of radioactivity. Although it appears that measures taken to isolate the radioactive wastes from dissolution in seawater have been effective, it is difficult to predict the time-table for future releases and continued monitoring of this dumpsite will be probably be required. However, this represents a far less severe radioactive contamination site that those within the Novaya Zemlya fjords where fuelled nuclear reactors have been deposited on the seabed.

Radioactivity results from the 1993, 1994 and 1995 CSS Louis S. St. Laurent icebreaker cruises and the 1995, 1996 and 1997 US Navy submarine cruises have revealed the broad distribution of radioactivity signals from European reprocessing plants throughout the Arctic Ocean. These results provide a clear outline of the “front” between Atlantic and Pacific-origin water in the western Arctic Ocean and show that this “front” is aligned along the Mendeleyev Ridge. They also provide evidence of the subsurface transport of Atlantic water as a boundary current along the continental margin of the Makarov and Canada Basins. These tracer distributions delineate the pathways that contaminants from European sources follow as they circulate through the Arctic Ocean and can show the extent to which these contaminants flow through the Canadian Archipelago. Further, comparisons of the $^{129}I/^{137}Cs$ ratios measured in water samples with source function data permits estimates of time scales for the transport of Atlantic water through the Arctic Ocean. Although levels of radioactivity in the Canada Basin are significantly in excess of background levels from nuclear weapons tests, they are still lower than those that would constitute a radiological threat to organisms or humans in the Arctic. Nevertheless, it is clearly important to have a radiological surveillance program operating in the Arctic marine environment, because transport from European industrial outfalls to the central arctic can occur on very rapid time scales.

The results from the Arctic Radioactivity Contaminants Program supported by funding from the Northern Contaminants Program are reported in the series of papers referenced on the following page.

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ORGANOCHLORINE AND PAH CONTAMINANTS IN ARCHIPELAGO AIR AND WATERS

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Project Team: C. Teixeira, NWRI, Burlington, ON; T.F. Bidleman, AES, Downsview, ON; L. Lockhart, G. Stern, FWI, DFO, Winnipeg, MB

OBJECTIVES

1. **Short-term:** To collect and analyse water, air and sediment samples for POPs during the passage of the CCGS St. Laurent through the Northwest Passage (Joint Oceanographic and Ice Studies) during 1997 and 1998.
2. **Long-term:** To provide data for and assess the bioaccumulation of POPs in food webs in the Archipelago; to evaluate the fluxes of contaminants through the Canadian Archipelago in an overall mass budget assessment of the Arctic Ocean.

DESCRIPTION

Control of POPs contaminants within the Arctic itself (e.g., UN-ECE-LRTAP POPs Protocols) rests on persuading governments outside the Arctic region of the importance of limiting POPs use within their jurisdictions. This, in turn, depends on presenting a case that the release of POPs in these countries is affecting levels in the Arctic region and will be remediated by any control action. These aspects of international control depend on a solid data base concerning present levels in the system and on spatial and temporal trends developed using past and present data. Domestically, the NCP workshop in Iqaluit (July, 1997) indicated a focus on bioaccumulation of POPs in traditional foods in the region; however, water, air and sediment concentrations will be needed model and quantify exposures in the region and to project trends in the food concentrations over time following national and international control measures. All biomagnification expressions ultimately must include a term for water concentration.

The Canadian Archipelago represents the major surface water output from the Arctic Ocean (CACAR, Chapter 2, 1997). While some recent data exist for concentrations of POPs contaminants in the Ocean itself (Strachan *et al.* 1998, CACAR, Chapter 2, 1997, papers presented in *Science of Total Environment,* Vol. 160/161, 1995), the data for the Archipelago are limited. Some work on the water and air of the region was done at Resolute Bay (Bidleman *et al.* 1995) and for air at Alert and Cape Dorset (summary in CACAR, Chapter 2 1997) but there have been no widespread assessments. Most emphasis has been on the relatively abundant HCHs with toxaphene being the subject of limited additional investigation. Other organochlorines have received much less attention.

In 1997, the Department of Fisheries and Oceans (DFO) and the US-National Science Foundation (NSF) initiated a surface heat budget study (SHEBA) of the Arctic in which a Canadian icebreaker was installed in the permanent ice cap along the Canada–U.S. border at 75-76°N. As part of the commissioning and decommissioning of SHEBA, supply ships were to pass through the Canadian Archipelago. The opportunity to use these vessels as sampling platforms was offered by DFO and provided the opportunity for this project.

ACTIVITIES IN 1997/98

In FY 1997/98, support was received to cover analytical costs of samples collected during the commissioning expedition (JOIS-I). CCGS Louis S. St. Laurent was used and water, air and sediment samples were collected from the western part of the Northwest Passage in September 1997. Limited samples were acquired due to scheduling changes required for commitments of the ship; samples received, however, were of good quality. Locations for water samples reflected northern inputs to Viscount Melville Sound rather than waters of the Passage itself. Air samples are representative of the region.

POP analytes investigated included the organochlorine pesticides (20 OCPs), the PCBs (132 congeners incl. 18 co-elutants plus total), the chlorobenzenes (9 CBs) and the PAHs (18 priority pollutants). All samples

Table 1. Concentrations of Selected Contaminants in Western Archipelago Waters: Dissolved (av. of duplicates) and Suspended Solids – Sept. 1997.

	Surface Water, ng/L						S.Solids, pg/L		
Station No.	**11[1]**	**22[2]**	**27[2]**	**32[2]**	**36[1]**	**Av.**	**22**	**27**	**32**
Date (1997)	**Sep.2**	**Sep.5**	**Sep.6**	**Sep.7**	**Sep.14**	**%rsd**	**Sep.5**	**Sep.6**	**Sep.7**
α-HCH	5.5	5.1	5.4	4.9	5.5	7	nd	nd	nd
γ-HCH	0.57	0.56	0.55	0.54	0.58	8	0.3	0.4	nd
dieldrin	0.011	0.022	0.075	0.015	0.015	140	0.3	0.6	nd
hept.epox.	0.001	0.005	0.006	0.005	0.006	32	nd	nd	nd
ΣDDT	0.001	0.003	0.034	0.045	0.001	127	nd	1.3	0.2
HCB	0.011	0.009	0.008	0.007	0.008	17	0.2	0.3	0.2
ΣPCB	0.32	1.65	0.87	0.60	0.01	24		340.	120.
fluorene	nd	0.77	0.48	0.62	0.03	32	21.	8.2	2.4
phenanthrene	0.13	2.2	1.9	2.0	0.15	23	350.	104.	44.
fluoranthene	0.08	0.50	0.39	0.47	0.02	20	790.	200.	71.
pyrene	0.12	0.30	0.16	0.15	0.04	58	530.	107.	51.
chrysene	0.08	0.08	0.06	0.04	0.01	22	390.	120.	34.
ΣPAH	2.1	4.8	4.5	3.9	0.68	17	4900	1450	384

[1] Whole water sample [2] Centrifuged water sample

collected are processed and analysed for the stated POPs except PAHs in the single sediment sample. Toxaphene has yet to be determined in any samples; a compositing strategy (2-3:1) is being developed to allow quantitating the low levels of individual components. Partial reporting occurred at the 1998 NCP Results Workshop in Calgary, 1998.

RESULTS AND DISCUSSION

The sampled sites included one to the east of Resolute Bay (#11, Wellington Channel), three in Viscount Melville Sound, in the Austin and Byam Channels and in the Sound itself south of the east end of Melville Island (#22, #27 and #32 , respectively), and one outside the Archipelago (#36, NW of Banks Is.). Air samples were in the same regions but were collected between stations when the ship was underway.

Surface water samples were of two types: whole water samples (ca. 75 L duplicates), obtained from separate casts of a 100L Go-Flo bottle when large volume sampling for suspended solids was precluded, and samples pumped on board and centrifuged (<0.5-0.7μ equivalent filter) into dissolved (80-160 L duplicates) and suspended solids (ca. 1800 L). Analyte extraction was by pumping the water sample through 75 g XAD-2 resin and refrigeration of the resin. Surficial sediment samples were opportunistic from a box corer from the top 1-2 cm. (Most of the sediment samples are undergoing core dating and analysis at FWI; only one is reported on here.) Sediments and suspended solids were bagged in pre-cleaned polyethylene bags and frozen. Air samples (av. 300 m^3 from a Hi-Vol sampler using PUF plugs) were from the bow of the ship and the used PUF plugs were replaced in their original jars and frozen.

All samples were analysed at the NWRI laboratories according to standard procedures. Results for selected analytes are presented in Table 1 for dissolved and suspended solids; those for the same analytes for air and the one sediment sample are given in Table 2. Detection limits were roughly 0.001 ng/L (dissolved), 0.0001 ng/L (susp. solids), 0.1 pg/m^3 (air) and 0.01 ng/g (sediment); values for PAHs are somewhat greater than this (5-10X). Toxaphene is another composite parameter and samples must be combined to achieve detection limits appropriate to expected levels; presently, combining three samples is being considered. Field blanks were collected for water and air samples; procedural blanks were done in the laboratory for the solid samples. Results presented are blank corrected. Replication among the duplicate water samples was generally within those expected for normal analytical limits. The values of the relative standard deviation (%RSD, Table 1) for ΣDDT was higher because this is a composite parameter each component of which is near its detection limit. Dieldrin also has a high level of imprecision; no explanation for this is apparent.

In water, the HCH values – both α-HCH and γ-HCH – were very constant throughout the region. Mean values for these two analytes were 5.3 and 0.56 ng/L dissolved; nd and 0.0002 ng/L were observed sorbed to the suspended solids. For dieldrin, ΣDDT and ΣPCBs, the concentrations at stations 22, 27 and 32 were higher than for the other two sites; heptachlor epoxide and HCB were more consistent. The PAHs were not apparently so constant but the number of samples is presently too small to clearly identify any spatial patterns. Those in dissolved state from stations 22, 27 and 32 seem to be at higher levels than those from 11 and 36; the latter was lowest of all and lies outside the Archipelago proper. Further assessment of spatial patterns will await additional sampling in 1998.

It is apparent from Table 1 that the contribution of the sorbed contaminants to the overall surface water burden is small. ΣDDT has the largest fraction of the OCPs in this sorbed state – 3% – others are less. The ΣPCBs with 22% in this form have a much more significant contribution. The PAHs show a gradually increasing proportion in the sorbed state ranging from 3% for fluorene to 76% for chrysene; the ΣPAH parameter averaged 20%.

Among the air data (Table 2), the HCHs also showed little variability – mean values for α-HCH were 91. pg/m^3; for γ-HCH 6.1 pg/m^3. The values for dieldrin and heptachlor epoxide were low occurring at sub-pg/m^3 for the most part. The ΣDDT and HCB were observed at more significant levels – means were 15. and 75. pg/m^3, respectively. In the case of the PCBs, there was no trends apparent among the three areas – west of Resolute (Sept. 5–8), south through Peel-Franklin-Victoria passage (Sept. 8–11) and west of Banks Island (Sept. 13–15). The PAHs were more variable but also with little correlation with position. Samples from September 8–13 were collected from the bow of the ship while the ship was continuously underway; results encompass much the same range as the other samples; for this reason, it is felt that there the samples collected throughout the cruise are reflective of Archipelago conditions rather than any contribution from the ship.

At this time, the sample numbers are too few to be definitive about any spatial patterns for the contaminants. The FY 1998/99 and that for 1999/2000 are expected to improve this situation.

Expected Project Completion Date: March 31, 1999

Table 2. Concentrations of Selected Contaminants in the Western Archipelago: Air and Sediment Sept. 1997.

Sample Dates (1997)	Air Sample (pg/m^3)								Sediment (ng/g-dry)
	Sept. 5 Sept. 6	Sept. 6 Sept. 7	Sept. 7 Sept. 8	Sept. 8 Sept. 9	Sept. 9 Sept. 10	Sept. 10 Sept. 11	Sept. 13 Sept. 14	Sept. 14 Sept. 15	Station 8
α-HCH	96.	90.	88.	97.	73.	77.	88.	116.	0.11
γ-HCH	5.9	6.3	6.0	6.5	4.9	4.5	6.1	8.3	0.02
dieldrin	2.2	1.3	0.7	0.8	0.7	0.8	0.7	1.4	0.06
hept.epox.		0.7							
ΣDDT	14.	8.6	10.4	29.	16.	19.	13.	12.	0.21
HCB	73.	73.	74.	98.	9.3	84.	87.	100.	0.02
ΣPCB	280.	210.	200.	280.	180.	170.	140.	160.	
fluorene	340.	53.	600.	170.	320.	660.	960.	260.	
phenanth.	480.	250.	700.	290.	350.	760.	790.	300.	
fluoranth.	69.	35.	69.	61.	45.	61.	47.	36.	
pyrene	37.	12.	33.	19.	15.	34.	19.	9.3	
chrysene	7.2	6.9	4.1	5.7	tr	5.4	nd	tr	
ΣPAH	1050.	407.	1660.	600.	850.	1810.	2100.	700.	

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IDENTIFYING SOURCES, QUANTIFYING PATHWAYS, AND PREDICTING TRENDS OF HCHS IN THE ARCTIC USING GLOBAL MODELS

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Project Team: Y.-F. Li and T.F. Bidleman, Atmospheric Environment Service

OBJECTIVES

The main objective of the project was to reproduce quantitatively with model calculations the observed historical and recent global distribution behaviour of an important organochlorine pesticides, α-HCH, with a view to:

1. quantify transport pathways into the Arctic, namely distinguishing between transport in the atmosphere and in the oceans (analysing both net and gross fluxes) and through the fresh water system
2. attempt an initial apportionment of sources by identifying in which latitudinal zone the POPs presently found in the Arctic originated and how long ago in the past they were released, and
3. predict what is likely to happen to the concentration levels in a variety of Arctic environmental media within the next decade
4. to substantiate and refine property criteria for classifying chemicals as being susceptible to long-range transport, particularly to Arctic regions
5. to compile a “geographic” model which is complementary to the “meridional” model and assess its relative performance

DESCRIPTION

There are several questions concerning the global fate and behaviour of persistent organic contaminants in general, and of α-HCH in particular, that can not be answered adequately without the help of models. Examples are:

1. What are the major reservoirs of a chemical on the global scale, i.e. in which environmental compartments and in which climate zones does most of the chemical reside?
2. What are the primary pathways of a chemical on a global scale? Is the primary pathway of α-HCH from the continents to the oceans via the atmosphere or via river flow? Does meridional transport of α-HCH to higher latitudes occur primarily in the atmosphere or in ocean currents?
3. How does the environmental behaviour of a chemical differ in different climate zones, namely are the major reservoir and pathways the same in various regions, or do different zones play different roles in the global picture of a chemical's fate?
4. Given certain assumption of how the emission will develop in the future, how will concentrations change? More specifically for α-HCH the question is how long will it take for the concentrations in the Northern Oceans to drop below a certain level assuming no more emissions world-wide.

In this project a zonally averaged global distribution model was employed to address these questions. A related model based on a geographic rather than a latitudinal subdivision of the globe was developed further. We show that a mass balance model can provide a comprehensive and consistent picture of global chemical fate that is difficult or even impossible to obtain by other means.

ACTIVITIES IN 1997/98

Work with the “Zonally Averaged” Model

The performance of the zonally averaged global model in describing the global fate of α-HCH was evaluated. The results compared reasonably well with the global behaviour of this chemical as determined by measurements of concentrations in the atmosphere and sea water, and the model could thus be employed to address questions of mass balancing, source apportionment and future trend prediction. An early version of this work was presented at the AMAP symposium in

Tromsø in June 1997 (Wania *et al.* 1997). A series of three papers summarizing this work was written and submitted for publication (Wania and Strand 1998, Wania *et al.* 1998, Wania and Mackay, 1998).

Work on the "Geographic" Model

A feature of the meridional model is that it lumps all regions at similar latitudes, regardless of the intensity of local use of chemicals. For example, the Sea of Japan and the Mediterranean Sea are combined. In an attempt to address this problem we have pursued a complementary approach to the existing meridionally segmented model in which the global environment is divided into a number of discrete, yet connected land and ocean surface segments. This has the potential to give a more realistic representation of environmental characteristics for a given area, as well as a basis for using emission data for specified geographic regions. The model is designed to provide a complete dynamic chemical mass balance for terrestrial and ocean compartments, estimates of chemical concentrations in all media as a function of time (to be validated to the extent possible using available concentration data), and amounts of chemical in each compartment that are degraded or transferred to ocean or lake sediment for permanent burial. The model should also be useful for predicting the amounts and resulting concentrations of chemical which are transported to Arctic regions from sources in tropical and temperate zones, and hence assessing levels of exposure experienced by humans and wildlife.

The geographic model segmentation was revised to a total of 24 segments; 14 terrestrial and 10 oceanic. The selection of terrestrial segments was largely based on political boundaries, mainly because environmental and chemical emission data are often available as national values. The selection of ocean segment boundaries was more subjective and was based on large scale atmospheric and oceanic movements – i.e. advective meridional and latitudinal transport in the atmosphere and in the surface ocean. As in the meridional model, each segment within the model contains a series of compartments which are connected by air mass movement, fresh water runoff and oceanic circulation. Terrestrial segments contain atmosphere, fresh water, fresh water sediment and two soil compartments, while ocean segments contain atmosphere and surface water compartments.

Volumes and relevant properties were assigned to individual compartments similarly to the meridional model. Atmospheric height is assumed constant at 6000 m, the depth of surface ocean layer is 200 m, the fresh water depth is 20 m, and the sediment depth is 5 cm. Two soil compartments are included: A cultivated soil that may receive pesticide input and an uncultivated soil. This separation, which is made on the basis of land use in a typical temperate environment, is considered necessary to avoid pesticides being excessively diluted on application. Depths assigned to cultivated and uncultivated soil compartments are 5 and 1.5 cm, respectively.

Parameters describing environmental properties and characteristics of the 24 global segments have been compiled from a number of sources. These include temperature, precipitation, runoff, runoff rate, fresh water depth, fresh water surface area, and soil organic carbon content. Most parameters are assumed to stay constant throughout the year, but some vary seasonally, following a sinusoidal function over the course of a year, and thus require the input of an annual mean value and the maximum annual amplitude. For example, temperatures have minima/maxima on 1 January and 1 July, while sea ice coverage in the northern and southern polar zones peaks on 1 February and 1 August, respectively. If the property has a value P_1 on 1 January, i.e. day zero, and a value of P_2 on 1 July, i.e. day 182, the property has a value at other days (t) as follows: $P = 0.5 (P_1 + P_2) + 0.5 (P_1 - P_2) \sin(2\pi t/365)$.

Using the compiled data a complete set of chemical transport and transformation rate expressions has been developed for a specified chemical as a function of time in the form of fugacity D values, and the entire set of equations can be solved by numerical integration. To simplify and speed up the calculation D and Z values are calculated for every process and medium on January 1 and July 1, and intermediate values selected using the sine function. The chemical mass balance program thus uses as input these Z and D values, as well as volumes and the specified emissions as a function of time. It then computes the mass of chemical in each compartment as a function of time. The output data can then be plotted and interpreted. This aspect of the work is ongoing with code being written and tested. When we have confidence that the coding is reliable and the method of solution robust the model will be applied to α-HCH in a manner analogous to that of Wania *et al.* (1998) in the complementary model. The output of the two models will then be compared.

RESULTS

Overall Global Mass Balance

The zonally averaged model was used to assemble a mass balance on the entire globe and for the entire 50-year release period of α-HCH showing major reservoirs, intercompartmental pathways, and loss processes (Figure 1). Such a mass balance suggests that most (99.0%) of the 6800 kt of α-HCH emitted into the global environment from 1947 to 1997 has been degraded, most of it in the agricultural soils of initial emission. Some degradation occurred in the atmosphere and the surface oceans. The model suggests that minor fractions have been buried in fresh water sediments (0.6%), and transferred to the deep sea (0.2%) and only 0.2% are still dispersed in the global environment today, most of it in the world oceans. The transfer of α-HCH from the agricultural soils to the world oceans is the dominant feature of intercompartment transport with 6% of the global total emission having reached the marine system. This transfer occurs both through the atmosphere by evaporation from soils and fresh water bodies and deposition to the oceans, and by direct run-off to the oceans. The atmospheric pathway is more important.

Distribution of Emission and Amounts Among Zones and Compartments

Figure 1 shows the environmental behaviour of α-HCH averaged across all climate zones and through 50 years of emission history, disguising any potential differences in space and time. The magnitude and spatial distribution of technical HCH usage underwent large changes, particularly after 1980 (Wania *et al.* 1998). The model suggests that this had a notable impact on the relative distribution of α-HCH among zones and compartments. The absolute and relative distribution of emissions and amounts among the zones and compartments shifted especially during the time period that technical HCH usage was phased out globally (Figure 2). There was a gradual shift in the relative distribution of the emissions of α-HCH among climate zones from the Northern temperate and subtropical zone, which received most of the global emissions in the early 1980s, to the Northern tropical zone, which accounted for 80% of global usage in the 1990s (Figure 2B). This shift is caused by a faster decrease in technical HCH usage in the mid-latitudes, rather than an increase in usage in the Tropics (Figure 2A).

The time period since 1980 also saw a dramatic shift in the distribution of the total global amount of α-HCH from the Northern temperate and subtropical zone to the boreal and polar zone (Figure 2D). In 1980 only about 5% of the global total inventory of α-HCH was found in

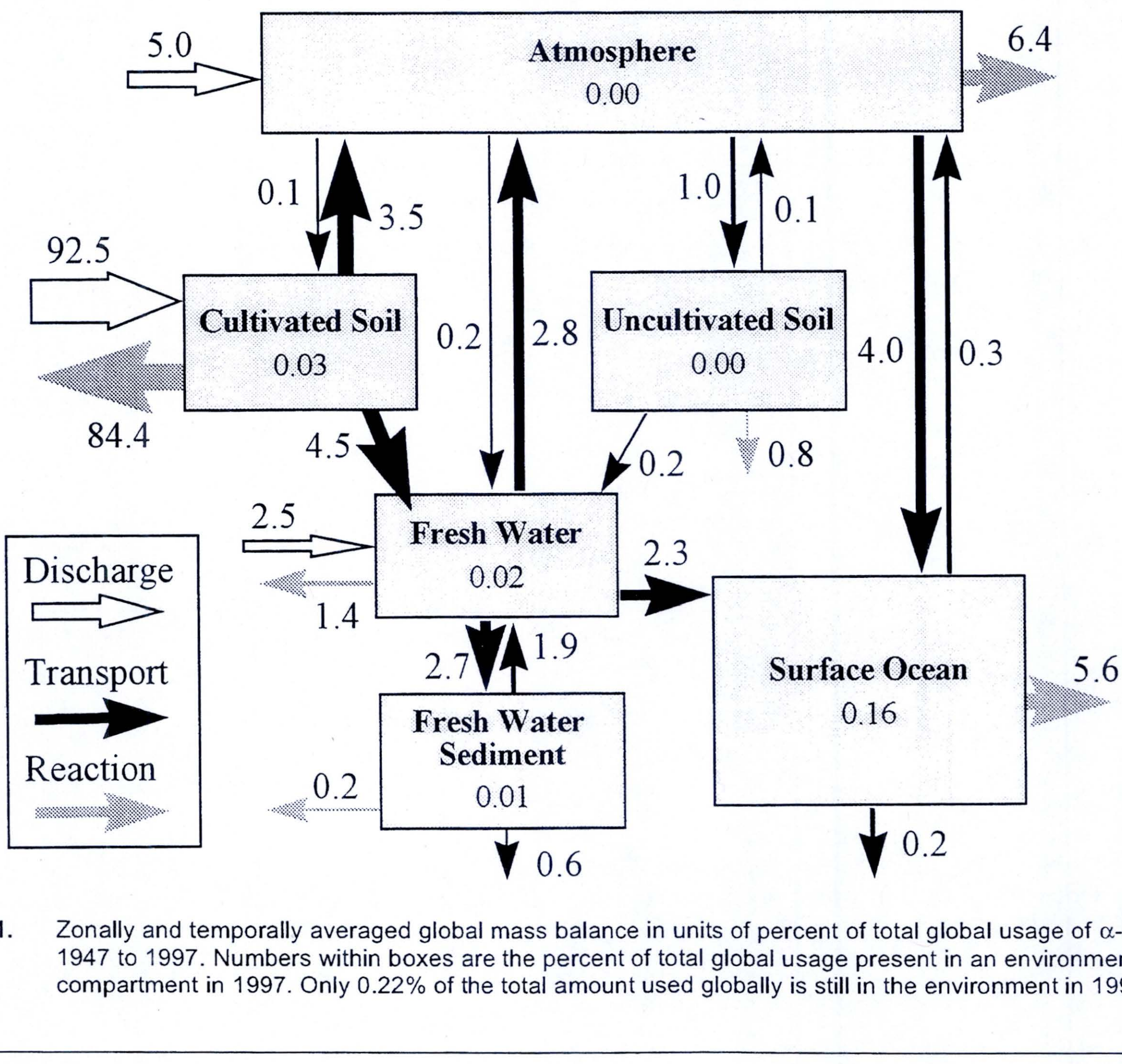

Figure 1. Zonally and temporally averaged global mass balance in units of percent of total global usage of α-HCH from 1947 to 1997. Numbers within boxes are the percent of total global usage present in an environmental compartment in 1997. Only 0.22% of the total amount used globally is still in the environment in 1997.

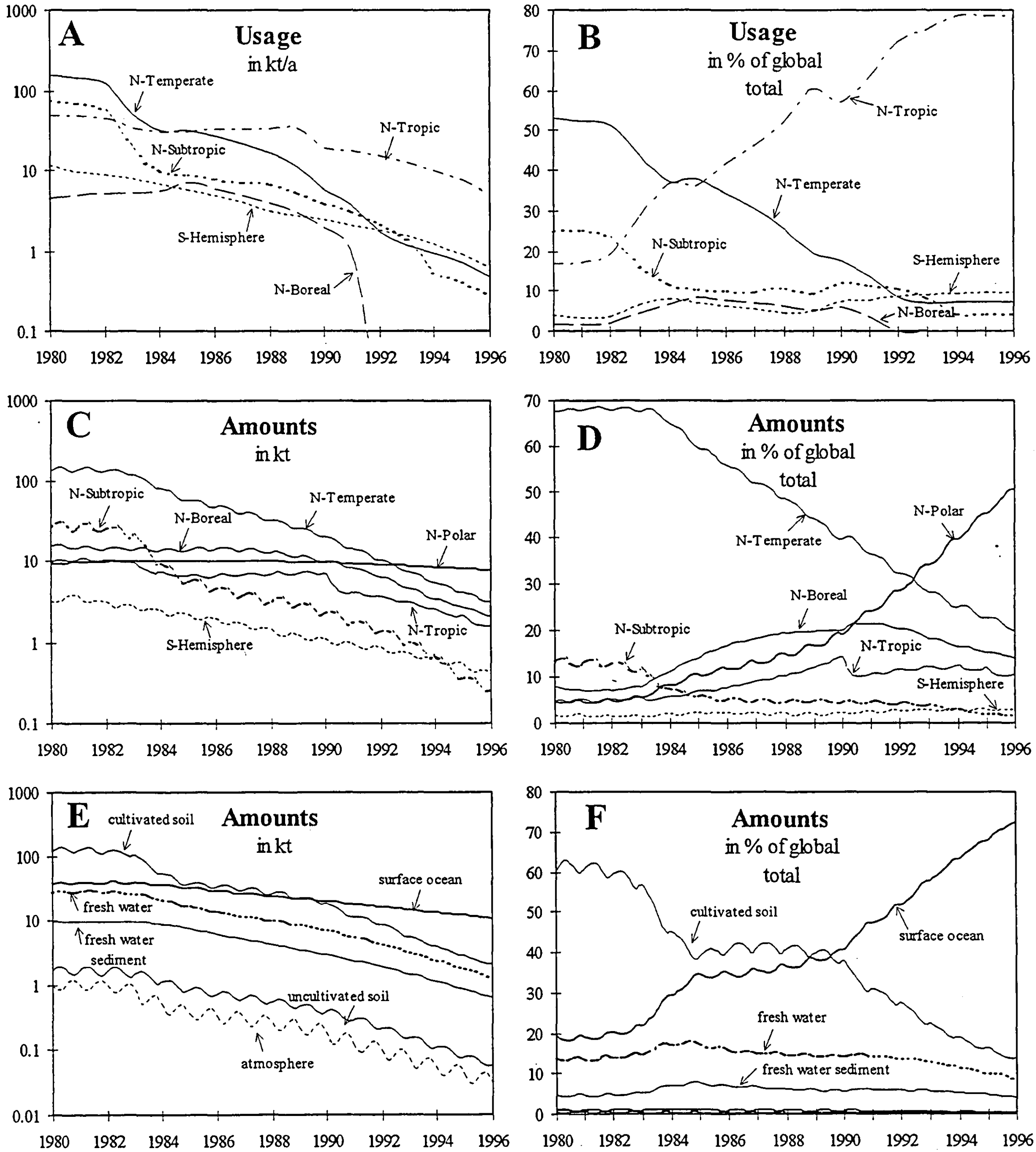

Figure 2. Change of the absolute and relative global distribution of the total global emission of α-HCH among climate zones (A+B), and of the total global amount of α-HCH among climate zones (C+D) and compartments (E+F) in the time period 1980 to 1996.

Table 1. Percentage of the amount of α-HCH found in a zone in the northern hemisphere in 1980 and in 1995 that has been emitted into a particular zone. Also given is the total amount in a zone in kt.

	Polar	Boreal	Temperate	Subtropic	Tropic
1980					
N-Polar	0%	0%	0%	0%	0%
N-Boreal	45%	78%	1%	0%	0%
N-Temperate	51%	21%	99%	4%	1%
N-Subtropic	4%	1%	1%	96%	2%
N-Tropic	0%	0%	0%	0%	97%
Southern Hemisphere	0%	0%	0%	0%	0%
Amount	**9.38 kt**	**15.13 kt**	**139.21 kt**	**27.50 kt**	**10.23 kt**
1995					
N-Polar	0%	0%	0%	0%	0%
N-Boreal	50%	76%	14%	5%	0%
N-Temperate	46%	22%	84%	16%	0%
N-Subtropic	3%	1%	1%	77%	0%
N-Tropic	0%	0%	0%	2%	100%
Southern Hemisphere	0%	0%	0%	0%	0%
Amount	**7.80 kt**	**2.37 kt**	**3.58 kt**	**0.32 kt**	**1.71 kt**

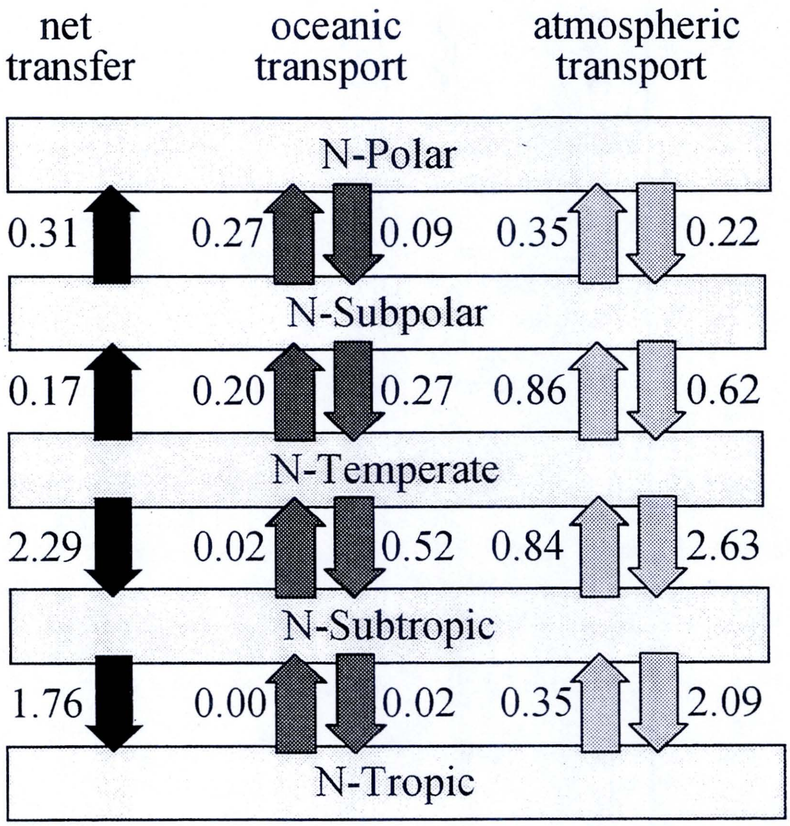

Figure 3. Calculated atmospheric and oceanic transfer rates of α-HCH between climate zones in the northern hemisphere in units of percent of total global emissions until 1997.

the Arctic. By the mid-1990s this share had increased steadily to 50%. Correspondingly, the fraction in the northern temperate zone dropped from almost 70% to less than 20% in the same time period. Interestingly, the increasing share of emissions into the Northern Tropics (Figure 2B) is not reflected in an increasing share of the accumulated amount in that zone (Figure 2D), presumably because α-HCH released in the Tropics is rapidly degraded within that zone. The shift in zonal distribution is accompanied in a similar dramatic shift in the distribution among compartments, sea water gradually replacing the agricultural soils as the major reservoir of α-HCH in the global environment (Figure 2F). A closer look reveals that this shift in relative distribution is not caused by interzonal chemical transfer, i.e. by a enormous northward transport of α-HCH to the Arctic, but rather appears to be primarily a reflection of slow degradation of α-HCH under Arctic conditions and fast removal under tropical conditions (Figure 2C). In fact, the shift in distribution of α-HCH is a reflection of the fact that the Arctic Ocean now constitutes the last refuge of this chemical, containing presently half of all the α-HCH dispersed globally.

Meridional Transport in Atmosphere and Oceans

Although the large fraction of the global inventory of α-HCH which is found in the Arctic is not caused primarily by northward transport (but rather differential persistence), the presence of the chemical there is of course a result of long-range transport from the South, which is evident by the lack of local sources in the polar zone. An analysis of the meridional transport pathways (Figure 3) shows that only a tiny fraction of the global total α-HCH emission actually reaches the Arctic, namely 0.6%, of which half is transferred back to more southerly latitudes. It is all the more noteworthy that this small fraction can amount to one half of the total global inventory. Interestingly, the atmosphere and the oceans are of about equal importance in delivering α-HCH to the Arctic. However, with decreasing latitude the atmosphere becomes the dominant meridional transport medium and the exchange of α-HCH between sub-tropical and tropical oceans is negligible.

A Source Apportionment for α-HCH in the Arctic Zone

The zonally averaged global distribution model was used to apportion the amount of α-HCH found in a zone of the Northern hemisphere in 1980 and 1995 to its various zones of origin, i.e. track into which zone it has been initially emitted (Table 1). This calculation suggests that most of the α-HCH found in the Arctic in 1980 and in 1995 originated in the Northern temperate and boreal zone, whereas the import from low latitudes, particularly the Tropics is minor. This suggest that it is likely the usage of technical HCH in the former Soviet Union that caused the presence of α-HCH in the Arctic. The model also reveals that most (often more than 95%) of the α-HCH present in the temperate, subtropical and tropical zone has been emitted within that zone. Compared to 1980, this autochthonous contribution decreased substantially in the subtropical and temperate zone in 1995. However, this was not due to increased import from tropical areas, where α-HCH usage continued, but rather by increased relative contributions from the neighboring zones to the North. This is likely due to the higher persistence in higher latitudes, which results in higher concentrations and thus higher inflow from the North. The contribution from the Southern hemisphere is always negligible.

Future Trend Prediction

Model calculations were performed beyond 1997 assuming no further emissions after that date in order to predict future arctic α-HCH concentration levels. The predicted concentration decrease in the arctic atmosphere with a half-life of four years and in the Arctic Ocean with a half-life of 11.5 years. Degradation (53%), transfer to deeper water (28%), and net outflow to the South (16%) contribute to the loss of α-HCH from the Arctic Ocean, whereas the loss by evaporation (3%) is negligible. This suggests that the reversal of diffusive air-sea exchange, which was both observed in the Northern seas (Bidleman *et al.* 1995) and reproduced by the model (Wania *et al.* 1998), is of little significance for the mass budget of α-HCH in the Arctic Ocean. Even if emissions are assumed to continue at 1997 levels, the rate of decrease is the same, indicating that emissions of α-HCH in tropical areas have little impact on present arctic concentration levels, thus confirming the findings of the source apportionment (Table 1).

DISCUSSION/CONCLUSIONS

Clearly, zonally averaged global multi-media models have the potential to provide quantitative estimates of the global transport pathways of persistent organic chemicals, can indicate in which climate zones they had been emitted, and have some capability to predict how concentration levels are likely to develop in the future. There are a number of lessons to be learned from this modelling exercise:

1. Elevated concentrations of a persistent chemical in the Arctic can result from even a tiny fraction of the global inventory being transferred there by long-range transport. For chemicals more persistent and more bioaccumulative than α-HCH, even smaller fractions should be sufficient to accumulate to levels of concern in the Arctic environment. This is because of the relatively small spatial extension of the polar regions, and an increased chemical persistence under Arctic conditions.

2. The environmental behaviour of a chemical can differ substantially from one climate zone to another. For example, a chemical which is considered not very persistent under conditions of temperate and tropical environments can be very persistent in polar regions. The evaluation of a chemical's persistence has to take into account the environmental condition of the environment into which it is released or into which it could be transported. It can be argued that emissions of persistent chemicals in Arctic areas should be subject to more stringent rules than in temperate (or even tropical) areas.

3. The results illustrate that the global ban of a persistent organic chemical can result in significant and immediate reductions in environmental concentrations. 15 years after the virtual global phase-out of this chemical, residue levels have decreased notably all over the world. However, the response to a phase-out of a chemical occurs obviously at different rates in different climate zones and in different environmental media. Tropical areas and the atmosphere are likely to respond rapidly, whereas polar areas and the marine environment are slower to react to changes in emissions of a chemical with the characteristics of α-HCH.

4. In the study of the long-range transport of persistent organic chemicals there has traditionally been a focus on the atmosphere as a transport medium. The example of α-HCH, however indicates that the oceans can contribute significantly to the transport of organic chemicals over long distances, if these are relatively water soluble and persistent enough in the aqueous phase that a significant fraction survives the journey of several years.

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MERCURY ACCUMULATION IN SNOW ON SEA ICE

Project Leader: H. Welch, Dept. Fisheries and Oceans, Winnipeg, MB

Project Team: K. Martin; L. Lockhart; G. Boila, DFO, Winnipeg, MB

OBJECTIVES

1. To determine the amount and regional distribution of mercury coming into the Canadian Arctic and sub-Arctic via long-range atmospheric transport, and accumulating in snow over sea-ice during winter.

DESCRIPTION

Mercury biomagnifies in aquatic food chains and as a result poses a continuing problem for the consumption and marketing of northern fish and marine mammal resources. Inputs of mercury are partly natural and partly anthropogenic. Anthropogenic sources are estimated to have approximately tripled the concentrations of mercury in air and seas of the Northern Hemisphere (Mason *et al.* 1994, Fitzgerald 1995), with similar increases in Arctic ecosystems (e.g., Lockhart *et al.* 1998). Mercury may also pose a biological risk for the animals themselves. Mercury enters the North principally with air masses that pass from temperate regions into the North. However, we have no estimates of actual rates of input of mercury to the Arctic. We have some estimates of anthropogenic fluxes to lake sediments and to Hudson Bay (Lockhart *et al.* 1998) but we have none to the Arctic Ocean. Without these estimates, pathways into and through the marine ecosystem cannot be assessed and the natural and anthropogenic contributions cannot be discriminated. The current project will provide estimates of the input of mercury to the Arctic Ocean with snow and furthermore will document contributions from individual snow events throughout a winter season in the Beaufort Sea.

The project is conducted largely by local communities throughout the Arctic, often through local school science classes. The local residents follow a rigorous protocol for collecting snow in cleaned containers and then send the samples to the Freshwater Institute for analysis.

The project has included only sites over sea ice since we do not wish to get into terrestrial sites where there will be debate about whether mercury in the snow came from the atmosphere or from the soil.

ACTIVITIES IN 1997/98

A pilot project was run during the winter of 1996/97 and it produced the distribution of mercury concentrations shown in Figure 1. Funding was applied for from the Northern Contaminants Program in the fall of 1997 to assist with the analyses of the 1996/97 samples and to permit the survey to be repeated during the winter of 1997/98. The activities in 1997/98 included completion of analyses with the results in Figure 1. The pattern observed from the 1996/97 samples was one of higher concentrations in the central Arctic than in the western Arctic or in the more eastern Arctic represented by Greenland. The intent in 1997/98 was to test whether the pattern observed in 1996/97 would be repeated. The communities that participated in 1997/98 were fewer because the early spring melt precluded sampling as planned in some communities. The communities that were able to get good samples were: Pelly Bay, Baker Lake, Tasiujaq, Taloyoak, Cambridge bay, Sanikiluaq, Whale Cove, Clyde River, Resolute, Kimmirut, Gjoa Haven, Arctic Bay, Iqaluit and Grise Fiord.

The reduced number of communities was offset by added collections of individual snow events. Dr. H. Welch has been stationed on the CCGS Des Grosseliers in the Beaufort Sea since October, 1997, and has collected snow from every snow event over the winter of 1997/98. Preliminary results from these snow events suggests a pattern of increasing concentrations in snow throughout the winter with highest concentrations recorded just before the spring melt (Figure 2). Complete results will be available during the winter of 1998/99.

DISCUSSION/CONCLUSIONS

Conclusions are premature and subject to change when the complete data are available. Mercury was measurable in all the samples with apparently higher concentrations in samples from the central Arctic than in either eastern or western sites. The event sampling in the Beaufort Sea during the winter of 1997/98 showed a gradual increase in mercury concentrations in show throughout the winter.

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Site	Number
North of Alert	1
Alert	2
Arctic Bay	3
Arviat	4
Cambridge Bay	5
Cape Dorset	6
Chesterfield Inlet	7
Churchill	8
Clyde River	9
Eureka	10
Gjoa Haven	11
Greenland (East)	12
Grise Fiord	13
Hall Beach	14
Igloolik	15
Iqaluit	16
Kimmirut	17
Kugluktuk	18
Mould Bay-buoy	19
Mould Bay	20
Pangnirtung	21
Paulatuk	22
Pelly Bay	23
Pond Inlet	24
Quaqtaq	25
Repulse Bay	26
Resolute (Jan. 97)	27
Resolute (Mar. 97)	28
Resolute (May 97)	29
Sachs Harbour	30
Sanikiluaq	31
Taloyoak	32
Tuktoyaktuk	33
Whale Cove	34

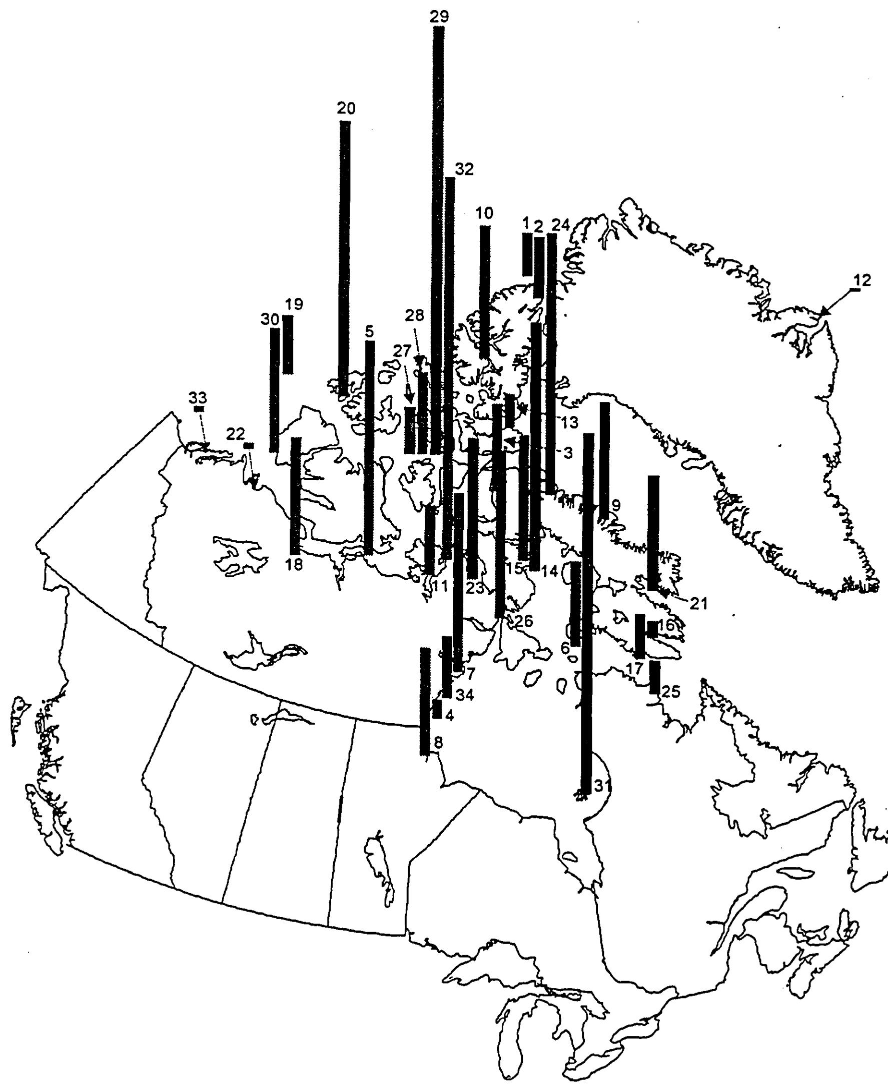

Figure 1. Locations where snow samples were taken (bases of bars) and relative concentrations of mercury at each site (heights of bars). Bars have been shifted slightly to reduce overlaps.

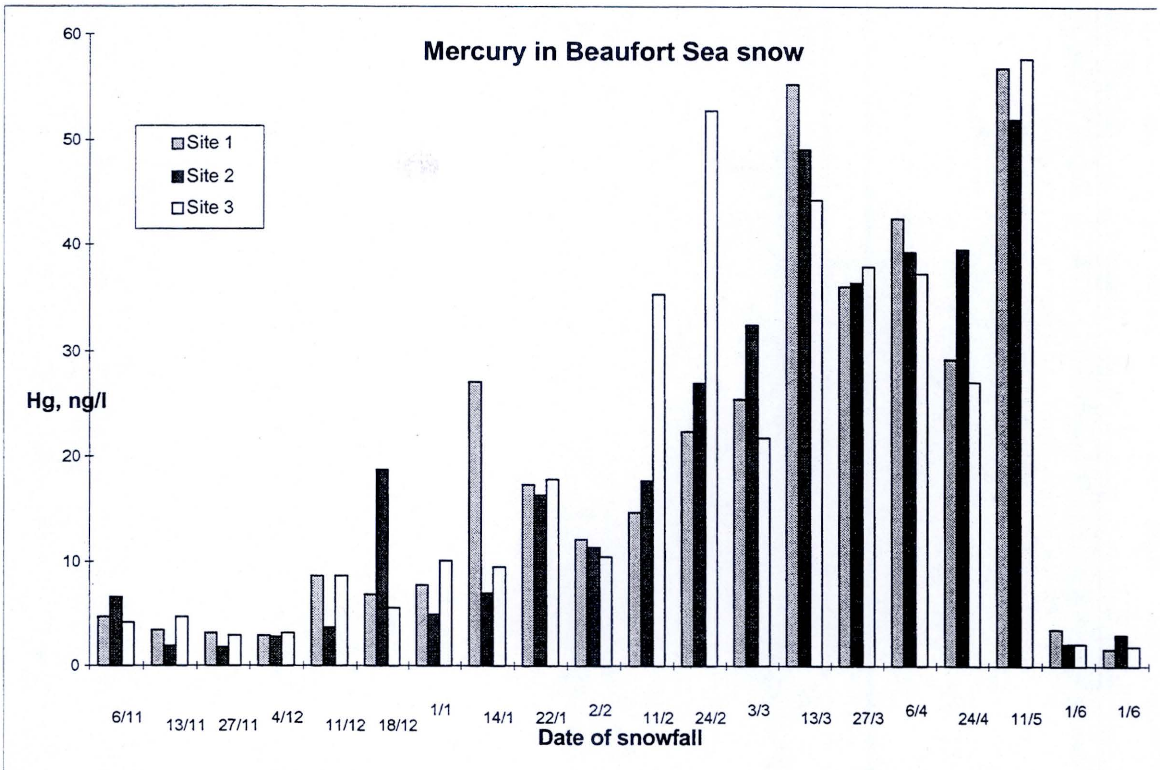

Figure 2. Mercury in snow collected during snow events during the winter of 1997/98 at the SHEBA site, Beaufort Sea.

II ECOSYSTEM CONTAMINANT UPTAKE AND EFFECTS

METALS IN LIVER AND KIDNEY OF WATERFOWL AND GAME BIRDS

Project Leader: B.M. Braune, National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada, Hull, PQ

Project Team: B. Wakeford (National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada); B. Malone (Malone Associates, Health Canada (Foods Directorate))

OBJECTIVES

1. to analyse archived tissues of selected waterfowl and gamebird species for mercury and selenium in liver (1997/98), and cadmium in kidney (1998/99) in to determine whether residue levels pose a health risk to the birds and to the people eating the birds.

DESCRIPTION

Between 1988 and 1995, the Canadian Wildlife Service (CWS), under the auspices of the Northern Contaminants Program (NCP), conducted a survey of residue levels of both organochlorines and metals in breast muscle of waterfowl and other game birds harvested in Northern Canada. Those data were submitted to Health Canada for evaluation of risk to humans eating those birds and the results communicated to the Northern Communities. It is generally accepted, however, that Northerners eat more than just the flesh (muscle) of birds and other animals. This point has been brought up at a number of northern workshops (Yukon Contaminants Workshop, Whitehorse, January 1994, 1995; Inuvik Contaminants Workshop, Inuvik, June 1995; Dene Environmental Gathering, Yellowknife, March 1996; Upper Mackenzie Basin Planning Workshop, Yellowknife, August 1997) as well as being documented in Receveur *et al.* (1996). Included among the other tissues/organs eaten are liver and kidney which are also target organs for many metals/elements such as cadmium (Furness 1996), mercury (Thompson 1996) and selenium (Heinz 1996). Target organs accumulate much higher metal residue levels than those found in muscle. Therefore, residue levels found in livers and kidneys also provide a much better indicator of wildlife health.

Livers and kidneys from all birds collected during the 1988-95 survey were archived in the CWS Tissue Bank. In addition to species identification, collection date and location, information on age and sex is available for most of the birds.

ACTIVITIES IN 1997/98

Based on a review of the existing residue data for mercury and selenium in breast muscle of birds collected by CWS under the NCP during 1988-95, archived livers for 10 species (Green-winged Teal (AGWT), Northern Pintail (NOPI), Barrow's Goldeneye (BAGO), Common Goldeneye (COGO), Common Eider (COEI), King Eider (KIEI), Oldsquaw (OLDS), Bufflehead (BUFF), Surf Scoter (SUSC), White-winged Scoter (WWSC)) were retrieved from the CWS Tissue Bank, processed, pooled and analysed for mercury and selenium. Livers were pooled by species, location and age (juvenile, adult), and adults were pooled by sex (male, female) in order to facilitate analysis of toxicity to the birds.

RESULTS/DISCUSSION

The residue levels of mercury in liver pools ranged as high as 3.8 mg/kg (ww) in Surf Scoters from Fort Good Hope area and levels of selenium ranged as high as 23 mg/kg (ww) in liver pools of Common Eiders from Arviaq area and Oldsquaw from Fort Good Hope area (Table 1). Figure 1 illustrates the mercury and selenium residue data by species using box and whisker plots showing median values, 25th and 75th percentiles, 10th and 90th percentiles as well as outliers. It would appear from Figure 1a that selenium levels were generally higher in livers of eiders and scoters than in other species. Differences in mercury levels among species were less pronounced (Figure 1b). Both mercury and selenium levels were lowest in Northern Pintails. The data will be assessed with respect to implications for wildlife health. As well, the data will be submitted to Health Canada for evaluation of risk to human consumers.

Expected Project Completion Date: Due to unforeseen funding difficulties, the completion date of this project has been delayed indefinitely.

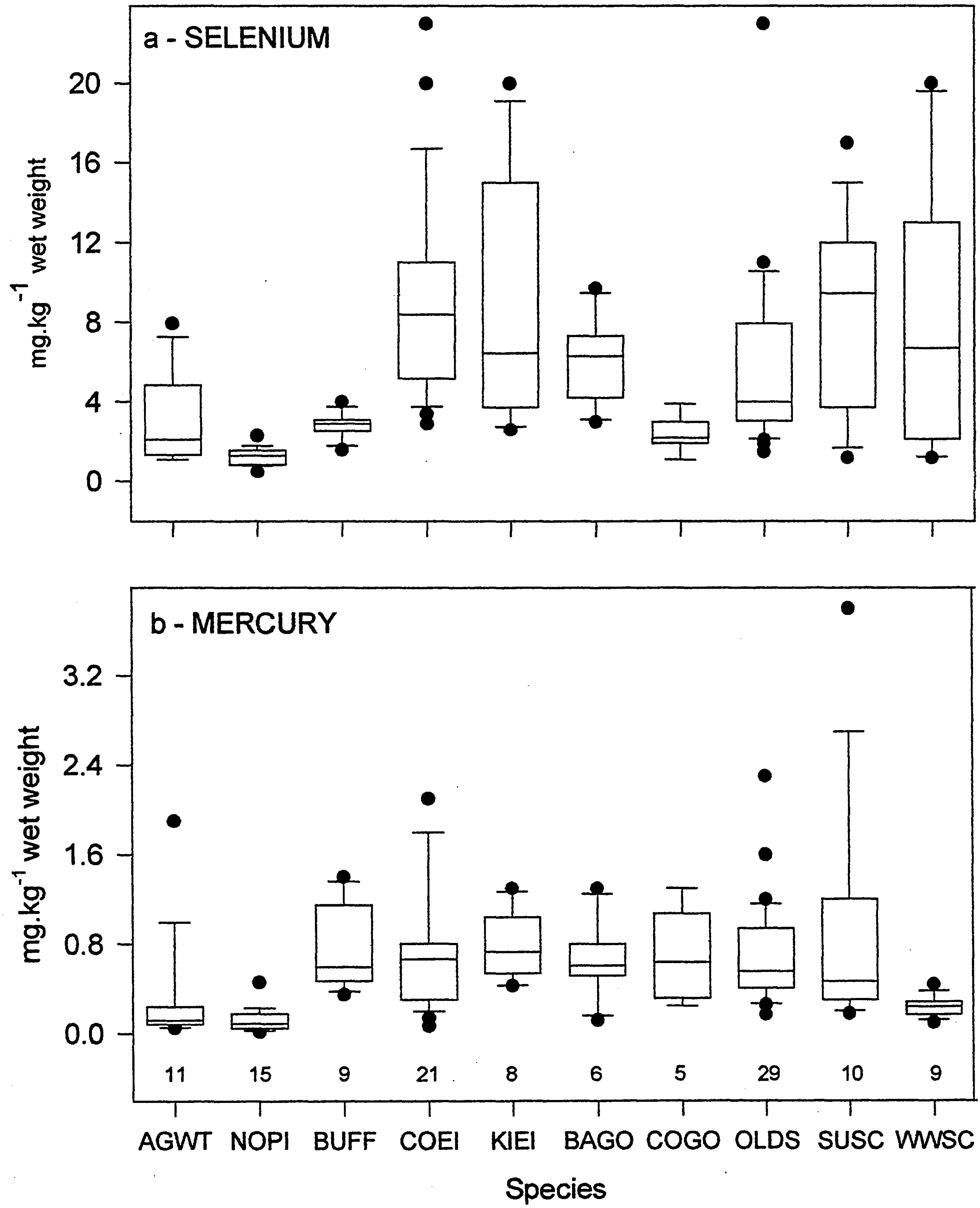

Figure 1. Levels of selenium and mercury in waterfowl liver (numbers under plots are sample sizes).

Table 1. Metals in waterfowl liver: 1988–94 (values in mg·kg^{-1} wet weight).

Species	Age I:A:U	Sex F:M:U	N	Year	Location	Prov	%H2O	Se	Hg
Dabbling Ducks									
Green-winged Teal	A	M	3	94b	Watson Lake	YT	72.0	6.8	0.390
Green-winged Teal	A	F	2	94b	Watson Lake	YT	71.0	8.0	0.120
Green-winged Teal	A	M	1	93b	Whitehorse	YT	73.0	1.1	0.076
Green-winged Teal	A	M	2	94b	Whitehorse	YT	70.0	2.6	0.100
Green-winged Teal	A	F	2	92b	Whitehorse	YT	75.0	1.8	0.250
Green-winged Teal	A	M	5	92b	Whitehorse	YT	74.0	2.1	0.120
Green-winged Teal	A	F	2	92b	Whitehorse	YT	71.0	5.6	1.900
Green-winged Teal	A	F	1	94b	Old Crow	YT	72.0	1.1	0.210
Green-winged Teal	A	M	4	94b	Old Crow	YT	72.0	1.3	0.140
Green-winged Teal	A	F	3	93b	Yellowknife/Great Slave Lake	NT	68.0	2.2	0.052
Green-winged Teal	A	M	5	93b	Yellowknife/Great Slave Lake	NT	69.0	1.5	0.055
Northern Pintail	I	M	1	93d	Churchill	MB	72.0	0.5	0.170
Northern Pintail	A	M	5	93d	Churchill	MB	71.0	0.8	0.200
Northern Pintail	A	F	4	93d	Churchill	MB	71.0	1.3	0.230
Northern Pintail	A	F	1	94b	Watson Lake	YT	71.0	0.9	0.016
Northern Pintail	A	F	1	94b	Dawson	YT	71.0	2.3	0.460
Northern Pintail	A	M	1	94b	Dawson	YT	68.0	1.6	0.092
Northern Pintail	I	F	1	88b	Whitehorse	YT	74.0	1.5	0.044
Northern Pintail	A	F	1	88b	Whitehorse	YT	72.0	0.8	0.024
Northern Pintail	A	M	5	88b	Whitehorse	YT	73.5	1.5	0.092
Northern Pintail	A	M	5	88b	Whitehorse	YT	73.0	0.9	0.059
Northern Pintail	A	F	1	94b	Old Crow	YT	74.0	1.0	0.066
Northern Pintail	A	M	5	90b	Old Crow	YT	72.0	1.4	0.094
Northern Pintail	A	M	4	94b	Old Crow	YT	70.0	1.7	0.180
Northern Pintail	A	F	2	93b	Yellowknife/Great Slave Lake	NT	69.0	0.8	0.029
Northern Pintail	A	M	5	93b	Yellowknife/Great Slave Lake	NT	70.0	1.8	0.088
Sea Ducks									
Bufflehead	A	F	1	94b	Watson Lake	YT	71.0	1.6	0.490
Bufflehead	A	F	2	94b	Watson Lake	YT	69.0	2.9	0.420
Bufflehead	A	M	2	94b	Watson Lake	YT	69.0	2.7	1.100
Bufflehead	A	M	1	94b	Teslin	YT	70.0	3.4	0.600

...cont'd **Table 1.** Metals in waterfowl liver: 1988–94 (values in mg·kg^{-1} wet weight).

Species	Age I:A:U	Sex F:M:U	N	Year	Location	Prov	%H2O	Se	Hg
Bufflehead	A	M	1	94b	Teslin	YT	70.0	2.1	0.350
Bufflehead	A	F	2	94b	Teslin	YT	69.0	4.0	1.400
Bufflehead	A	F	2	94b	Teslin	YT	70.0	2.9	0.540
Bufflehead	A	M	3	93b	Yellowknife/Great Slave Lake	NT	68.0	3.0	1.300
Bufflehead	A	F	2	93b	Yellowknife/Great Slave Lake	NT	68.0	3.0	0.740
Common Eider	A	F	3	93b	Aujuittuq (Grise Fjord)	NT	69.0	6.1	0.430
Common Eider	A	M	7	93b	Aujuittuq (Grise Fjord)	NT	70.0	10.0	0.700
Common Eider	A	F	6	93b	Arviaq (Arviat)	NT	69.0	8.4	0.670
Common Eider	A	M	4	93b	Arviaq (Arviat)	NT	69.0	23.0	2.100
Common Eider	A	F	6	93b	Salliq (Coral Harbour)	NT	69.0	11.0	1.800
Common Eider	A	M	4	93b	Salliq (Coral Harbour)	NT	69.0	20.0	1.800
Common Eider	A	F	2	93b	Kinngait (Cape Dorset)	NT	69.0	8.7	0.320
Common Eider	A	M	4	93b	Kinngait (Cape Dorset)	NT	71.0	10.0	0.800
Common Eider	A	M	4	93b	Kinngait (Cape Dorset)	NT	68.0	12.0	0.670
Common Eider	I	U	5	90a	Cumberland Sound	NT	69.0	5.1	0.400
Common Eider	A	F	3	90a	Cumberland Sound	NT	72.0	7.0	0.270
Common Eider	A	F	1	91c	Salluit/Ivujivik/Digges Is.	PQ	69.5	4.0	0.620
Common Eider	A	M	2	91c	Salluit/Ivujivik/Digges Is.	PQ	71.0	6.8	0.710
Common Eider	A	F	3	91d	Inukjuaq	PQ	71.0	5.0	0.070
Common Eider	A	F	2	88d	Sanikiluaq	NT	71.0	5.2	0.700
Common Eider	A	M	5	88d	Sanikiluaq	NT	68.0	6.9	0.270
Common Eider	I	U	5	88d	Sanikiluaq	NT	71.0	3.4	0.420
Common Eider	A	M	1	91c	Kangiqsualuujjuaq (George R.)	PQ	70.5	14.5	0.820
Common Eider	A	F	5	91c	Kangiqsualuujjuaq (George R.)	PQ	68.0	8.8	0.880
Common Eider	A	F	1	93d	Nain	LB	71.0	11.0	0.240
Common Eider	I	U	6	93d	Nain	LB	73.0	2.9	0.140
King Eider	A	M	7	93c	Melville Peninsula	NT	70.0	7.0	0.760
King Eider	A	F	3	93c	Melville Peninsula	NT	69.0	5.9	0.880
King Eider	I	M	1	91d	Inukjuaq	PQ	70.0	3.1	0.430
King Eider	A	M	1	91c	Inukjuaq	PQ	71.0	4.3	0.645
King Eider	A	F	1	91d	Inukjuaq	PQ	72.0	2.6	0.440
King Eider	A	F	3	89b	Holman	NT	67.0	13.0	0.700
King Eider	A	M	4	89b	Holman	NT	65.0	17.0	1.200
King Eider	A	M	4	89b	Holman	NT	67.0	20.0	1.300

...cont'd **Table 1.** Metals in waterfowl liver: 1988–94 (values in mg·kg^{-1} wet weight).

Species	Age I:A:U	Sex F:M:U	N	Year	Location	Prov	%H2O	Se	Hg
Barrow's Goldeneye	A	F	1	94b	Whitehorse	YT	72.0	3.0	0.120
Barrow's Goldeneye	A	M	2	90b	Whitehorse	YT	72.0	4.2	0.800
Barrow's Goldeneye	A	M	2	94b	Whitehorse	YT	72.0	6.8	0.520
Barrow's Goldeneye	A	F	2	94b	Teslin	YT	71.0	7.3	0.540
Barrow's Goldeneye	A	M	2	94b	Teslin	YT	69.0	5.8	0.680
Barrow's Goldeneye	A	M	1	94b	Old Crow	YT	67.0	9.7	1.300
Common Goldeneye	I	M	1	94b	Watson Lake	YT	69.0	1.1	0.340
Common Goldeneye	A	M	4	94b	Watson Lake	YT	70.0	2.7	0.640
Common Goldeneye	I	F	1	89d	Whitehorse	YT	68.0	2.2	0.245
Common Goldeneye	A	F	1	94b	Teslin	YT	72.0	2.2	1.000
Common Goldeneye	A	M	2	94b	Old Crow	YT	71.0	3.9	1.300
Oldsquaw	A	F	1	94d	Teslin	YT	66.0	4.0	2.300
Oldsquaw	I	M	1	94d	Teslin	YT	68.0	3.2	1.200
Oldsquaw	A	M	1	94d	Teslin	YT	67.0	3.1	1.600
Oldsquaw	A	F	2	93c	Melville Peninsula	NT	69.0	1.9	0.560
Oldsquaw	A	M	4	93c	Melville Peninsula	NT	70.0	3.2	0.560
Oldsquaw	A	M	4	93c	Melville Peninsula	NT	70.0	2.5	0.920
Oldsquaw	A	M	5	93b	Qamanit'tuaq (Baker Lake)	NT	67.0	4.9	0.410
Oldsquaw	A	F	4	93b	Qamanit'tuaq (Baker Lake)	NT	69.0	4.5	0.460
Oldsquaw	A	F	3	93b	Arviaq (Arviat)	NT	69.0	2.1	0.300
Oldsquaw	A	M	7	93b	Arviaq (Arviat)	NT	70.0	3.5	1.100
Oldsquaw	A	F	7	93b	Kinngait (Cape Dorset)	NT	65.0	2.9	0.560
Oldsquaw	A	M	3	93b	Kinngait (Cape Dorset)	NT	68.0	3.5	0.320
Oldsquaw	A	M	3	92d	Salluit/Ivujivik/Digges Is.	PQ	68.0	9.8	0.170
Oldsquaw	A	F	1	91d	Inukjuaq	PQ	70.0	2.2	0.460
Oldsquaw	I	U	4	91d	Inukjuaq	PQ	70.0	1.5	0.280
Oldsquaw	A	F	5	93d	Sanikiluaq	NT	69.0	3.3	0.260
Oldsquaw	A	M	5	93d	Sanikiluaq	NT	70.0	4.3	0.400
Oldsquaw	A	F	3	91c	Kangiqsualuujjuaq (George R.)	PQ	71.0	2.2	0.490
Oldsquaw	A	M	2	91c	Kangiqsualuujjuaq (George R.)	PQ	67.0	4.3	0.910
Oldsquaw	A	M	5	93b	Mackenzie River Delta	NT	68.0	9.8	1.050
Oldsquaw	A	M	5	93b	Mackenzie River Delta	NT	67.0	11.0	1.100
Oldsquaw	A	F	5	94b	Mackenzie River Delta	NT	71.0	7.4	0.710
Oldsquaw	A	M	4	94b	Mackenzie River Delta	NT	71.0	9.0	0.680
Oldsquaw	A	F	2	93c	Holman	NT	67.0	11.0	0.440

Species	Age I:A:U	Sex F:M:U	N	Year	Location	Prov	%H2O	Se	Hg
Oldsquaw	A	M	4	93c	Holman	NT	67.0	7.6	1.000
Oldsquaw	A	M	4	93c	Holman	NT	64.0	3.4	0.470
Oldsquaw	A	M	1	93d	Fort Good Hope	NT	70.0	23.0	0.250
Oldsquaw	A	F	5	93b	Qurluqtuq (Coppermine)	NT	69.0	6.0	0.430
Oldsquaw	A	M	5	93b	Qurluqtuq (Coppermine)	NT	68.0	9.9	0.780
Surf Scoter	I	F	1	94d	Finlayson Lake	YT	72.0	2.2	0.180
Surf Scoter	A	F	1	90b	Whitehorse	YT	69.0	8.9	0.530
Surf Scoter	A	M	3	90b	Whitehorse	YT	72.0	10.0	1.200
Surf Scoter	A	F	1	90b	Old Crow	YT	74.0	8.2	0.230
Surf Scoter	A	F	1	94b	Old Crow	YT	70.0	13.0	0.300
Surf Scoter	A	M	4	90b	Old Crow	YT	72.0	12.0	0.410
Surf Scoter	A	M	4	94b	Old Crow	YT	69.0	12.0	1.100
Surf Scoter	I	M	1	93d	Fort Good Hope	NT	70.0	1.2	0.410
Surf Scoter	A	M	4	93d	Fort Good Hope	NT	69.0	17.0	1.600
Surf Scoter	A	F	3	93d	Fort Good Hope	NT	69.0	3.7	3.800
White-winged Scoter	I	F	1	94d	Finlayson Lake	YT	70.0	4.5	0.160
White-winged Scoter	I	M	1	90b	Whitehorse	YT	71.0	6.7	0.240
White-winged Scoter	A	M	5	90b	Whitehorse	YT	70.0	8.4	0.290
White-winged Scoter	A	F	1	90b	Old Crow	YT	70.0	20.0	0.280
White-winged Scoter	A	F	1	94b	Old Crow	YT	73.0	2.4	0.170
White-winged Scoter	A	M	6	90b	Old Crow	YT	69.0	19.0	0.440
White-winged Scoter	A	F	5	94d	Old Crow	YT	70.0	1.3	0.100
White-winged Scoter	A	M	4	94b	Old Crow	YT	70.0	11.0	0.190
White-winged Scoter	A	F	2	93c	Fort Good Hope	NT	71.0	1.2	0.270

Age & Sex: I - Immature; A - Adult; F - Female; M - Male; U - Unknown
Year: - The year code consists of the year and a season code: a -Jan-Mar; b - Apr-Jun; c - Jul-Aug; d - Sep-Dec
Se = Selenium; Hg = Total Mercury;

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RETROSPECTIVE SURVEY OF MERCURY IN ARCTIC SEABIRD EGGS

Project Leader: B.M. Braune, National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada, Hull, PQ

Project Team: B. Wakeford (National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada); B. Malone, (Malone Associates)

OBJECTIVES

1. to analyse archived arctic seabird egg contents for mercury and selenium in order to determine whether those residue levels have been increasing or decreasing since the mid-1970s.

DESCRIPTION

In the recently published Canadian Arctic Contaminants Assessment Report, Muir *et al.* (1997) concluded that: "The lack of temporal trend information for most contaminants is perhaps the most significant knowledge gap at the present time." It is further stated that "The need for temporal trend information in the case of mercury is particularly important because of the observation that levels are increasing in beluga and ringed seal." The interaction between mercury and selenium, where each counteracts the toxicity of the other, is well documented (Cuvin-Aralar and Furness 1991). Metal levels can accumulate to quite high levels in some seabird species, and the organic forms of mercury and selenium, which are the most toxic forms, are readily transferred to the eggs (Thompson 1996, Heinz 1996).

The Canadian Wildlife Service (CWS) seabird egg monitoring program was established to provide an index to contamination of the marine ecosystem and possible implications for seabird health. As well, many Northerners harvest seabirds and their eggs for consumption (see harvest summaries in Wong 1985 & in Coad 1994). Monitoring of arctic seabird eggs for organochlorine residues has been ongoing since 1975 and all unused portions of the egg samples have been archived in the CWS Tissue Bank. A variety of seabird species, representing different habitats and trophic levels, have been monitored. Prior to 1993, arctic seabird eggs were not analysed for mercury.

ACTIVITIES IN 1997/98

Archived egg content samples were retrieved from the CWS Tissue Bank, processed and pooled for Black-legged Kittiwake (1975: N=12; 1976: N=6; 1987: N=3), Northern Fulmar (1975: N=15; 1976: N=12; 1977: N=15; 1987: N=6) and Thick-billed Murre (1975: N=11; 1976: N=9; 1977: N=9; 1987: N=9; 1988: N=9). Samples have been submitted for mercury and selenium analyses.

RESULTS/DISCUSSION

Mercury and selenium data are already available for egg contents of all three species from 1993 (Braune 1994). Chemical residue data for mercury and selenium are not yet available for the archived samples (1975-1988). The archived samples will be analysed in pools of three eggs each according to CWS protocol for seabird eggs. The results will produce time trend data for mercury and selenium, and provide data for evaluation of reproductive implications of the residue levels found.

Expected Project Completion Date:
Due to unforeseen funding difficulties, the completion date of this project has been delayed indefinitely.

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CONTAMINANTS IN NORTHERN QUÉBEC WILDLIFE

Project Leader: L. Champoux (Canadian Wildlife Service, Québec region, Environment Canada)

Project team: J. Rodrigue Canadian Wildlife Service, Québec region, Environment Canada), co-leader; B. Braune, (NWRC); D. Leclair (Makivik); Nunavik Health and Nutrition Committee

OBJECTIVES

1. to study the fate and effects of toxic substances in Northern Québec wildlife
2. to complete an existing data base on contaminant levels in wildlife species consumed by Nunavik communities
3. to follow temporal trends and improve the spatial coverage of contaminant data in Nunavik wildlife
4. to collaborate with the Nunavik Health and Nutrition Committee in providing information to Nunavik communities on contaminants in their food and in the ecosystem.

DESCRIPTION

At the end of the first phase of the NCP, participants to Regional Contaminants Forums emphasized the lack of data on the fate and effects of contaminants from Northern Québec wildlife. Since 1990, CWS-Québec has collected information the on Northern Québec contaminant levels in mammal and bird tissues (James Bay, Hudson Bay and Ungava Bay). Collections of marten carcasses and fur from different mammals were done for all Québec territory. A study was conducted with Hydro-Québec to study mercury exposure of Ospreys living close to reservoirs. Samples were also collected as part of the national study of contaminants in game birds and waterfowl (Braune 1995). Many of these tissues were archived in the National Wildlife Research Center (NWRC) tissue bank in Hull for future chemical analysis; this constitutes an opportunity to increase our knowledge of northern contamination. Following an evaluation of risks associated with wild food consumption, Health Canada recommended priority species and contaminants for further evaluation. These are: lead in ptarmigan, selenium in scoters, mercury in mergansers and PCBs in Oldsquaw (Braune 1995). In 1995, following Health Canada's concerns about high levels of selenium in scoters, a study was designed to increase the number of samples. Local communities were consulted at the Kuujjuaq workshop in May 1997, in order to determine their needs and interests in research and communication and to get information on their food habits and their traditional ecological knowledge. Wildlife species have shown their usefulness as indicators of ecosystem contamination and effects of toxic substances. Potential health effects observed in wild species in studies combining ecological, chemical and toxicological parameters can help evaluate risks to humans.

ACTIVITIES IN 1997/98

A total of 82 Ptarmigan (31 Willow Ptarmigans, *Lagopus lagopus*, in 1997; 18 Willow Ptarmigans and 33 Rock Ptarmigans, *Lagopus mutus*, in 1998) were collected by local hunters during the winters of 1997 and 1998 in the Kuujuuaq and Great River areas. Tissues from the 1997 samples were analysed, and those from 1998 are being analysed, for lead and cadmium at the National Wildlife Research Centre in Hull.

All new data were entered in to the data base. Only data for specimens collected north of the 55th parallel were considered for this work. All data were converted to a wet weight basis except data for feathers and fur, which are in dry weight. For each species, the data is divided by date (1981, 1981–1990 and 1991–1997) and location (east and west of the 71st meridian, which falls west of Ungava Bay). Descriptive statistics have been calculated for the resultant groups. The data base only includes data on birds and terrestrial mammals. Requests for data on marine mammals and fish have been made to other organizations.

RESULTS

Results of analyses are presented for specimens collected north of the 55th parallel. Data are available for 34 species of birds and 8 species of mammals. Only data from the main tissues are presented here (liver, kidney, muscle and eggs), but the data base also contains data on brain, bones, intestine, fur and feathers. Metal levels in birds and mammals are presented in Tables 1 and 2 respectively. Levels of PCBs (sum of 27 to 43 congeners depending on laboratories and year of analyses) and other organochlorine contaminants in birds, eggs and mammals are presented in Tables 3, 4 and 5 respectively.

For metals in birds (Table 1) most data (81%) comes from the west zone. The highest mercury level is 24.36 mg·kg^{-1} wet wt. in livers of Common Merganser (Mergus merganser) collected between 1981 and 1990. Twenty (20) per cent of mercury values are over 1 mg·kg^{-1}, mainly in piscivorous birds and seabirds, while 27% of selenium values, 18% of lead values, 9% of cadmium values and 10% of arsenic values are over 1 mg·kg^{-1}. The highest selenium levels is 4.3 mg·kg^{-1} in Black Scoter *(Melanitta nigra)* liver. Data for scoters collected in 1997 are not shown because they were all collected south of the 55th parallel. Lead was also highest in this species, followed by Willow Ptarmigan. New data for lead in Willow Ptarmigan collected in winter 1997 show lower levels. However, cadmium levels in these Ptarmigan are high, particularly in kidneys. We also expect to receive other analyses on Ptarmigan before the end of 1998.

For metals in mammals (Table 2) the majority of the data come from the western portion of Northern Québec, 67% for mercury and 100% for other metals. The highest mercury level is 7.6 mg·kg^{-1} in a mink (Mustela vison) liver collected before 1981. Thirty-seven per cent of mercury values are more than 1 mg·kg^{-1}, while only 12% of selenium values, 6% of lead values, and 18% of cadmium values are more than 1 mg·kg^{-1}. The highest cadmium level is 23.8 mg·kg^{-1} in the kidneys of two snowshoe hares *(Lepus americanus)*. Arsenic was undetectable in all samples. Data from before 1981 are only available for mink and marten *(Martes americana)*, while there is no data on mink for the period 1991-1997.

The highest PCB level in birds appears in Herring Gull *(Larus argentatus)*, both in muscle and in liver (Table 3). Liver levels are only available for two species. For other organochlorines, levels are generally low, but have not been compiled for all species yet. In eggs, the Peregrine Falcon *(Falco peregrinus)* presents the highest PCB level with 7.1 mg·kg^{-1}, followed by seabird eggs (Table 4).

In mammals, the highest PCB level, 0.48 mg·kg^{-1}, is in an arctic fox (Alopex lagopus) which also shows the highest dieldrin level, 0.24 mg·kg^{-1} (Table 5). Levels of the other organochlorines are low in all species.

DISCUSSION/CONCLUSION

Among waterfowl species used for food, the highest levels of mercury and PCBs have been observed in piscivorous and molluscivorous species, and in some cases in higher levels in Northern Québec than in the NWT. Most chemical analyses on wildfowl have been made on breast muscle to study risk of exposure from consumption of these tissues by humans. However, native people also eat other tissues. Liver, gizzard and lung of Canada Goose (Branta canadensis) are consumed by Cree people (D. Belinksky, CINE, pers. comm.) while ptarmigan liver and kidneys are also consumed (Flemming et al. 1995; A. Reed and J. Hughes, CWS, pers. comm.). High levels of Cd were found in ptarmigan liver (38.8 mg·kg^{-1} dry wt.) and kidneys (143.0 mg·kg^{-1} dry wt.) from Yukon (Gamberg 1996) and Finland (Fimreite 1993). In Québec ptarmigan, the mean Cd level in liver and kidneys are 8.9 and 52.6 mg·kg^{-1} wet wt., respectively, but with large variation.

In liver of mink from the NWT, mercury ranged from 0.12 to 3.30 mg·kg^{-1} wet wt. (Poole and Elkin 1996), which were considered low compared to levels in other regions of North America. Cadmium levels in kidneys and liver of snowshoe hare from Yukon were 20.7 and 2.4 mg·kg^{-1} dry wt. respectively (Gamberg 1996), comparable to levels found in Québec.

Mean PCB levels in peregrine falcon eggs are similar to those of Johnstone et al. (1996) from NWT, without the extreme maximum values. Levels from Northern Québec do not appear to be of biological significance. In Poole and Elkin (1996), mean PCBs and DDT levels in liver of mink ranged from 0.005 to 0.093 mg·kg^{-1} wet wt. and 0.001 to 0.014 mg·kg^{-1} wet wt., respectively. These levels were considered low compared to levels in other regions of North America. Levels in liver of marten from Northern Québec are higher than these numbers but are from one pool only.

It is too early to draw conclusions on these data since detailed analyses are not completed yet. Overall, levels of metals and organochlorines in birds and mammals do not seem of concern, however some levels are higher and need to be looked more thoroughly. There is a lack of data from the eastern region of Northern Québec, both for birds and mammals. Data should be compared with data from southern Québec and rest of the Canadian Arctic to study spatial variation. Temporal trend and spatial coverage of contaminants in wild food and indicator species should be followed on a regular basis. Mergansers and Oldsquaws should be collected to have a better knowledge of their contamination.

Table 1. Mean levels of metals in tissues of birds harvested in Northern Québec (µg·g⁻¹ wet wt.)

	Period	Zone	Tissue	N(pool)	Hg	Se	Pb	Cd	As
Browsers									
Rock Ptarmigan	91–97	W	Muscle	1(4)	<0.05	0.23	6.13	0.06	0.02
	91–97	E	Muscle	2(4)	<0.05	0.16	4.09	0.25	0.002
Willow Ptarmigan	81–90	W	Muscle	7(7)	<0.05	0.16	<0.10	0.21	<0.05
	81–90	W	Liver	2(4)	0.18	0.25	0.24	5.90	<0.05
	91–97	E	Muscle	1(1)	<0.05	0.09	10.75	<0.10	0.02
	91–97	W	Muscle	1(1)	0.20	0.20	<0.02	<0.04	0.002
	1997	E	Muscle	31(31)			0.06		
	1997	E	Liver	31(31)				8.94	
	1997	E	Kidney	31(31)				52.60	
Grazers									
Canada Goose	81–90	W	Muscle	25(25)	0.06				
	81–90	W	Liver	27(27)	0.09				
	91–97	W	Muscle	9(25)	<0.05				
Snow Goose	91–97	W	Muscle	8(26)	<0.06	0.45	0.27	<0.07	0.003
Surface-feeding Ducks									
Northern Pintail	81–90	W	Muscle	14(19)	0.23	0.33	0.12	<0.07	<0.03
	81–90	W	Liver	13(13)	0.48				
Green-winged Teal	81–90	W	Muscle	24(24)	0.29	0.18	0.03	<0.07	<0.03
	81–90	W	Liver	29(29)	0.37				
Mallard	81–90	W	Muscle	2(2)	0.18				
	81–90	W	Liver	2(2)	0.53				
Black Duck	81–90	W	Muscle	18(18)	0.25				
	81–90	W	Liver	19(19)	0.71				
Diving Ducks									
Ring-necked Duck	81–90	W	Muscle	10(10)	0.28	0.31	8.24	<0.06	<0.03
	81–90	W	Liver	10(10)	0.43				
Greater Scaup	81–90	W	Muscle	26(26)	0.30				
	81–90	W	Liver	26(26)	0.48				
Common Goldeneye	81–90	W	Muscle	3(3)	0.59				
	81–90	W	Liver	3(3)	2.97				
Oldsquaw	91–97	E	Muscle	1(5)	0.24	0.82	<0.05	<0.10	0.09
	91–97	W	Muscle	3(8)	0.10	1.05	0.05	<0.10	0.17
White-winged Scoter	81–90	W	Muscle	3(3)	0.3				
	81–90	W	Liver	3(3)	0.87				
Black Scoter	81–90	W	Muscle	24(24)	0.20				
	81–90	W	Liver	23(23)	0.69				
	91–97	W	Muscle	1(2)	0.19	0.66	<0.02	<0.05	0.33
	91–97	W	Liver	7(7)		4.35			
Surf Scoter	81–90	W	Muscle	28(28)	0.29				
	81–90	W	Liver	29(29)	0.51				
	91–97	W	Muscle	1(1)	0.11	1.52	12.56	0.07	0.63
	91–97	W	Liver	1(1)	12.90				
Common Eider	91–97	E	Muscle	1(6)	0.24	1.22	0.21	0.18	0.26
	91–97	W	Muscle	2(6)	0.15	0.71	0.07	0.12	0.26
King Eider	91–97	W	Muscle	3(3)	0.22	0.71	0.16	0.10	0.19
Piscivorous Ducks									
Common Loon	81–90	W	Muscle	1(1)	0.93				
	91–97	E	Liver	3(3)	4.27				
	91–97	E	Muscle	3(3)	0.64	0.67			
	91–97	E	Liver	3(3)	1.90	3.42			
	91–97	E	Kidney	3(3)	1.549	2.77			
	91–97	W	Muscle	10(14)	0.782	0.67		<0.05	0.39
	91–97	W	Liver	5(5)	1.935	2.11			
	91–97	W	Kidney	5(5)	1.954	2.39			

Table 1. cont'd...

	Period	Zone	Tissue	N(pool)	Hg	Se	Pb	Cd	As
Piscivorous Ducks ... cont'd									
Red-throated Loon	91–97	E	Muscle	1(2)	0.297	0.85	<0.06	<0.1	0.26
Hooded Merganser	81–90	W	Muscle	11(11)	0.689				
	81–90	W	Liver	11(11)	3.697				
Common Merganser	81–90	W	Muscle	18(18)	1.398	0.49			
	81–90	W	Liver	10(10)	24.36				
Red-breasted Merganser	81–90	W	Muscle	22(22)	0.518				
	81–90	W	Liver	32(32)	2.693				
	91–97	E	Muscle	2(2)	0.653	0.65	<0.04	<0.02	0.09
	91–97	W	Muscle	3(7)	0.678	0.64	<0.04	<0.02	0.17
Seabirds									
Black Guillemot	91–97	E	Muscle	1(5)	0.32	1.02	0.10	0.04	0.41
	91–97	W	Muscle	1(5)	0.29	0.91	0.08	0.27	0.58
Herring Gull	81–90	W	Muscle	20(20)	0.88				
	81–90	W	Liver	20(20)	2.47				
	91–97	W	Muscle	9(29)	0.69	0.93	0.12	0.50	1.07
	91–97	W	Liver	4(16)	1.30	1.01	<0.10	0.46	1.24
Glaucous Gull	91–97	W	Muscle	4(5)	0.34	0.41	0.05	0.09	0.11
Arctic Tern	81–90	W	Muscle	2(2)	0.55				
	81–90	W	Liver	2(2)	1.63				
Thick-billed Murre	91–97	W	Muscle	2(9)	0.37	0.99	0.06	0.48	1.06
Raptors									
Peregrine Falcon	81–90	W	Muscle	1(1)	0.2				
	81–90	W	Liver	1(1)	0.46				
Osprey	81–90	W	Muscle	3(3)	0.27	0.57	<0.10	0.07	<0.05
	81–90	W	Liver	3(3)	0.52	3.39		0.07	<0.05
	81–90	W	Kidney	3(3)	0.69	2.30		0.13	<0.05

Table 2. Mean levels of metals in mammals harvested in Northern Québec ($\mu g \cdot g^{-1}$ wet wt.)

	Period	Zone	Tissue	N (pool)	Hg	Se	Pb	Cd	As
Greenland Caribou	1981-90	E	muscle	37(37)	0.02				
Snowshoe hare	1981-90	W	liver	2(2)	0.4	0.43	0.22	0.53	<0.05
	1981-90	W	muscle	5(5)	0.12	0.15	<0.10	<0.20	<0. 05
	1981-90	W	kidney	2(2)				23.83	
	1991-97	W	liver	3(3)	0.05	0.33	2.07	0.37	<0.05
	1991-97	W	muscle	2(2)	<0.05	0.30	<0.10	<0.20	<0.05
	1991-97	W	kidney	2(2)				6.19	
Red fox	1981-90	W	liver	3(3)	0.38	0.61	0.29	0.22	<0.05
	1981-90	W	muscle	3(3)	0.11	0.17	0.13	<0.20	<0.05
	1981-90	W	kidney	2(2)				0.33	
	1991-97	W	liver	2(2)	0.41	0.75	0.10	0.46	<0.05
	1991-97	W	muscle	2(2)	0.22	0.20	<0.10	<0.20	<0.05
Arctic Fox	1981-90	W	liver	2(2)	0.25	0.70	<0.10	0.25	<0.05
	1981-90	W	kidney	–	–			0.43	
Gray wolf	1981-90	W	liver	2(2)	4.83			0.42	
	1981-90	W	kidney	4(4)				0.58	
Am. Marten	b. 1981	E	liver	1(1)	1.48				
	b. 1981	E	muscle	1(1)	1.51				
	b. 1981	E	kidney	1(1)	5.17				
	1981-90	W	liver	2(4)	0.41	0.85	<0.10	0.47	<0.05
	1981-90	E	liver	5(5)	0.45				
	1981-90	W	muscle	5(6)	0.25	0.242	0.08	0.26	<0.05
	1991-97	W	liver	6(6)	0.52	1.00	<0.10	0.90	<0.05
	1991-97	W	kidney	5(5)				1.41	
	1991-97	E	kidney	5(5)				2.45	
Shorttail weasel	1981-90	W	liver	1(2)	0.19	0.75			<0.05
	1981-90	W	muscle	1(2)	0.11	0.30	<0.10	<0.30	<0.05
Mink	b. 1981	E	liver	1(1)	7.60				
	b. 1981	E	muscle	2(2)	2.13				
	b. 1981	E	kidney	3(3)	2.54				
	1981-90	W	liver	1(1)	3.47	1.60	<0.10	0.80	<0.05
	1981-90	W	muscle	1(1)	1.94	0.35	<0.10	<0.20	<0.05

Table 3. Mean levels of PCBs and organochlorines in tissues of birds harvested in northern Québec (µg·g⁻¹ wet wt.)

	Period	Zone	Tissue	N (pool)	ΣPCBs	DDE	Dieldrin	Mirex	HCB
Browsers									
Rock Ptarmigan	91–97	E	Muscle	2(4)	0.0054	<0.0001	<0.0001	<0.0001	<0.0001
	91–97	W	Muscle	1(4)	0.0051	<0.0001	<0.0001	<0.0001	<0.0001
Willow Ptarmigan	81–90	W	Muscle	4(4)	0.0232	<0.0001	<0.0001	<0.0001	0.00002
	91–97	W	Muscle	1(1)	0.0052	<0.0001	<0.0001	<0.0001	<0.0001
	91–97	E	Muscle	1(1)	0.0052	<0.0001	<0.0001	<0.0001	<0.0001
Grazers									
Canada Goose	91–97	E	Muscle	1(5)	0.0053				
	91–97	W	Muscle	7(16)	0.0049				
Snow Goose	91–97	W	Muscle	8(26)	0.0051				
Surface-feeding Ducks									
Northern Pintail	81–90	W	Muscle	1(6)	0.0036				
Green-w. Teal	81–90	W	Muscle	1(5)	0.0043				
Diving Ducks									
Ring-necked Duck	81–90	W	Muscle	1(1)	0.0043				
Oldsquaw	91–97	E	Muscle	1(5)	0.0332				
	91–97	W	Muscle	3(8)	0.0172				
Black Scoter	91–97	W	Muscle	2(7)	0.0237	0.0094	<0.0001	0.0003	0.0004
Surf Scoter	81–90	W	Muscle	1(4)	0.0134	0.0051	0.0007	<0.0001	0.0004
	91–97	W	Muscle	1(1)	0.0512	0.0175	0.0005	0.0008	0.0011
Common Eider	b. 1981	E	Muscle	1(1)		0.0049	<0.0001		
	91–97	E	Muscle	1(6)	0.0070	0.0017	<0.0001	<0.0001	0.0008
	91–97	W	Muscle	2(6)	0.0053	0.0012	<0.0001	<0.0001	0.0012
King Eider	91–97	W	Muscle	3(3)	0.0068				
Piscivorous Ducks									
Common Loon	91–97	W	Muscle	5(14)	0.1354	0.0422	0.0069	0.0007	0.0112
	91–97	E	Muscle	1(3)	0.1597	0.0697	0.0058	0.0084	0.0023
Red-throat. Loon	b. 1981	E	Muscle	3(3)		1.1810	0.0310		
	91–97	E	Muscle	1(2)	0.2462	0.0879	0.0095	0.0008	0.0044
Red-br. Merganser	91–97	W	Muscle	3(7)	0.0442	0.0219	0.0048	0.0268	0.0017
	91–97	E	Muscle	2(3)	0.2378	0.1371	0.0005	0.0268	0.0017
Seabirds									
Black Guillemot	b. 1981	E	Muscle	5(5)		0.0113	0.0005		
	91–97	E	Muscle	1(5)	0.0157	0.0063	0.0014	0.0001	0.0055
	91–97	W	Muscle	1(5)	0.0183	0.0083	0.0009	<0.0001	0.0046
Herring Gull	b. 1981	E	Muscle	1(1)	0.5431	0.0002			
	91–97	W	Muscle	9(29)	0.4927	0.1564	0.0052	0.0045	0.0053
	91–97	W	Liver	4(16)	0.8189	0.2394	0.0052	0.0181	0.0073
Glaucous Gull	91–97	W	Muscle	4(5)	0.3602	0.3195	0.0132	0.0066	0.0136
Thick-bill. Murre	b. 1981	E	Muscle	3930		0.0260	0.0040		
	91–97	W	Muscle	2(9)	0.0171	0.0177	0.0008	<0.0001	0.0059
Raptors									
Osprey	81–90	W	Liver	3(3)	0.0036	0.0011	0.0002	<0.0001	0.0002

Table 4. Mean levels of PCBs and organochlorines in eggs harvested in Northern Québec ($\mu g \cdot g^{-1}$ wet wt.)

	Period	Zone	N (pool)	ΣPCBs	DDE	Dieldrin	Mirex	HCB
Grazers								
Canada Goose	91–97	E	2(5)	0.0117	0.0080	0.0029	<0.0001	0.0015
Diving Ducks								
Common Eider	91–97	E	2(5)	0.0132	0.0037	0.0029	<0.0001	0.0024
	91–97	W	1(7)	0.0192	0.1874	0.0345	0.0033	0.0069
Seabirds								
Black Guillemot	91–97	E	5(5)	0.0343	0.0131	0.0038	0.0006	0.0069
	91–97	W	1(8)	0.0643	0.0328	0.0045	0.0012	0.0155
Herring Gull	91–97	E	5(5)	0.6347	0.2137	0.0058	0.0034	0.0070
	91–97	W	2(10)	0.4768	0.2767	0.0122	0.0104	0.0063
Great B.-b. Gull	91–97	W	1(5)	0.8466	0.0064	0.0129	0.0004	0.0045
Arctic Tern	91–97	W	1(7)	0.0150	0.0053	0.0001	0.0005	0.0022
Raptors								
Peregrine Falcon	81–90	E	3(3)	7.1422	2.5717	0.3719	0.1478	0.0209
Osprey	81–90	W	3(3)	0.1774	0.0961	0.0021	0.0017	0.0002

Table 5. Mean levels of PCBs and organochlorines in mammals harvested in Northern Québec ($\mu g \cdot g^{-1}$ wet wt).

	Period	Tissue	Zone	N (pool)	ΣPCBs	DDE	Dieldrin	Mirex	HCB
Snowshoe hare	81–90	muscle	W	5(5)	0.0050	0.00003	0.0001	0.0001	0.00002
	91–97	muscle	W	2(2)	0.0056	0.00003	0.00013	0.0001	0.00002
	91–97	liver	W	3(3)	0.0054	0.00001	0.00010	0.0001	0.00020
Red fox	81–90	muscle	W	3(3)	0.0082	0.00020	0.0002	0.0001	0.0019
	81–90	liver	W	3(3)	0.0169	0.0007	0.0014	0.0003	0.0027
	91–97	muscle	W	1(1)	0.0156	0.0019	0.0005	0.0003	0.0008
	91–97	liver	W	1(1)	0.0124	0.0002	0.0009	0.0001	0.0016
Arctic Fox	81–90	muscle	W	3(3)	0.0434	0.0005	0.0055	0.0006	0.0012
	81–90	liver	W	2(2)	0.0660	0.0005	0.0145	0.0027	0.0031
	91–97	liver	W	1(1)	0.4825	0.0029	0.2353	0.0460	0.0085
Am. Marten	81–90	muscle	W	4(5)	0.0069	0.0002	0.0001	0.0001	0.0002
	81–90	liver	W	1(3)	0.0518	0.0002	0.0016	0.0002	0.0010
	91–97	liver	W	1(10)	0.4562	0.0209	0.0035	0.0035	0.0050
	91–97	liver	E	1(10)	0.2076	0.0047	0.0015	0.0033	0.0047

First contacts with local communities have shown their concerns and interest in that kind of information, both for their health and their environment. We hope to be able to continue this collaboration, to study the fate and effects of toxic substances in Northern Québec wildlife and provide information to Nunavik communities on contaminants in their food and the ecosystem.

Expected completion date: March 31, 1999.

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MODELLING AND EVALUATION OF CONTAMINANT ACCUMULATION IN THE ARCTIC MARINE FOOD WEB

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OBJECTIVES

1. to develop a model or models describing the accumulation of persistent organic pollutants (POPs) in Arctic marine food webs.

2. to use the model(s) for the evaluation of existing food web contaminant data and relate contaminant levels in biota to other environmental media.

3. to provide a framework for the design and evaluation of future field studies (e.g., Arctic Archipelago Project).

DESCRIPTION

Persistent, bioaccumulative contaminants such as PCBs, DDTs, toxaphene, chlordane, and mercury pose the greatest concerns for human and ecosystem health in the Arctic. The primary source of these contaminants to northern peoples is from the consumption of marine mammals such as beluga (*Delphinapterus leucas*), narwhal (*Monodon monocerus*), ringed seal (*Phoca hispida*) and walrus (*Odobenus rosmarus*). The high contaminant levels found in marine mammals result from bioaccumulation processes through the marine food web where marine mammals are at or near the top of the web. Previous work resulted in the development of models describing the processes and rates of contaminant accumulation of persistent organic pollutants (POPs) by marine mammals for both individuals and populations, particularly for beluga and ringed seals (Mackay *et al*, submitted; Kingsley and Hickie 1993). Bioaccumulation by marine mammals is a life-long process influenced by diet composition and contaminant levels, and life-history related factors (longevity, metabolic rate, growth, sex, birth rate, lactation, body condition, contaminant clearance rates). The models have shown good agreement with data from monitoring programs for ringed seals and beluga, and are valuable aids in interpreting spatial and temporal trends in marine mammal contamination. Marine mammals have been shown to be effective long-term integrators of POPs in marine ecosystems.

The models for marine mammals were developed with a rudimentary link to other components of the marine food web owing to the paucity of contaminant data for lower trophic levels at that time. Recent studies, particularly the Polarpro study at Resolute in 1993 (Hargrave *et al.* 1997, CACAR 1997, Hargrave, unpubl. data), have provided sufficient contaminant data to initiate modelling bioaccumulation through the lower trophic levels and link this to the marine mammal models. The development of a comprehensive Arctic bioaccumulation model will offer a number of benefits. The model will provide a quantitative description of our understanding of bioaccumulation processes in this ecosystem which can be used as an aid for interpreting existing data and results from future studies. Such models may also be used to assess the relative importance of various processes and assist in identifying those which require further study. Modelling can ultimately assist in understanding the linkages between physical and biological processes of contaminant transport, deposition, fate, bioavailability and accumulation through food webs, and ultimately, into species that northern people hunt and consume.

ACTIVITIES IN 1997/98

Activities during the first year of this project focussed on assembling the information required to develop and test the initial food web bioaccumulation model. The goals were to develop an operational steady-state model and to identify areas requiring further refinement or research. Model development progressed along four main avenues: characterization of the food web and selection of species; selection of chemicals for initial model evaluation; development of computer program code; evaluation of model performance. Owing to the existence of the detailed models for beluga and ringed seals, the preliminary food web model concentrates on bioaccumulation in the lower trophic levels with the goal of predicting the contaminant concentrations in primary prey of these marine mammals, namely Arctic cod (*Boreogadus saida*) and the amphipod *Themisto libellula*. An additional reason for excluding marine mammals from this model is that they accumulate POPs throughout their lifetime (about 20 to 30 years) and thus would not fit readily within the steady-state modelling approach currently used in food web bioaccumulation models.

Model development has focussed on the marine food web as characterized in studies from the vicinity of Resolute (Lancaster Sound - Barrow Strait) NWT. This area has been studied more intensively than any other (e.g., Welch *et al* 1992, Hobson and Welch 1992), and was the location for the Polarpro year-round contaminant study (Hargrave *et al.* 1997). The food web of this area is also considered to be representative of the marine ecosystem across the Canadian Archipelago (H.E. Welch, personal communication) and is the preferred location for the proposed "integrated archipelago contaminant study". Development of the food web model requires general information on the structure and dynamics of the food web, and detailed information on the key species to be included in the model such as life history, size, growth rate, lipid content, feeding preferences, respiration rate and feeding rate. Eight species or groups were included in the preliminary model which was based primarily on summer open water conditions: pelagic phytoplankton, two size classes of herbivorous zooplankton, the herbivore *Mysis oculata*, predaceous invertebrates *Themisto* and chaetognaths (e.g., *Parasagitta* sp.), and two age classes of Arctic cod. The model will be expanded to include other important species or groups in the future, including Arctic char (*Salvelinus alpinus*) and benthic species such as clams and sculpins. Inclusion of seasonally limited components such as ice algae is also possible but the steady-state nature of the preliminary model limits our ability to evaluate their importance.

The preliminary model was adapted from the steady-state matrix model developed for the Lake Ontario food web by Campfens and Mackay (1997). This model is similar in many respects to other currently used food web bioaccumulation models, but offers several advantages for this project. First, model output is in both concentration and fugacity units. The fugacity concept is advantageous when comparing contaminant levels between different environmental media such as air, snow, water, sediment and biota. Second, the matrix structure enables modelling of complex food webs. This provides flexibility to model different food web structures, feeding preferences and exposure scenarios, and new species can be added easily. Finally, the model structure is relatively simple and can be modified readily to meet future needs. Features added to the Campfens/Mackay model include data tables of organism and food web characteristics for three seasonal periods (spring, summer, and fall-winter) and characteristics of selected contaminants. Model input and output subroutines were enhanced and a bioenergetics subroutine used to calculate organism respiration and feeding rates was also modified to suit Arctic species.

Chemicals selected for the initial model trials included α–HCH and γ–HCH (hexachlorocyclohexane), hexachlorobenzene (HCB), Σchlordane (Chl), ΣDDT and ΣPCB. These chemicals were selected based on a number of criteria. They are among the chemicals of greatest concern in the Arctic environment. There are sufficient data available to test the current model, and they vary sufficiently in hydrophobicity to provide a robust assessment of model performance. Log Kow (octanol-water partition coefficent) values range from 3.8 for ΣHCH to 6.6 for ΣPCB. Biomagnification is not expected for chemicals with log K_{ow} values less than about 5.2, while a log K_{ow} of 6.6 is in the range where biomagnification is maximized. Biomagnification is expected to decline when log Kow exceeds a value of about 7.0 due to reduced bioavailability and/or gill uptake efficiency (Burkhard 1998).

Model performance was evaluated by conducting a sensitivity analysis and by comparisons between observed and predicted concentrations for the six selected chemicals. The evaluation studies focussed on the summer period (July to September) since the contaminant data set is most complete then. Model sensitivity was assessed by observing the effect that small (10%) changes in individual input parameters had on the predicted contaminant concentration in adult Arctic cod which occupy the highest trophic level in the model food web. Sensitive model parameters were those that caused a greater than proportional change in cod concentrations.

RESULTS AND DISCUSSION

Figure 1 shows the relationship between the model predicted and observed mean concentrations (ng/g wet wt) from the summer period (July to September) of the Polarpro year round study. The only changes in model variables between trials were to the chemical

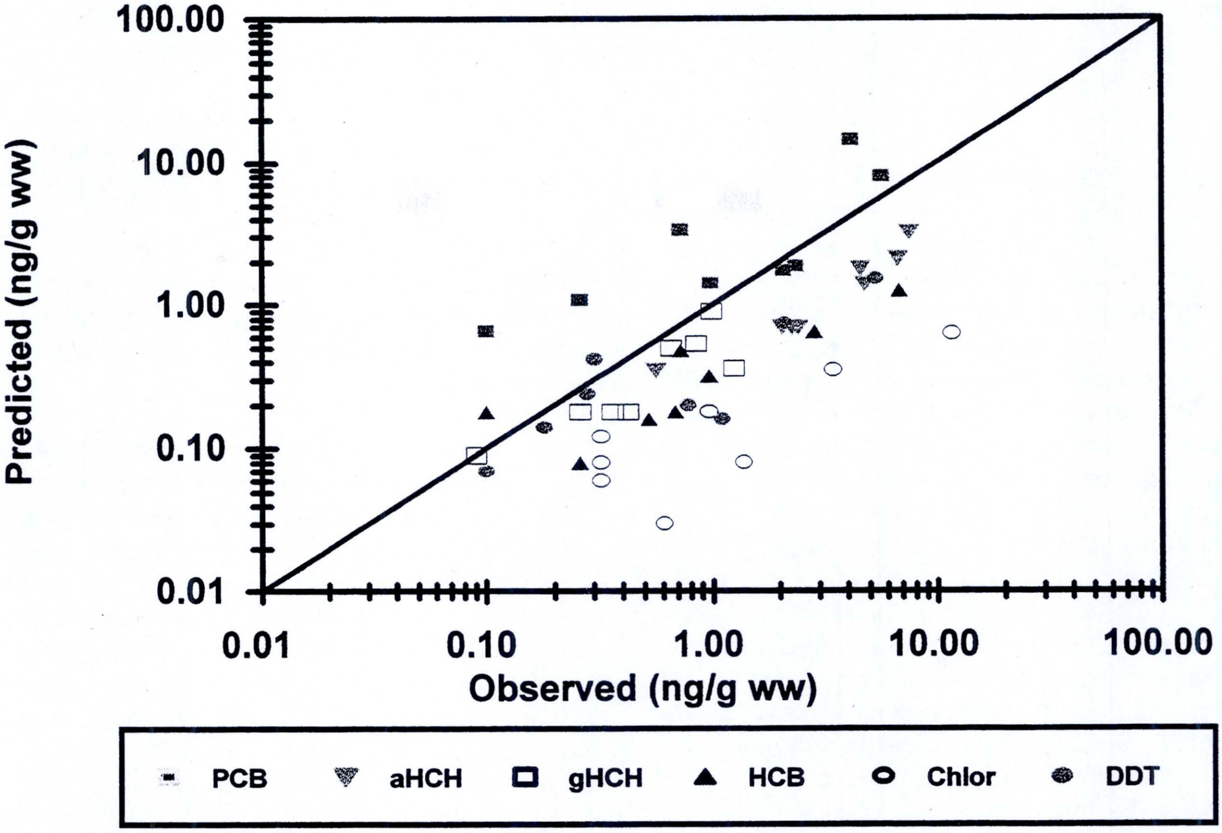

Figure 1. Plot of model-predicted and observed concentrations of the six test chemicals in organisms from the Arctic marine food web. The diagonal line depicts the ideal 1:1 relationship.

characteristics (molecular weight, log K_{ow}, Henry's constant) and to the concentration in water. Sediment concentrations had no effect on model results since no benthic species were included in the preliminary model. All other parameters were default values incorporated into the model data tables. Overall there was reasonable agreement between observed and predicted values as shown by the spread of data about the line denoting the ideal 1:1 relationship. About one-third of the predicted values fell within a factor of two of the measured values, while about two-thirds fell within a factor of three. This level of resolution is similar to that reported for the Campfens/Mackay model and other food web models (Gobas 1993, Thomann *et al.* 1992) when applied to the Lake Ontario food web.

Four of the six chemicals showed good agreement between observed and predicted values, the exceptions being Σchlordane and ΣPCB. On average ΣPCB concentrations were overpredicted by a factor of 2.9, while Σchlordane levels were underpredicted by a factor of 10.4. ΣPCB was modelled using an average log Kow of 6.6, the value used by Campfens and Mackay (1997) when modelling Lake Ontario. This value may be too high when modelling the Arctic marine food web since long-range atmospheric transport processes favour the less chlorinated congeners. This problem would be avoided by modelling individual congeners in the future. In the case of Σchlordane, the model-predicted biomagnification factor (BMF) from phytoplankton to juvenile Arctic cod of 2.9 is considerably lower than the observed value of 10.8. The underprediction of the BMF for chlordane (and other chemicals with log K_{ow} 5.5-6.0) could only be addressed by making modest changes to the model structure.

The low predicted tissue concentrations could also result from using a water concentration below the true value. Accurately measuring the extremely low concentrations of many POPs in Arctic seawater, such as chlordane (~2 pg/L; Hargrave *et al.* 1997) and PCB congeners, presents a tremendous analytical challenge.

Despite these problems, the model-predicted wet wt. concentrations are positively related to observed tissue concentrations for all chemicals. Variations in the tissue concentrations of αHCH and γ–HCH could be explained largely by the differences in lipid content between species or groups, hence no biomagnification was apparent as expected. Biomagnification does occur for the other four chemicals since lipid content alone could not account for their differences in concentration between species. Predicted lipid-normalized BMFs from phytoplankton to juvenile cod were 1.7, 2.3, 2.5 and 3.4 for HCB, Σchlordane, ΣDDT and ΣPCB respectively.

The sensitivity analysis confirmed that the model behaved as expected and verified that the program code was free of errors. Of the model parameters examined, the most sensitive were the octanol water partition coefficient (K_{ow}), the lipid content of organisms, an allometric scaling factor which affects organism respiration rates, and to a lesser extent a parameter Q which influences contaminant assimilation efficiency from the diet. Feeding preferences of species or group were not examined in detail, but modest changes for individual species had little effect owing to the relatively short food web considered in the present model. There is, however, considerable uncertainty in the feeding preferences for some of the species. This is particularly true when seasonal changes in feeding are considered. The effects of sediment related parameters were also not examined since no benthic species were included in the model. Sediment related parameters have been shown to be among the most sensitive in other food web models (Burkhard 1998).

CONCLUSIONS

Overall, the preliminary model performed adequately in predicting tissue concentrations within a factor of two or three of observed concentrations for four of the six test chemicals. Concentrations of ΣPCB tended to be overpredicted while Σchlordane concentrations were markedly underpredicted. Results from the first year of this project indicate the need for further work in several areas.

1. The model structure should be reexamined and modified to improve predictions of biomagnification for chemicals with intermediate log K_{ow} values (range ~ 5.5 to 6.2).

2. The model should be extended to other species including Arctic char and benthic species such as clams and sculpins. The inclusion of benthic species is currently limited by a lack of data for them and for marine sediments.

3. The current steady state formulation of the model limits our ability to evaluate what effects the strong seasonal variations in productivity may have on the fate, bioavailability and bioaccumulation of POPs in the Arctic marine ecosystem. For example, particulate organic carbon and chlorophyll concentrations increase by factors of about 5 and 20 respectively during the summer open water period (Hargrave, unpublished data).

4. The ice algae community is another seasonal component of the food web that may be important. The limited data available (Hargrave, unpublished) shows that concentrations of some POPs such as PCBs can be several times higher in the ice algae than in pelagic algae found following the ice breakup. When possible, a means of predicting contaminant concentrations in ice algae should be developed and added to the food web model.

5. Several data gaps and research needs pertinent to this project have been identified. First, contaminant data are needed for marine sediments and benthic organisms from areas where benthos are part of the food web leading to marine mammals. Second, additional measurements of seawater concentrations of low level POPs (e.g., PCB congeners, chlordane, DDT and metabilites) are needed to augment and/or confirm the limited data currently available. Field studies are also required to characterize the processes of contaminant accumulation by ice algae and the resulting contribution of ice algae to the food web.

Expected project completion date: March 31, 2002.

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COMMUNITY-BASED MONITORING OF ABNORMALITIES IN WILDLIFE

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Project Team: M. Boucher, Ft. Resolution Environmental Working Committee (Ft. Resolution); L. Stromin, K'asho Got'ine Renewable Resource Council (Ft. Good Hope); Kugluktuk Hunters' and Trappers' Organization (Kugluktuk); A. Veitch, Sahtu Regional Biologist (Norman Wells); J. Nishi, Kitikmeot Regional Biologist (Kugluktuk); D. Panayi, Wildlife Technician (Kugluktuk); T. Bollinger, Canadian Cooperative Wildlife Health Centre (Saskatoon)

OBJECTIVES

1. to develop a community-based monitoring program in which harvesters can document and communicate observations of changes in wildlife in a systematic and useful way.

2. to provide an "early warning system" to detect changes or patterns in wildlife health at an ecosystem level. This systematic monitoring may identify areas requiring further study and aid in hypothesis development.

3. to integrate scientific and traditional ecological knowledge to increase general understanding of changes in the health status of wildlife.

4. to allow communities to participate and build local capacity to identify, investigate and respond to changes in the wildlife resources they harvest.

DESCRIPTION

People in the Northwest Territories have a long history of dependence on wildlife and the environment. The subsistence harvesting of fish, terrestrial wildlife, marine mammals and migratory birds provides northerners with significant nutritional, economic, social and cultural benefits. Traditional pursuits such as hunting, fishing and trapping have long been the basis of the northern economy. The replacement value of country food and other renewable resources is approximately $60 million per year (1990 dollars). Confidence in the health of wildlife populations and the availability of safe and healthy meat is extremely important for the maintenance of both subsistence harvesting and the commercial use of wildlife.

Although most wild animals are healthy, abnormalities such as diseases, parasites, tumours and deformities can occur in any wildlife population. Some conditions appear to be increasing in frequency or are new to an area. Local people want to know if there is a connection between the environmental contaminants they hear about and their observations of changes or abnormalities in wildlife. Documenting the occurrence of these changes is the first step in addressing these questions, and may serve as a sentinel to identify problems requiring further investigation.

Changes in wildlife health can have significant impacts on individual animal and population health, as well as human use of the resource. Changes seen in wildlife at an ecological level may result from multiple stressors, and a holistic approach is required to look at all potential causes including chemical and biological contaminants. By identifying observed changes in the field, future research can be focussed to test for linkages between observed changes and known effects of specific contaminants.

Information on abnormalities in wildlife is currently obtained in several ways. There have been a number of specific studies focussing on particular aspects of wildlife health in individual species. Changes are also noted opportunistically when handling animals during other wildlife studies or commercial wildlife harvests. Samples or reports of abnormalities are occasionally brought in to Renewable Resource Officers by hunters who come across unusual findings, but this system is primarily a reactive process to individual cases. Under this system, the number of samples or observations received is low compared to the number of animals harvested, the expertise of the harvesters is not fully accessed, and it is difficult to differentiate localized vs. widespread patterns.

Through their land-based subsistence lifestyles, local hunters have developed a wealth of experience and understanding of the ecosystems in which they live. Experienced hunters have spent many hours observing wildlife, and can recognize changes in animals and trends in the occurrence of some conditions over time. This field of ecological knowledge is commonly known as Traditional Ecological Knowledge (TEK), and includes empirical knowledge gained through experience and observation. This is consistent with western science, where experience and observation form the basis of modern empirical research. The scientific process differs in that it has developed a formal method by which these experiences and observations can be systematically documented and verified. The opportunity exists to integrate these two systems to increase information on changes in wildlife health, and to increase trust and cooperation between resource harvesters and researchers.

ACTIVITIES IN 1997/98

In 1997/98, a series of training and information sessions were held in each of the three participating communities. These sessions were designed to introduce the project, provide background information on wildlife health, and begin to build local capacity to manage the project and respond to changes in the wildlife resources they harvest. Training sessions were held with the following groups:

Fort Good Hope:

K'asho Got'ine Renewable Resource Committee
Sahtu Renewable Resources Board
GNWT Resources, Wildlife & Economic Development (Sahtu)
Community Learning Centre (Aurora College)
Community/public workshops & meetings

Fort Resolution:

Deninu Kué First Nation
Fort Resolution Environmental Working Committee
GNWT Resources, Wildlife & Economic Development (S. Slave)
Deninoo School students
Community/public workshops & meetings

Kugluktuk:

Kugluktuk Hunters' and Trappers' Association
Kitikmeot Region Renewable Resource Officers
GNWT Resources, Wildlife & Economic Development (Kitikmeot)
Kugluktuk High School students
Game Management CTS course students
Community/public workshops & meetings

In addition to community-based workshops and meetings, field training courses were held in Kugluktuk (November 5-8, 1997) and Ft. Resolution (February 23–27, 1998). Local hunters, elders and students participated in hands-on training in the field, applying information and techniques from the training sessions on harvested animals in the field.

A first draft of program resource materials was developed in 1997/98, including a sampling and identification guide, report/submission forms, and field sampling kits. These materials were field tested by the three communities during the first year of the program, and will be evaluated by the community coordinators and project leader at the end of the first year. The material will be revised and field-tested again during 1998/99.

Community-based monitoring of abnormalities in wildlife began in the three participating communities in 1997/98. Various approaches were considered for the collection of samples and documentation of observations from wildlife harvesters within each community. Survey design and planning was initiated for the Traditional Ecological Knowledge surveys of elders and experienced wildlife harvesters, with surveys conducted in both Ft. Resolution and Ft. Good Hope in 1997/98. Results from the sample/observation collection and TEK survey are currently being evaluated.

RESULTS AND DISCUSSION

This initiative is being conducted as a pilot project to test the concept, design and implementation in three NWT communities. The communities were selected to reflect regional differences in wildlife species and harvesting patterns: Kugluktuk (Arctic Coast), Ft. Good Hope (Mackenzie Valley) and Ft. Resolution (Slave River Delta). The project is comprised of two primary components:

1. Development of a community-based system to systematically collect and investigate hunter observations/samples of abnormalities in wildlife.

2. Traditional knowledge survey of disease/abnormalities in wildlife (elders and experienced resource harvesters)

As a community-based process, a local coordinator has been identified in each community. This individual helps organize community wildlife health/sampling workshops, routinely talks with local hunters to document abnormalities in harvested wildlife, collects samples of abnormalities from hunters & submits them for testing, facilitates result reporting, and organizes traditional knowledge surveys of respected local hunters about abnormalities in wildlife. The system is designed to rely on key observers or monitors in each community who are recognized for their wildlife harvesting and observation skills.

1. Community-Based Monitoring Program

i) Development of an information/sampling package

Development of a self-contained package of resource materials will be completed in 1998/99. This package will be used by the community coordinators and resource harvesters to assist with uniform collection and recording of information, sample collection and testing, and interpretation and reporting of results. The resource kit will include standardized observation/data reporting forms, visual (photographic) identification guides to assist with identification of abnormalities, sampling information and supplies, and other materials deemed appropriate.

ii) Local training sessions

Training and information sessions are being held in each community. These sessions cover basic wildlife anatomy and pathology, sampling procedures, interpretation of results, and details on the monitoring program. As the emphasis is on community participation, these sessions target a wide-range of community groups including wildlife harvesters, food preparers, and local youth.

iii) Sample/information collection

Information is collected on the occurrence of abnormalities in wildlife from local hunters by either oral reports or actual samples which are sent for analysis. Reports will be produced annually summarizing the field observations and diagnostic results.

2. Traditional Ecological Knowledge Survey

Interviews are conducted with experienced, long-time local harvesters about the occurrence of abnormalities and disease in wildlife. The community coordinators, or alternate local wildlife harvesters, conduct the interviews. This eliminates the need for simultaneous translation, ensures the interviewer is familiar with the topic, and enables elders to relax and share their knowledge of the subject. Results from the 1997/98 surveys are currently being evaluated.

METAL AND RADIONUCLIDE ACCUMULATION AND EFFECTS IN CARIBOU *(Rangifer tarandus)*

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Project TeaM: C. Macdonald, Northern Environmental Consulting and Analysis (Pinawa, MB); J. Nishi, Kitikmeot Regional Biologist (Kugluktuk, NT); D. Panayi, Kitikmeot Wildlife Technician (Kugluktuk, NT); Kugluktuk Hunters' and Trappers' Association (Kugluktuk, NT); M. A.D. Ferguson, Baffin Regional Biologist (Pond Inlet, NT); Mayukalik Hunters' and Trappers' Association (Kimmirut, NT).

OBJECTIVES

1. to verify high levels of metals (cadmium, aluminum, manganese) and radionuclides (lead-210 and polonium-210) detected in previous studies in caribou.

2. to assess biological effects by (i) assaying tissues for evidence of chromosomal damage due to metal and radiation exposure, and (ii) monitoring histological and urinary markers of kidney damage and contaminant exposure.

3. to analyse several tissues for a range of elements and isotopes (uranium, thorium, stable strontium, titanium) that may provide insight into the source of contamination.

4. to contribute information on temporal trends in contaminant exposure in the mainland Bluenose and south Baffin Island caribou herds.

DESCRIPTION

Barren-ground caribou (*Rangifer tarandus groenlandicus*) are found across the Northwest Territories, and are a major component of the traditional diet in northern communities. Many factors can influence the individual and population health of caribou, and changes are often multifactorial in origin. Contaminants are one group of stressors which may influence the health status of a herd by altering tissue structure and function, and by acting in association with other stresses to impair reproduction, immune function or other body functions. The need for work on the biological effects of contaminants in caribou was highlighted by the results of earlier studies (Elkin and Bethke 1995, Macdonald *et al.* 1996) that showed elevated levels of metals and radionuclides in some caribou herds. The concentrations of metals (cadmium) and naturally-occurring radionuclides (lead-210 and polonium-210) in the south Baffin Island caribou herd near Kimmirut (Lake Harbour) have been shown to be higher than other herds in the central and western Arctic.

The potential biological and ecological effects of these higher tissue loads of metals and radionuclides remain largely unknown. The current state of knowledge on animal adaptation to naturally occurring metals and nuclides is very limited. Cadmium is known to disrupt kidney function and reduce the kidney's ability to retain low molecular weight proteins and carbohydrates (CEPA 1994). A critical tissue concentration of 30 mg/kg in kidney has been recommended for mammals (CEPA 1994, Outridge *et al.* 1994). Elkin and Bethke (1995) reported a mean cadmium concentration in kidney of 32 mg/kg ww at Kimmirut, indicating that animals from this herd may exceed the tissue residue guidelines. Urinary β2 microglobulin and urea/creatinine analysis offers a way to examine possible kidney damage due to Cd exposure.

The radionuclide levels in caribou are notable because the resulting doses to the animals are significantly higher than background doses and may be approaching levels in some where biological responses may occur (Amiro and Zach 1993). Radionuclides generally cause effects to the blood-forming or hemopoietic system (bone marrow, spleen and blood). Radionuclides are also known to cause single and double-strand breaks in DNA and may produce high levels of variation in genetic structure, although doses required to cause these effects are relatively high (i.e. in excess of 500 mGy/y). The major contributor to the dose in the south Baffin herd is the alpha-emitter polonium-210, a nuclide that is known to accumulate on the endosteal (inner) surface of the bone in caribou (Salmon *et al.* 1995). This results in slightly higher doses to marrow than expected from deposition in the matrix of the bone. Metals such as chromium and nickel are also known to produce genotoxic effects and may add to the damage to genetic material caused by radiation.

The metal and radionuclide data suggest that south Baffin caribou are unique in that several metals and radionuclides are higher than in other herds across the Arctic, and may be approaching concentrations at which molecular and genetic effects could be expected. In the case of radionuclides, radiation doses to the animals are among the highest observed in wild species in Canada. This study will confirm the results from earlier studies, provide additional information on sources of the compounds, and provide some indication of temporal trends by determining levels five years after the initial testing. It will also provide preliminary information on possible biological effects from metals and radionuclide exposure.

ACTIVITIES IN 1997/98

Field Sampling

In 1997/98, field collections were conducted in cooperation with the Kugluktuk Hunters' and Trappers' Organization, utilizing local hunters in planning and conducting the field work. Twenty caribou were collected from the Bluenose caribou herd. Sex, body condition and other biological and morphometric data were collected, and a central incisor removed for aging by cementum analysis. Liver, kidney, muscle and bone samples were collected for metal and radionuclide analysis. Blood, spleen and bone marrow were collected for genetic analysis. Urine samples were collected for urinary $\beta 2$ microglobulin, urea/creatinine and Cd/Po^{210} analysis. Blood and tissue samples were collected for general health and disease assessment. Upon completion of the field collection, the caribou meat from the collection was provided to the community for local use.

In 1998/99, 20 animals will be collected from the South Baffin caribou herd near Kimmirut, and samples will be analysed for radionuclides and metals. Given seasonal fluctuations in contaminant levels, sampling will be done in the late winter to ensure that elements such as cesium-137 and other radionuclides are at their annual peak in caribou tissues.

Community consultation will occur in each community prior to and following field collections. This included discussions and meetings with the local Hunters' and Trappers' Organizations (HTOs), and wildlife research permit approval by these organizations. The field components of the study are planned and conducted with the cooperation and participation of local hunters. Local Renewable Resource Officers are also involved in the study and kept informed of the results.

Contaminant Analysis

Liver, kidney, bone and muscle were frozen and transported to Northern Environmental (Pinawa) for processing and shipment to appropriate laboratories for analysis. Metals in tissues and rumen samples are being analysed by ICP_MC under contract with Elemental Research, Vancouver, BC. Metals were selected for their toxicological significance (cadmium, copper, aluminum, zinc, iron, nickel, mercury) or for their importance as tracers of the source of the metals and nuclide (uranium, thorium, radium, titanium, stable strontium). All gamma-emitting radionuclides (cesium-137, cesium-134, potassium-40, stable strontium) are being analysed by gamma spectrometry. Samples have been banked for possible organochlorine analyses in the future. All chemical analyses are being monitored using standard reference materials, blank samples, spiked samples, duplicates and replicates.

Genetic variation in the two herds are being surveyed by high resolution flow cytometry under contract with Dr. John Bickham, Texas A & M. Blood, spleen and bone marrow were frozen at the time of collection and shipped on dry ice. Flow cytometry uses a laser to measure the chromosomal content in approximately 30,000 cells that have been labelled with fluorescent markers. High variability in the genetic structure may indicate larger amounts of chromosomal damage in this herd. The technique has been used successfully to show increased genetic damage in mammals at sites with mixed wastes in the US, and in birds and turtles exposed to radiation at sites contaminated with radionuclides. This technique will be used as a preliminary screening tool to indicate the levels of genetic variation in the Lake Harbour herd. Urine samples are being tested for Cd/Po^{210} levels, as well as urinary $\beta 2$ microglobulin and urea/creatinine levels as an indicator of kidney damage due to Cd exposure.

Data Analysis & Communication of Results

Data will be released in accordance with the AES and NWT Environmental Contaminant Committee's communication protocols. Upon completion of the study, results will be presented to the participating communities at HTO or community meetings, and in poster format. All print information will be provided in both English and Inuktitut. Results will also be published in peer-reviewed scientific journals.

DISCUSSION

All contaminant residue data, histological data, urinalysis results, and genetic analysis are currently being assessed, and will be statistically analysed and interpreted in 1998/99. A preliminary report on the assessment of the data will be available by fall 1998.

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MERCURY TOXICOLOGY IN BELUGA WHALES

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OBJECTIVES

1. to examine tissues of beluga whales for indications of risks of mercury poisoning or evidence of detoxification of mercury by measuring total mercury, methylmercury and selenium in blood, liver, brain and spinal cord of beluga whales from the Mackenzie Delta.

DESCRIPTION

There is extensive evidence documenting the concentrations of mercury in edible tissues of arctic marine mammals as a result of surveys made to define human dietary intakes of mercury. Virtually all the whales have levels of mercury that exceed the level recommended for human consumption of fish in at least one organ. Unfortunately, there has been no study of the potential for mercury to affect the animals themselves. For example, measurement of mercury in human blood has been used because levels in these tissues can be diagnostic of risk of mercury poisoning in people. Ms. Carissa Hyatt has made the first study of levels of mercury in blood of arctic beluga. Furthermore, there were also no data on target organs like the nervous system and she has also made the first study of mercury in brain and spinal cord.

Ms Hyatt presented preliminary findings at the International Conference on Mercury as a Global Pollutant in Hamburg in 1996, with the aid of a travel scholarship provided by the conference and with a DFO Director's graduate student travel award (Hyatt *et al.* 1996). Over the duration of the project, support has been received from the Northern Contaminants Program, the Department of Fisheries and Oceans, and from the Fisheries Joint Management Committee of the Inuvialuit Settlement Region.

ACTIVITIES IN 1997/98

The field collection work began in 1994 and continued in 1995 and 1996. Project personnel participated with local hunters during the summer hunt at Hendrickson Island in Kugmallit Bay and were able to obtain a variety of organ samples including blood, brain, spinal cord and others. There were no further field collections in 1997 or 1998. During 1997, work was on the analyses of the samples collected earlier for mercury and selenium, and, for some of the samples, methylmercury. It was anticipated that the final report from the project would be completed during the winter of 1997 but Ms. Hyatt took leave from the project in September, 1997, to enter the veterinary medicine program at the University of Saskatchewan and so she was absent from September, 1997 on. Consequently the results available now are not very different from those available for the previous report (Lockhart 1997). Ms. Hyatt will return to the project for the summer of 1998 to work on final analyses and preparation of her thesis. Her oral defence will have to be scheduled around classes in Saskatoon and is anticipated sometime by mid-1999.

RESULTS

The main additional result not available at the time of the previous report is information on the distribution of total mercury in various whale organs. There has not been previous information of this kind available for arctic whales except for liver, kidney, muktuk and muscle. Table 1 lists the mean mercury concentrations found in a number of beluga organs. Most of the mean values exceeded the maximum level recommended by Health Canada for consumption of fish (0.5 µg/g wet weight). Further information on these tissues will be generated during the summer of 1998.

Taking the collections as a whole, liver mercury levels were the highest of any organ and were related to age ($r^2 = 0.44$, Figure 1) but those in kidney ($r^2 = 0.05$) and muscle ($r^2 = 0.13$) were not. The data reported here lend themselves to estimates of time trends for mercury in beluga organs since previous studies have reported mercury in some of the same organs of whales from the same area. Wagemann *et al.* (1990) reported mercury

Table 1. Total mercury in beluga whale organs from collections at Hendrickson Island, NWT, from 1994 to 1996.

Organ	Mean Hg (µg/g wet wt)	Std. dev.	N
Whole blood	0.55	0.29	48
Lung	1.06	1.08	32
Gonad	0.82	0.57	33
Muktuk	0.81	0.40	64
Liver	33.6	29.5	65
Kidney	6.02	3.37	66
Adrenal gland	1.83	1.41	10
Spleen	3.78	4.87	33
Muscle	1.49	0.70	65
Milk	0.08		1
Brain	5.55	5.44	52
Spinal cord	2.34	1.63	14
Heart	0.50		1
Intestine	0.92	0.49	11
Urinary bladder	1.42	0.76	11
Urine	0.03	0.01	11
Eye lens	1.13	0.61	18
Eye sclera	0.30	0.23	16

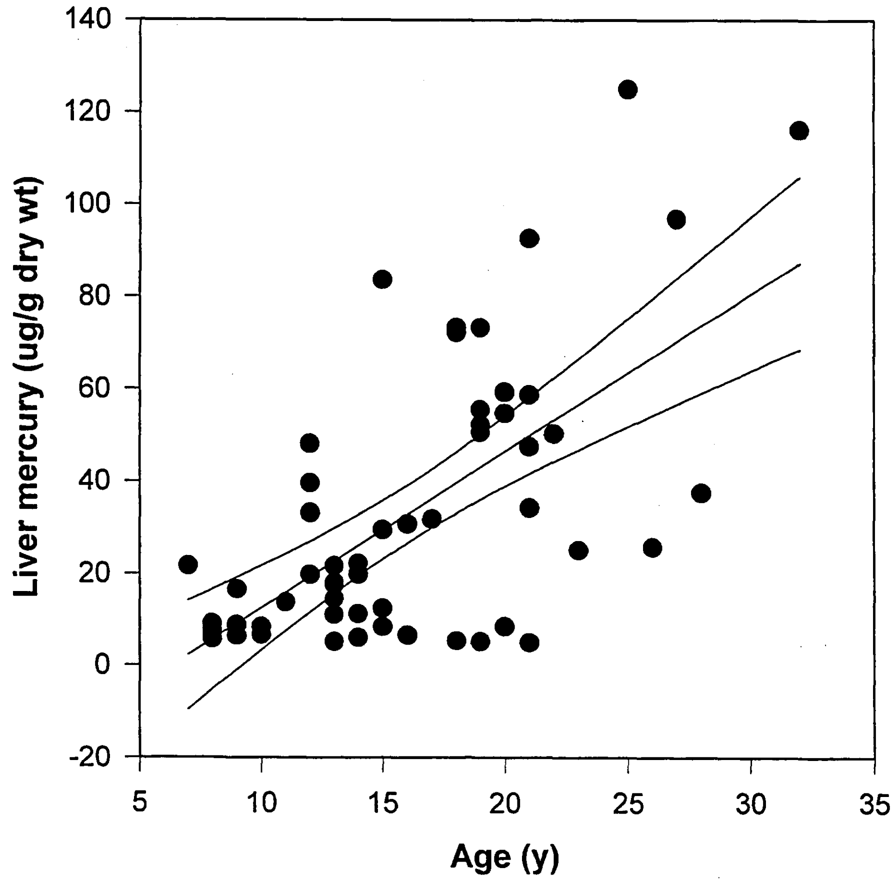

Figure 1. Liver mercury in beluga as a function of age

in liver, kidney and muscle of beluga from the Mackenzie Delta on a dry weight basis show in Table 2. Mean levels of mercury from Wagemann *et al.* (1990) were converted to wet weights using the formula:

Mercury (μg/g wet wt.) = Mercury (μg/g dry wt.) * ((100 - per cent moisture)/100).

In a preliminary analysis, the calculated wet weight values from Wagemann *et al.* (1990; 1996) were compared with those from the beluga reported in this study and the more recent levels appear to be higher. (Note that no allowance has been made in the current data for effects of whale age on liver mercury.) Wagemann *et al.* (1996) reported striking increases in mercury levels in whales between the 1980s and the 1990s and the current data suggest continued increases.

Many of the tissues have also been analysed for selenium since that element has been found to ameliorate the toxicity of mercury, at least in some species (e.g., Eaton *et al.* 1981). It may prove helpful in assessing the risks of mercury to the beluga themselves or to human consumers of beluga. Figure 2 shows a graph of concentrations of selenium in whale organs as a function of the concentrations of mercury in the same organs. In general, most organs displayed increasing concentrations of selenium with increasing concentrations of mercury. However, blood and muktuk showed little indication of such a relationship. Two clusters of points representing muktuk and muscle were removed from the general pattern displayed by the other organs with muktuk having high selenium for its content of mercury and muscle having low selenium for its amount of mercury.

Human blood levels of mercury in excess of 0.1 μg/g are an indication that the person is "at risk" of mercury toxicity. Whale blood values were frequently above this level and so this may indicate that whales are at some risk. It should be noted that almost all the blood mercury was in the red cell fraction, not in the plasma. Furthermore, whales have much higher hematocrits than humans and so the difference may not be as striking if reported on the basis of mercury per weight of hemoglobin rather than mercury per weight of whole blood. A number of previous studies with laboratory animals suggest that levels of mercury in the brain in the 10-20 μg/g range are associated with toxic symptoms and some of the beluga brains exceeded 10 μg/g. On that basis, we might anticipate mercury toxicity in some of the whales. However, two factors complicate the interpretation of mercury concentrations in terms of risk of toxicity. Firstly, most of the mercury in the whale brains and spinal cords was not methylmercury which is the neurotoxic form. Secondly, there were strong correlations between mercury and selenium in brain and spinal cord and these may have ameliorated the toxicity of the mercury.

In addition to the chemical contamination studies, most of the whales sampled in this project have been examined for antibodies to *Brucella* species. Brucellosis is a zoonotic disease that can cause serious disease in humans, however the implications of the disease in whales is not clear. Certainly, *Brucella* spp. have been isolated from seals (including ringed seals from Arctic Canada) and they are known to cause disease in humans. Through the efforts of Ole Nielsen, a biologist at DFO, Winnipeg, 53 beluga whales from Hendrickson Island have been tested for the presence of antibodies to *Brucella* spp. Blood samples were tested using a competitive enzyme-linked immunosorbent assay (C-ELISA) by Dr. Klaus Nielsen, Canadian Food Inspection Agency, Nepean, Ontario. One of these beluga was identified as having antibodies and was also considered to be infected with *Brucella*. So far no isolations of *Brucella* spp. have been made from beluga or narwhal though seropositive animals have been identified from most regions in Arctic Canada. This information has been passed on to the various Hunter's and Trapper's Associations involved in the sampling programs as well as FJMC, Nunavut Wildlife Management Board, Department of Health of the Northwest Territories, and Health Canada.

DISCUSSION/CONCLUSIONS

All beluga organs analysed to date have measurable levels of mercury with highest levels found in liver, kidney, brain, spleen, spinal cord, adrenal gland and muscle. Mean levels in all organs except milk, urine and eye sclera exceeded human consumption guidelines for commercial fish (0.5 μg/g). In view of that, and after consultation with the Fisheries Joint Management Committee (Norman Snow, Bob Bell), the original set of data are being forwarded to Headquarters for submission to Health Canada for evaluation from the perspective of human consumption.

With regard to temporal trends in levels of mercury in beluga organs, preliminary comparison with earlier data suggests increasing levels, in agreement with the earlier study (Wagemann *et al.* 1996).

With regard to the interpretation of mercury levels in terms of biological risk to the whales, blood levels and brain levels both suggest that the whales contain enough mercury to pose a biological risk to them. However, the

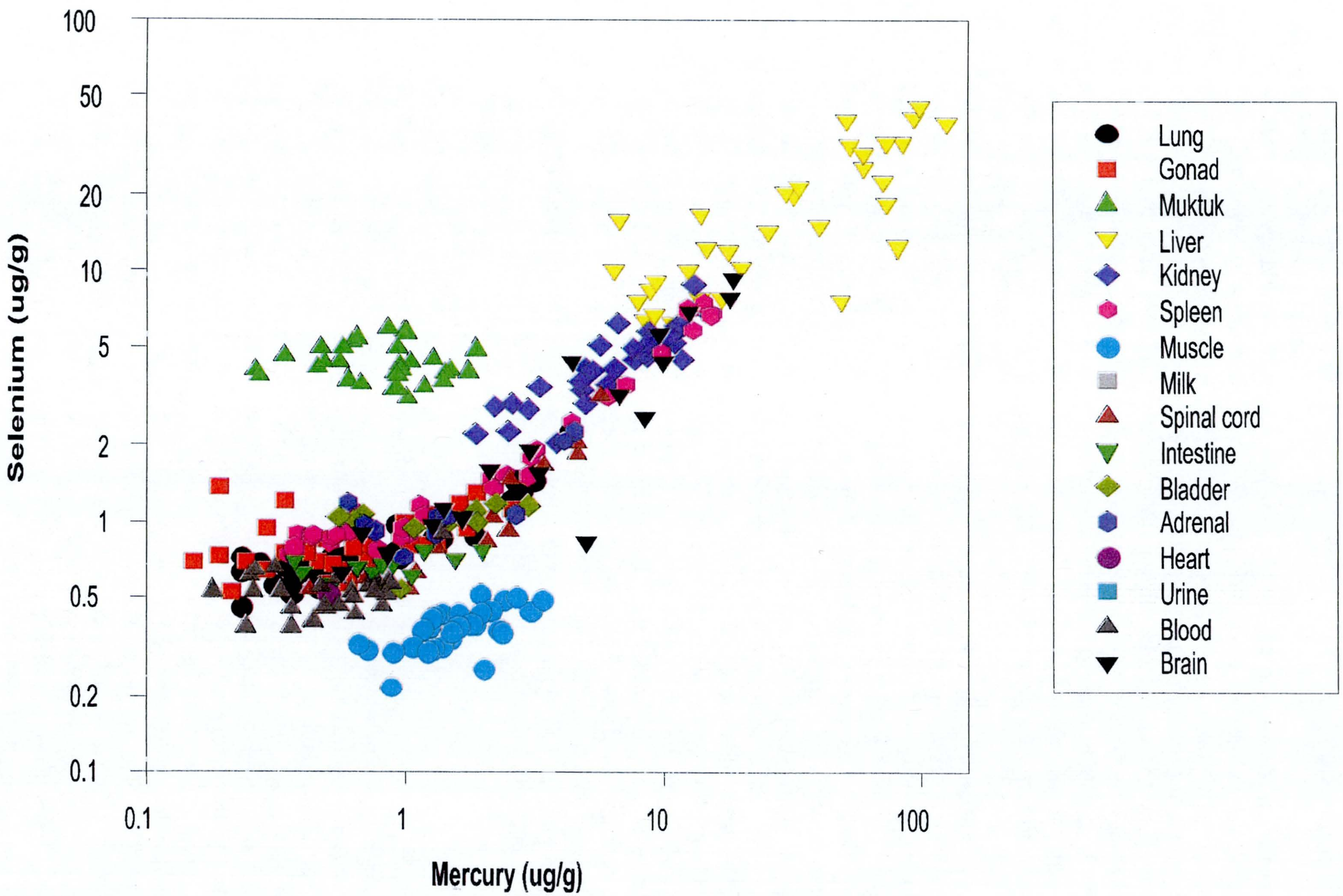

Figure 2. Mercury and selenium in beluga organs

Table 2. Comparison of mean mercury concentrations in beluga from the western Arctic for liver, kidney and muscle among data of Wagemann *et al.* (1990), Wagemann *et al.* (1996) and beluga reported here (Table 1).

Source of data	Measurement	Liver	Kidney	Muscle
Wagemann *et al.* 1990	Mercury (mean) (µg/g dry wt)	44.1	13.1	3.86
	Moisture (mean) (%)	72.8	78.4	71.9
Calculated from above	Mercury (µg/g wet wt)*	12.0	2.83	1.08
Wagemann *et al.* 1996	Mercury (mean) (µg/g wet wt) 1981-1984	11.8	2.83	1.07
Wagemann *et al.* 1996	Mercury (mean) (µg/g wet wt) 1993-1994	27.1	4.91	1.34
Beluga reported here	Mercury (mean) (µg/g wet wt) (from Table 1)	33.6	6.02	1.49

*Mercury (µg/g wet wt) = Mercury (µg/g dry wt) * ((100 - per cent moisture)/100).

relatively low proportions of methylmercury in nervous tissue and the strong correlation with selenium make the interpretation of mercury levels problematic. These observations have caused us to formulate the hypothesis that arctic whales demethylate mercury in brain and store the demethylated mercury as a non-toxic selenide. The question of whether any such storage form could be converted back to a toxic form by human consumers remains. The organ distribution data put in place some of the information required to begin phamacokinetic modelling of mercury in beluga.

An abstract describing these results has been submitted for presentation at the Fifth International Conference on Mercury as a Global Pollutant in Rio de Janiero in May, 1999.

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MERCURY IN FISH FROM SURVEYS IN LAKES IN THE WESTERN NORTHWEST TERRITORIES

Project Leader: W.L. Lockhart, Department of Fisheries & Oceans, Winnipeg, MB

Project Team: R. Allen (DFO, Inuvik, NWT); G.Low (DFO, NWT); J. Delaronde (DFO, Winnipeg, MB); R. Garrett (Geological Survey of Canada, Ottawa ON); G. Stephens (DIAND, Yellowknife, NWT)

OBJECTIVES

1. to determine the occurrence and geographic distribution of mercury, selenium and arsenic in fish from those inland lakes in the NWT being assessed for their ability to produce sustained yields of fish for subsistence consumption by northern people.

2. to evaluate the levels of mercury found in the fish in terms of the age/size relationships of the fish and also in terms of the geological setting of each lake and its drainage, with a view to developing a management strategy of recommending levels of consumption based on species and size of fish on a lake-by-lake basis.

DESCRIPTION

Several independent lines of evidence suggest that inputs of mercury to northern Canada have increased over pre-industrial levels. Mercury in marine mammals has increased since the 1970s (Wagemann *et al.* 1996). Sediment core data from a number of lakes in the NWT have suggested that recent mercury inputs are substantially above pre-industrial levels (Lockhart *et al.* 1993, 1995, 1998). Given these considerations, it is important to assess the levels of mercury in stocks of fish being used now or being assessed for potential harvest in the near future. The data to date generally suggest that fish feeding near the base of the food chain (whitefish, cisco, sucker) contain relatively little mercury while those feeding near the top of the food chain (walleye, pike, lake trout) often contain levels high enough to require consumption advisories. The question of the biological implications for the fish themselves is not considered in this project although future expressions of biological risk in terms of concentrations of mercury in different organs may make expressions of risk possible.

Several factors appear to influence the level of mercury in fish tissues including fish age (or length), the structure of the supporting food chain, water chemistry, lake temperature, microbiological processes in the sediments, fish biochemistry, the supply of mercury to the lake and the nature of the drainage (e.g., rocks, uplands, wetlands etc.). The supply of mercury is a mixture of natural geological contributions with any human-related appearing as additions to the natural supply.

This project is an extension of the previous project on contaminant trends in freshwater and marine fish. Results of that project and earlier surveys, largely by Fisheries Inspection Service, have indicated that many remote lakes in the Canadian North contain fish with high mercury levels. Extensive community consultation has taken place in order to select lakes for fish survey work and a list of such consultations are available if desired. Part of the survey activity has become the analyses of the fish for mercury since levels are often high enough in some species to bear on decisions regarding consumption of the fish or marketing of them.

This project is a companion to the water chemistry study by Glen Stephens.

ACTIVITIES IN 1997/98

As a result of analyses earlier in this project, several consumption advisories have been issued by Health Canada as shown below:

It is noteworthy that Health Canada also advised that women of child-bearing age and young children limit consumption to half the amounts stated.

Lakes sampled in 1997/98 included Manuel, Loon and Rorey all near Fort Good Hope, the Mackenzie River near Norman Wells, Sibbeston and Tsetso lakes near Fort Simpson and Kelly Lake near Tulita.

Table 1. Health Canada advisories on consumption.

Lake	Species	Consumption
Cli	Lake whitefish	no limit
	Lake trout	225 g/week
	Burbot	more samples needed
Little Doctor	Lake whitefish	no limit
	Sucker	no limit
	Lake trout	no limit
	Pike and walleye	250 g/week
Turton	Lake whitefish	no limit
	Lake trout	330 g/week
Lac à Jacques	Lake whitefish	no limit
	Walleye	200 g/week
	Northern pike	390 g/week
	Walleye + pike	200 g/week
Manuel Lake	Burbot	no limit
	Lake whitefish	no limit
	Northern pike	430 g/week

Analyses for mercury, selenium and arsenic have been completed for muscle tissue from six species taken from the Mackenzie River at three locations, Canyon Creek, Sucker Creek and Oscar Creek, near Norman Wells in June, 1997. The species taken were arctic grayling, inconnu, northern pike, burbot, walleye and longnose sucker with good sample numbers obtained only for arctic grayling. Total mercury concentrations in muscle tissue of the 6 species are listed in Table 2. All were below the health guideline of 0.5 µg/g for commercial sale and most were below the subsistence guideline of 0.2 µg/g. The highest value obtained (0.451 µg/g) was from a burbot taken at Canyon Creek. Some larger burbot were obtained from Sucker Creek but the levels of mercury were lower.

Since mercury levels often correlate with fish age and size, the mercury concentrations have been plotted against fish length in Figure 1. In general, the larger fish tended to have higher concentrations.

The burbot mostly had surprisingly high arsenic concentrations. Only five burbot were obtained from the collection in 1997, 3 from Sucker Creek, 1 from Canyon Creek and 1 from Oscar Creek. The 3 burbot from Sucker Creek had muscle arsenic concentrations of 6.7, 3.3 and 5.4 µg/g while that from Oscar Creek was 5.9 µg/g and the one from Canyon Creek was only 0.17 µg/g. All but one of the inconnu in this collection had muscle levels of arsenic of 0.05 µg/g or less and that exceptional fish had an arsenic concentration of 1.2 µg/g. We have previously noted some high levels of arsenic in inconnu from further downstream at Ramparts Rapids and Little Chicago for which arsenic levels ranged from <0.05 to 7.2 µg/g. Those earlier samples, together with the more recent ones reported here from the Norman Wells area are shown together in Figure 2. We have little information on arsenic in marine fish in the Arctic. A few liver samples of arctic cod from Resolute in 1997 were analysed and the mean arsenic concentration was 4.4 ± 0.61 (S.D.) µg/g.

In some species, selenium can ameliorate the toxicity of mercury and it was therefore of interest to determine the selenium content of the same fish being analysed for mercury. Generally with freshwater fish, we have found little indication of a relationship between mercury and selenium. For example, mercury and selenium concentrations in Mackenzie River fish are shown together in Figure 3 and there is only the weakest suggestion of any relationship between the two.

Forty-eight fish were obtained from Rorey Lake in November, 1997; all were lake trout ranging in size from about 1 to about 9 kg. The mean muscle mercury levels was 0.46 µg/g (± 0.15 S.D.) and the range was from 0.215 to 1.02 µg/g. There was a relatively weak relationship (r^2=0.44) between fish length and mercury with larger fish usually having higher mercury levels than smaller ones (Figure 4, top). This relationship, however, was probably not good enough to justify using size as a surrogate to discriminate mercury levels. Selenium levels ranged from 0.1 to 0.28 µg/g with little apparent relationship (r^2=0.15) between mercury and selenium (Figure 4, bottom). Muscle arsenic levels were all quite low, with 34 fish not exceeding detection limits of 0.05 µg/g and the remaining 14 fish in the range of 0.05 to 0.1 µg/g.

The Kelly Lake sample in February/March, 1998, contained 5 burbot, 4 inconnu, 31 lake trout, 13 northern pike and 79 lake whitefish. Muscle mercury levels are listed in Table 3 and were relatively high in all species except whitefish. Comparing mercury levels in fish from the same species from Kelly Lake with those from the Mackenzie River (Table 2), the Kelly Lake fish were

Table 2. Muscle mercury levels in fish from the Mackenzie River near Norman Wells, February/March, 1998.

Species	Mean muscle Hg (µg/g)	Std. dev.	Minimum	Maximum	N
Inconnu	0.082	0.020	0.036	0.113	20
Longnose sucker	0.111	0.057	0.051	0.193	10
Burbot	0.200	0.142	0.116	0.451	5
Walleye	0.191	0.068	0.116	0.247	3
Northern pike	0.162	0.043	0.098	0.240	11
Arctic grayling	0.071	0.026	0.037	0.136	20

Table 3. Muscle mercury levels in fish from Kelly Lake, February/March, 1998.

Species	Mean muscle Hg (µg/g)	Std.dev.	Minimum	Maximum	N
Burbot	0.381	0.234	0.225	0.774	5
Inconnu	0.396	0.030	0.369	0.430	4
Lake trout	0.482	0.211	0.221	1.19	31
Northern pike	0.546	0.186	0.312	0.863	13
Lake whitefish	0.165	0.073	0.034	0.524	79

Table 4. Muscle mercury levels in lake trout and inconnu from Yaya Lake, November, 1995.

Species	Mean muscle Hg (µg/g)	Std. dev.	Minimum	Maximum	N
Lake trout	0.210	0.113	0.064	0.446	28
Inconnu	0.168	0.036	0.095	0.243	30

considerably higher. There was a tendency for the larger fish to have higher mercury concentrations (Figure 4, top) but there was little relationship within a species between mercury and selenium (Figure 4, bottom).

The previous Synopsis Report (Muir *et al.* 1997) gave preliminary data on a few fish from Yaya Lake in the Mackenzie Delta taken late in 1995. Two species were obtained, inconnu and lake trout, and the analyses for mercury and selenium are available now. The mercury levels were among the lowest we have seen in the western Arctic for those two species (Table 4). Larger individuals of both species tended to have higher levels of mercury (Figure 6, top). However, unlike other samples where there was no clear relationship between mercury and selenium, larger lake trout tended to have lower levels of selenium.

DISCUSSION/CONCLUSIONS

The questions of consumption and marketing of fish are the driving forces behind this project. The results from this project have been responsible for the issuance by Health Canada of several fish consumption advisories based on the mercury content of the fish. As additional surveys are completed, it may become necessary to issue more. There are reported to be approximately 2600 advisories in effect in Canada and about 95% of those are on the basis of mercury. A similar situation applies in USA. The principal questions which seem likely to arise from the results are the extents to which the mercury in the fish results from natural and anthropogenic activities, the trends over time, the extent of the problem in other lakes and the meaning of the mercury to the stocks.

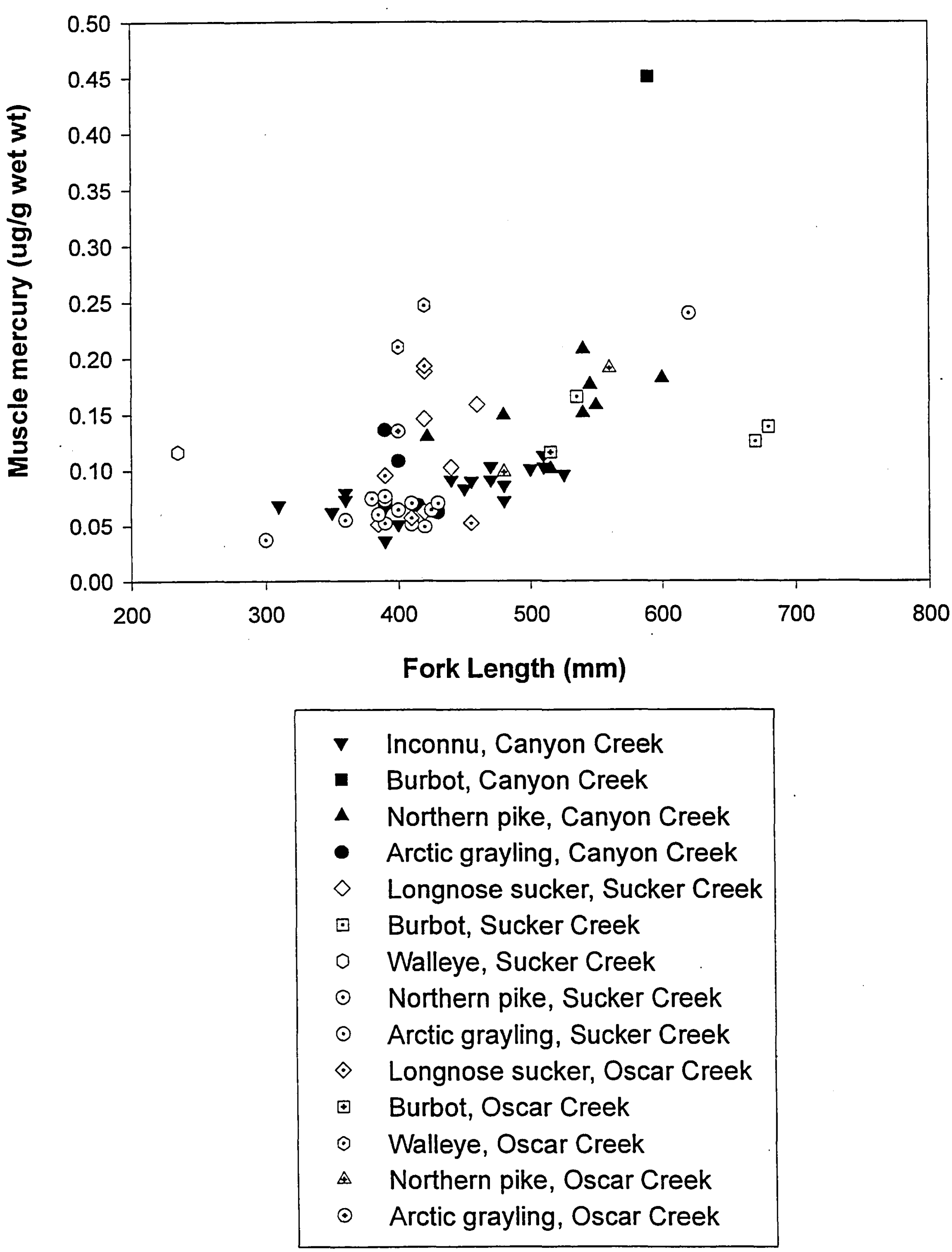


Figure 1. Muscle mercury in fish from the Mackenzie River near Norman Wells, June, 1997

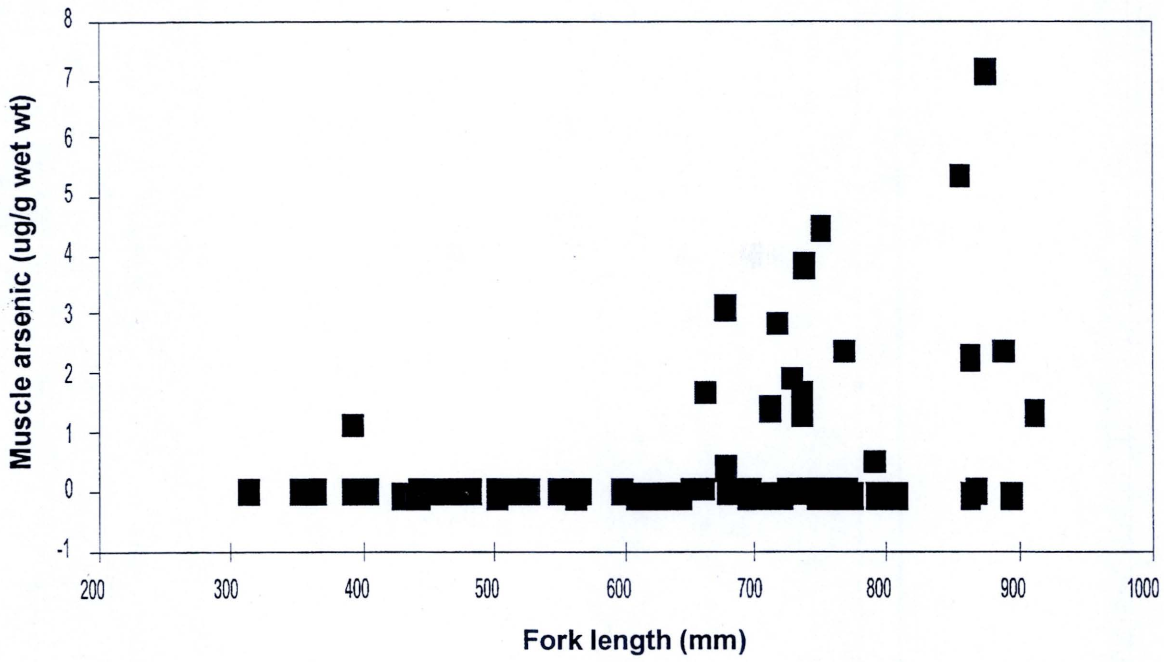


Figure 2. Muscle arsenic µg/g in inconnu, Mackenzie River, 1995 and 1998

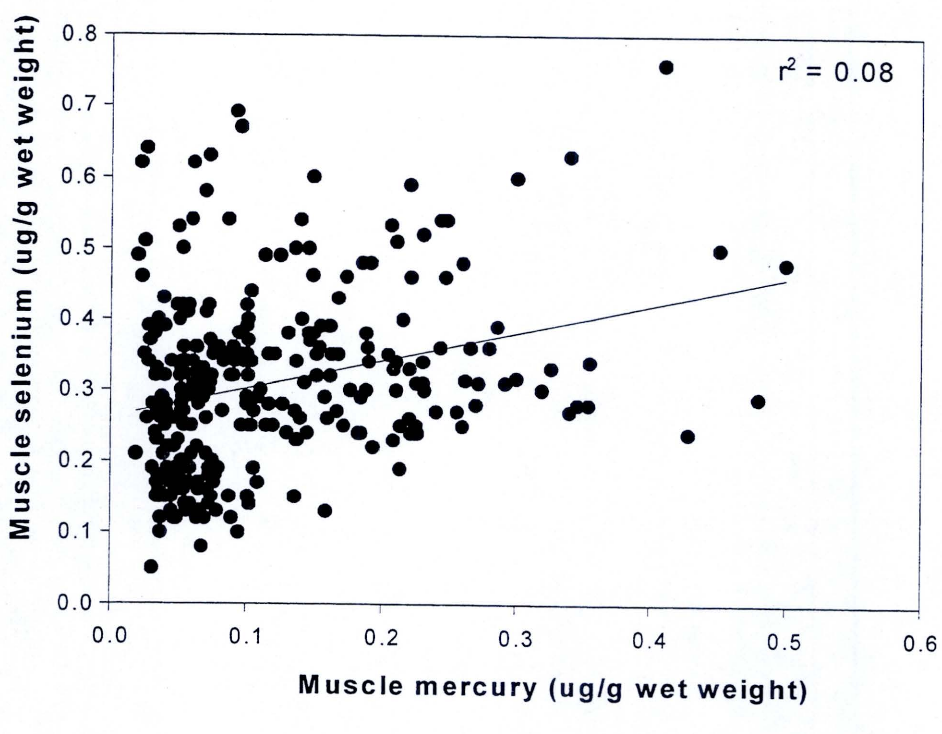
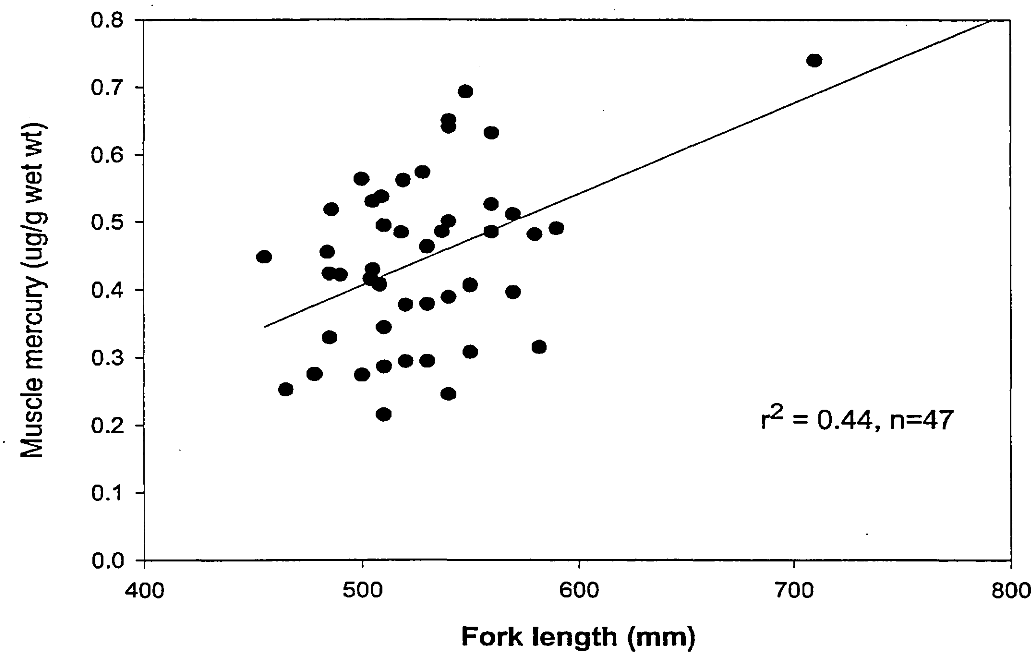


Figure 3. Muscle mercury and selenium, several species of freshwater fish, Mackenzie River, 1995–1997



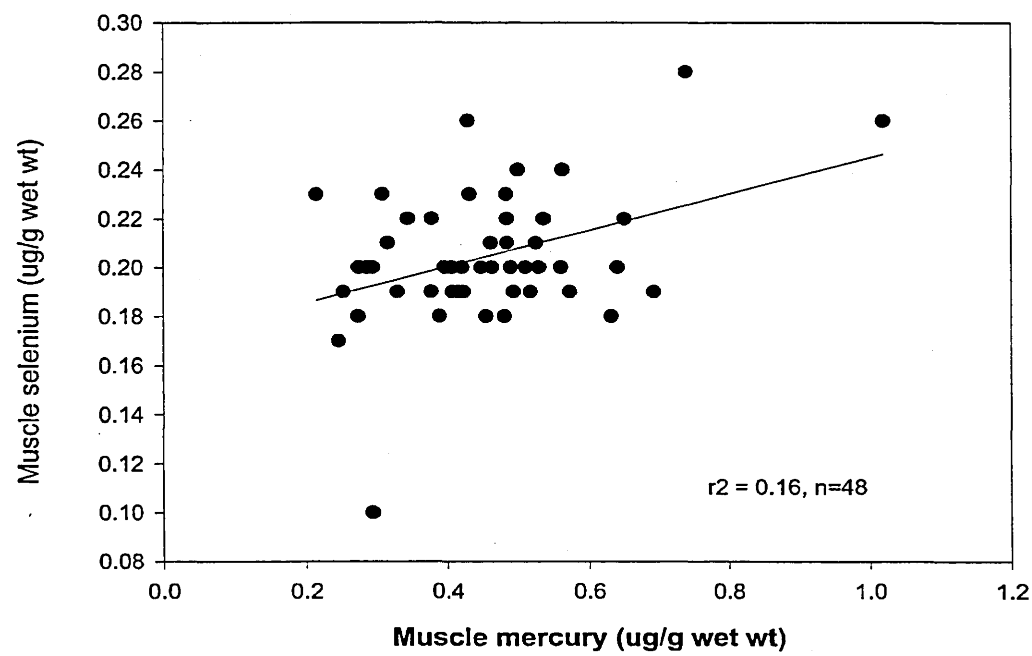
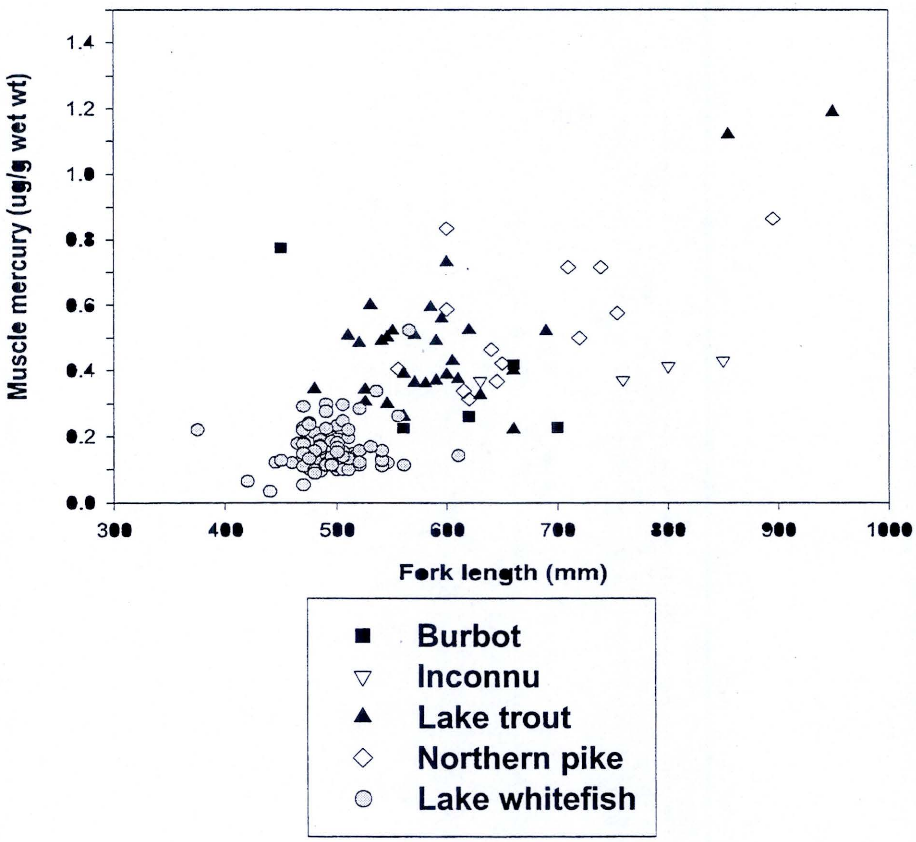


Figure 4. Muscle mercury as a function of fish length, Rorey Lake, NWT, 1997 (top) and muscle selenium as a function of muscle mercury in the same fish (bottom).



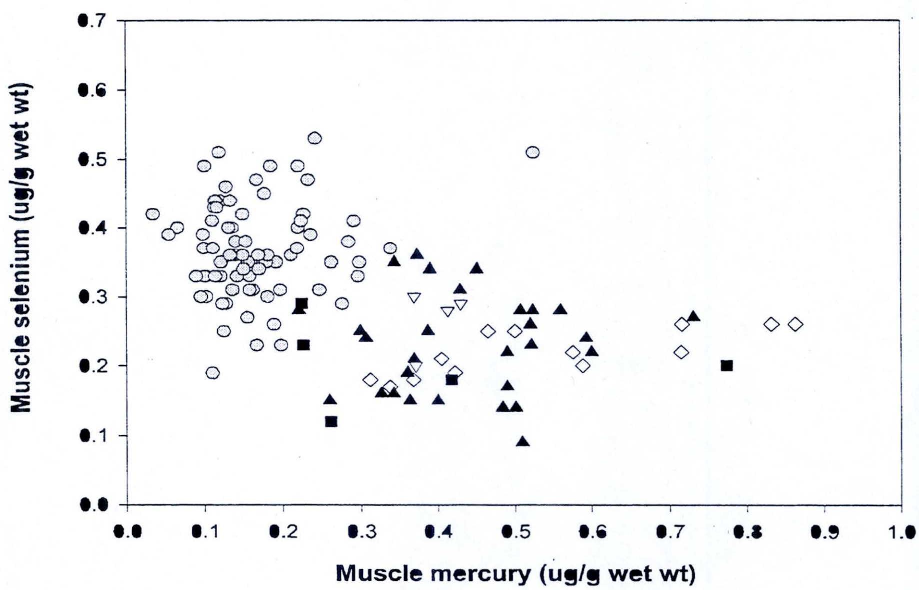


Figure 5. Muscle mercury as a function of length in fish from Kelly Lake, February/March, 1998 (above). Muscle selenium as a function of muscle mercury in same fish (below).

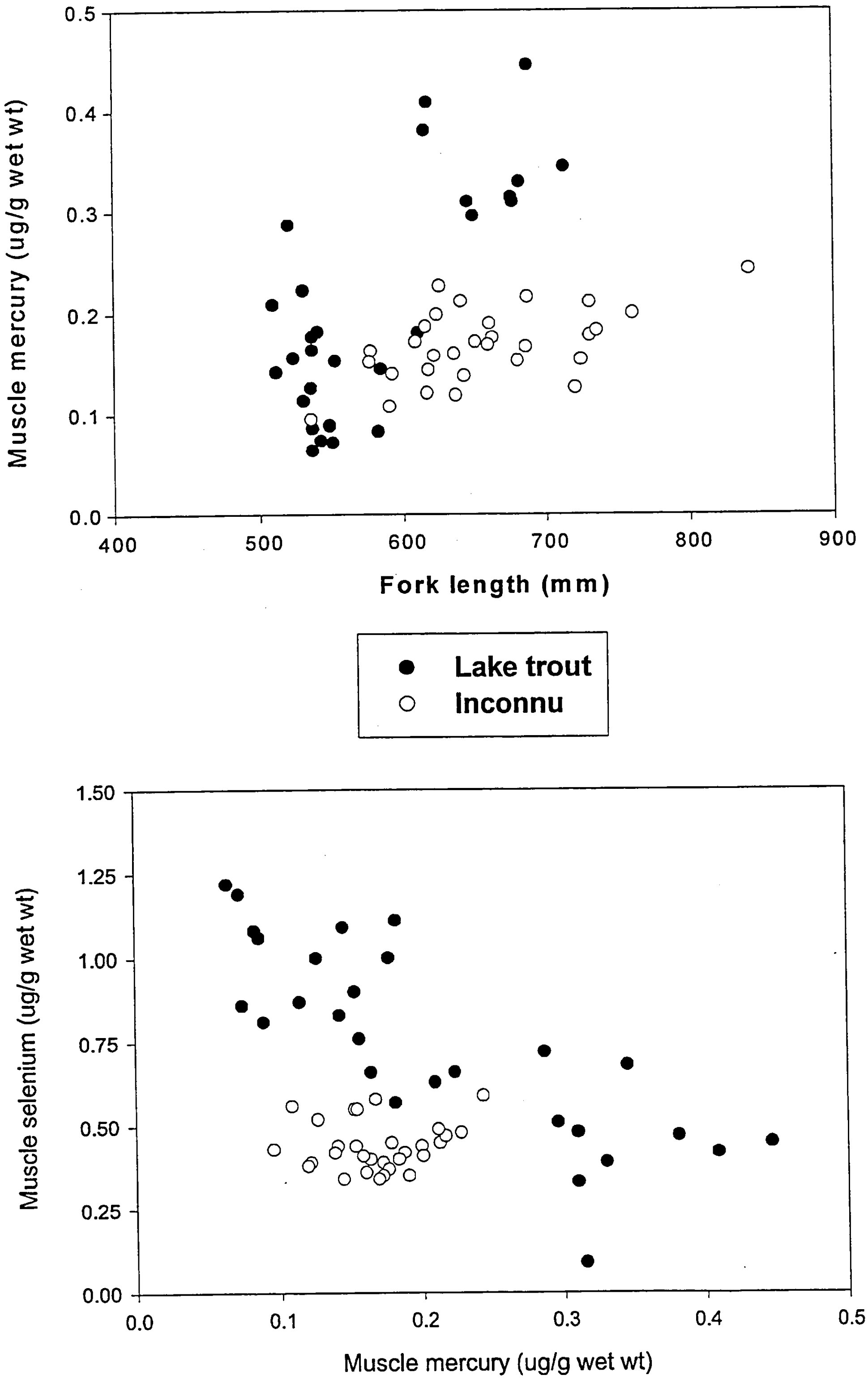


Figure 6. Muscle mercury as a function of fish length for lake trout and inconnu from Yaya Lake, NWT, (above). Muscle selenium as a function of muscle mercury for the same fish (below).

So far, no clear picture has emerged which would allow the prediction of mercury levels based on lake characteristics. We have some estimates of loadings of mercury inferred from sediment core studies (e.g., Lockhart *et al.* 1998) but the lakes for which we can estimate loadings are generally not the same ones chosen for fish survey work. The Cli Lake project (M. Evans, principal investigator) may offer an opportunity to do that.

Other factors also play important roles in governing the mercury in fish. We can see the effect of feeding habits on the mercury levels since species like northern pike generally exceed species like whitefish. What is not obvious is the reason why the same species in different lakes have different levels. For example, the lake trout and inconnu in Yaya Lake (Table 4) have lower mercury levels than those from Kelly Lake (Table 3). One hypothesis is that the water chemistry, particularly its colour, determines the availability of mercury and that is being tested in the companion project with G. Stephens as principal investigator. The geological settings of the basins of these lakes may be important determinants of the mercury cycling in them and those are being described by the Geological Survey of Canada as time permits.

The arsenic in the burbot and inconnu from the Mackenzie River appears to be an anomaly. Our survey knowledge of arsenic in freshwater fish is quite limited and additional data will be required. At the moment we can hypothesize that it represents exposure to marine food chains but we do not have sufficient data to test the argument thoroughly.

For the moment, these analyses of fish offer empirical descriptions required to facilitate decisions regarding consumption and marketing of fish and also establish present-day levels against which to judge future trends. In the longer term they will offer opportunities to test hypotheses regarding the dynamics of mercury, selenium and arsenic in the environment, and for evaluating biological risks of these elements in fish.

An abstract incorporating some of these data has been submitted for presentation at the Fifth International Conference on Mercury as a Global Pollutant in Rio de Janiero in May, 1999.

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RADIATION EXPOSURE IN LUTSEL K'E

Project Leader: Chair of the Lutsel K'e Environment Committee.

Project Team: The Lutsel K'e Environment Committee: S.Papik, Dene Nation; C. Mills, Indian and Northern Affairs, Yellowknife; L. Chan, Center for Indigenous Peoples' Nutrition and Environment, McGill University; C. Macdonald, Northern Environmental Consulting & Analysis, Pinawa, MB.

OBJECTIVES

This study was initiated in response to concerns from the community of Lutsel K'e about past and present exposure to radioactivity. The objective of the study is to survey the environment for radiation and to assess the exposure of the people of the community through the major pathways of food, air, water and background terrestrial radiation, and to compare the exposure with levels in the south and other areas in the North.

Specific objectives are:

1. to determine the radionuclide levels in the Lutsel K'e environment, including air, water, s oil and food.
2. to estimate exposure through dietary intake, inhalation and dermal exposure.
3. to educate the community regarding the physical properties of radionuclides and their effects on human health.
4. to increase the capacity of communities to design, monitor and implement research.

DESCRIPTION

Radiation remains one of the major environmental concerns in Lutsel K'e, a community situated on the east arm of Great Slave Lake in an area rich in mineral resources, including uranium and base metal deposits. The concern arises from:

1. the presence of the abandoned Stark Lake uranium mine near the community which may be releasing radionuclides to the surrounding environment,
2. the presence of the Russian satellite Cosmos 954 which deposited fragments of a radioactive power source in the area in 1978, and
3. recent studies which have shown that caribou, an important traditional food source, may contribute a relatively large amount of radioactivity in some northern communities because of the accumulation of naturally occurring radionuclides of the ^{238}U decay chain (Berti *et al.* 1998a).

Based on the results of the detailed diet studies conducted in the Dene/Métis Nation (Berti *et al.* 1998b), CINE has recently completed an exposure analysis for dietary intake of radionuclides from caribou among the Dene/Metis communities (Berti *et al.* 1998a) showing mean exposure levels of 2.96 $mSv \cdot a^{-1}$ in the South Slave. These exposure levels are slightly higher than background exposure level from the diet in the Great Lakes Basin. The present study seeks to provide more detailed information of the levels of radionuclides in food items but also to measure the levels of radionuclides in water, food, soil and air in the Lutsel K'e environment for evidence of radiation from Cosmos 954 and the Stark Lake mine and to permit an assessment of exposure through all major pathways. All of these issues were raised by members of the community in a workshop on radiation held in the community on October 31, 1997.

The study is a collaborative partnership between the Lutsel K'e Environment Committee, who led the study, the Dene Nation, the Department of Indian Affairs and Northern Development (DIAND), the Centre for Nutrition and the Environment of Indigenous Peoples (CINE) and Colin Macdonald of Northern Environmental Consulting & Analysis (NECA) who provided advice on the types of analysis required. Samples were collected primarily by Roy Desjarlais, the Lutsel K'e environmental coordinator. This report will summarize the results of the first year of the radiation survey and the analysis of water, air and food samples. The second year of the study will use this analytical information for a detailed radiation exposure assessment for the community.

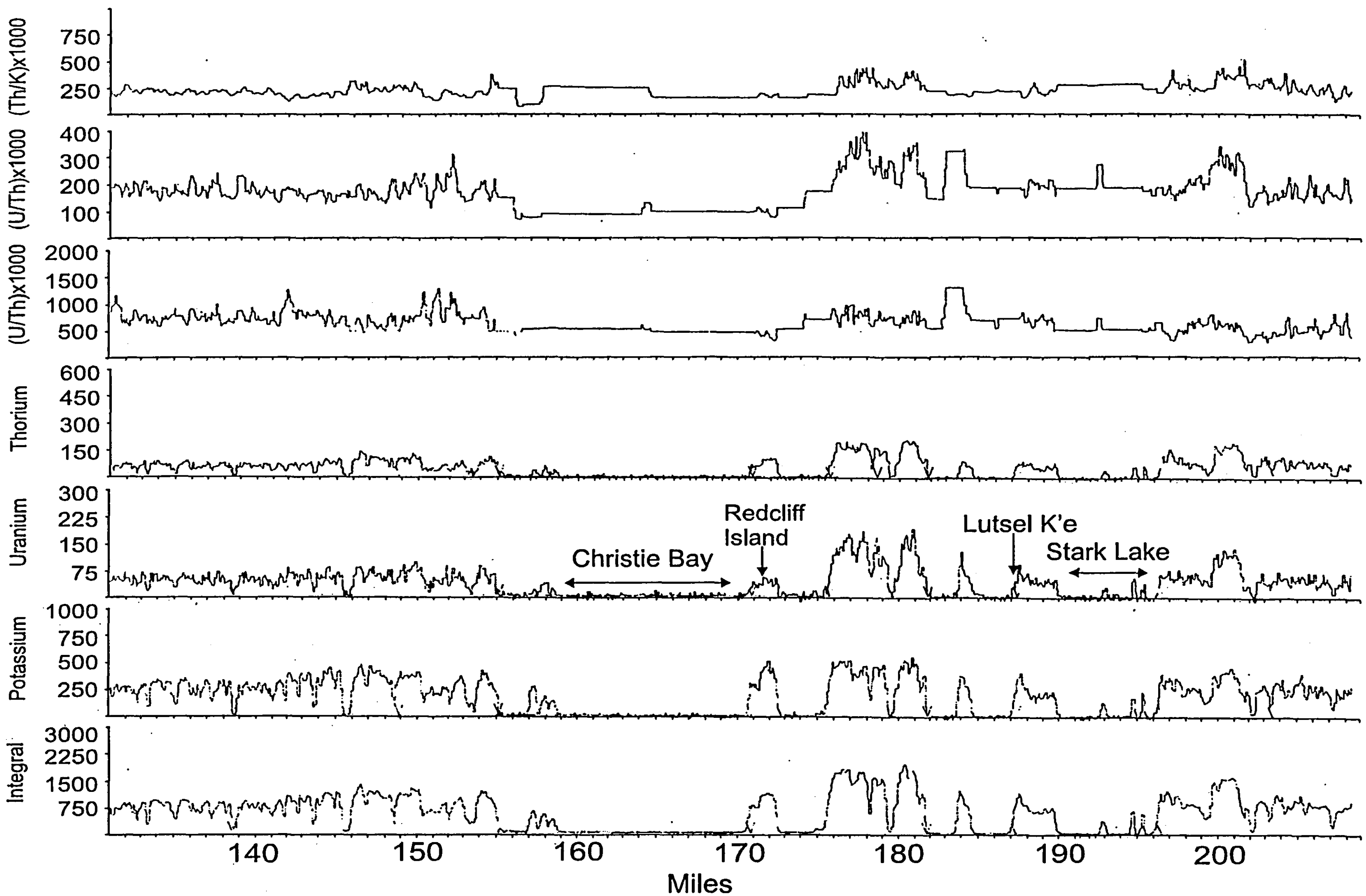

Figure 1. Uranium, potassium (^{40}K) and thorium in surface soils and rock in Transect 39 of the 1971 aerial survey of the Geological Survey of Canada. The transect roughly corresponds to 62° 20'N which passes close to Lutsel K'e.

ACTIVITIES IN 1997/98

RESULTS

Community Workshop

A community workshop on radiation was held in Lutsel K'e on October 31, 1997 involving all the project partners and members of the community. The workshop was conducted to inform the community about radiation and to provide a forum for the members of the community to openly discuss their concerns. Information on northern contaminants, diet and nutrition and basic radiation was presented. Concerns from members of the community included a perception of higher cancer rates in the community since Cosmos 954, a general concern about water quality and the potential for contamination from the Stark Lake mine to enter Stark Lake and contaminate drinking water and fish. There was also a general concern about the quality of the environment because the community consumes many of the traditional country foods from the land (caribou, muskox, rabbits, berries) and water (lake trout, whitefish, loche liver). The sampling and analytical portion of this study sought to address many of these concerns.

Background Gamma Radiation

Radiation from the ground can comprise a large fraction of the total radiation exposure for people living in uranium-rich areas (UNSCEAR 1982). For a broad overview of radiation in the top 30 cm of soil and rock, data on U, radioactive potassium (^{40}K) and Th concentrations as measured by aerial surveys were obtained for the Great Slave Lake region from the Geological Survey of Canada. Transect 39 of the 1971 survey corresponded roughly to latitude 62° 20'N, running from the east shore of the North Arm of Great Slave Lake eastward for about 400 km, passing close to Lutsel K'e (Figure 1). The data shown in Figure 1 are the number of counts recorded at a height of about 150 m in 2.5 seconds for the isotopes and 0.5 seconds for the integrated value. For uranium and thorium, 22 counts and 9 counts are equivalent to 1 $mg \cdot kg^{-1}$, respectively, while 134 counts are equivalent to 1% potassium. The data show that the surface soils and rocks in the immediate vicinity of Lutsel K'e have U concentrations of about 3–5 $mg \cdot kg^{-1}$, although the levels of U and ^{40}K are about twice as high to the east and west of the community in traditional hunting areas. None of the areas on the transect are considered to be high for any of the radio isotopes, particularly relative to other areas identified in other transects.

Background gamma radiation was measured at several random sites and public buildings in the community on October 31 and November 1, 1997. The survey was conducted at 1 m height and at ground level using a hand-held Ludlum 19 gamma ratemeter which was calibrated for environmental temperatures of <–10° C. The objective of the survey was to look for any radioactive fragments remaining from Cosmos 954 and to determine the average background gamma rates for people within the community. The meter was periodically checked with a ^{137}Cs check source. The response of the meter was generally good however because the survey was conducted at low temperatures in November (about –20° C), the analogue meter was slow to respond to changes in gamma radiation, as would be expected from small radioactive fragments from Cosmos 954. The buildings surveyed included the Lutsel K'e Band Office, the Nursing Station, the school yard, and the Community Hall. Some sites were also checked outside the community (Stark Lake Road, the new dump) to compare with the community measurements.

Dose rates in air within the community ranged from about 0.5 to 1.1 $mSv \cdot a^{-1}$ (Figure 2), averaging about 0.8 $mSv \cdot a \cdot kg^{-1}$. The highest dose rate observed was 1.9 $mSv \cdot a^{-1}$ at the face of a cliff on a road south of the community. The average dose rate in air of 0.8 $mSv \cdot a^{-1}$ is twice as high as the 0.4 $mSv \cdot a^{-1}$ used as an average for dose in air for the general population in the U.S. (NCRP 1975) and 0.35 $mSv \cdot a^{-1}$ estimated for terrestrial radiation exposure in humans worldwide (UNSCEAR 1982).

Radon in Air

Radon was measured in public buildings and the houses of volunteers using alpha track detectors marketed by the Canadian Institute for Radiation Safety (CAIRS, 102-110 Research Drive, Saskatoon, SK S7N 3R3; ph (306) 975-0566). The measuring devices consist of an alpha track detectors connected to small aquarium pumps which pull air through a filter at a constant rate for one week. The detectors are supplied and analysed by the CAIRS facility in Saskatoon.

Readings were taken in both the private residences of volunteers and in public buildings within the community (Figure 3). The first set of measurements was taken in late November, 1997. Radon levels in all private residences were ≤1 mWL. Levels in the school, Nursing Station, Band Office and Co-op were all greater than 1 but lower than 5 mWL. The highest radon concentrations were observed in the Community Hall (24 mWL) which exceeded the U.S. guideline but were well below the Canadian guideline of 110 mWL. Because of this high value, a second reading was taken in the school and two in the Community Hall. The level in the school remained relatively low (7 mWL) but the two readings in the Community Hall were higher than the first reading at 44 and 60 mWL.

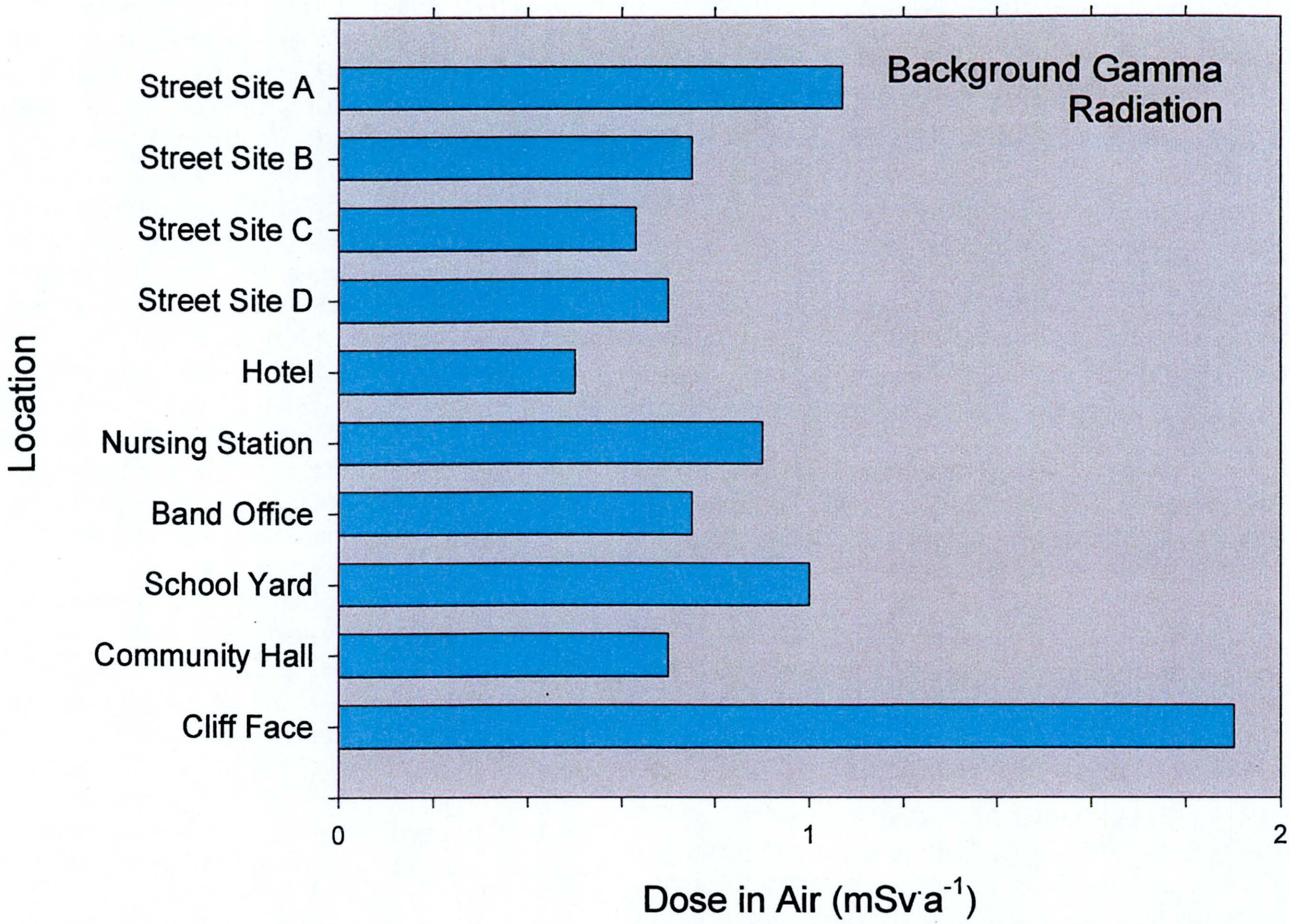

Figure 2. Background radiation measurements made in October/November, 1997 in Lutsel K'e. Readings were taken with a Ludlum 19 hand-held gamma ratemeter at waist height. Sites were randomly chosen during a general survey of the community. The high dose rate reading was taken at a cliff face on a road south of the Community.

Table 1. Uranium concentrations in drinking water, Stark Lake and Great Slave Lake water. The Canadian Drinking Water Standard is currently 100 $\mu g \cdot L^{-1}$ but is under review and may be decreased to about 20 $\mu g \cdot L^{-1}$ or less.

Location	n	Mean Concentration ($\mu g \cdot L^{-1}$)
Great Slave Lake	5	0.36 (SD = 0.05)
Stark Lake (through ice)	5	0.14 (SD = 0.05)
Pump Intake (community)	5	0.39 (SD = 0.03)

Table 2. Analysis of pooled water samples for gamma radionuclides. Concentrations are in $Bq \cdot L^{-1}$.

Location	^{137}**Cs**	^{226}**Ra**	^{232}**Th**	^{235}**U**
Great Slave Lake	0.04 (CE = 0.02)	<0.05	0.06 (CE = 0.04)	<0.09
Stark Lake	<0.02	<0.05	0.05 (CE = 0.03)	<0.09
Pump Intake	<0.03	<0.05	0.06 (CE = 0.03)	<0.09

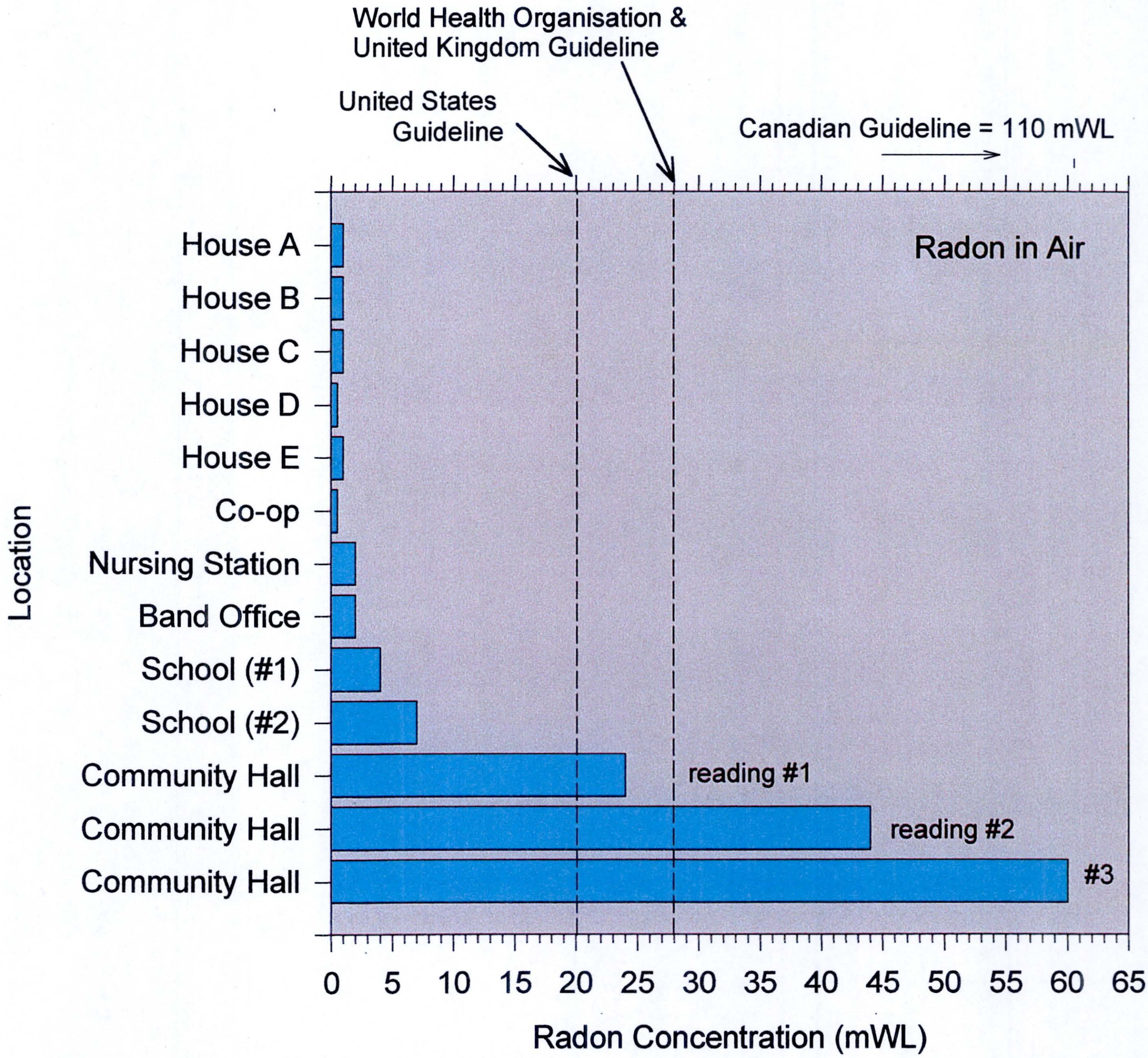

Figure 3. Radon concentration in private residences and public buildings in the fall of 1997 and winter of 1998 in Lutsel K'e. The second set of readings in the school and the Community Hall are indicated as #2 and #3. The guidelines for radon in houses in the U.S. (20 mWL) and by the World Health Organisation (28 mWL) are indicated. The Canadian guideline of 110 mWL is off-scale.

Table 3. Summary of radionuclide concentrations in food items collected in November-December, 1997 near Lutsel K'e, NWT. Values in brackets are standard deviations.

Species	Sample Type	Collection Date	Collection Site	Number of Samples	% Dry Weight	% Ash Wt.	^{40}K (Bq·kg^{-1})	^{137}C (Bq·kg^{-1})	^{210}Pb (Bq·kg^{-1})	^{226}Ra (Bq·kg^{-1})	^{232}Th (Bq·kg^{-1})	^{210}Po (Bq·kg^{-1})
Mammals												
caribou	meat	Nov. 1997	Lutsel K'e area	2	24.1	n/a	180	143	< 2.0	7.20		12.3
					(1.02)		(4.95)	(9.90)		(5.02)	< 1.0	(2.26)
	kidney	Nov./Dec. 1997	Lutsel K'e area	3	20.3	n/a	139	276	65.6	< 0.20	< 1.0	187
					(1.27)		(23.0)	(67.6)	(38.5)			(87.8)
	liver	Nov./Dec. 1997	Lutsel K'e area	5	31.1	n/a	136	115	87.0	< 0.20	< 1.0	270
					(1.32)		(36.5)	(59.0)	(37.1)			(67.4)
	stomach	Nov. 1, 1997	Lutsel K'e area	1	23.7	n/a	198	159	< 2.0	< 0.20	< 1.0	34.3
rabbit	meat	Dec. 15, 1997	Lutsel K'e area	1	24.7	0.79	103	12.4	< 1.4	< 0.24	< 0.34	0.84
moose	meat	Dec. 15, 1997	Lutsel K'e area	1	25.3	0.59	99.4	2.21	<0.65	0.09	<0.13	0.50
Fish												
Loche	liver	Dec. 1997	Great Slave Lake	7	35.9	0.98	121	1.91				4.47
(Burbot)					(4.22)	(0.21)	(13.9)	(0.87)	< 5	< 0.5	< 1.2	(3.01)
whitefish	flesh	Dec. 1997	Stark Lake	3	21.4	0.62	105	4.83	< 0.9	< 1.30	< 0.18	0.10
					(1.46)	(0.18)	(33.0)	(2.27)				(0.02)
lake trout	flesh	Dec. 1997	Stark Lake	3	21.9	0.64	107	3.29				
					(0.55)	(0.23)	(27.9)	(1.43)	<1.0	< 0.17	< 0.2	< 0.3
white sucker	flesh	Dec. 11, 1997	Stark Lake	1	18.2	0.77	141	2.28	< 0.81	< 0.12	< 0.16	< 0.01
jackfish (pike)	flesh	Dec. 11, 1997	Stark Lake	1	20.5	0.67	119	2.78	< 0.64	< 0.10	< 0.13	< 0.07
Berries												
cranberries	whole	Dec. 15, 1997	Lutsel K'e area	1	17.5	0.097	26.2	2.09	< 1.7	0.30	< 0.46	0.52

Analysis of Water

Water from Stark Lake (adjacent to the Stark Lake mine), Great Slave Lake and the pumphouse that supplies water to the Lutsel K'e community was analysed for uranium and radionuclides. Because of the small amount of water sampled at each place (5 samples of 100 mL each), five separate samples were analysed for uranium by fluorometry (n = 5) and the pooled samples for each site were analysed by gamma spectrometry after evaporation into plastic. Gamma-emitting radionuclides were detected using a gamma spectrometer with a p-type well detector with count times of 18 hours.

The concentration of uranium in the drinking water from the pumphouse (0.39 $\mu g \cdot L^{-1}$, SD = 0.03) was virtually the same as in Great Slave Lake from which the water was taken (0.36 $\mu g \cdot L^{-1}$, SD = 0.05) (Table 1). QA of the analysis was very good with 97% of U spikes recovered and recovery of standards at 90 to 95%. The water samples collected in Stark Lake had a lower mean concentration of uranium (0.14 $\mu g \cdot L^{-1}$, SD = 0.05) than both the Great Slave Lake and pump house samples. All samples collected during the study were well below the current Canadian guideline for uranium in drinking water of 100 $\mu g \cdot L^{-1}$ and the proposed guideline of 20 $\mu g \cdot L^{-1}$.

The analysis of the water samples for gamma-emitting radionuclides showed traces of ^{137}Cs and ^{232}Th however ^{226}Ra and ^{235}U were below detection limits in all samples (Table 2). The ^{137}Cs found at trace levels was probably due to historic nuclear weapons testing and the Chernobyl nuclear accident, because there are no known local sources of this man-made nuclide. Thorium-232 is a natural radionuclide which is present in the rocks of the area at a concentration of several parts per million. The concentrations of all anthropogenic and natural radionuclides were very low.

Food Samples

Samples of several food items were collected between November, 1997 and February, 1998 and sent to Whiteshell Laboratories in Pinawa, MB for radionuclide analysis. The samples were freeze-dried and analysed for radionuclides by gamma spectrometry using a p-type well-detector. The same samples were analysed for ^{210}Po by alpha spectrometry, after digestion and deposition onto silver discs, using ^{209}Po as a tracer.

The list of samples collected and the summary of results are presented in Table 3. Cesium-137, ^{40}K, ^{210}Po were found in all samples collected. Cesium-137, which remains from the atmospheric nuclear tests in the 1960s, was highest in caribou kidney and other caribou tissues, but much lower in all fish, rabbit and moose samples. The levels in the two caribou meat samples agree with other studies which show that ^{137}Cs is still decreasing in caribou from very high levels 20 to 30 years ago (Macdonald *et al.* 1996). Potassium-40 is a natural radionuclide that has been on Earth since it was formed 5 billion years ago and is in all living material at about the same concentration. The other radionuclides (^{210}Pb, ^{226}Ra, ^{210}Po and ^{232}Th) are in the ^{238}U decay chain and hence are natural in origin. The highest concen-trations of ^{210}Po, an alpha-emitting nuclide which comprises a major fraction of the dose to humans, were observed in caribou liver, but much lower levels were found in caribou meat and in the other species tested. The values observed in all food items correspond to levels reported elsewhere. There was no evidence of anthropogenic radionuclides that would indicate a source of contamination such as Cosmos 954.

CONCLUSIONS

The objective of this study was to provide information on the present levels of radiation exposure in the community of Lutsel K'e, and to determine if specific sources of radiation, such as fragments of the Cosmos 954 and output from the Stark Lake mine, were detectable. The ground surveys and analysis of water and food samples were conducted specifically to look for evidence of contamination from Cosmos 954 and the mine site. The ground survey showed that background radiation is slightly higher in Lutsel K'e than in the south however the exposure remains within the range considered to be normal. The survey did not identify any areas of high background radiation within the community which would suggest fragments of the Cosmos 954 satellite. The lack of specific point sources of radiation indicates that the radioactive pieces identified in 1978 (Gummer *et al.* 1980) were removed from the area in the original clean-up or have lost their radioactivity. The slightly higher radiation measured south of the community during the survey is probably due to elevated levels of U in the exposed rock of the cliff face. The ground survey data are consistent with the aerial survey data showing about 3-4 $mg \cdot kg^{-1}$ U in the soil. The implications of the higher background dose and higher radon levels in the Community Hall, in terms of total annual radiation exposure, will be addressed in 1998–99 when a detailed exposure assessment will be conducted.

Water quality remains a major concern of the residents of Lutsel K'e. This study reports that U and other radionuclides are low in Stark Lake and Great Slave

Lake at the time of testing, however because the samples were collected through the ice in December, the tests should be repeated during the open water season when nuclides from the Stark Lake mine site may be entering the water. Drinking water quality should be routinely checked for general water quality parameters in response to concerns of the community.

The levels of radionuclides found in the food samples agree with other studies of radionuclides in the North. A detailed review of studies on radionuclides in traditional country foods in Lutsel K'e and other communities (Reid Crowther 1997) reported levels of ^{137}Cs and ^{40}K in lake trout, whitefish and northern pike which correspond closely with the levels observed in this study. Although the present study also reported levels of ^{232}Th and ^{226}Ra in some samples, there was no evidence of nuclear fuel waste nuclides which would indicate a local source of contamination, such as fragments of Cosmos 954 (Gummer *et al.* 1980). The levels of natural radionuclides from uranium are low in most food items, and the higher levels found in caribou have been found in other studies across the Arctic (Thomas 1992, Macdonald *et al.* 1996).

At this phase of the study, we conclude that present levels of radiation within the community are probably equivalent to or slightly higher than the annual doses received in southern Canada, and in other areas of the North. Elevated levels of radon in the Community Hall should be monitored and remedial action taken if levels increase from the present levels. A detailed assessment of dose from the major pathways will be conducted in the second phase of the project (1998/99) after more data are collected for food items.

Expected Project Completion Date: March 31, 1999.

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MERCURY TRENDS AND CONCENTRATIONS IN ENVIRONMENTAL MEDIA OF THE CANADA BASIN

Project Leaders: R. Macdonald (IOS, Sidney, BC), C. Gobeil (IML, Mont Joli, PQ)

Project Team: D. Schell (U. Alaska, Fairbanks); R. Addison (IOS Sidney, BC)

OBJECTIVES

1. to derive recent Hg trends using archived dated bowhead baleen samples.

DESCRIPTION

Recent assessments strongly suggest that Hg fluxes are increasing in the Arctic (Macdonald and Bewers 1996, Barrie *et al.* 1997) and that these increases, if real, pose a serious concern for country foods. The evidence for Hg increases comes from:

1) atmospheric concentrations which are reported to be increasing in the northern hemisphere by 0.6% to 1.5% per year (Slemr and Langer 1992, Fitzgerald 1995, Fitzgerald *et al.* 1998),
2) Hg profiles from dated sediment cores collected in the Arctic (Lockhart *et al.* 1995, Landers *et al.* 1995),
3) Global Hg budgets wherein it is estimated that 50% to 70% of the Hg presently cycling through the atmosphere is due directly or indirectly to human activities (Linqvist *et al.* 1991, Mason *et al.* 1995, Nriagu and Pacyna 1988), and
4) Arctic biological samples which show increases in Hg in modern samples (Wagemann *et al.* 1996, Hansen *et al.* 1991, Wheatley and Wheatley 1988).

Taken together, these observations support the conclusion that there is a coupling between levels of Hg in arctic biota and human impacts over the past century on the global Hg cycle. This coupling is certainly plausible and would very likely parallel the "physical/ chemical transport – food web magnification" sequence observed for organochlorines with HCH providing a good analogue. Although the increasing trend of Hg in the Arctic is clearly a priority concern in that some country foods already contain Hg concentrations at or above consumption advisory levels, the present data base is extremely thin and does not provide a confident view of present trends. Although the weight of evidence suggests that modern Hg fluxes to the Arctic are greater than pre-industrial, each of the lines of evidence has weaknesses.

As is well known from work in other regions, use of biological tissue such as hair samples has proven to provide valuable insight into Hg uptake by animals, including humans, and to provide a way to determine trends (e.g., see Lebel *et al.* 1996; Hansen *et al.* 1991). Baleen in whales is a biological product that, like hair, grows continuously, can be aged, and therefore has potential as a recorder of trends in environmental conditions. Schell *et al.* (1989) have used $\delta^{13}C$ analyses on archived baleen (Bowhead whale *[Balaena mysticetus]*) to determine seasonal and geographic variations in diet. Since the whales record their diet in the isotopic composition of the baleen as they migrate from the Pacific into the Arctic and back, detailed analyses have allowed these researchers to determine the year, and even the season, corresponding to a given baleen sample. Essentially, this provides the age of each sample, but it also provides important information on diet. To make a preliminary evaluation of the potential of baleen to record regional variations and trends in Hg, we have used the dated archive at the University of Alaska as a sample stock from which to run high quality Hg analyses.

ACTIVITIES IN 1997/98

The University of Alaska was visited in August, 1997, and after consulting the $\delta^{13}C$, $\delta^{15}N$ records for a number of archived baleen samples (Schell 1992) three baleen plates were selected for sub-sampling. Using the $\delta^{13}C$ sampling locations as a guide, small pieces of plate were clipped off the archive material at the University of Alaska and over 300 samples from the three plates were returned to the Laboratory at IML where they were analysed.

Method

Three bowhead baleen plates were sub-sampled every 2.5 cm by clipping small pieces off using a wire cutter. The sub-samples were decontaminated following a three-step procedure:

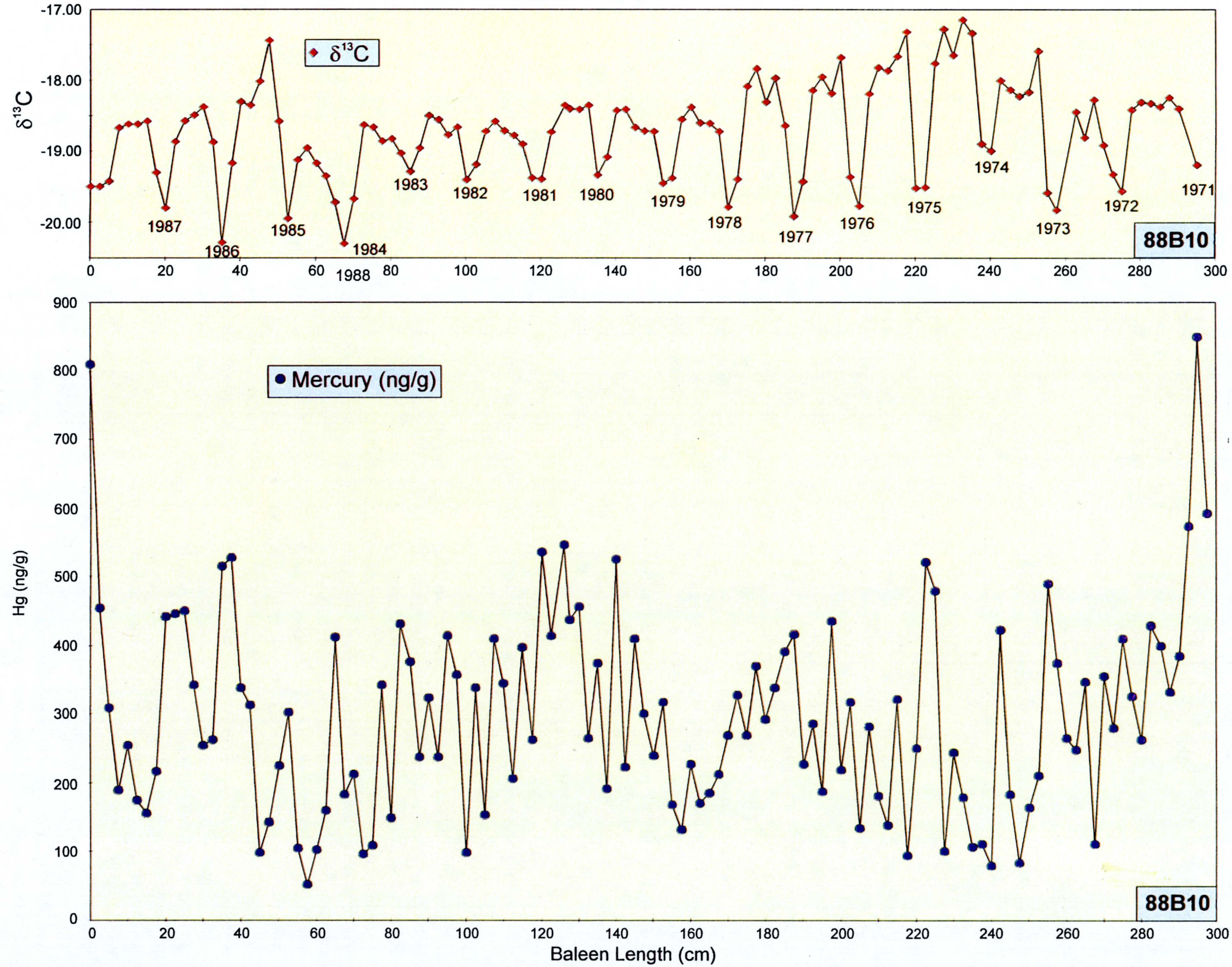

Figure 1. The record of Hg (blue) and d[13]C (red) in baleen 88B10.

1) Baleen pieces (50-100 mg) were placed in Teflon tubes with 5 mL of nitric acid solution (0.2 N) and left in an ultra sonic bath for 15 min.,
2) They were rinsed three times with deionized water and left again in an ultra sonic bath for 30 min. with nitric acid,
3) Rinsed again with water, soaked for one night in 5 mL of nitric acid solution and finally rinsed with water.

The cleaned baleen samples were then digested with concentrated nitric acid at 90 °C. Mercury concentration was determined by gold amalgamation fluorescence atomic spectroscopy. Precision, expressed as the coefficient variation of replicate analysis (n = 61) of the human air certified material GBW 09101, was 10.9%. The accuracy was -2.7%.

RESULTS

The three selected baleen plates were (Schell 1992):

- 88WW3: A male bowhead whale, killed on 6 May, 1988, 2.07m plate (record from 1977–1988)
- 88B10: A male bowhead whale, killed on 17 Sept., 1988, 3.02m plate (record from 1971–1988).
- 90B5: A female bowhead whale, killed on 23 May, 1990, 2.79m plate (record from 1975–1990)

These particular plates were selected because they had clear $\delta^{13}C$ seasonal records which provided unequivocal dating, they provided a range of mean $\delta^{13}C$ levels, and because they included male and female samples. It should be noted that baleen whales graze zooplankton and are therefore integrating food from the 2nd or 3rd trophic levels, putting them at the 3rd to 4th level themselves. Although this is lower in the food chain than the toothed whales, for example, with the result that they are expected to have lower Hg burdens, they are nevertheless ideal integrators in view of the amount of zooplankton they must filter.

Over 300 Hg data points were produced for comparison to the stable isotope records (Figures 1, 2, 3).

DISCUSSION/CONCLUSIONS

The seasonal cycle of $\delta^{13}C$ reflects feeding patterns for these whales (Schell 1992, Schell *et al.* 1989): light $\delta^{13}C$ occurs during summer feeding in the Chukchi and Beaufort seas whereas heavy $\delta^{13}C$ occurs during winter feeding in the Bering Sea. The Hg records also show seasonal variation, although not as clearly as the $\delta^{13}C$ records. Perhaps the best example of the seasonal signal is provided by the female baleen plate (90B5) shown in Figure 3. It is clear throughout this particular record that Hg is about 100-200 ng/g higher during periods of light $\delta^{13}C$ implying that Hg is higher during feeding in the Arctic Ocean relative to the North Pacific. Although the difference of 200 $ng \cdot g^{-1}$ is not large in an absolute sense, it does represent a doubling of Hg between the bottom envelope and the top envelope. An important implication of these data is that baleen records a Hg signal and preserves it for the life of the baleen (20 years or so). Furthermore, the coherence between $\delta^{13}C$ and Hg evident in Figure 3 also suggests that baleen responds quickly to diet, both in terms of carbon and Hg; that is, there does not appear to be a large reservoir or body effect. This latter property is a desirable characteristic in terms of seeking trends in baleen.

We have noticed that the most recently produced baleen tends to have much higher Hg content (e.g., see Figure 2, 88W3) which might be caused by some remaining soft tissue or it may be due to an aging process wherein a season is required for a labile Hg component to be lost under environmental conditions (i.e., plate polishing, surface ablation during use). In addition to the seasonal cycle, the baleen samples show intriguing longer-term cycles which are particularly evident in 88B10 (Figure 1). For 88B10, the cycle shows minima at 60 cm, 160 cm and 240 cm offset by maxima at about 30 cm, 120 cm, and 290 cm. It is noteworthy that the $\delta^{13}C$ seasonal cycles also show longer term cycling (top panel) with boundaries between episodes corresponding approximately to changes in Hg. Further work is continuing with these data to apply time-series techniques to tease out the dominant frequencies.

Finally, none of the baleen plates shows evidence of a significant increasing or decreasing trend of Hg during the period in question (1970-1990). Our detection limit for such a trend would be about 4% yr^{-1} which is slightly higher than most evidence would suggest - although it is significantly lower than suggested by Wagemann *et al.* (1996).

Expected project completion date: March 1, 1998

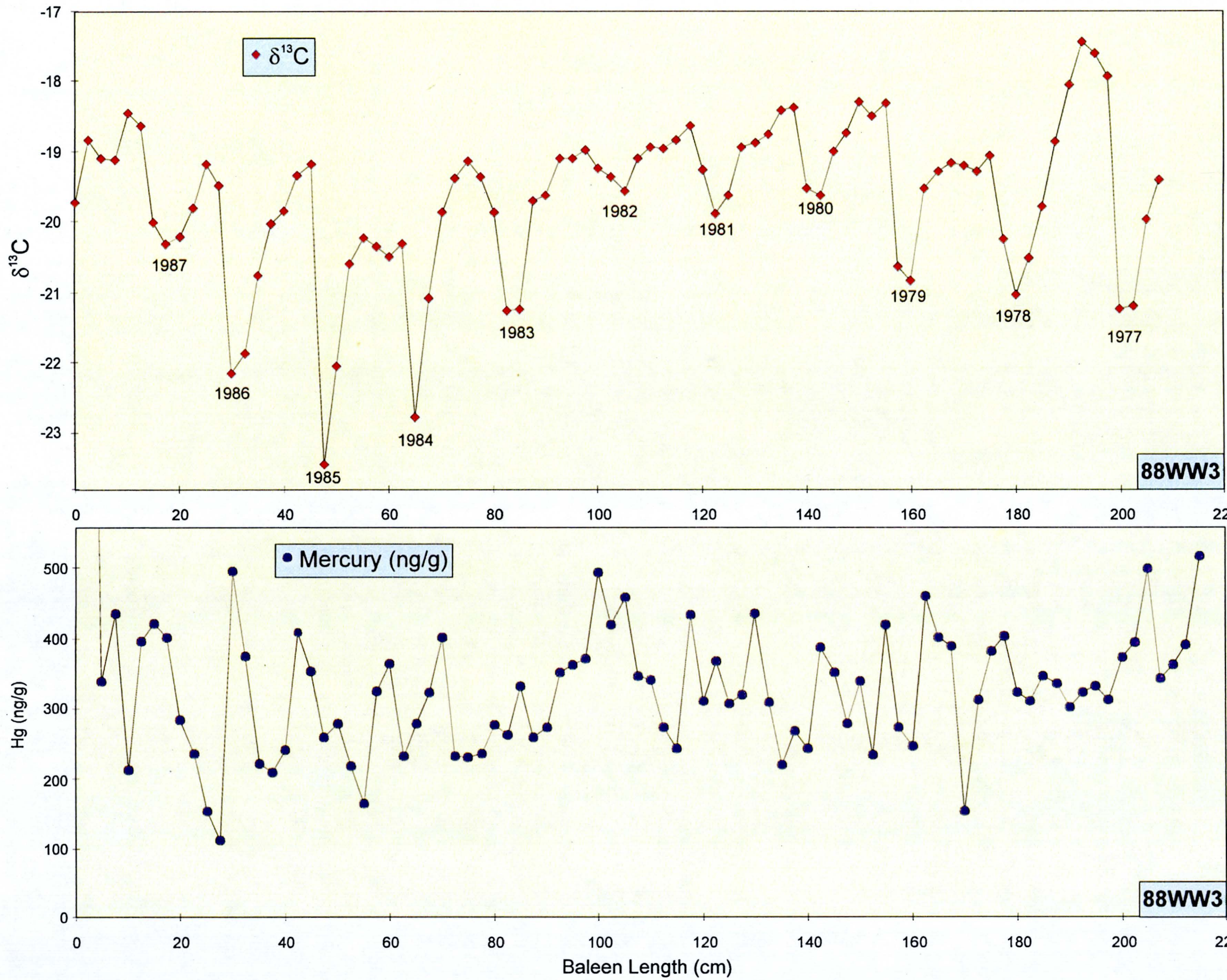

Figure 2. The record of Hg (blue) and d[13]C (red) in baleen 88W3

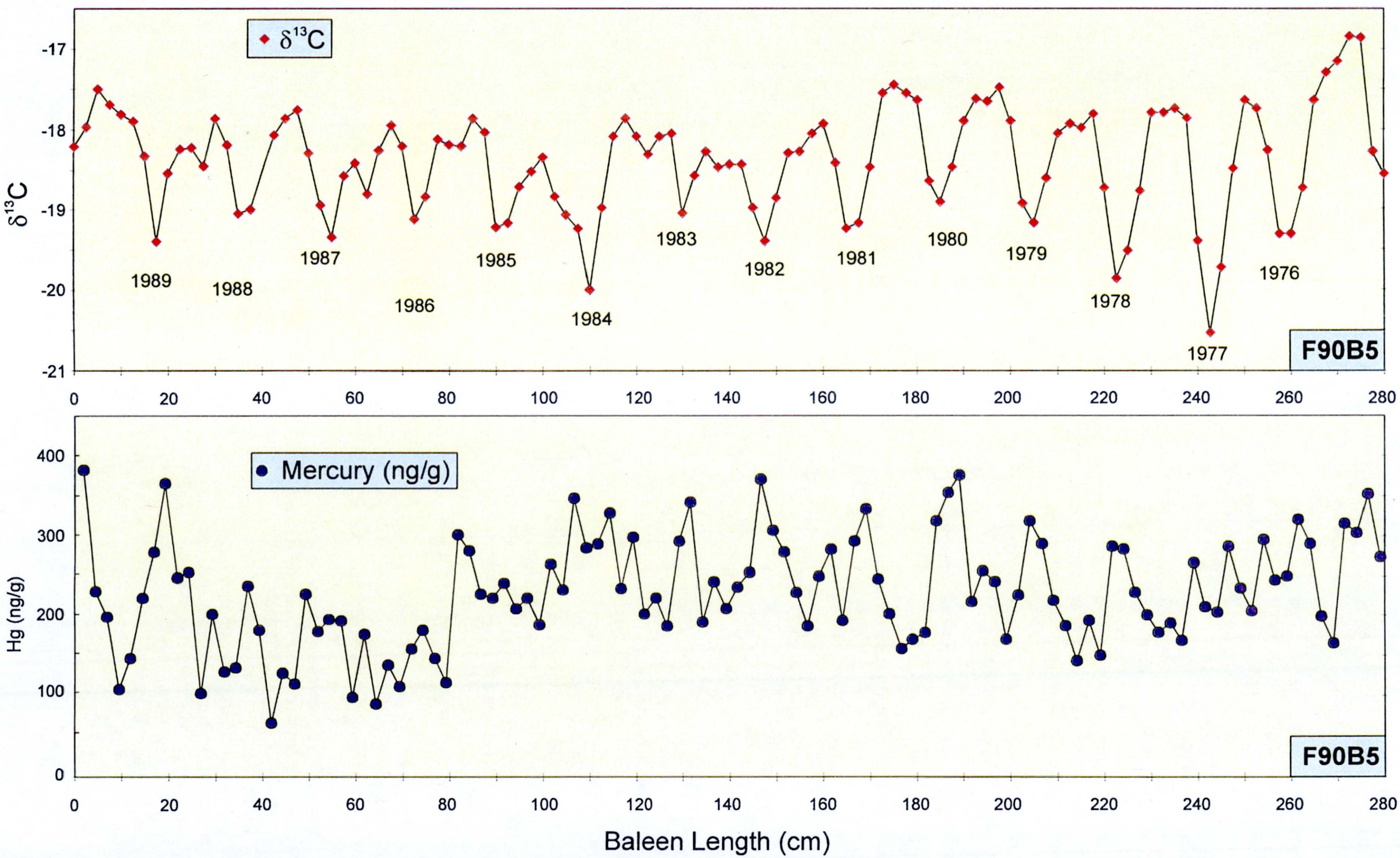

Figure 3. The record of Hg (blue) and d[13]C (red) in baleen 90B5

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DATA INTERPRETATION AND COMMUNICATION OF RESULTS ON CONTAMINANT TRENDS IN ARCTIC FISH AND MARINE MAMMALS

Project Leader: D.C.G. Muir (Environment Canada, NWRI, Burlington ON)

Project Team: X. Wang (NWRI), M. Weis (U of Windsor); C. Macdonald (Northern Environmental Consulting & Analysis, Pinawa MB); S. Innes, R. Stewart, K. Kidd, K. Koczanski, M. Loewen, G. Stern and L. Lockhart (DFO Winnipeg).

OBJECTIVES

1. to interpret data, prepare papers and communicate results on organochlorine (OC) contaminants in Arctic Fish and Marine Mammals. Specifically: To complete the interpretation and publication of results on persistent organochlorine contaminants that were measured by two projects funded during 1991–1997 under DIAND's NCP Phase I.

DESCRIPTION

Under DIAND's NCP Phase I two projects "Spatial and Temporal Trends of Organochlorines in Arctic Marine Mammals" and "Contaminant Trends in Freshwater and Marine Fish" lead by Muir and Muir and Lockhart, respectively, generated substantial data which was used in the Canadian and AMAP assessments of Arctic pollution (Jensen *et al.* 1997, AMAP 1998).

1. *Contaminants in fish:* This project determined geographic trends of OC and metal contaminants in lake (and broad) whitefish, lake trout, arctic char, inconnu, pike, and burbot from about 40 lake and river locations in NWT and a limited number in northern Québec. This included ~ 400 individual samples of fish analysed for 130 OC components (about 90 routinely detected) and ~ 500 samples analysed for mercury (about 300 for other metals).

2. *Organochlorines in marine mammals:* This project determined spatial trends in PCBs and other organochlorines in important marine mammal species including ringed seals, walrus, beluga and narwhal. It provided data on contaminant levels in marine mammal tissues to NWT Health and Health Canada as part of surveys of dietary contamination. Over the period 1991 to 1997 approximately 500 marine mammal samples were analysed, mainly blubber and muktuk. The majority of samples were from beluga and ringed seals. Additional work was carried out in companion projects on co-planar PCBs (1994–96) and on toxaphene (1994–95). Some results were published (e.g., Muir *et al.* 1995) but much more data is available now that the data sets for OCs in beluga and ringed seal are complete.

ACTIVITIES IN 1997/98

Statistical analyses were carried out on lake trout and on ringed seal and beluga data sets. Three scientific manuscripts were prepared for future publication and two papers were published or in press. Results were presented at the NCP Results workshop (Calgary, Jan. 1998) and at workshops in Yellowknife, Kuujjuaq and Iqaluit during 1997.

RESULTS

Organochlorines in fishes

Statistical analysis was carried out on the lake trout data to examine effects of lipid, age/weight and location on OC levels. Principal components analysis was also used to examine geographical trends. No clear conclusions were reached. There were few significant differences between locations except that lake trout from Kusawa Lake had higher PCBs and toxaphene than those in any other lake (see Figure 1). Leaving aside Kusawa, lipid and weight adjusted results showed a weak trend to higher ΣHCH and ΣPCB in eastern NWT/Northern Québec sampling sites. Effects of lake size and watershed area and slope are currently being examined. In most cases this data was not available and has had to be generated from topographical maps hence the work is still in progress. The intention is to publish the results as a descriptive scientific paper depending upon the conclusions of the attempt to link the results to lake size/watershed area characteristics. The paper is currently in preparation: Muir, D., X. Wang, K. Kidd, K. Koczanski, C. Ford, B. Rosenberg, L. Lockhart, J. Reist. 1998. Influence of lipid and weight on levels and patterns of persistent organochlorines in lake trout from the Canadian Arctic.

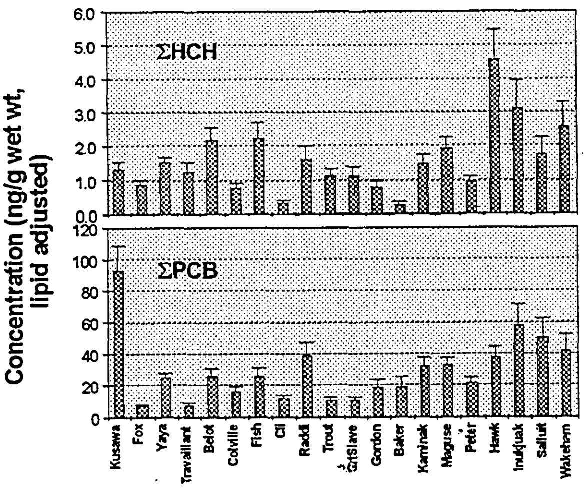

Figure 1. ΣHCH and ΣPCB concentrations in lake trout muscle (lipid adjusted) arranged by longitude – west to east (Muir *et al.*, in prep).

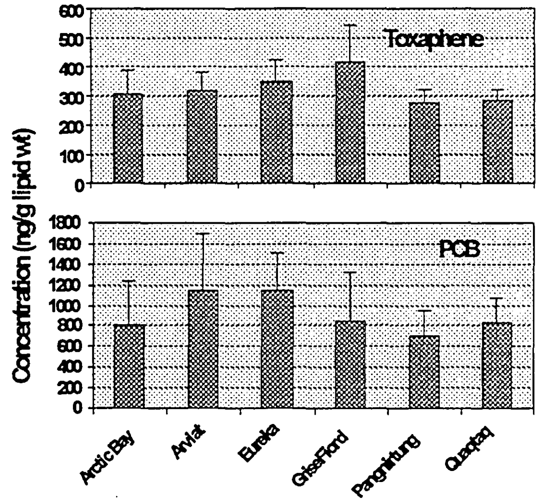

Figure 2. ΣPCB and toxaphene concentrations (geometric means ± SD) in ringed seal blubber adjusted for age, blubber thickness and sex (Weis *et al.*, in prep).

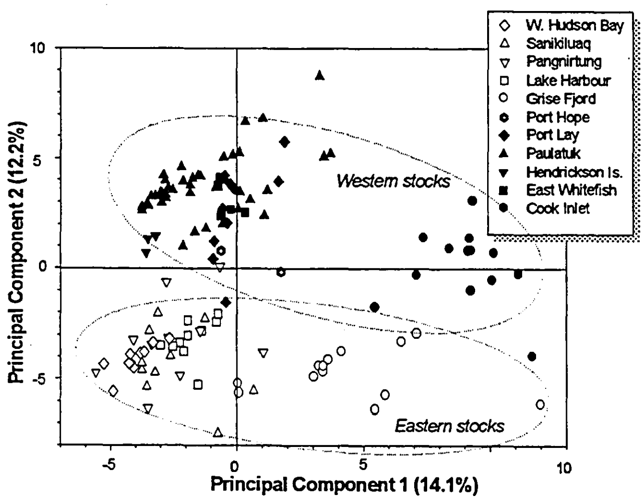

Figure 3. Principal components plot based on 120 organochlorines (autoscaled and normalized data) a shows that western and eastern North American stocks can be differentiated. Higher proportions of toxaphene, DDE and chlordane compounds are found in eastern Arctic beluga (Muir *et al.*, in prep).

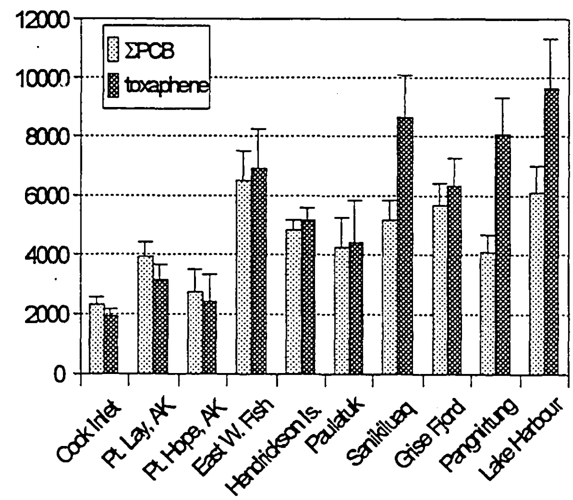

Figure 4. Geometric mean (±SE) concentrations (ng/g, adjusted for length) of ΣPCB and toxaphene in beluga from Alaska and Canada, arranged from west to east (Muir *et al.* in prep.)

Organochlorine results for lake trout and arctic char from Peter Lake were combined with other data for food web organisms and water in a paper written by Karen Kidd which examined the food web transfer of selected organochlorines. The results of the food web study illustrated that large, old lake trout in Peter Lake could achieve high concentrations of persistent organic pollutants such as PCBs and toxaphene because of their position in the food web. This paper is currently in press: Kidd, K. A., R. H. Hesslein, K. Koczanski, G.R. Stephens, and D.C.G. Muir. 1998. Bioaccumulation of Organochlorines through a Remote Freshwater Food Web in the Canadian Arctic. *Environ. Pollut.* In press. Accepted Feb. 1998.

Organochlorines in marine mammals

Statistical analysis was carried out on a large set of data for organochlorines in ringed seal blubber (7 locations in the eastern and central Canadian Arctic). This analysis, carried out by M. Weis, examined differences in concentrations of major OCs after adjustment for the effects of age, sex and blubber thickness (6 locations). The influence of blubber thickness on OC levels was previously demonstrated by Cameron *et al.*(1996) using ringed seals from Sankiluaq. With our much larger data set we were able to show that blubber thickness was a key parameter for examining geographical differences, especially for PCBs. After age/sex and blubber thickness adjustment, PCBs were significantly higher at Eureka and Arviat than at Pangnirtung, Quaqtaq and Arctic Bay (Figure 2). The reasons for this difference are not clear. A paper examining these geographical trends along with more detailed study of effects of age and sampling season on levels of OCs in seals is in preparation: Weis, M., D. Muir, K. Koczanski, B. Grift, D. Tretiak, C. Ford, R. Stewart and S. Innes. 1998. Spatial and temporal trends and effects of age on organochlorine contaminants in ringed seal from the Canadian Arctic. In prep.

Principal components analysis has been used successfully to compare patterns of OCs in eastern and western North American Arctic beluga stocks (Figure 3). The work was carried out by C. Macdonald. Analysis of covariance was also used to examine effects of age/size and sex on levels of major OCs in the same stocks. After adjustment for length, mean concentrations of major OCs were clearly higher in eastern Arctic beluga than in the western animals especially in the case of Cook Inlet animals which had the lowest levels of PCBs and toxaphene of any beluga stock analysed to date (Figure 4). A paper describing these analyses is currently in preparation: Muir, D., C. Macdonald, K. Koczanski, B. Grift, D. Tretiak, P. Becker, M. Schantz, R. Stewart. 1998. Spatial and temporal trends of organochlorine contaminants in beluga from the Canadian Arctic and Alaska. In prep.

The eastern Canadian data set of OCs in beluga has been combined with the older Greenland data and subjected to canonical discriminate analysis by S. Innes (DFO Winnipeg) with the objective of using the results for stock assessment of beluga in the eastern Canadian Arctic and Greenland. The results look very promising and are presented in a manuscript which is close to completion: Innes, S., D. C. G. Muir, R.E.A. Stewart, and M. P. Heide-Jørgensen. 1998. Stock identity of beluga *(Delphinapterus leucas)* based on multivariate analysis of the concentrations of organochlorine contaminants. To be submitted to *Can J. Fish Aquat. Sci.*

A paper on the identification of toxaphene components in ringed seal blubber, resulting from the work of MSc student M. Loewen (who received partial support from NCP) was completed with the help of Gary Stern: Loewen, M.D., G.A. Stern, J.B. Westmore, D.C.G. Muir, and H. Parlar. 1998. Characterization of three major toxaphene congeners in Arctic ringed seal by electron ionization and electron capture negative ion mass spectrometry. *Chemosphere* 36: 3119-3135.

CONCLUSIONS

This project has conducted a much more detailed analysis of the organochlorine data for lake trout and for ringed seals and beluga than was possible for the CACAR or AMAP assessments. The results so far show that it is important to have as much ancillary data as possible to be able to interpret the data.

In the case of lake trout for example, there was little information on the characteristics of each lake, e.g., food webs, size, watershed area. The exceptions were Peter, Fox and Kusawa Lakes where food web samples were obtained by Karen Kidd as part of her PhD and postdoctoral research. With the food web information, including ^{15}N results, it was possible to interpret the variation of organochlorine concentrations in fishes from Peter Lake.

For seals, blubber thickness was available for seals from 6 of 7 locations enabling the adjustment of results to take into account varying blubber mass of the animals. Blubber thickness had not been available previously for a large number of seals sampled in the late 1980s and reported on recently (Weis and Muir 1997). For beluga, age, sex and size influence levels of organochlorines. A problem in interpreting the data has been the lack of ages for some animals. Skin biopsy samples from western Hudson Bay beluga were included in the principal components analysis but could not be used in other univariate analyses to compare mean concentrations between stocks because of lack of data on the length and ages of the animals.

Project completion date: March 31, 1998.

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NEW PERSISTENT AND BIOACCUMULATIVE CHEMICALS IN ARCTIC AIR, WATER/SNOW, AND BIOTA

Project Leaders: D.C.G. Muir (NWRI); T.F. Bidleman (AES); G.A. Stern (FWI)

Project Team: B. Strachan; M. Alaee (NWRI); T. Harner; L. Barrie; K. Brice (AES); G. Tomy (FWI); P. Fellin (Conor-Pacific)

OBJECTIVES

1. To determine the extent of contamination of Arctic air, water, snow and biota with persistent and bioaccumulative contaminants not currently monitored by NCP but of potential concern based on known persistence and toxicology.

DESCRIPTION

Among the many findings of the Canadian Arctic Contaminants Assessment (Jensen *et al.* 1997) and the AMAP assessment of persistent organic pollutants (POPs) was the evidence that a wide range of currently used agricultural pesticides, flame retardants and other industrial organic chemical byproducts may be present in arctic abiotic and biotic environments (Barrie *et al.* 1997, DeMarch *et al.* 1998). Barrie *et al.* (1997) noted that the degradation rates of these chemicals, many of which are regarded as relatively non-persistent in temperate environments, may be much longer in the Arctic, especially in sea water. In reviewing data on contaminants in arctic food webs, Muir *et al.* (1997) found that information was limited or non-existent on levels of chlorinated paraffins, polychlorinated naphthalenes (PCNs), as well as on chlorinated and brominated diphenyl ethers (BDPEs). These contaminants have been detected in biota in Svalbard and in Northern Sweden (Jansson *et al.* 1993, Sellström *et al.* 1993).

From a national and international regulatory perspective the presence of other contaminants, not currently included in the list of 16 POPs, in the Arctic is of interest because of the implication that these compounds are sufficiently persistent in the atmosphere and sea water to be transported long distances from sources. If present in top predators in arctic food webs there is the added threat that the compounds are bioaccumulative and are present in human food. Both the Canadian Toxic Substances Management Program and the United Nations Economic Commission for Europe (UN ECE) protocol on POPs include the presence of chemicals in remote environments as evidence of persistence.

ACTIVITIES IN 1997/98

The project was approved for funding by NCP in mid-October 1997.

Air

Two sets of air samples were used. Bulk air samples (prepared by P. Fellin of Conor-Pacific) representing spring, summer and winter months (by combining equal portions of archived weekly samples extracts from 1994) were analysed for BDPEs. The samples consisted of six polyurethane foam (PUF) extracts and three filter (glass fiber) extracts plus a blank filter and a blank PUF. Samples for SCCP analysis were obtained from PUF and filter extracts collected in fall 1992 (weeks 37-52) at Alert that had been previously analysed and stored by DFO Winnipeg.

Marine mammal extracts

Six pooled beluga and ringed seal blubber (3 females/3 males for each species) from DFO Winnipeg were circulated among participating labs.

Seawater

Three large volume seawater sample (100 L) from the Canadian archipelago, collected by B. Strachan (NWRI Burlington) during the Sept. 1997 JOIS cruise were extracted with the intent of analysing them for a range of compounds. Samples have not yet been split among the three labs for analysis.

Samples were analysed for short chain chlorinated paraffins (SCCPs) by high resolution electron capture negative ion mass spectrometry (GC-ECNIMS) by Gary Stern and Gregg Tomy (DFO Winnipeg) using the method of Tomy *et al.* 1997. This method is highly specific for the chlorinated decane to -tridecane components of SCCP products. SCCPs are quantified using either 60% C_{10}-C_{13} or 70%C_{10}-C_{13} chloroalkane commercial products because no synthetic standards exist. ^{13}C-mirex was added as an internal standard. Prior to GC-MS analysis, the SCCPs in sample extracts were separated from PCBs by chromatography on a Florisil column.

Brominated diphenyl ethers (BDPEs) were determined in air and marine mammal samples by high resolution electron ionization mass spectrometry using the method described by Sergeant *et al.* (1998). Prior to GC-MS analysis the BDPEs were isolated by elution from 3% deactivated silica gel column with dichloromethane. BDPEs were quantified using a suite of 24 authentic standards purchased from Cambridge Isotopes. ^{13}C-chlorinated diphenyl ethers were used as internal standards to monitor extraction efficiency, instrument performance and sample volume.

RESULTS

Air

Penta- and hexabromodiphenyl ethers were detected in PUF and filter extracts at low pg/m^3 levels. BDPEs were nondetect in the filter blank and present only at very low levels in PUF blanks. The BDPE congeners detected include 2,2',4,4',5 - penta , 2,3',4,4',6 penta, 2,2',3,4,4' penta , and 2,2',4,4',5,5' hexabromo-congeners (Figure 1). No concentrations are reported because the method of quantitation is still in the development phase. Nevertheless the results provide clear evidence for the presence of BDPEs in arctic air from Alert NWT.

Short-chain chlorinated paraffins were also detected in four individual samples of arctic air analysed by DFO Winnipeg (Table 1). Concentrations ranged from <1 to

Table 1. Short chain chlorinated paraffins and PCBs in Arctic air[1].

Sample	Date	SCCPs, pg/m^3	PCBs pg/m^3
AA-92-37	Sept 14	5.7	9.0
AA-92-38	Sept 21	<1	27
AA-92-39	Sept 28	2.1	21
AA-92-52	Dec 28	8.5	20

[1] PCB results from Stern *et al.* 1997.

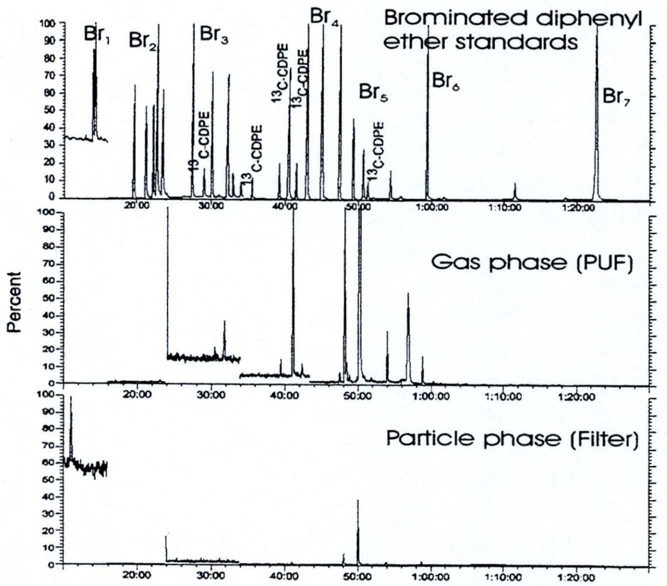

Figure 1. Brominated diphenyl ethers in air samples (gas phase and particles) from Alert NWT (1992). The major peak in the gas phase chromatogram is 2,2',4,4',5-BDPE.

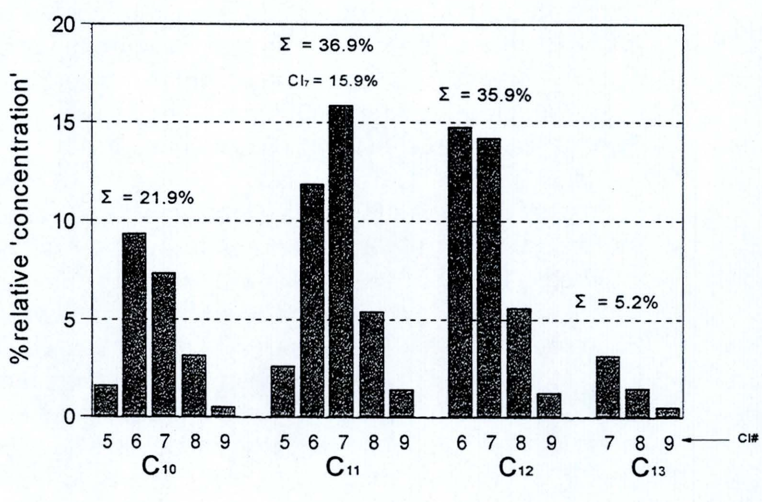

Figure 2. Profile of short chain chlorinated paraffins in air (gas phase) from Alert NWT (collected 1992). The major component (15.9%) is a heptabhloroundecane. Numbers (%) above each cluster of bars refer to the % of each group in the total C10-C13 chloroalkanes.

8.5 pg/m^3 in gas phase samples. Blank samples from the air sampling program at Alert also contained low levels of SCCPs but at concentrations lower than air samples. SCCPs were present at about 10 to 50% of PCB levels in the same samples. The profile of chlorinated alkanes in one Arctic air sample (AA-92-37) is shown in Figure 2. Heptachloroundecane was the major component of the SCCPs and undecanes were the predominant alkane group. Tomy (1997) previously analysed air samples, collected at Egbert ON in 1990, for SCCPs and found similar profiles with chlorodecanes and chloroundecanes predominating.

Marine mammals

Brominated diphenyl ethers were detected in ringed seal and beluga blubber samples at low ng/g concentrations (Table 2). Tetra-bromo DPEs were by far the major homolog group detected in both species. Tri and pentabromo compounds were present at about 1/10 of the concentrations of the tetrabromo group. Higher concentrations were found in males than in females consistent with other organochlorines. This difference can be attributed to excretion of these lipophilic compounds via lactation. Concentrations of ΣDBPE were relatively low compared with PCBs (Table 2). Levels in seals and beluga differed only by a factor of 2 to 3 compared with a factor of about 10 for PCBs. The low levels and similar concentrations in both species may indicate a capability to degrade BDPEs. Jansson *et al.* (1993) found that DBPEs did not biomagnify to the same extent as PCB 153, a very biologically stable congener. Jansson *et al.* (1993) found about 40x higher levels of tetrabromoDPEs in ringed seal from Svalbard compared with the results for ringed seal from the Canadian Arctic.

SCCPs were detected in ringed seal and beluga blubber samples at ng/g levels (Table 2). Concentrations were similar in both species with slightly higher mean levels in males than females. Total SCCPs concentrations were 6 to 10 times lower than SPCB in seals and 30-40 times lower in beluga blubber. The SCCPs profile consisted of similar proportions of chlorodecanes-, undecanes and dodecanes with very low or negligible amounts of tridecanes. There are few other published data on SCCPs in marine mammals for comparison and differences in analytical methodology make comparisons problematic. Jansson *et al.* (1993) reported 130 ng/g SCCPs in ringed seal blubber from Svalbard which is quite similar to levels found in this study. However their analytical procedure involved detection of chlorine ions (Cl_2 or m/z 70) by GC-ECNIMS at low resolution which was less specific than the high resolution technique employed for this study.

CONCLUSIONS

This study has identified brominated diphenyl ethers and chlorinated paraffins for the first time in samples of air and marine marine mammals from the Canadian Arctic. The BDPEs were present at very low levels in marine mammals compared to reports for seals in Svalbard and the Baltic Sea, however, SCCPs were present at levels similar to the one other published report on levels in marine biota. Sample sizes used here were small. Further study is required to confirm the relative amounts of SCCPs and BDPEs compared with known POPs, to examine temporal trends in air, and to investigate the extent of food chain transfer. The study has yet to examine a range of other compounds such as organophosphate pesticides in air and seawater and chlorinated naphthalenes in biota. Further work is planned in 1998 to address these gaps.

Table 2. Brominated diphenyl ethers (BDPEs), chlorinated paraffins (SCCPs) and other OCs in marine mammal blubber

Species/Location	Sex	N		Concentrations (ng/g) in blubber							
Brominated diphenyl ethers				Br_1DPE	Br_2-DPE	Br_3-DPE	Br_4-DPE	Br_5-DPE	Br_6-DPE	Br_7-DPE	ΣBDPE
Ringed seal	F	3	Mean	<0.001	0.001	0.053	0.33	0.112	0.004	<0.001	0.50
Pangnirtung			SD	–	0.001	0.019	0.15	0.011	0.002	–	0.18
	M	2	Mean	<0.001	0.001	0.126	0.76	0.090	0.003	<0.001	0.97
Beluga	F	3	Mean	<0.001	0.005	0.144	1.09	0.186	0.012	<0.001	1.44
Kimmirut			SD	–	0.005	0.113	0.82	0.060	0.012	–	1.01
	M	3	Mean	<0.001	0.012	0.347	2.14	0.319	0.021	<0.001	2.84
			SD	–	0.007	0.190	0.66	0.071	0.006	–	0.90
C_{10}-C_{13} SCCPs & other OCs*				C_{10}	C_{11}	C_{12}	C_{13}	ΣSCCPs	ΣDDT	ΣPCB	Toxaphene
Ringed seal	F	3	Mean	23.0	31.0	35.0	<1	89.0	510	585	207
Pangnirtung			SD	11.4	15.4	17.4	–	44.1	190	180	33
	M	3	Mean	18.0	57.2	42.8	<1	100	1200	976	185
			SD	4.8	15.4	11.5	–	26.8	1660	1090	121
Beluga	F	3	Mean	39.3	34.9	37.4	4.0	116	3540	4390	7350
Kimmirut			SD	17.9	15.8	17.0	1.8	52.4	2620	3120	4460
	M	3	Mean	46.9	56.3	57.7	6.5	168	7110	7650	16290
			SD	9.6	11.7	11.9	1.3	34.5	3360	2870	8890

* Concentrations of ΣDDT, ΣPCB and toxaphene determined by GC-ECD and previously reported for a larger dataset from each location by Muir (1998).

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SPATIAL TRENDS AND PATHWAYS OF POPS AND METALS IN FISH, SHELLFISH AND MARINE MAMMALS OF NORTHERN LABRADOR, NUNAVIK AND NUNAVUT

Project Leaders: D.C.G. Muir, National Water Research Institute, Burlington ON; J. Banoub, Fisheries and Oceans, St. John's, NF; M. Kwan, Kuujjuaq Research Centre, Kuujjuaq, QC

Project Team: J. Lampe, K. Harris and F. Andersen (Labrador Inuit Assoc.); B. Sjare and B. Dempson (DFO, St. John's, Nfld); M. Comba and S. Backus (NWRI, Burlington).

OBJECTIVES

General

1. to determine spatial and temporal trends of persistent organic pollutants (POPs) and metals, in freshwater and anadromous fish, shellfish, and marine mammals, important to Inuit communities of Northern Labrador, Nunavik and Nunavut - for use in human health risk assessment and to contribute to discussion of the effectiveness of international actions to control POPs.

Specific for 1997/98

2. to conduct the first measurements of POPs and metals in tissues of important species from Northern Labrador

DESCRIPTION

The Nunavik/Labrador action Plan meeting (May 1997) recommended that a comprehensive contaminants monitoring program should be developed in Nunavik and Labrador – with a special emphasis on studies in Labrador. This meeting was attended by community representatives from Labrador and Nunavik as well as by representatives of various agencies dealing with contaminant and human health issues in the north. The proceedings of the workshop were circulated to attendees in the fall of 1997 (Muir 1997).

The assessment of spatial and temporal trends of contaminants conducted by the NCP (Jensen *et al.* 1997, Muir *et al.* 1997) found that, with the exception of waterfowl and game birds, there was no information on contaminants in biota important to the communities of Northern Labrador. There were information gaps in contaminants in Nunavik and Nunavut especially for anadromous and freshwater fishes and for mussels—all identified as very important to the communities at the Nunavik/Labrador action Plan meeting.

ACTIVITIES IN 1997/98

The project was approved for funding by NCP in mid-October 1997. This left things late in the season for sample collection. Blue mussels (*Mytilus edulis*) were successfully collected by LIA at two locations in Labrador (Nain and Makkovik). KRC was unable to obtain mussels in Ungava Bay but used samples previously obtained from Deception Bay (east of Salluit PQ). Ringed seal (*Phoca hispida*) and Arctic char (*Salvelinus alpinus*) samples could not be obtained by local hunters in late fall so samples previously collected by DFO Nfld. during 1997 were provided by B. Sjare and B. Dempson. Biological data on the seals (e.g., age, size, sex, blubber thickness) was provided by B. Sjare.

Samples were analysed for heavy metals (cadmium, mercury, lead, selenium and arsenic) at KRC (Kuujjuaq) in M. Kwan's lab using atomic absorption spectrometry. Analysis for butyl tins was conducted by electrospray ionization tandem mass spectrometry or MS/MS in J. Banoub's lab. POPs (e.g., PCBs, DDT, etc.) were determined in seal, char and mussels at NWRI by the National Laboratory for Environmental Testing (M. Comba and S. Backus).

TBT, dibutyl (DBT) and monobutyltin (MBT) were extracted from fish and mussel tissues with n-butanol. The butanol extract was centrifuged and washed with hexane to remove part of the fats. The extract was then evaporated under reduced pressure, diluted with methanol containing 1mM ammonium acetate and introduced in the mass spectrometer ion source. Butyl tins were analysed with a "Quattro" MS/MS instrument equipped with an electro-spray ionization source. Samples were introduced using a continuous flow of acetonitrile-water (70:30) and quantification of TBT, DBT and MBT was done using MS/MS (multiple reaction monitoring with five different channels method using electrospray ionization).

PCBs and other organochlorines were analysed by gas chromatography with electron-capture detection (GC-ECD). In brief: fish and mussel samples were homogenized and Soxhlet extracted with dichloromethane:hexane (1:1). Organochlorines were isolated by gel permeation chromatography followed by silica gel cleanup then analysed by GC-ECD. ΣPCBs represented the sum of 120 congeners. Toxaphene was analysed by low resolution GC-negative ion MS using a HP 5973 MSD in negative ion mode.

RESULTS

Heavy metals

Low concentrations of most heavy metals were found in char and mussel samples from Labrador and Nunavik (Table 1). Cadmium and lead were undetectable (<0.001-<0.006 μg/g wet wt) in char muscle and levels of mercury, selenium and arsenic were very low. Arsenic was the most prominent of the five metals determined in mussels. Concentrations ranged from 1.5 μg/g ww in samples from Makkovik to 2.2 μg/g ww in samples from three locations in Deception Bay in Nunavik. Doidge *et al.* (1993) found similar, low, μg/g (ww) levels of cadmium (0.5 μg/g ww) and mercury (0.03 μg/g ww) in blue mussels from six communities in the Hudson Bay, Hudson Strait and Ungava Bay area. Arsenic has been previously found to be present at μg/g levels in mussels from Nunavik (Doidge *et al.* 1993) but has not been routinely determined in marine or anadromous fishes from other areas of the Canadian Arctic.

Muscle samples from ringed seals in the Nain area contained low μg/g concentrations of the five metals (Table 1). Mercury levels in muscle averaged 0.12 μg/g in females and 0.16 μg/g in males. Ringed seal liver contained relatively high concentrations of cadmium, mercury and selenium as has been observed in previous studies of Arctic seals (Muir *et al.* 1997, Wagemann 1995). For example, mercury in ringed seal liver from the eastern Arctic (including N. Quebec, Resolute, Arctic Bay) averaged 8.3±7.0 μg/g ww while cadmium concentrations averaged 11.9±9.0 μg/g ww. The mercury and cadmium results for ringed seals from Nain, although lower than average, would probably not differ statistically from the larger group of animals from the eastern Arctic analysed by Wagemann (1995).

Organochlorines

Low (ng/g wet wt) levels of organochlorines were detected in arctic char muscle (+ skin) from the Nain area. PCBs were the most prominent contaminants averaging 20 ng/g ww. DDT group (sum of *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT and *o,p'*-DDT) were present at much lower levels (3.4 ng/g ww). In general these levels are similar or lower than reported in char muscle from Ungava Bay and Hudson Strait communities (Muir *et al.* 1997).

PCBs and other organochlorines were also present at very low levels in mussels from Nain and Makkovik in Labrador and Deception Bay in Nunavik (Table 2). PCBs were the most prominent contaminants (means of 3.7–7.0 ng/g ww) in mussel tissues followed by chlordane and HCH isomers. PCBs consisted primarily of lower chlorinated congeners which, like the HCH isomers, are primarily in the dissolved phase in sea water. Doidge *et al.* (1993) found low ng/g (ww) levels of PCBs and OC pesticides in blue mussels from six communities in Nunavik.

PCBs were the major contaminants in seal blubber, averaging 750 ng/g in females and 710 ng/g in males. Similar concentrations of PCBs have been found in ringed seal blubber at other eastern Arctic locations (Muir 1998, Weis and Muir 1997). ΣDDT and chlordane (ΣCHL) concentrations were much lower than reported recently for several Canadian Arctic locations such as Quaqtaq and Grise Fiord (Muir 1998). Much lower concentrations of PCBs were found in seal liver than in blubber (Table 2).

Butyl tins

TBT was been included in this study (for the first time in NCP studies), because it has been identified as an important contaminant in seals in the North Pacific and Bering Seas (Iwata *et al.* 1994) and because of its known toxicity to vertebrates and invertebrates (endocrine dysfunction/imposex). Once released to water TBT is degraded to dibutyl- (DBT) and monobutyltin (MBT). Sediments are potentially an important reservoir for butyl tins because they are highly particle reactive.

TBT was detected at low ng/g ww concentrations in all samples. In mussels from Labrador, TBT concentrations ranged from 5.2 to 38 ng/g ww (Table 3). TBT, DBT and MBT concentrations averaged 10, 4.9 and 4.3 ng/g ww, respectively, in samples from Deception Bay near Salluit. These concentrations are at the low end of the range found in *Mytilus edulis* in the US east coast (TBT = 10-1200 ng/g ww; Uhler *et al.* 1993).

Butyl tins were also detected in ringed seal blubber and arctic char muscle. In seals, DBT was the most prominent butyl tin, possibly reflecting metabolism of TBT. Similar ratios of TBT to DBT and MBT have been found in grey seal livers (Law *et al.* 1998) and sea lions (Kim *et al.* 1996). This is the first report, as far as we are aware, of butyl tins in Arctic ringed seals. Concentrations

Table 1. Heavy metals in seals, mussels and Arctic char samples from Labrador (µg/g wet wt), 1997.

Species	Location/sex	Sex	Tissue	N	Cd	Hg	Pb	Se	As
Ringed seal	Nain	F	muscle	5	0.03 ± 0.02	0.12 ± 0.07	0.5 ± 1.04	0.50 ± 0.16	0.10 ± 0.02
	Nain	M	muscle	5	0.01 ± 0.01	0.16 ± 0.19	<0.01 –	0.37 ± 0.08	0.10 ± 0.03
Ringed seal	Nain	F	liver	5	3.74 ± 4.22	3.57 ± 4.51	0.02 ± 0.01	3.3 ± 2.4	0.25 ± 0.07
	Nain	M	liver	5	1.44 ± 0.41	3.92 ± 7.61	0.01 ± 0.00	2.9 ± 3.3	0.19 ± 0.03
Blue mussels*	Makkovik, Big Island	–	tissue	1	0.27 –	0.02 –	0.10 –	0.60	1.54 –
	Makkovik, Ranger Bight	–	tissue	1	0.29 –	0.02 –	0.22 –	0.52	1.80 –
	Makkovik, Grassy Point –	tissue	1	0.33 –	0.01 –	0.10 –	0.49	1.79 –	
	Nain, Ten mile Bay	–	tissue	1	0.40 –	0.02 –	0.12 –	0.72	2.07 –
	Nain, Metres Harbour	–	tissue	1	0.33 –	0.01 –	0.06 –	0.58	2.00 –
	Deception Bay, Que.	–	tissue	3	0.39 ± 0.02	0.01 ± 0.001	0.28 ± 0.20	0.69 ± 0.09	2.21 ± 0.39
Arctic char	Nain	–	muscle	6	<0.001 –	0.03 ± 0.01	<0.006 –	0.25 ± 0.05	0.19 ± 0.05

*Mussel samples represent a subsample from 1 pool (1 kg) per site.

Table 2. Concentrations (ng/g wet wt.) of major organochlorines in tissues of ringed seal, Arctic char and Blue mussels from Labrador and Northern Quebec, 1997.

Species	Location	Sex	Tissue	N	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB
Ringed seal	Nain	F	Blubber	5	32 ± 2.3	226 ± 88	81 ± 40	390 ± 160	752 ± 268
	Nain	M		5	37 ± 15	186 ± 72	96 ± 54	199 ± 104	712 ± 307
	Nain	F	Liver	5	0.96 ± 0.24	2.4 ± 0.61	3.7 ± 0.72	1.1 ± 1.3	133 ± 21
	Nain	M		5	1.2 ± 0.61	2.3 ± 0.67	2.7 ± 0.65	1.8 ± 3.3	109 ± 38
Arctic char	Nain	–	muscle	6	2.2 ± 0.81	4.6 ± 2.8	2.0 ± 0.60	3.4 ± 1.3	20 ± 7.4
Blue mussels	Nain	–		2	0.31	3.5	5.6	1.2	7.0
	Makkovik	–		3	0.15 ± 0.04	4.3 ± 3.0	6.5 ± 6.6	1.9 ± 0.74	5.8 ± 2.4
	Deception Bay	–		3	0.15 ± 0.05	1.7 ± 0.40	1.9 ± 1.2	0.68 ± 0.40	3.7 ± 1.2

Table 3. Concentrations of butyl tins (ng/g ww) in samples from Northern Labrador and Nunavik

Species	Location	Tissue	N	TBT	DBT	MBT
Ringed seal	Nain, female	Blubber	1	2.9 –	20.1 –	4.6 –
Ringed seal	Nain, male	Blubber	1	5.1 –	22.0 –	5.9 –
Blue Mussel	Deception Bay	tissue	3	10.4 ± 4.1	47.8 ± 10.4	<1 –
Blue Mussel	Nain, Metres Harbour	tissue	1	4.6 –	23.3 –	<1 –
Blue Mussel	Nain, Ten Mile Bay	tissue	1	37.8 –	8.4 –	<1 –
Blue Mussel	Makkovik, Big Island	tissue	1	13.0 –	18.6 –	<1 –
Blue Mussel	Makkovik,Grassy Point	tissue	1	10.2 –	34.3 –	<1 –
Blue Mussel	Makkovik, Ranger Bight	tissue	1	5.2 –	20.1 –	<1 –
Arctic char	Nain	muscle	6	8.8 ± 2.7	4.9 ± 1.8	4.3 ± 3.3

of total butyl tins in ringed seal blubber were at the low end of the range reported for sea lion livers from the coast of Japan (18-460 ng/g ww; Kim *et al.* 1996).

CONCLUSIONS

This report provides some of the first data on heavy metal, organochlorine and butyl tin contaminants from Nain and other coastal areas in Labrador. Levels of heavy metals in seal tissues, char muscle and mussels were found to be similar to those in Nunavik and other eastern Arctic locations. Levels of PCBs and organochlorine pesticides in char and seal tissues were similar or lower than concentrations found in the same species sampled in Ungava, Hudson Strait and eastern Hudson Bay. Butyl tin levels found in seal blubber were relatively low compared to reports of these compounds in seal livers in the UK and Japan. Ringed seal livers have yet to be analysed for butyl tins. In cetaceans, higher butyl tin levels have been found in liver than in blubber so the seal livers should be examined in future work. Overall, a relatively small number of samples were analysed in this preliminary study of contaminants in Labrador and Nunavik. Further work is planned for 1998 to develop a more complete data set and to communicate this information to communities in the region.

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TRENDS AND EFFECTS OF CONTAMINANTS IN POLAR BEARS

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OBJECTIVES

1. complete analysis of circumpolar data set to determine regional patterns of bioaccumulation, and how this is influenced by sex and season.

2. complete analysis of data for the study on kinetics of organochlorine dynamics in individual bears, and rates of transfer to cubs via milk.

3. determine the immunotoxic effects of PCBs and other organochlorines in polar bears throughout a gradient of exposure (Alaska, low; Hudson Bay, intermediate; Svalbard, high).

4. study the sensitivity of the polar bear to adrenocorticolytic agents such as methylsulfone DDE, which we know is formed in the polar bear.

5. Determine the significance of hydroxy-PCBs in PCB toxicology by: identifying structures of hydroxy-PCBs accumulating in plasma, relating these to exposure and metabolic capability of the species, developing a method for quantitative determination, and studying the effects of this class of compounds, especially on circulating thyroid hormone and vitamin A concentrations.

DESCRIPTION

It has now been well documented that the polar bear is among the most highly organochlorine-contaminated of arctic mammals, due to its almost exclusive diet of ringed seal. Monitoring of polar bear tissues for both organochlorines and heavy metals has been an important part of the Northern Contaminants Program (NCP) of the Arctic Environmental Strategy, and the international Arctic Monitoring and Assessment Program (AMAP). Results to date have been included in the major reports to be published in 1997 by DIAND on the five-year NCP (Canadian Arctic Contaminants Assessment Report) and AMAP on Arctic contaminants in general.

Far less is known about the potential effects of organochlorines on polar bears than is known about levels and trends. Levels of organochlorines have not changed very significantly since the beginning of accurate population assessments in the early 1970s, therefore it is impossible to say one way or the other whether there are subtle effects on polar bear reproduction. Decreases in the number of polar bear cubs per potentially reproducing female showed steady declines in Hudson Bay throughout the 1970s, but have recently stabilized. This is probably due to ecologically-based factors (density dependent effects, weather, etc.), however, the presence of persistent organochlorines may also be a contributing factor. A decrease in cub survival at Svalbard has been noted by Norwegian scientists, and it has been suggested that PCBs may be involved (Bernhoft *et al.* 1996). Utilization of fat reserves causes relocation of organochlorine compounds from adipose tissue to target organs. During times of nutritional stress (e.g., poor hunting due to unfavourable ice conditions most of the year), organochlorine toxicity might be much more expressed than under more favourable conditions. We have established that liver enzymes associated with exposure to dioxin-like compounds (CYP1A) are induced, and correlate with several PCB congeners in polar bears (Letcher *et al.* 1996). In the same study we established that the more general mixed-function oxidase system induced by a number of organochlorines (CYP2B) is also induced, and correlates with a combination of PCB and chlordane levels.

Immune effects are considered to be the most sensitive endpoint of PCB (and probably other organochlorine) exposure so far studied in wildlife. Polar bears in some areas have levels of PCBs well above those found to cause immune disfunction in seals (De Swart *et al.* 1994). High body burdens of DDTs, $MeSO_2$-DDEs and $MeSO_2$-PCBs has been postulated as one possible explanation for a disease syndrome observed in Baltic seals, characterized in part by adrenocortical hyperplasia (Olsson 1994). The DDT metabolites 4,4'-DDD, 2,4'-DDD, 4,4'-DDE and 3-methylsulfone-4,4'-DDE have been shown to be bioactivated to adrenocorticolytic metabolites that irreversibly bind to proteins in the adrenal cortex of birds and several mammalian species, including man (Brandt 1994). In some cases, steroid metabolism *in vitro* was affected, suggesting the reactive metabolites may disturb adrenal glucocorticoid production *in vivo*. Polar bears metabolize DDE at a rather high rate, and elevated levels of 3- methylsulfone-DDE are found in liver. These findings suggest that research on immunotoxic effects and adrenal function and morphology in polar bears is required. Preliminary results from Uppsala University with archived adrenal glands have shown some sensitivity of the polar bear to exposure to adrenocortolytic agents. Several polar bear blood samples have been taken from wild and zoo bears for immunotoxicological testing.

It has usually been assumed that parent halogenated compounds are the immediate cause of toxic effects, except in carcinogenesis, where alkylating metabolites, such as aromatic epoxides, are known to be involved. More recently it has become evident that a large spectrum of toxic consequences can arise from metabolites of halogenated aromatic compounds. In the case of PCBs and DDE, both major contaminants at high trophic levels globally, there are two classes of metabolites that need to be considered for a complete risk assessment due to PCB exposure: methylsulphone-PCBs (MSF-PCBs), hydroxy-PCBs (OH-PCBs).

Hydroxy-PCBs are an important class of metabolite that may be involved in expression of PCB toxicity. Some of these metabolites have been shown to interfere with vitamin A and thyroid hormone transport through binding with the plasma transthyretin (TTR) carrier protein (Brouwer and van den Berg 1986), as well as drastic reduction in plasma thyroxin levels in rats, mice and marmoset monkeys (Brouwer *et al.* 1990). The mode of action was through competitive inhibition of T_4 binding to TTR in plasma; 4-OH-TCB bound 4 times more strongly than T_4. T_4 and 4-OH-TCB have very similar structures on one ring, i.e., one para hydroxy and two meta halogens (I in the case of T_4 and Cl in the case of 4-OH-TCB). Because of the selective binding to TTR, 4-OH-TCB levels were elevated in plasma. Although other hydroxy metabolites of CB-77 are formed, they were not present in plasma, presumably because of poor binding to TTR. Being complexed to the protein presumably prevents hydroxy-PCBs from being conjugated and excreted. Hydroxy-PCBs do not accumulate in fat or liver because there is no specific binding protein.

Recently it has been discovered that structurally similar metabolites of major PCBs: CB-105, CB-118, CB-138, CB-128, CB-156 and CB-170 are also found in plasma of rats fed Aroclor 1254, and in Swedish grey seals and humans (Bergman *et al.* 1994). In most cases, the metabolites had the 4-hydroxy-3,5-dichloro substitution, indicating that they were probably bound to TTR in plasma. Concentrations of hydroxy-PCBs in human plasma were about 10% of the major PCB congener, CB-153.

When Aroclor 1254 was fed to rats, the main hydroxy-PCB present in plasma was a 4-hydroxy pentachlorobiphenyl, presumably a metabolite of CB-105 (D. Morse, Ph.D. thesis, U. of Wageningen 1995). Levels of this one compound in plasma were up to 10 times higher than that of CB-153, the major accumulating PCB congener in Aroclor 1254, because PCBs do not bind to TTR. This metabolite has a binding affinity to TTR which is 10 times higher than T_4. Recent evidence shows that there is no competitive binding of hydroxy-PCBs and T_4 to the main T_4 carrier protein in human plasma, which is a globulin, unlike rats, where TTR is dominant (M. Lans, Ph.D. thesis, U. of Wageningen 1995). However, TTR is still probably the main carrier protein for vitamin A. The importance of TTR in polar bears is not known and needs to be determined.

There is therefore reason to believe that exposure of an animal to PCBs in the diet can affect the plasma transport of T_4 and retinol (vitamin A) if these animals are capable of metabolizing PCBs to hydroxy metabolites. Skaare *et al.* (1994) found a negative correlation between total plasma PCB and retinol concentrations, suggesting interference of retinol transport. Most of the information to date is based on a relatively small number of mammalian species. The potential influence of hydroxy-PCBs in the homeostasis of thyroid hormone and vitamin A, and the interaction with related toxic effects (e.g., the effect of dioxin-like PCBs on hepatic vitamin A stores), is important in understanding PCB toxicity. PCBs are the class of organochlorines with the highest concentration in high trophic level species. A much better understanding of the importance of metabolites in PCB toxicity is required to unravel the multitude of toxic effects that PCBs can elicit.

Preliminary results have shown some of the same hydroxy PCBs in polar bear plasma as were found in humans (Sandau and Norstrom 1996). Satisfactory methods of methylation prior to determination have been developed. Considerable effort has been expended on developing a suitable extraction method for plasma. Several approaches have been tried, all of which have yielded unsatisfactory recoveries of some compounds, possibly due to protein binding. Intensive efforts have been made to develop a suitable Sep-Pak method, but this has not proven fruitful, and liquid/liquid extraction will be used instead.

The above initiatives are directly in line with the recommendations from the AMAP Assessment Report:

> *A research program directed at immunotoxicology and immunosuppression in the species identified as most at risk (peregrine falcon, white-tailed sea eagle, glaucous and herring gulls, alcids, kittiwake, otter, harbor porpoise, some walrus populations, polar bears and arctic fox) is a high priority given the fact that these species have the highest levels of PCBs and other OCs. Similarly, research on reproduction in key Arctic species should be done, particularly with reference to the possible sensitivity of species with delayed implantation [polar bears].*

> *More research into multiple stressors is required. In particular, the effects of starvation and other environmental stressors combined with mobilization of lipid associated OCs may be an important exposure pathway.*

ACTIVITIES IN 1997/98

Completion of Data Analysis and Publication

Multivariate analysis (PCA and SIMCA) of the polar bear geographical trend data was used to examine differences in bioaccumulation patterns among areas and possible differences in organochlorine loading on a longitudinal basis, as well as examine an area of abnormally high PCB contamination in the high Canadian arctic. A large sub-population of bears from Hudson's Bay was used to examine effects of age, sex and seasonal fasting on PCB and Chlordane percent composition. Results were presented at the SETAC'97 conference in San Francisco in November, 1997 and the manuscripts are currently being drafted.

Temporal Trends of OCs in Individual Bears and Kinetics of Transfer to Cubs Via Milk

More than 300 samples of plasma and adipose tissue biopsies of females, their cubs, and milk were analysed for PCBs and OCs in 1995–1997. The samples were collected in summer at the beginning of fasting and in fall after 3 to 4 months of fasting. All bears lost total body mass, lean body mass, and adipose tissue mass during fasting. The data were statistically analysed in 1997/98. Variation in tissue concentrations of chlorobenzenes (ClBzs), hexachlorocyclohexanes (HCHs), chlordanes, DDTs, and PCBs was assessed with respect to season and fasting status. Body composition and total body burdens of OCs were also determined before and after fasting for all bears. Considerable variation occurred among compounds and tissues. Bears that were handled sequentially provided the most useful information.

Adrenocorticolytic Toxicants in Polar Bear

An archived whole adrenal gland from each of 8 male polar bears from Barrow Strait, 1993, was sent to Uppsala University in Sweden to determine the mitochondrial, cytochrome P450-mediated bioactivation *in vitro* from exposure to ^{14}C-labelled 4,4'- DDT, 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, 3-$MeSO_2$-4,4'-DDE and several $MeSO_2$-PCBs. No results were reported from Prof. Brandt's laboratory.

Polar Bear Immunotoxicology

The lymphocyte proliferation assay was chosen to test immune function for its ease in execution considering the technical limitations of the field laboratory. Lymphocyte proliferation is an important component of the immune response. This assay detects the competence of lymphocytes to be activated and to proliferate. Assays were conducted using modifications of existing methods (DeGuise *et al.* 1996, Ahmed *et al.* 1994)

Peripheral blood was obtained from 88 polar bears in the vicinity of Resolute, NWT, Canada (74° 42'N, 94° 50'W) in the spring of 1997. Five PCBs tested *in vitro* on polar bear lymphocytes were PCBs 138, 153 and 180, which are highly abundant in polar bear tissues, and PCBs 156 and 157, chosen since they are of the principal PCBs contributing to total TEQs in polar bears (Muir *et al.* 1988, Letcher *et al.* 1996). PCB concentrations were determined in a number of plasma samples to see if there was any correlation between lymphocyte proliferation and PCB concentrations, as well as to range-find where the dose-response curve of the assay fitted with real environmental concentrations.

Hydroxy PCBs

Work towards an efficient extraction method for HO-PCBs from whole blood and plasma was undertaken. Recoveries of HO-PCBs were initially unacceptably low which was due to the choice and quantity of solid phase sorbents. A variety of sorbents and quantities of sorbents were tested, including – C_8, C_{18}, anion exchange, and two different polystyrene divinylbenzene sorbents – XAD2 and LMS. Very good recoveries were achieved with the LMS sorbent. Development of the method was continued using spiked plasma samples. The recoveries were again quite variable, probably due to protein binding. This was remedied by testing a variety of denaturing agents. The best results came with the use of phosphoric acid as denaturant with a phosphate buffer for dilution. This combination gave consistent recoveries for all recovery standards from plasma. The method was tested for use with whole blood but recoveries were insufficient once again. The SPE method was temporarily abandoned and use of liquid:liquid extraction from already published methods was implemented for the analysis of Inuit whole blood samples.

Fully isotopically-labelled ($^{13}C_{12}$) recovery standards for tetrachloro to heptachloro-hydroxybiphenyls were obtained from Wellington Laboratories. The standards were incorporated into the liquid:liquid extraction method developed for the multi-residue extraction of whole blood. The liq:liq extraction method is being used for the analysis of HO-PCBs, PCBs, OCs and MSF-PCBs in Inuit human whole blood taken as part of a Santé Quebec Inuit health survey. A control sample from the southern Quebec population will also be analyzed for comparison. The method has been producing consistent recoveries for HO-PCBs (70%) and OCs/PCBs (75%). Authentic standards were used to identify the metabolites found in both humans and polar bears.

RESULTS

Geographical, Age and Sex Differences in PCB and Chlordane Accumulation

Summary data on geographical distribution of PCBs, chlordanes, DDE and dieldrin are reported in Norstrom *et al.* (1998). Five chlordane compounds which contribute significantly to the ΣCHL (Heptachlor epoxide, oxychlordane, U-4, MC-6, *trans-* Nonachlor) were examined and found to be significantly higher in bear fat in Eastern Hudson Bay. The lowest levels were found in Wrangel Island in eastern Russia. Using principal components analysis and multiple regression analysis, we found significant linear relationships between some chlordane compounds (MC-2, MC-5 photoheptachlor) and latitude of sampling location. Thus, these compounds constituted a higher proportion of total chlordane in bears at more northern latitudes.

The highest levels of hepta- and octachlorinated PCB congeners (180, 170/190, 194) were in East Greenland and Svalbard. Levels of these PCBs were similarly high in M'Clure Strait from the Canadian Arctic. However, SIMCA statistical analysis showed that overall pattern of PCBs in the M'Clure Strait bears was more similar to those in the rest of the Canadian Arctic than the Svalbard and Greenland bears. The lowest proportion of highly chlorinated PCBs was consistently found in Wrangel Is. and the Bering Sea. On an east-west axis, we found a significant relationship with longitude and highly chlorinated CBs, that is an increasing proportion of CB 170/190 is found in bears at more easterly sampling sites.

Analysis of age effects on PCB concentrations showed that maximum total PCB concentration in sub-adults occurred in cubs (due to lactational transfer). Among the major PCB congeners in sub-adult polar bears, CB 99 exhibited the strongest tendency to decrease with age from peak concentrations in cubs (Figure 1). The age effect was much more flat for CB 60 as well as the more highly chlorinated congeners CB 180 and CB 194 (Figure 1). The likely explanation for this is that less chlorinated congeners such as CB 60 are excreted relatively quickly by the cubs whereas the more highly chlorinated congeners are transferred less efficiently from the female to the cub. This tends to lower the effect of lactational transfer in the overall dynamics, and results in a less significant age effect for these congeners in sub-adults. The lactational transfer of PCBs was sufficient for adult females to rapidly come to steady state with dietary intake for all congeners. There is therefore no significant age effect for any PCB congener or total PCBs in adult females. The lack of lactational transfer resulted in higher and much more scattered concentrations of most PCB congeners in adult males than females. Because of the scatter, no particular age trend could be modelled for males, although there was an apparent trend for CB 194 to increase with age (Figure 1). There was no age effect for CB 60 in adult males and females, and no significant differences between the sexes. This suggests that non-lactational excretion is important for this congener.

Age effects on concentrations of chlordane-related compounds showed that the highest levels of the most abundant metabolite, oxychlordane, occurred in cubs. The age trend is similar to that of CB 99, thus oxychlordane appears to be transferred efficiently from the mother (Figure 2). However, higher concentrations of oxychlordane are found in females than in males and the difference is sustained at all ages. It has been postulated that this is due to higher enzyme induction in males due to their higher PCB body burden, and faster

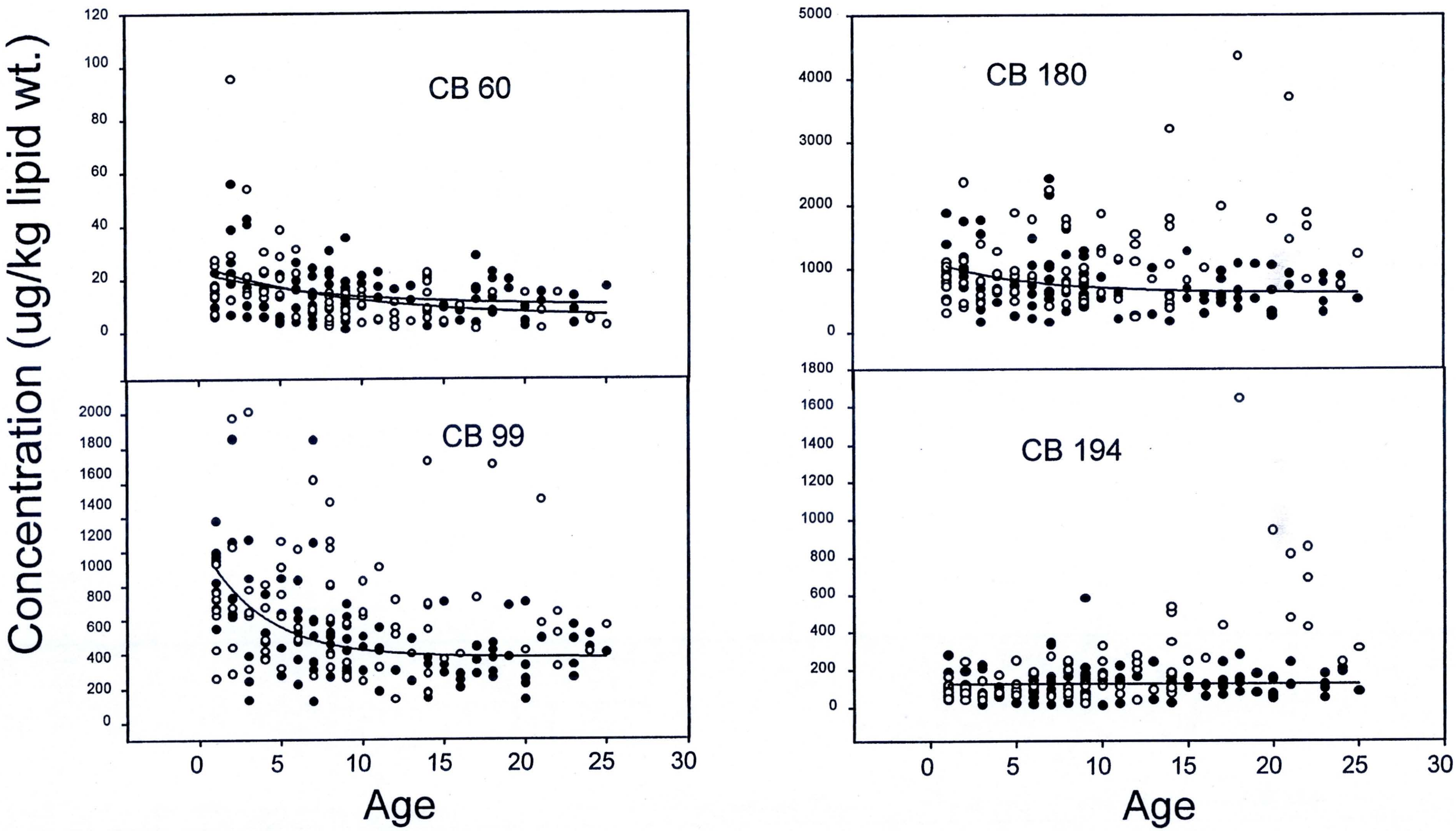

Figure 1. Concentrations of four PCB congeners in polar bear adipose tissue from Hudson's Bay as a function of age.

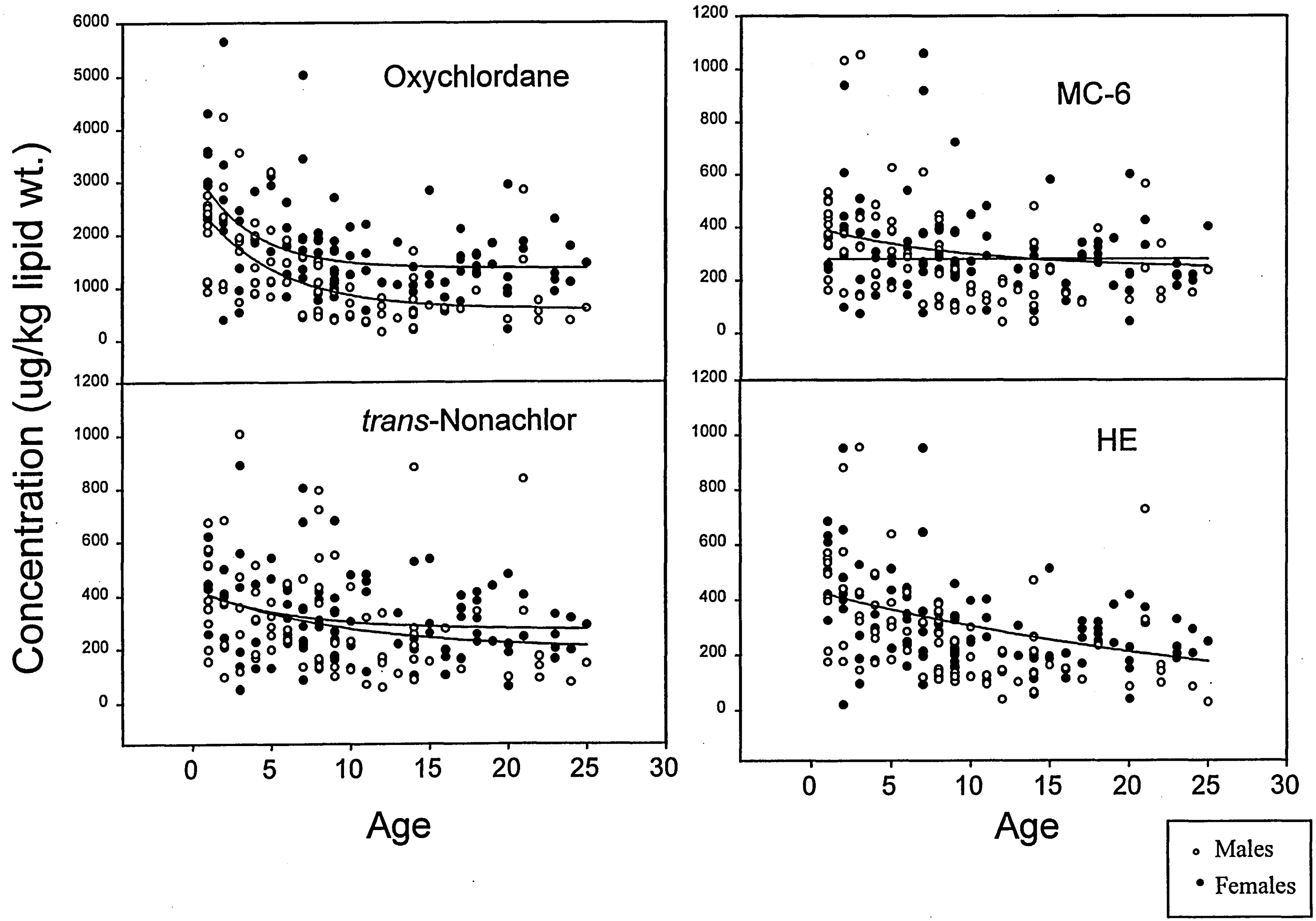

Figure 2. Concentrations of four Chlordane related compounds in polar bear adipose tissue from Hudson's Bay as a function of age.

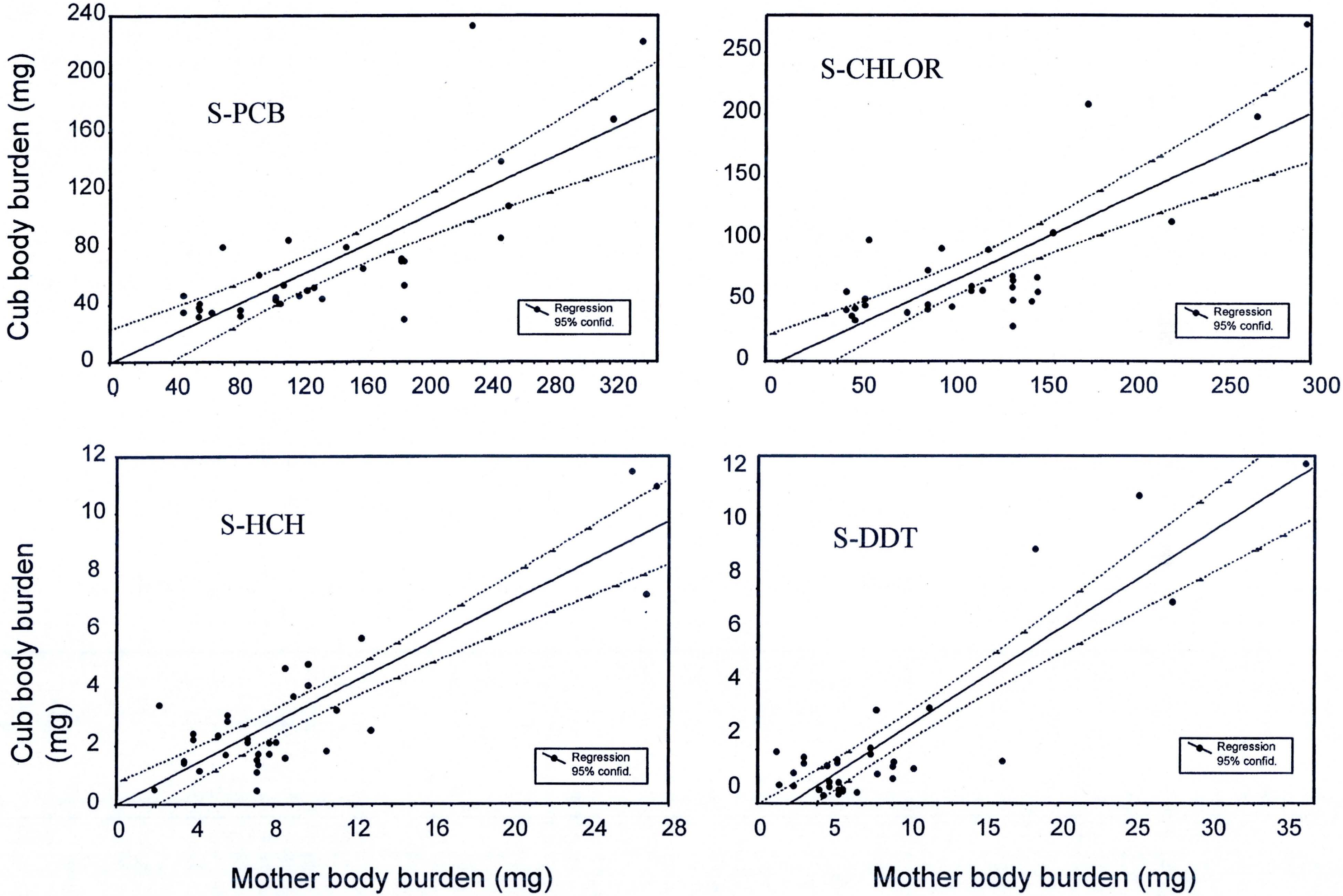

Figure 3. Body burdens (mg) of organochlorine contaminants in mothers and their associated cubs.

metabolism of oxychlordane (Norstrom *et al.* 1998). The results of analyses examining the effects of fasting on PCB composition showed that there is a selective excretion of less chlorinated congeners during fasting in the summer, autumn and early winter. The higher uptake of all congeners during periods of hyperphagia in the spring and early summer increases the proportion of less chlorinated congeners. We found that the proportion of oxychlordane peaks during periods of hyperphagia and is therefore the highest during times of exposure or formation and there is a decrease relative to other chlordane components during periods of fasting, signalling excretion. *Trans*–nonachlor appears to be the least easily excreted of the chlordane related products, in that the proportion doubles from 6% to 14% at the peak of fasting.

Effect of seasonal fasting on OC concentrations in Mothers and Cubs

Organochlorine concentrations in adipose tissue from bears handled sequentially from Summer to Fall increased for ΣClBzs, ΣChlordanes, and ΣPCBs; remained the same for ΣHCHs; and decreased for ΣDDTs (Tables 1, 2). Milk OC concentrations did not change in concentration during fasting for bears handled sequentially, although milk samples collected in fall had higher concentrations of ΣClBzs, ΣHCHs, and ΣChlordanes compared to summer samples (Table 2). Plasma OC concentrations from bears handled sequentially during fasting increased for ΣClBzs and ΣDDTs, and decreased for ΣHCHs, ΣChlordanes, and ΣPCBs (Table 2). When bears were grouped according to status, there were no significant differences between plasma collected in summer compared to fall.

Total body burdens of ΣClBzs, ΣChlordanes, and ΣPCBs did not change during fasting while burdens of ΣHCHs and ΣDDTs decreased from summer to fall (Table 1). Body burdens of OCs for females with COYs were related positively to their cub's OC body burdens. Organochlorine body burdens for females with yearlings did not correlate with their cub's OC body burdens, suggesting milk was not the primary source of food for yearling cubs. Females with high adipose tissue OC concentrations also had high milk concentrations thus, the greater transfer of OC burdens to their cubs (Figure 3). During fasting, COYs receive OC burdens from their mother via lactation, as well as, mobilizing OCs from their own adipose lipids. Since COYs are growing but also losing weight during fasting, these cubs could be more sensitive to toxic effect of OCs.

Immunotoxicology

The proliferative response of polar bear lymphocytes was significantly ($p<0.05$) reduced by exposure to PCBs 153 and 156 at concentrations of 50, 60, and 75 ppm, and by exposure to PCBs 138 and 180 at 50 and 75 ppm, when compared to both the unexposed and vehicle controls. Conversely, all treatment concentrations of PCB 157 did not differ significantly from controls.

Data from the 5 or 6 highest concentration treatment groups for PCBs 138, 153, 156, 180 were expressed as percent proliferation values and plotted against log-concentration scales. The resultant curves were linear, with r^2 values of 0.647, 0.494, 0.561, and 0.429, respectively for PCBs 138, 153, 156, and 180 ($p<0.0001$), indicating the moderately negative correlation between percent proliferation and log-concentration (Figure 4). The IC_{50} values for PCBs 138, 153, 156, and 180 were 44 mg/kg, 67 mg/kg, 89 mg/kg and 73 mg/kg, respectively.

The plasma of 11 individuals was used for chemical residue analysis. The mean concentrations of total PCBs found in plasma was 15.7 µg/kg on a wet weight basis and 1.75 mg/kg on a lipid weight basis, the latter being slightly lower than lipid weight values commonly found in polar bear adipose tissue (Polischuk *et al.* 1995, Norstom and Muir 1994). PCBs were the OC group detected in highest concentration and DDTs (i.e. DDT and metabolites) in lowest concentrations, which is the pattern generally found in polar bear tissues (Norstrom and Muir 1994). Natural concentrations of PCBs in the plasma were therefore several thousand times lower than the IC_{50}s of the PCBs in decreasing proliferative response.

OC concentrations were compared to maximal proliferation responses and to IC_{50} values. No parameter consistently correlated with any other. However, between male and female sub-adults (but not adults), IC_{50} values differed significantly for PCB 153 ($p<0.01$) and for PCB 138 ($p<0.05$), where sub-adult males had significantly higher IC_{50} values than adult males and all females.

Hydroxy PCBs

Figure 5 shows the GC-MS (ECNI) spectra of the HO-PCBs in the phenolic fraction from the extraction of polar bear pooled blood plasma. Structures are given as solid when identity has been confirmed and light when confirmation with authentic standards is needed. Tentative structures will be confirmed using standards and comparing retention times on at least 3 columns. All other peaks are unidentified and characterized solely by chlorination and fragmentation patterns.

The main metabolite in polar bear, 4HO-CB187, is the same metabolite identified previously in humans and grey seals (Bergman *et al.* 1994) and consistently makes

Table 1. Mean (± SD) organochlorine concentrations in adipose tissue (ng/g, lipid weight) and total body burdens (mg) for females with cubs-of-the-year (fem/COY), females with yearlings (fem/YRLG), COYs, YRLGs, and sub-adult and adult male polar bears in summer at the beginning of fasting and in fall after 3-4 months of fasting. Sample size given for concentrations (n^c) and body burdens (n^b). Asterisks designate significant differences between summer and fall (Tukey's, $p<0.05$).

Status (season)	n^c n^b	ClBzs ng/g	ClBzs mg	HCHs ng/g	HCHs mg	Chlordanes ng/g	Chlordanes mg	DDTs ng/g	DDTs mg	PCBs ng/g	PCBs mg
Fem/COY (sum)	9^c 9^b	98 ± 28	7 ± 4	152 ± 45	11 ± 7	1646 ± 462	110 ± 54	160 ± 59	11 ± 7	1811 ± 540	121 ± 61
Fem/COY (fall)	15^c 15^b	143 ± 46	6 ± 3	195 ± 112	9 ± 8	3104 ± 1068	136 ± 72	184 ± 141	9 ± 10	3749 ± 1493	163 ± 90
Fem/YRLG (sum)	6^c 5^b	99 ± 32	8 ± 2	153 ± 47	12 ± 3	1742 ± 294	137 ± 19	239 ± 58	20 ± 8	1937 ± 644	157 ± 38
Fem/YRLG (fall)	12^c 12^b	176 ± 130	9 ± 9	183 ± 92	8 ± 3	2720 ± 1396	122 ± 42	205 ± 108	10 ± 4	3196 ± 1490	148 ± 58
YRLGs (sum)	10^c 9^b	156 ± 41	7 ± 3	197 ± 63	8 ± 5	3090 ± 1713	129 ± 110	225 ± 60	9 ± 4	2702 ± 668	110 ± 40
YRLGs (fall)	16^c 15^b	214 ± 97	8 ±5	217 ± 177	8 ± 9	4503 ± 1803	157 ±87	209 ± 167	8 ± 8	4831 ±1692	163 ± 80
COYs (sum)	13^c 14^b	216 ± 48	4 ± 2	212 ± 48	4 ± 3	4100 ± 1414*	68 ± 43	138 ± 43	3 ± 3	3715 ± 1490*	61 ± 37
COYs (fall)	21^c 20^b	262 ± 166	3 ± 3	217 ± 182	3 ± 2	6649 ± 3687*	81 ± 60	167 ± 239	2 ± 3	6303 ± 3463*	77 ± 57
Males (sum)	10^c 9^b	142 ± 101	19 ± 22	174 ± 83	17 ± 5	3182 ± 2657	371 ± 351*	228 ± 102	30 ± 24*	2942 ± 1535	294 ± 123
Males (fall)	17^c 14^b	174 ± 92	13 ± 10	146 ± 44	10 ± 6	2487 ± 1698	152 ± 67*	146 ± 112	12 ± 14*	3858 ± 1500	240 ± 156

up approximately 30% of the total HO-PCBs found in polar bear plasma. The HO-PCB pattern is similar among individual samples. The second largest metabolite, tentatively identified as 4-HO-CB109, was also found in human and grey seal (Bergman *et al.* 1994). It constitutes about 12% of the total HO-PCBs. The only other confirmed structures in polar bear plasma, 4HO-CB146 and 4HO-CB193 make up 7% and 8% of the total, respectively. Of these two metabolites, only 4HO-CB146 was identified in humans and grey seal (Bergman *et al.* 1994).

Table 3 lists the mean concentration of HO-PCB in humans and polar bears. The Inuit whole blood was sampled from 15 individuals as part of an Inuit Health Survey. The individuals sampled ranged in age from 18 to 72 and included both males and females. The HO-PCB pattern does not vary much between individuals and preliminary results indicate a very good correlation among HO-PCB concentration, PCB concentration and age for humans. The percentage of each congener to the total for the two main metabolites found in polar bears and humans is very similar with 4HO-CB187 and 4HO-CB109 making up 29% and 16% of the total in human, respectively. The lower chlorinated congeners seem to be more important in humans as compared to the polar bear. If the whole blood data are transformed to a plasma weight basis, the average concentration of total HO-PCBs in Inuit plasma is about 9 times less than in polar bear pooled plasma.

DISCUSSION/CONCLUSIONS

Statistical analysis of the data from the large circumpolar study conducted in the early 1990s revealed that there were some differences in patterns of PCB residues between the European and the North American Arctic. The former tended to have a higher proportion of highly chlorinated PCBs, in addition to having significantly higher concentrations than most other areas. This suggests that there are additional loadings of heavier PCBs which are specific to this area of the Arctic. This may be due to transport from Eurasia via the atmosphere or ocean currents. Another possibility has recently been raised by Norwegian scientists that polar bears from Svalbard may have access to harp seals migrating from further south. Harp seals are known to have higher concentrations of PCBs than resident arctic ringed seals. The one area in Canada where polar bears have similar levels is in the Arctic Ocean surrounding M'Clure Strait. Simca analysis indicates that these bears have patterns of PCBs more similar to other Canadian bears than they do to the Greenland/Svalbard bears. This suggests that there is an ecological explanation for the relatively high concentrations of PCBs found in the M'Clure Strait bears.

Some temporal trend data has been gathered for polar bears, as indicated in last year's report. Consideration should be given to repeating the survey at selected sites in 2001 as part of the NCP and AMAP long-term trend monitoring program.

The effect of age and sex on concentrations and patterns of PCBs in polar bears is rather complex. Both ease of metabolism and pharmacokinetics of transfer from female to cub appear to play a role in the effect of age. Thus, less chlorinated PCBs such as CB 60 are easily metabolized, so steady state is achieved in both males and females, regardless of lactation and age. Highly chlorinated PCBs like CB 194 are not readily transferred in milk, so concentrations are probably not much different in milk than in ringed seal, and cubs are not exposed to higher levels than adults. There is no age effect for any congener in adult females, since lactation is sufficient to create a steady state balance between uptake and excretion. However, concentrations of highly chlorinated PCBs like CB 180 and CB 194 tend to increase with age in older males because they are not readily metabolized or excreted. For moderately chlorinated PCBs that are readily transferred from the female, but not easily cleared, such as CB 99, cubs are exposed to relatively higher levels than adults, and there is a distinct decrease with age in female cubs to sexual maturity around age 5. Adult males consistently have lower levels of chlordanes than females. This may be due to lower exposure from dietary preferences, e.g., seal pups, or metabolism differences in males and females.

Studies on the effect of the effect of 3 to 4 month summer fasting on dynamics of OCs in polar bears indicated that little or no net excretion of PCBs, chlordanes and chlorobenzenes occurred, even in lactating females. That is, although concentrations in adipose tissue increased in many cases, it was compensated by loss of fat, and the body burdens remained the same. Although the period of time was relatively short, these results suggests that active feeding is required for excretion of these compounds, possibly by partitioning into gut contents. That is, conversion to polar metabolites is not an important prerequisite to excretion. A notable exception is the significant decrease in chlordanes and DDTs in males, but not females. This finding lends some credence to the hypothesis that the difference in concentrations of chlordanes in males and females is due to the males' greater ability to metabolize them. Lumping body burdens for all sexes and ages together, it appears that only DDTs and HCHs were significantly metabolized and excreted during the fast. As expected, there was an excellent correlation between the cub's

Table 3. Mean concentration (standard deviations) of hydroxy–PCBs in humans and polar bears.

PCB Metabolites (pg/g)	Inuit Whole Blood Mean	% Total	Pooled Polar Bear Plasma	% Total
Cl5 (RI – 0.69) 4HO–CB120	1.4 (0.5 – 2.5)	1	8.9	< 1
4HO–CB109 (RI – 0.66)	26.6 (2.6 – 56.5)	16	307.1	12
Cl6 (RI – 0.78) 3HO–CB153	11.7 (0.3 – 32.3)	7	163.2	6
4–HO–CB146 (RI – 0.70)	11.7 (0.6 – 34.5)	7	176.6	7
Cl5 (RI – 0.92) 3HO–CB138	14.3 (0.7 – 58.2)	9	57.9	2
Cl7 (RI – 0.81) mixture	5.4 (0.2 – 18.2)	3	111.4	4
4–HO–CB187 (RI – 1.00)	47.6 (4.2 – 128.3)	29	777.6	30
Cl6 (RI – 1.05)	1.4 (0.1 – 8.1)	1	21.5	1
Cl8 (RI – 1.12)	3.1 (0.1 – 11.4)	2	58.9	2
Cl7 (RI – 1.17) 3HO–CB180	3.4 (0.1 – 18.2)	2	24.9	1
Cl7 (RI – 1.18)	9.8 (1.4 – 30.9)	6	98.4	4
4–HO–CB193 (RI – 1.22)	1.9 (0.2 – 4.2)	1	208.9	8
Total HO–PCBs (pg/g)	**161.6**		**2605.1**	

Table 2. Relationship between changes in adipose tissue, milk (ng/g, lipid weight) and plasma (ng/g, wet weight) concentrations and total body burdens (mg) for polar bears captured sequentially before and after fasting. (Wilcoxon Matched Pairs Test, p<0.05).

OC	*n*	Adipose tissue	Body Burden	*n*	Plasma	n	Milk
ClBzs	47	Increased	No change	43	Increased	11	No change
HCHs	47	No change	Decreased	43	Decreased	11	No change
Chlordanes	47	Increased	No change	43	Decreased	11	No change
DDTs	47	Decreased	Decreased	43	Increased	11	No change
PCBs	47	Increased	No change	43	Decreased	11	No change

*N/C = No change.

and their mother's body burdens. The concentrations of most OCs in the cub's adipose tissue was roughly twice that of their mother's, but even more interesting is that the body burdens in cubs were nearly one half those in their mothers, in spite of the large difference in size. Further studies on the effect of PCBs and chlordanes on cubs are warranted.

The immunotoxicology studies that have been carried out to date are insufficient to determine the immune status of polar bears, or whether they are likely to be sensitive to the effects of PCBs, such as those noted in harbour seals with similar PCB concentrations. Agglutination of leukocytes remains a significant problem, and prevents carrying out many potentially useful *in vitro* tests. Furthermore, cryospreservation for subsequent laboratory tests was found to not yield useful results. The requirement for use of fresh cells makes many tests impractical because of the expense and difficulty of setting up the necessary equipment in the field. The lymphocyte proliferation test is not very sensitive, and probably not ecologically relevant. It would be far more useful to study the response of the whole immune system of the bear to challenge from injected antigens. Norwegian scientists have begun such a study in 1998 on the highly contaminated Svalbard population. A collaborative study will be proposed for the less contaminated Hudson Bay bears in 1999 in order to obtain a good gradient of exposure to PCBs. Other tests which may be useful are differential leukocyte counts (CD3:CD4 T-cell ratios) and, NK cell assays.

Polar bears have total hydroxy-PCB concentrations in plasma which are in the 3 μ/kg range on a wet weight basis. This is the same order of magnitude as total PCBs, which ranged from 7-25 μ/kg in the immunotoxicology study. This finding is similar to those in other studies on laboratory animals and humans, which suggests that specific binding to plasma proteins is occurring. Whether this is TTR remains to be proven. The great similarity in pattern between humans and polar bears is another indication that a very specific binding site is involved. Thus, there is potential for interference in vitamin A and thyroid hormone transport in polar bears by displacement from their binding sites. Further studies are underway in 1998 to show whether there is a correlation between hydroxy-PCB and vitamin A and free and bound T4 concentrations. Samples from both Svalbard and Canada will be used in these studies to produce a large gradient of exposure. The presence or absence of TTR in polar bears will also be determined.

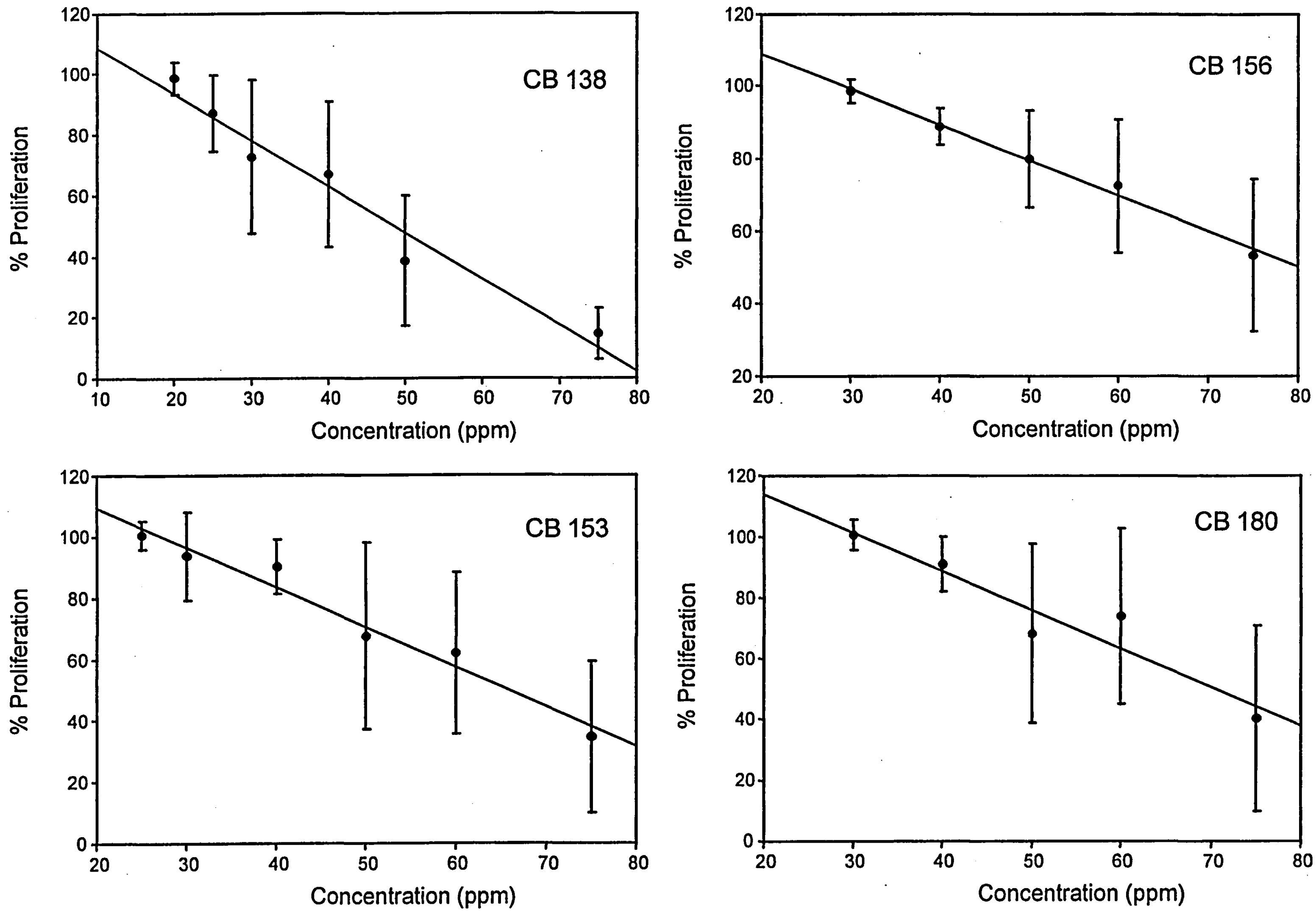

Figure 4. Proliferatative response (%) of polar bear lymphocytes as a function of four PCB congener concentration (ppm).

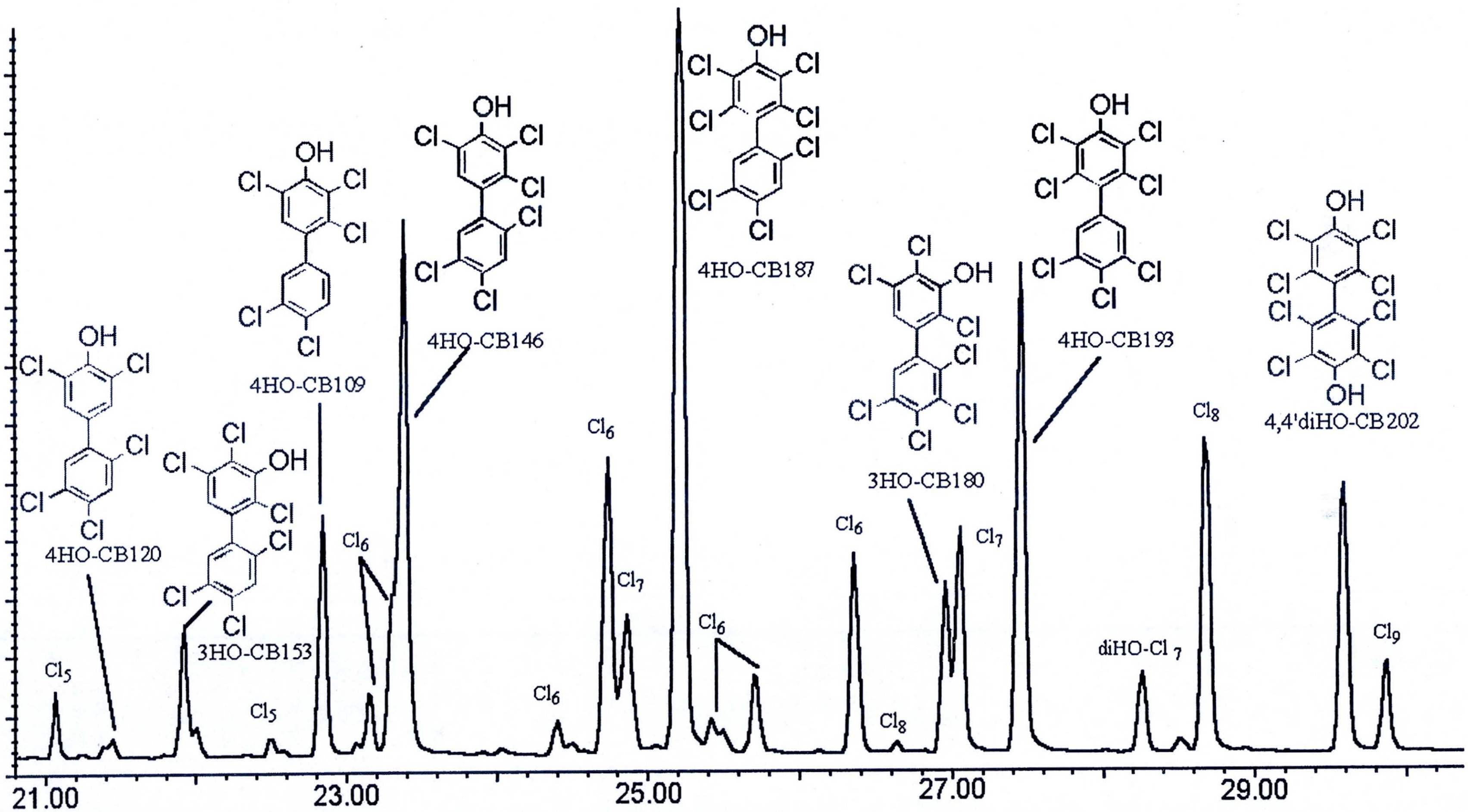

Figure 5. GC-MS (ECNI) spectra of hydroxy-PCBs from extraction of pooled polar bear plasma samples. Solid coloured structures have confirmed identities with authentic standards, and light coloured ones have not been confirmed.

Further work towards the validation of the SPE method for plasma will be completed. The method will be validated using polar bear plasma and comparing recoveries and cleanliness with the established liquid:liquid method mentioned above.

Future studies may include *in vitro* metabolism of PCB congeners by microsomal fractions from polar bear liver. Polar bears rapidly metabolize a number of normally recalcitrant PCB congeners, and are therefore a good model species to study the structure-activity rules for metabolism of congeners to hydroxy-PCBs, as well as to the epoxide intermediates of methylsulfone-PCBs.

Expected project completion date: 2003

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CONTAMINANTS IN YUKON MOOSE AND CARIBOU - 1997

Project Leaders: M. Palmer, Chair, Yukon Technical Committee on Contaminants in Northern Ecosystems and Native Diets

Project Team: Yukon Territorial Government: Renewable Resource Officers and Biologists; Yukon Conservation Society, Yukon Hunters.

OBJECTIVES

1. to develop baseline data on levels of inorganic contaminants in Yukon moose and caribou
2. to identify potential health risks to First Nations and others using moose and caribou as a food source
3. to identify potential health problems in wildlife populations as a result of contaminant loading
4. to identify potential temporal and geographical trends in inorganic contaminants in Yukon moose and caribou.

DESCRIPTION

This project is part of the ongoing monitoring of contaminants in Yukon wildlife that started in 1992 with a study of the Finlayson caribou herd (Gamberg 1993), continued with a comprehensive look at contaminants in country foods (Gamberg 1998a), and is now monitoring temporal and geographical trends using moose and caribou as key species (Gamberg 1997, 1998b).

ACTIVITIES IN 1997/98

Yukon hunters were requested to submit kidney, liver and muscle samples, as well as an incisor, from moose and caribou killed during the 1997 hunting season. The incentive for the submissions was a chance at a free charter flight. Each hunter's name was put in the draw once for each tissue submitted, and one extra time if all samples requested were provided. Hunters submitted their samples to their local Renewable Resources office where a sample form was completed. All samples were stored in freezers at –20˚C until processed.

Samples were submitted from 97 moose and 127 caribou. The incisor was used to age the animals, and kidney samples were analysed for 26 elements by Elemental Research Laboratories Inc. in Vancouver, BC. Liver, muscle and some kidney samples were archived in freezers for possible future analysis. Although data for all 26 elements are presented in a previous report (Gamberg 1998b), only elements of interest are discussed in this report.

RESULTS

Because of potential differences among caribou herds, and low numbers of aged caribou from each herd, only moose and Porcupine caribou were used to test the effect of age on element concentration. Renal cadmium increased significantly with age in moose, while kidney copper decreased with age. These trends existed in the Porcupine caribou but were not significant, probably because of the low sample size of 10.

Similar data collected in 1996 (Gamberg 1997), were compared to data from the current year to determine if element concentrations are changing over time. Copper, lead and zinc concentrations in moose kidneys were higher in 1996 than in 1997, while arsenic levels were higher in 1997 (Figure 1). In caribou, copper, selenium and zinc concentrations were all higher in 1996, while, as with moose, arsenic levels were higher in 1997 (Figure 1). In all cases the ranges from year to year are small and well within normal ranges described for domestic cattle (Puls 1994). The biological significance of the differences is minimal at best.

Cadmium levels were highest in the Finlayson and Tay caribou herd and in moose, while concentrations in the Porcupine and Bonnet Plume caribou herds were lower and more similar to other arctic caribou (Froslie *et al.* 1986, Elkin and Bethke 1995). Levels in the Hart River herd spanned the difference between the two groups (Figure 2). Although there is no evidence from this study that cadmium levels are causing renal stress in these animals, a previous study (Gamberg 1997) indicated that there may be a small number of moose who may

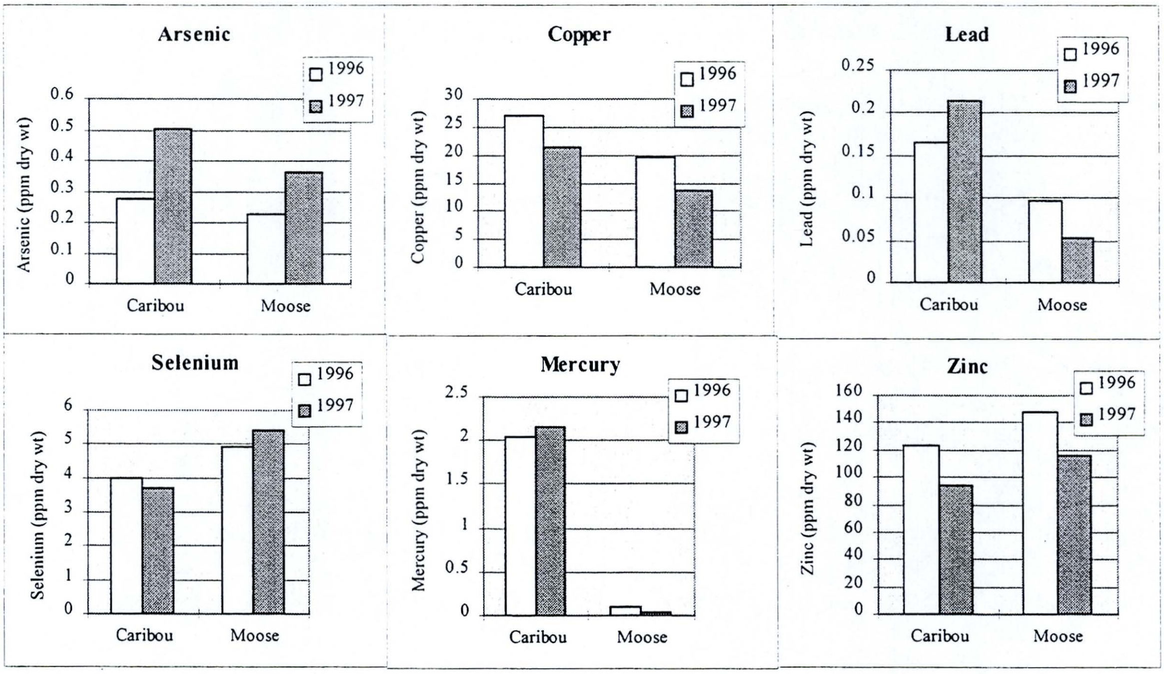

Figure 1. Element concentration in Yukon moose and caribou from 1996 and 1997.

experience some renal dysfunction as a result of high cadmium concentrations in their kidneys. Health Canada has evaluated the previous work of this type in the Yukon and recommended limiting consumption of kidneys from moose and caribou among other species (Gamberg 1998). The data from this year's study showed that the level of cadmium in moose and caribou has not changed over the last year, so the recommendations should still be relevant.

Kidney mercury concentrations in caribou were somewhat higher than in moose (Figure 1). Previous work has shown that methylmercury concentrations in Porcupine caribou kidneys were below detection limits, indicating that the mercury present was in the less toxic form of inorganic mercury. It is likely that observed high levels of cadmium and mercury in the Canadian Arctic reflect naturally occurring geological sources rather than industrial pollution (Eaton and Farant 1982, Braune *et al.* 1991), and concentrations found in this study should be considered background levels.

CONCLUSIONS

For the most part, element concentrations found in Yukon moose and caribou kidneys are at background levels and are not of concern to the animals themselves, or those who consume them. However, Health Canada has recommended limiting consumption of kidneys from Yukon moose and caribou because of high cadmium concentrations in kidneys from both moose and caribou, and high mercury levels in caribou. It is likely that these elements are accumulating from natural sources in this mineral-rich area, and are acquired by the animals through the consumption of specific plants that are adept at absorbing these elements from the natural environment. Although cadmium levels tend to be higher in older animals, there has been no significant change in the levels found in moose or Porcupine caribou over

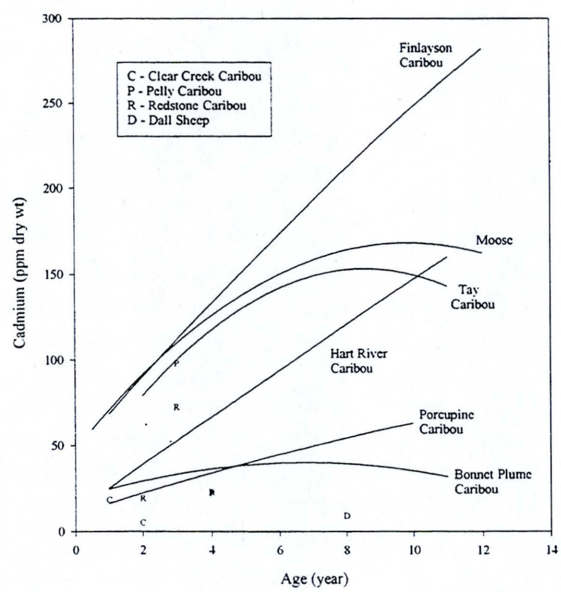

Figure 2. Cadmium concentrations in Yukon moose and caribou, Regression lines taken from Gamberg (1997, 1998).

the last two years. Similarly, there has been no significant change in mercury levels in the Porcupine caribou over the last two years. These elements do not appear to be changing over time. Those concerned about the consumption of cadmium or mercury from moose or caribou should follow the guidelines provided by Health Canada.

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SOURCES, PATHWAYS AND LEVELS OF CONTAMINANTS IN FISH FROM YUKON WATERS

Project Leader: M. Palmer, Chair, Yukon Technical Committee on Contaminants in Northern Ecosystems and Native Diets

Project Team: Government of Yukon Fisheries; Dept Fisheries and Oceans; DIAND; Environment Canada; Council of Yukon First Nations

OBJECTIVES

Short-term

1. to verify results from previous organochlorine analyses in order to address concerns raised by health advisories based on existing data
2. to determine spatial variability in contaminant loadings, and to assess short term trends.

Long-term

1. to investigate the sources, processes and rates of contaminant deposition and transport into and within the waters of the Yukon
2. to determine levels of contaminants for use in long term trend analysis
3. to develop additional monitoring on levels of organic contaminants within the Yukon
4. to provide additional information for use in updating health advisories.

DESCRIPTION

Burbot liver and lake trout flesh samples from headwater lakes in the Yukon River system (Tagish, Laberge, etc.) in the early 1990s had elevated levels of organochlorine industrial chemicals and pesticides. In response to elevated toxaphene levels, Health Canada issued a public health advisory on Laberge and Atlin lakes. The advisory recommended that consumption of lake trout flesh be limited on Lake Laberge and that burbot livers not be consumed on Lake Laberge and limited on Atlin Lake. This has affected the various fisheries on the lakes, and generated considerable concern from residents who used the fisheries resources throughout the Yukon.

The primary purpose of this multi-year fish survey is to assure Yukoners of the safety of fish for human consumption. For this reason, sampling is designed as a survey of fish stocks that are important primarily in aboriginal fisheries. Lake trout and whitefish were the species sampled in most lakes, as these fish are widespread and commonly eaten. Burbot livers, which are a traditional First Nations food, were sampled where possible. Arctic grayling and northern pike were sampled in Lake Laberge and at several other locations for comparison. In 1993, salmon samples were taken from important native fishing areas and from the Whitehorse Fishway.

ACTIVITIES AND RESULTS

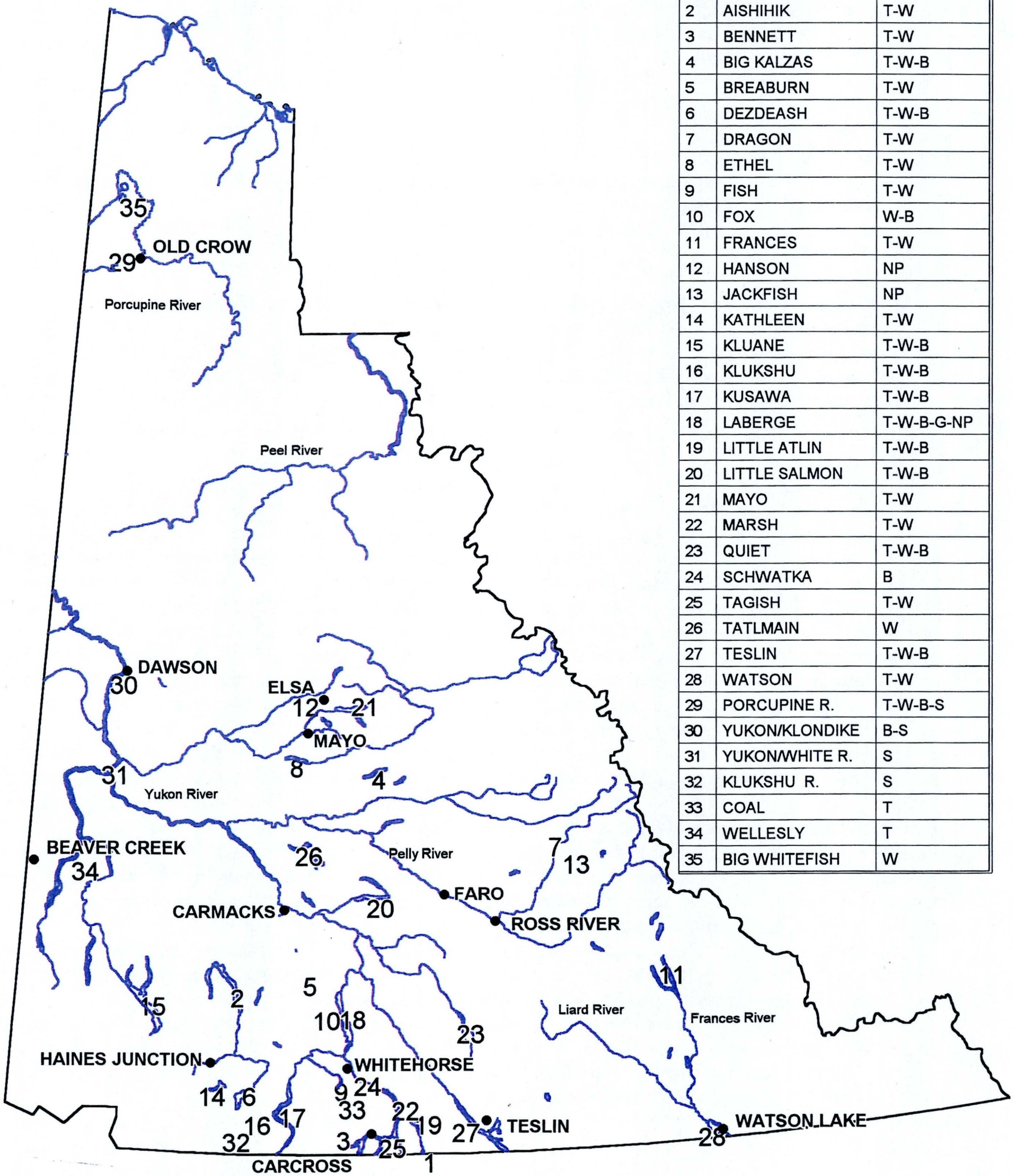
Since 1991, fish have been sampled from lakes and rivers throughout the Yukon (see Figure 1). Yukon First Nations recommended sampling locations and fish species, based on traditional use of fish and on community concerns. Additional lakes were chosen to provide broad geographic coverage. Fish samples were analysed by Axys Analytical laboratories in Sidney, B.C. and at the Department of Fisheries and Oceans laboratory in Winnipeg, Manitoba.

Methods and results of analyses of fish muscle tissue and burbot liver samples collected through this program are presented in more detail in recent Northern Contaminants Program documents (Yukon Contaminants Committee 1997, and Muir *et al.* 1997) and in a Yukon Contaminants Committee data report (Yukon Contaminants Committee in press).

In 1996 the Yukon Government sampled lake trout and burbot from Lake Laberge as part of the Lake Recovery Program. Samples of burbot liver and trout muscle tissue were analysed for organochlorines. The results were similar to the 1993 sample set and confirm the downward trend for some organochlorines, especially in lake trout.

Analysis of fresh and archived duplicate samples was undertaken in 1997/98 to verify and extend several data sets. In particular, sampling was directed towards confirming the apparent decrease in organochlorines in

YUKON FISH SAMPLING LOCATIONS 1991 - 1998



NO	WATERBODY	FISH
1	ATLIN	T-W-B
2	AISHIHIK	T-W
3	BENNETT	T-W
4	BIG KALZAS	T-W-B
5	BREABURN	T-W
6	DEZDEASH	T-W-B
7	DRAGON	T-W
8	ETHEL	T-W
9	FISH	T-W
10	FOX	W-B
11	FRANCES	T-W
12	HANSON	NP
13	JACKFISH	NP
14	KATHLEEN	T-W
15	KLUANE	T-W-B
16	KLUKSHU	T-W-B
17	KUSAWA	T-W-B
18	LABERGE	T-W-B-G-NP
19	LITTLE ATLIN	T-W-B
20	LITTLE SALMON	T-W-B
21	MAYO	T-W
22	MARSH	T-W
23	QUIET	T-W-B
24	SCHWATKA	B
25	TAGISH	T-W
26	TATLMAIN	W
27	TESLIN	T-W-B
28	WATSON	T-W
29	PORCUPINE R.	T-W-B-S
30	YUKON/KLONDIKE	B-S
31	YUKON/WHITE R.	S
32	KLUKSHU R.	S
33	COAL	T
34	WELLESLY	T
35	BIG WHITEFISH	W

Figure 1. Yukon fish sampling locations, 1991–1998

Table 1. Organochlorines in burbot from Quiet Lake and in lake trout from Coal Lake, Yukon (values are ng/g mean (sd) wet weight; year is sample year).

A. Quiet Lake burbot liver

Year	N	Lipid (%)	Σ-DDT	Σ-HCH	Σ-CBZ	Σ-Chlor	Tox (GC/ECD)[1]	Tox(GC/MS)[2]
1992	5	47 (3.1)	70 (81)	29 (5.0)	23 (4.3)	59 (36)	536 (254)	
1994	5	21 (12)	41 (50)	10 (5.9)	11 (5.7)	30 (23)	250 (185)	
1997	7	30 (12)	93 (37)	15 (4.8)	7.6 (2.8)	22 (8)	77 (27)	59 (23)

B. Coal Lake lake trout muscle

Year	N	Lipid (%)	Σ-DDT	Σ-HCH	Σ-CBZ	Σ-Chlor	Tox (GC/ECD)[1]	Tox(GC/MS)[2]
1995	5	1.3 (0.3)	7.4 (3.5)	0.48 (0.15)	0.38 (0.17)	4.7 (1.7)	4.1 (1.8)	0.30 (0.08)

[1] Toxaphene: Gas chromatography/electron capture detection

[2] Toxaphene: Gas chromatography/electron capture negative ion high resolution mass spectometry

Lake Laberge noted above, and towards evaluating toxaphene and DDT levels in lakes with confirmed or potential local sources. Further sampling and analysis will be required in 1998/99 to complete this project.

New samples of lake trout from Coal Lake and burbot liver from Quiet Lake were also analysed. Coal Lake (a small subalpine lake in the Wolf Creek Research Basin) had very low levels of organochlorines, and the results from Quiet Lake were generally consistent with previous samples, with a lower average total toxaphene level. All 1997/98 analyses were conducted by DFO, Winnipeg.

DISCUSSION/CONCLUSION

Main findings of the multi-year program

- Organochlorine contaminants are present in lakes and rivers throughout the Yukon, as in other regions of the circumpolar North.
- Yukon whitefish, Northern pike, Arctic grayling, and salmon have consistently low levels of organochlorines.
- Lake trout organochlorine contaminant levels vary a lot from lake to lake and within lakes, partly in relation to whether or not the trout eat fish or invertebrates.
- Burbot (lingcod) all have very low levels of organochlorines in their muscle tissue, but contaminants build up in the large, fatty livers. Contaminant levels also vary a lot from lake to lake.

Analysis of new and archived samples from Lake Laberge and other southern Yukon lakes, followed by a review of contaminant levels and consumption advice, remain priorities for the Yukon Contaminants Committee through 1998/1999.

Project Completion Date: Ongoing

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TEMPORAL TRENDS OF ORGANOCHLORINE CONTAMINANTS IN SOUTH EASTERN BAFFIN BELUGA

Project Leader: G.A. Stern, Department of Fisheries and Oceans (DFO); Freshwater Institute, Winnipeg, MB

Project Team: Gregg Tomy, Krystyna Koczanski, Thor Holldorson (DFO, FWI); Derek Muir (DOE, NWRI)

OBJECTIVES

1. to document the temporal trends of bioaccumulating substances such as PCBs, DDT, toxaphene (CHBs, chlorinated bornanes) in Arctic marine ecosystems so as to determine whether contaminant levels in marine mammal tissues, and thus the exposure to people living in Arctic communities who consume them as part of their traditional diet, are increasing or deceasing with time.

2. to analyse for "current use" chemicals which will provide a "baseline" against which future measurements can be compared.

3. to provide data on contaminant levels in marine mammal tissues as part of surveys of dietary contaminantion and for use by the Arctic Monitoring and Assessment Program (AMAP).

DESCRIPTION

Marine mammals are an important part of the traditional diets of people living in the Arctic coastal communities. These animals occupy high tropic levels in marine food webs and so accumulated relatively high concentrations of persistent organochlorine (OC) contaminants. Documentation of temporal trends in the extent of contamination of these compounds will contribute to an assessment of the risk incurred on exposure to them.

Analysis of "current use" chemicals such as chlorinated n-alkanes (PCAs) will provide a "baseline" against which future measurements can be compared. In Canada, short chain PCAs (C_{10}-C_{13}) are classified as Priority Toxic Substances under Canada's Environmental Protection Act (CEPA), and in the U.S., have been placed on the Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI). Short chain PCAs are of particular interest because of their possible adverse effects on terrestrial and aquatic organisms, and potential carcinogenicity to humans [Kato and Kenne 1996].

In this study, blubber samples from 65 Pangnirtung beluga, collected at four different time periods (see Table 1) covering a 14 and 10 year time span for male and female animals, respectively were analysed for OC contaminants. This study has an advantage over previous temporal trend studies in that the blubber from all of these animals were analysed in the same laboratory, by the same analyst, using the methodology and instrumentation.

Short-chain PCAs in male beluga blubber samples, collected from various regions of the Canadian Arctic, were quantified using high resolution gas chromatography electron capture negative ion high resolution mass spectrometry (HRGC/ECNI/HRMS) and their levels compared to those of other persistent organochlorine contaminants.

ACTIVTIES IN 1997/98

Samples

Beluga blubber samples from SE Baffin Island (Pangnirtung) animals, collected in the years 1982 through to 1996 as part of a whale sampling program conducted by DFO and funded partly by the Nunivut implementation fund (NIF) and the Nunavut Wildlife Management Board (NWMB), were available for analysis from the archive maintained at the Freshwater Institute (FWI).

Methods

Samples of blubber were analysed for 130 individual organochlorine contaminants (90 PCB congeners, and 40 other OC pesticides) as described by Muir *et al.* (1990). In brief, 2 g of each blubber sample was combined with anhydrous sodium sulfate (heated at 600° C) for 16 hours prior to use. The mixture was then extracted twice with 50 ml of hexane using a ball mill, centrifuging and decanting the hexane between

Table 1. Number of blubber samples from male and female Pangnirtung animals (>2 years of age) analysed for organochlorine contaminants (n_{total} = 65).

	1982	1986	1992	1996
Male	9	16	10	6
Female	–	4	10	10

Table 2. Summary of ANOVA results used to assess the affects of year to year collections (temporal trends), age of the animals and age*year interactions (homogeneity of the slope between age and [DDT]) of DDT in male Pangnirtung beluga blubber samples.

	Year (Pr)	Age (Pr)	Age*year (Pr)	R^2 (model)
ΣDDT	0.0133	0.0004	0.0013	0.61
o,p'-DDE	0.0008	0.0001	0.2554 (ns)	0.75
p,p'-DDE	0.0447	0.0003	0.0082	0.56
o,p'-DDD	0.0001	0.0001	0.1718 (ns)	0.84
p,p'-DDD	0.0005	0.0009	0.1301 (ns)	0.67
o,p'-DDT	0.0227	0.0013	0.0606 (ns)	0.56
p,p'-DDT	0.0506	0.0170	0.0001	0.40

ns = not significant (Pr > 0.05)

Table 3. Organochlorine concentrations and [standard deviation] in blubber from male beluga sampled at different locations throughout Canada (ng/g, wet wt.).

Location	Year	n	Age	%Lipid	ΣCHL	ΣDDT	ΣPCB	ΣCHB	ΣHCH	ΣPCA
Hendrickson	93-95	39	16.6	90.9	2158	3388	4673	5315	342	626[a]
			[4.5]	[2.5]	[631]	[1090]	[1469]	[1897]	[80.3]	[499]
Arviat	1993	5	nd	98.6	210	1595	2230	5537	367	204
				[10.4]	[56.9]	[329]	[895]	[815]	[85.2]	[54.5]
Sanikiluaq	1994	5	35.6	94.8	4769	14738	7908	15414	405	323
			[13.9]	[10.7]	[1463]	[6854]	[1579]	[8157]	[84.7]	[76.2]
Pangnirtung	82-96	41	8.8	90.5	1709	4531	3768	9273	233	457[b]
			[6.0]	[3.2]	[521]	[1835]	[1388]	[2781]	[62.9]	[306]
St Lawrence[d]	87-90	15	20.5	82.2	9872	124188	108583	22042	500	832[c]
			[7.5]	[11.1]	[6029]	[100557]	[99658]	[12986]	[189]	[500]

[a]n=17, [b]n=31, [c]n=3, [d]Muir *et al.* [1996], nd = not determined

extractions. Surrogate recovery standards of PCB 30 and octachloronaphthalene (OCN) were added prior to extraction. Extractable lipids were determined gravimetrically on one-tenth of the extract. A portion of the extract equivalent to approximately 100 mg was then separated into three fractions of increasing polarity on a Florisil column (8 g, 1.2% H_2O deactivated). The first fraction was eluted with hexane and contained PCBs, *pp*-DDE, chlorobenzenes, mirex, and a small portion of CHBs (toxaphene), most notably T2/B8-1413 (Stern *et al.* 1992, Andrews and Vetter 1992). Fraction two was eluted with hexane:DCM (85:15) and contained HCHs, chlordanes, and the remainder of the CHBs. The final fraction was eluted with a 1:1 mixture of hexane:DCM. Each of the three fractions were then analysed by high resolution gas chromatography with electron capture detection (HRGC/ECD) using a 60 m x 0.25 mm DB-5 capillary column (0.25 μm film thickness) with hydrogen carrier gas. Total PCB (ΣPCB) corresponds to the sum of all congeners. Total chlordane (ΣCHL) to the sum of all chlordane related compounds and DDT (ΣDDT) to the sum of *p,p'*-DDE, *o,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD, *p,p'*-DDT and *o,p'*-DDT. Toxaphene (ΣCHB) was quantified using a single response factor based on 27 peaks in the technical mixture. Approximately 75-80% of ΣCHB in beluga blubber is ascribed to two individual congeners, an octa- and non-achlorobornane, referred to as T2 (Palar#26, B8-1413) and T12 (Parlar#50, B9-1679) (Stern *et al.* 1992, Andrews and Vetter 1995). After HRGC/ECD analyses were completed, extracts F2 and F3, for each blubber sample were combined, spiked with $^{13}C_8$-Mirex and concentrated to a known volume (~100 ul) for analysis of short chain (C_{10}-C_{13}) chlorinated n-alkanes by high resolution gas chromatography electron capture negative ion high resolution mass spectrometry (HRGC/ECNI/HRMS) as described by Tomy *et al.* (1997).

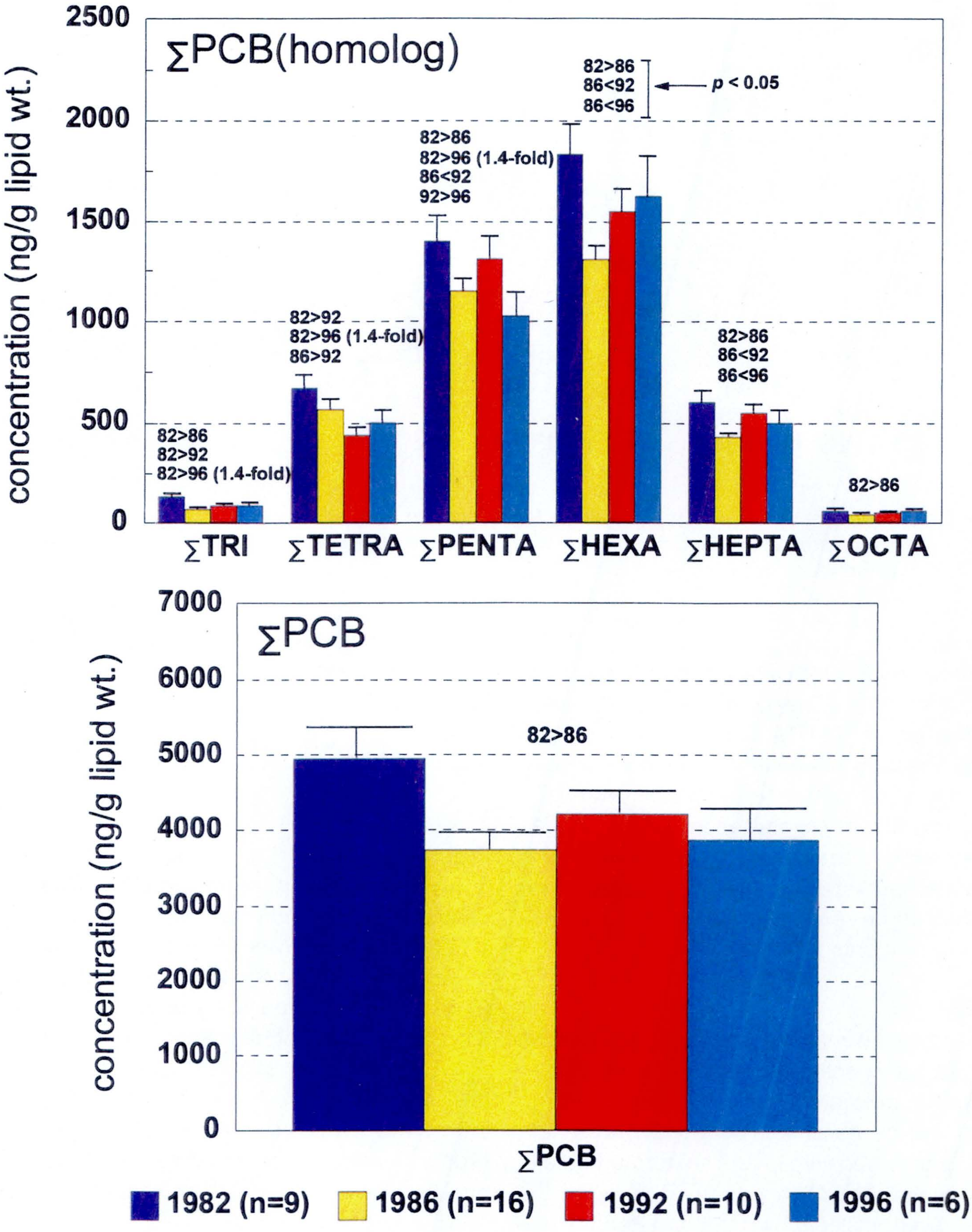

Figure 1. Temporal trends of lipid normalized (age adjusted least square mean) concentrations of ΣPCB and individual homologue groups in Pangnirtung male beluga blubber samples.

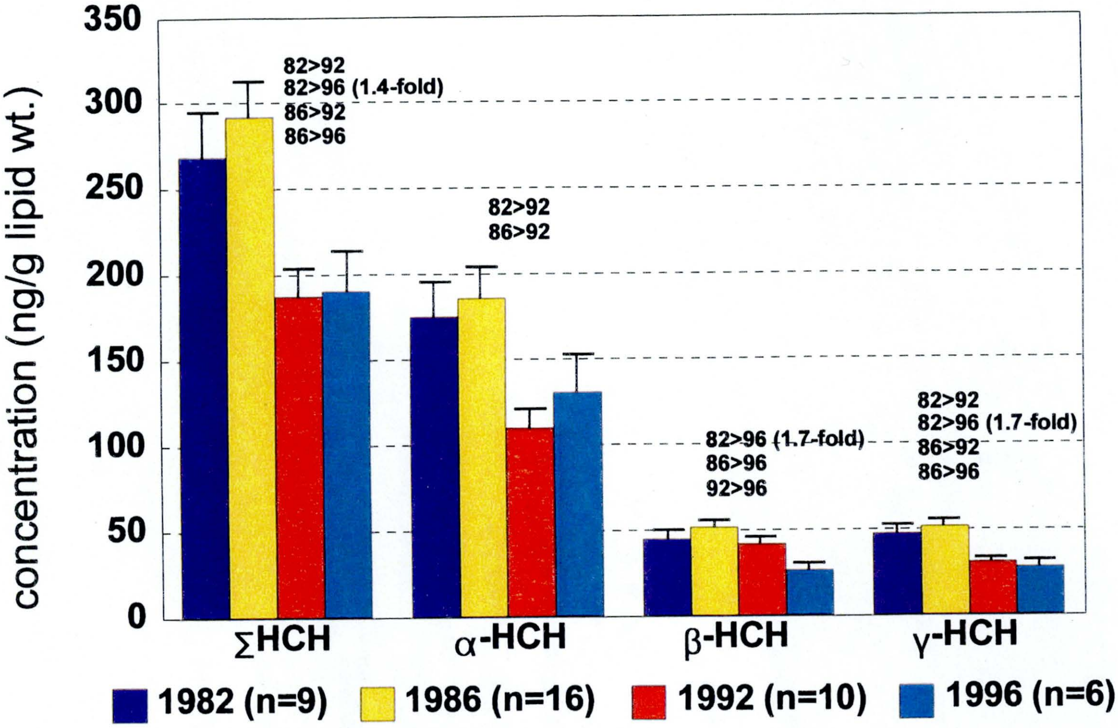

Figure 2. Temporal trends of lipid normalized (age adjusted least square mean) concentrations of ΣHCH, α-, β-, γ-HCH in Pangnirtung male beluga blubber samples.

Quality assurance

The average recovery for both internal standards, PCB 30 and OCN, was 96%. The Cod liver oil standard reference material (SRM-1588) from NIST (Gaithersburg, Va) was used as a laboratory control sample for major organochlorine pesticides and PCB congeners and was run with every second set of samples (8 samples per set). One duplicate sample was also run with every second set of samples and blanks were run approximately every ten samples to check contamination of reagents and glassware.

Statistical analysis

All results were lipid normalized and were grouped by sex, because of large concentration differences between male and female animals of most organochlorine contaminants, and by collection period. All univariate analyses were performed with $\log_{10}$ transformed data to adjust for skewness. ANCOVA was used to asses the effects of year to year collections (temporal trends), age of the animals and age*year interactions (homogeneity of slope between age and [OC]) using the model [OC] = year age age*year, where [OC] = log concentration of each organochlorine group. Differences between collection years were examined with paired comparisons of age adjusted least squared mean concentrations (SAS Institute 1991). Only results for animals older than two years of age were included in the analysis of covariance because of the large variations in concentrations seen in younger animals (Stern *et al.* 1994, Muir *et al.* 1996).

RESULTS

Temporal trends

Figure 1 shows the temporal trends of the lipid normalized, age adjusted least square mean concentrations of the individual PCB homologue groups and ΣPCB in the male Pangnirtung beluga blubber samples. Years in which statistically significant differences ($p < 0.05$) were observed have been noted. For the lower chlorinated homologue groups (Cl_3-Cl_5) an approximate 1.4 fold decline in concentrations was observed over the 14 year interval from 1982 to 1996. No significant difference was observed for the Cl_6-Cl_8 homologue groups over the same time period. ΣHCH concentrations declined by approximately 1.4 fold from 1982 to 1996 and by 1.7 fold for both the β- and γ-HCH isomers (Figure 2). For chlordane and toxaphene (Figure 3), no significant differences were observed. Age year interactions (age*year) were observed for ΣDDT, *p,p'*-DDE and *o,p'*-DDT. As a result ANCOVA could not be used to correct for the observed age affects (Table 2). For the remaining components, where age*year interactions were not significant, a substantial amount of variation was observed and so no real conclusions

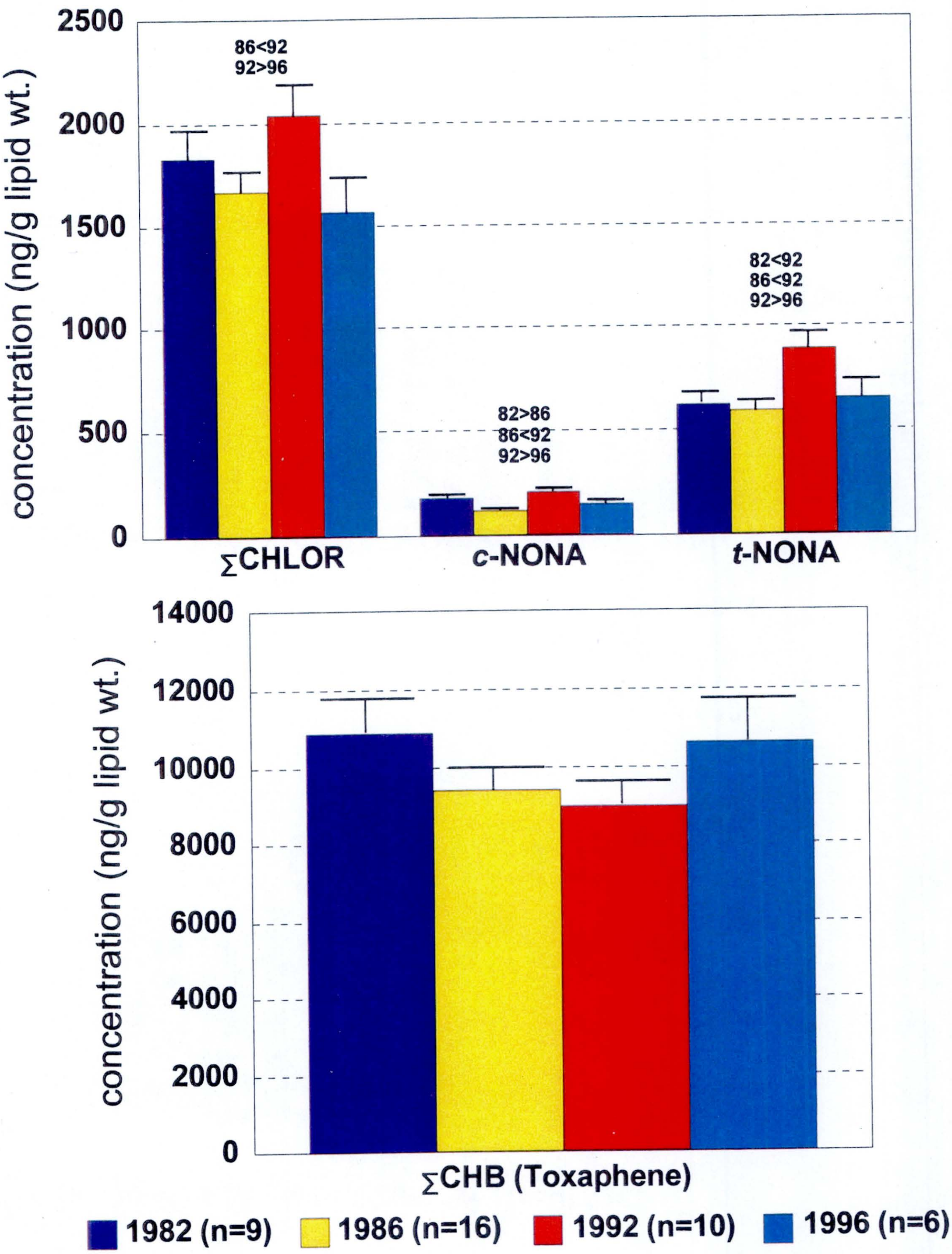

Figure 3. Temporal trends of lipid normalized (age adjusted least square mean) concentrations of ΣCHLOR, *cis* and *trans-* nonachlor and toxaphene in Pangnirtung male beluga blubber samples.

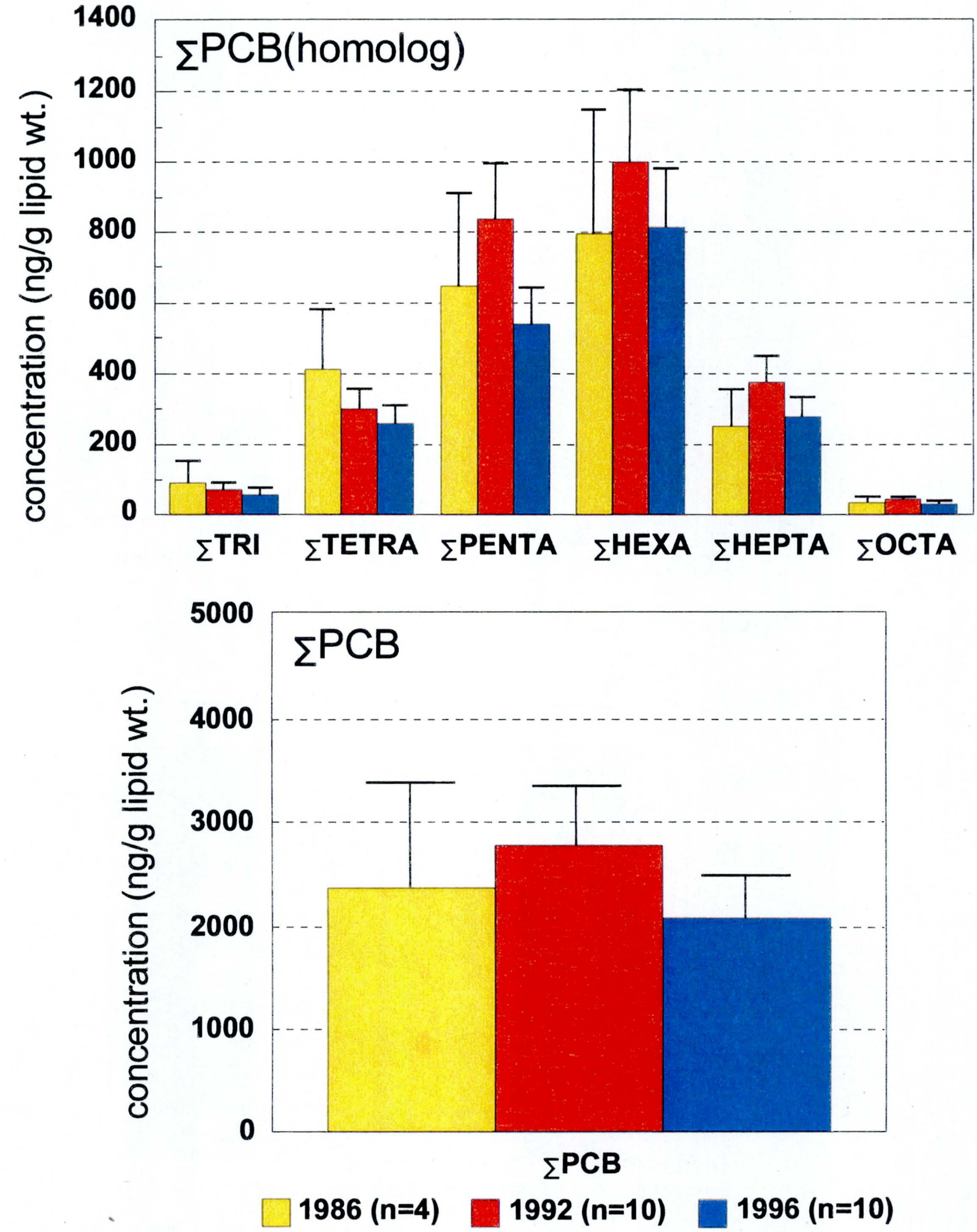

Figure 4. Temporal trends of lipid normalized (age adjusted least square mean) concentrations of ΣPCB and individual homologue groups in Pangnirtung female beluga blubber samples.

could be made. In female animals, much greater variability in age adjusted least square mean concentrations of OCs is observed (Figure 4). This variability, however, is not unexpected and can be ascribed to the differences in the reproductive history of the animals analysed (Stern *et al.* 1994) and to the small 1986 sample size (n = 4).

Chlorinated n-alkanes (C_{10}-C_{13})
Mean wet weight concentrations of ΣPCAs along with other major organochlorine contaminant groups in beluga blubber from male animals only, are listed in Table 3. Mean ΣPCA concentrations in the samples collected from Pangnirtung and Hendrickson Island were significantly higher (t-test, $p<0.05$) than those from Hudson Bay. The Sanikiliuaq (Belcher Island area in southern Hudson Bay) animals had levels significantly higher than those from Arviat (western Hudson Bay). Like ΣHCHs, ΣPCAs are present at levels at least one order of magnitude lower than other more recalcitrant organochlorine contaminant groups such as ΣPCB and ΣDDT. Mean ΣPCA concentrations in blubber from the St. Lawrence beluga ranged from about 1.3 to 4 times higher than the levels in the Arctic beluga. Published data show that the most abundant compounds in air and seawater (ΣHCH and HCB) are those with the lowest concentrations in Arctic marine biota from all trophic levels [Jensen *et al.* 1997]. These results suggest that the biomagnification of various organochlorines in the marine food web depend on physical properties such as Henry's Law constants (HLC) and water solubility, as well as the biological factors. Drouillard *et al.* (1997), based on direct measurements, have shown that short chain chlorinated n-alkanes have water solubilities and HLCs in the range of semi-volatile organics such as the HCH isomers. It is not surprising, therefore, that levels of short chain ΣPCAs are similar to those of ΣHCH which do not biomagnify from zooplankton to whales/seals [Jensen *et al.* 1997].

CONCLUSION AND UTILIZATION OF RESULTS

The availability of archived beluga blubber samples, combined with the fact that all the analysis (samples collected from animals over the 14-year period from 1982–1996) were analysed by the same analyst using the same methodology and instrumentation makes this study very unique. Significant declines were observed for the lower chlorinated PCB homologue groups (Cl_3-Cl_5) and HCHs in blubber from male beluga over the 14-year period from 1982–1996, while no significant changes were observed for the higher chlorinated homologues (Cl_6-Cl_9), ΣCHB (toxaphene) and ΣCHL. Due to significant age year interactions (age*year) and a substantial amount of variation in the least square mean concentrations, no conclusions could be made for ΣDDT and its components. In female animals, a large variation in the least square mean concentrations of all major OC contaminant groups was observed and is attributed to differences in the reproductive history of the animals and small sample sizes.

The presence of short chain PCAs in beluga blubber samples from animals located throughout the Canadian Arctic provides evidence for long-range atmospheric transport and the subsequent uptake of these compounds into remote marine food webs.

Future work will involve analysis for OCs and PCBs in beluga blubber samples from male animals collected in 1997 to augment the small (n = 6) 1996 sample size and additional analysis (1982–1997) for coplanar PCBs, dioxins and furans and other "new" chemicals in the Arctic such as chlorinated anisoles, brominated diphenyl ethers (BDPEs) and polychlorinated naphthalenes (PCNs).

Results of the work will be provided to Health Canada and have been presented at the Northern Contaminants Workshop held in Calgary Alberta, January 1998.

Project completion date: March 31, 1999

Partners: Nunavut Wildlife Management Board, Nunavut Settlement Area Hunters

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METHYLMERCURY AND HEAVY METALS IN TISSUES OF NARWHAL, BELUGA AND RINGED SEALS.

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Project Team: L. Lockhart, M. Kingsley, S. Innes, G. Boila (DFO); E. Trebacz (contractor)

OBJECTIVES

General:

1. to delineate the different kinds of mercury species making up the total burden of mercury in organs and tissues of Arctic marine mammals which are part of the traditional native diet, and

2. to assess these data in relation to consumer guidelines.

In the short term, we will analyse tissues of belugas, ringed seals and bearded seals for the different mercury species, and in the longer term we will extend this investigation to other species and tissues and the analysis of individual mercury species for temporal and spatial trends.

DESCRIPTION

Indications are, based on preliminary data, that the **total** Hg concentration in liver and brain tissue is not a good indicator of mercury's toxicity to animals or consumers of marine mammal tissues since most of the mercury may have been rendered inert by combination with selenium. The total mercury burden in the liver is made up of at least 4 different categories of mercury species including mercuric selenide (HgSe). Preliminary data indicate that most of the inorganic mercury in the liver is in this form and comprises a substantial fraction of the total mercury. Aside from methylmercury, other forms of organic mercury (probably toxic) are also indicated. Mercury species differentiation in tissues of marine mammals has been identified as a knowledge gap in previous workshops (November, 1996 "Ideas Workshop"; Yellowknife, November 26-28, 1996, INAC 1997). There has been little work done to date on speciation of mercury in biota. Improved consumption quotas for animal tissues and assessment of "effects" will require knowledge of the different mercury species and their toxicities and concentrations. These preliminary findings require confirmation with statistically significant sample sizes. The findings from this investigation will influence the approach to the setting of consumption guidelines in the future if it is confirmed that much of the total mercury is in the form of HgSe.

ACTIVITIES IN 1997/98

While much of the mercury species data are lacking, the data base for *total* mercury and total cadmium in ringed seals and belugas produced under the Northern Contaminants Program is now quite extensive and has been documented and published annually under the Northern Contaminants Program Reports (Wagemann 1992; 1993, 1994, 1995), in Journals (Wagemann *et al.* 1993, 1994, 1995, 1996), presented at Workshops (April, 1995, Shetland Islands; June 1995, Inuvik; September, 1995, York University), and summarized in an overview paper in Sci. Total Environ, 1996. Methylmercury data have been produced to date for marine mammals from the across the Arctic (Wagemann 1994, 1998), some of which have been forwarded to Health and Welfare Canada for evaluation. The proposed mercury speciation work will include some additional methylmercury determinations in tissues of ringed seals. Spatial and temporal trends for total mercury in tissues of some Arctic marine mammals have been documented and published (Wagemann *et al.* 1996). Data for metals for walrus in Canadian Arctic waters are very limited, consisting of a group of animals from one location in the eastern sub-Arctic.

SAMPLES

The program outlined was carried out in fiscal 1997/98, in cooperation with project participants. It involved the analysis of liver samples from 45 ringed seals (*Phoca hispida*) (20 from the west coast of Victoria Island in the western Canadian Arctic, and 25 from the west coast of Hudson Bay in the eastern Canadian Arctic) already in hand for mercury species analysis (protein-bound inorganic mercury, insoluble inorganic mercury (HgSe), methylmercury and organic mercury). Liver of ringed seals is a preferred dietary supplement for vitamins and minerals. Tissues were excised with a clean stainless steel knife, placed in acid-cleaned polyethylene sample bags, frozen in the field and shipped frozen to the Freshwater Institute, Winnipeg, where they were kept frozen at −35°C until analysed. Prior to analysis samples were thawed just sufficient to be cut. An analytical sample was then excised from the interior of the bulk sample, cut into smaller pieces, weighed into a test tube and homogenized and extracted or digested as required in preparation for the various analyses.

METHODS

Total Mercury

A quantity of tissue (ca 0.2 g) was digested with a mixture of nitric and sulfuric acids (1:4 v/v) for 2 hours at 90°C, cooled, potassium permanganate (15 mL, 6% aqueous) was added and the digest was allowed to stand overnight. The solution was clarified by the dropwise addition of hydrogen peroxide while vortexing, made up to volume. total mercury was determined by cold-vapour atomic absorption spectroscopy (CVAAS), using the air-segmented, flow-injection method (Armstrong and Uthe 1971). A TM 3200 (TSP Thermo Separation Products) mercury monitor was used. Data were recorded with a "Chrom Jet Integrator" (TSP Thermo Separation Products). Aqueous working standards (1-10 µg/L) were prepared daily from a "Baker instra-analysed" 1000 µg/ml Hg stock solution. The detection limit for Hg by the CVAAS method under the operating conditions employed was 5 ng/g wet weight.

Organic Mercury

The release of MeHg and other organic forms mercury from the tissues was achieved by the commonly used procedure of Uthe *et al.* (1972). Approximately 1 g of wet tissue was homogenized with an aqueous solution of acidic sodium bromide (5 mL of 30% in 4 N H_2SO_4) and cupric sulfate (7.5 mL of 2.5% in 4 N H_2SO_4). MeHg and other forms of organic mercury were then extracted by vortexing the tissue homogenate with a 3:2 v/v mixture of DMC (dichloromethane)-hexane (5-10 mL) followed by centrifugation to separate the organic layer from the solids and aqueous layer. The density of the DMC-hexane mixture was such that the organic layer separated uppermost. An aliquot (1 mL) of the organic phase was withdrawn, added to a test tube containing 5 mL of HNO_3/H_2SO_4 mixture (1:4 v/v) and heated for 30 minutes at 60°C. The organic solvent mixture evaporated without detectable loss of MeHg. The remaining aqueous phase was digested and analysed as for total mercury. The detection limit for organic mercury by this method was 10 ng/g of tissue (wet weight).

Organic Mercury other than Methylmercury

Organic mercury as such included methylmercury. From this experimentally determined quantity methylmercury was subtracted to obtain the quantity called "organic mercury other than methylmercury".

Inorganic Mercury

As described under "Organic Mercury" the simultaneous extraction of liver tissue with aqueous and organic solvents produced three distinct layers after centrifugation: an upper organic layer, an aqueous middle layer and a solids (pellet) bottom layer. The mercury remaining in the aqueous layer after removal of the organic layer was considered to contain only inorganic mercury. A 0.5 mL aliquot of the aqueous layer was withdrawn, digested and analysed for mercury as described under "Total Mercury".

Methylmercury

The acidic sodium bromide and cupric sulfate tissue homogenate was extracted with DMC-hexane, and separated as described under "Organic Mercury". A fraction of the organic layer was withdrawn (2 mL) and extracted with (3-4 mL) aqueous thiosulfate (0.005 N aq. $Na_2S_2O_3$) by vortexing for 1 minute and centrifuging. To the separated thiosulfate solution (1-2 mL), KI (0.5 mL, 3 M aqueous) was added and this solution was then back-extracted (vortexed for 1 minute) with toluene (1.5-3.0 mL). The toluene was separated by centrifuging for 2 minutes at 2500 rpm. The toluene extract was dried over anhydrous sodium sulfate and injected (1 mL) into the GC column for MeHg analysis.

A Varian model 3400 gas chromatograph with a ^{63}Ni electron capture detector (ECD), temperature programmable injector (SPI), and a 5 m, SPB-5 mega-bore column (0.53 mm ID) with a bonded film (5 µm) of polysiloxane (94% dimethyl, 5% diphenyl, 1% vinyl) was used. The carrier gas was helium (12 mL/minute), the make-up gas nitrogen (28 mL/minute). The temperature of the column and injector was maintained at 50°C for 1 minute, programmed to increase to 240°C (at 20°C / minute), and maintained at this temperature for 15 minutes before the cycle was repeated. The detector was maintained at 300°C at all times.

Working MeHg standards (5-100 ng/mL Hg in toluene) for GC analysis were prepared daily from a toluene/MeHg stock solution (1 µg/mL Hg). Within the concentration range of these working standards, the ECD response was linear. The absolute detection limit for CH_3HgCl by GC-ECD was 2 pg (based on 3 x sd of blank analyses), or 10-80 ng/g Hg wet weight (depending on dilution factor) in terms of the procedure used.

Total Selenium

Essentially the semi-automatic borohydride method of Vijan and Wood (1976) was used. Tissue samples were digested with nitric, perchloric and sulfuric acids (4:1:0.5 v/v), and the resulting digest was diluted with hydrochloric acid and water to 30% hydrochloric acid. The diluted digest and reductant (2% borohydride solution) were combined at flow rates of 4 and 1 mL/ minute respectively, using a Technicon pump, Model III, coupled to a Varian programmable Model 55 sampler. The hydride was decomposed in a heated quartz tube and the selenium was analysed at a wavelength of 196.1 nm using a Varian Spectra AA-20 Atomic Absorption Spectrometer.

Mercuric Selenide (HgSe) in Liver Tissue

Because of the insoluble nature of mercuric selenide this compound if present would remain in the tissue pellet after the tissue was extracted with the aqueous acidic bromide and cupric sulfate solution and the organic solvent mixture. Approximately 0.1 g of the pellet was digested and analysed for elemental mercury as described under "Total Mercury". Approximately, 0.2 g of the tissue pellet was digested and analysed for selenium as described under "Total Selenium Determination". To minimize interference from copper in the pellet in the analysis of selenium the final digest was diluted 10 times before analysis. The very low solubility of mercuric selenide in acidic aqueous solution and in organic solvents is well known (CRC Hand Book 1982-1983, Smith and Martell 1976, Wagemann *et al.* 1997). Because of the known presence of mercuric selenide in liver tissue of marine mammals (Martoja and Berry 1980, Nigro 1994), the 1:1 stoichiometric relationship between mercury and selenium in liver tissue of marine mammals (Koeman *et al.* 1973, Itano *et al.* 1984, Wagemann *et al.* 1990, Leonzio *et al.* 1992) and the low solubility of mercuric selenide, the remaining mercury in the pellet after the tissue was extracted with aqueous and organic solvents was assumed to originate from mercuric selenide.

Quality Assurance

Marine mammal liver tissue with relatively high organic mercury and MeHg content was used to test recovery and successive extraction efficiencies of MeHg. On average the extraction efficiencies (recoveries) with one extraction were 90 and 92% for organic and MeHg, respectively, as previously reported (Wagemann *et al.* 1997). Tests for accuracy of MeHg determinations using certified reference materials (Dorm-1 and Dorm-2, NRC, Ottawa), standard MeHg solutions, and spiked liver samples were generally within the error range of the certificate values, the standard solution value or the spiked value. The precision, $\pm$ xx % was obtained from five repeat injections, some on different days.

RESULTS

This report summarizes the results of surveys of mercury species in the liver of 45 ringed seals from the Canadian Arctic. Four types of mercury species namely, methylmercury, organic mercury other than methylmercury, inorganic mercury and insoluble mercury associated with the pellet, were found in the liver. On average, methylmercury, at 2%, made up the smallest fraction of the total mercury in the liver of these of animals, although the form of mercury consumed by them is mostly methylmercury, predominantly from muscle tissue of fish. Most of the mercury, 53%, was insoluble mercury, considered to be largely mercuric selenide (HgSe). In the past, other workers also found this compound to be present in mammalian liver and definitively identified it to be that. Organic mercury other than methylmercury made up 4%, and inorganic mercury 42% of the total mercury in the liver. Since the variables in question were significantly correlated in our sample, these average percentages were obtained by regression analysis. Mercuric species represent a range of toxicities to animals. Mercuric selenide appears to be one of the final stable, inert end-products of the demethylation of methylmercury with the least toxicity, if any. HgSe is known to be relatively inert and not readily eliminated from the liver. Thus, only approximately half of the total mercury in the liver was potentially toxic. All four mercury species were positively correlated with the age of animals, the regression slope on age being 20 times larger for insoluble Hg (HgSe) than for MeHg which is readily explained by the temporal accumulation of HgSe in the liver. A number of other reported observations such as the long half-life of Hg in liver ($\geq$10 years), the dependence of Hg on age, and the often-observed regression slope of 1 (on a molar basis) of mercury on selenium are in accord with the presence of HgSe in the liver.

The sum of the independently determined mercury species agreed well with the total mercury concentration in the liver.

Linear regression of total selenium on total mercury in liver of ringed seals was significant and gave, in terms of g-atom concentrations, a regression slope of approximately, indicating that the two elements are stoichiometrically associated in this tissue in a 1:1 ratio as they are in HgSe.

The differentiation of mercury into species will provide a more accurate assessment of the health risk to animals and humans from the consumption of contaminated animal tissues, and underscore the inadequacy of total mercury concentrations as an indicator of toxicity to animals.

DISCUSSION/CONCLUSIONS

Mostly MeHg is taken up by marine mammals, predominantly from muscle tissue of fish (muscle tissue makes up most of the mass of the fish), but only a small fraction of the total mercury in the liver was MeHg. The results presented here and those of others (Palmisano *et al.* 1995, Dietz *et al.* 1990) show that the mean MeHg concentration in liver of marine mammals is usually not much higher than in muscle, seldom exceeding 2.0 µg/g, representing only a small fraction of the total Hg in the liver, despite the fact that the total mercury concentration in the liver is several factors higher than in muscle. This is in contrast to muscle and skin where the percentage of MeHg to total mercury is generally 90–100%. Demethylation in the liver leads, we hypothesize, to the formation of inorganic mercury (Hg^{++}) and finally the detoxification of the latter by reaction with selenium to form mercuric selenide (HgSe). Although the mercury species were identified here only operationally, HgSe has been definitively identified as such in the liver of marine mammals and humans by other investigators (Martoja and Berry 1980, Hansen *et al.* 1989, Pelletier 1985, Nigro 1994). This compound (HgSe) consists of amorphous, highly insoluble, small, inert particles located mainly within the liver macrophages. We have found, as have others (Koeman *et al.* 1973, Nielsen *et al.* 1990, Skaare *et al.* 1994, Wagemann and Stewart 1994), that total selenium and total mercury in the liver were significantly, positively correlated with a regression slope of approximately 1, in terms of g-atom concentrations, indicating that these two elements are associated in a ratio of 1:1 as they are in HgSe.

Based on the relatively low fraction of MeHg in the liver, not withstanding the fact that the predominant form of mercury taken up via food is MeHg, and the relatively high concentration of an insoluble form of mercury, it is postulated that the formation and deposition of mercuric selenide (HgSe) in the liver is part of the demethylation process of methylmercury in this tissue. Additionally, the long half-life of total mercury in the liver (10 years in humans, Friberg *et al.* 1979), the positive, high correlation between total mercury and age of animals (Wagemann *et al.* 1996), the strong, positive correlation between mercury and selenium with a regression slope of approximately 1, and the relatively short half-life of MeHg (20–500 days in ringed seals, Tillander *et al.* 1972) are consistent with the progressive accumulation in the liver of mercuric selenide (HgSe) with age, and the formation and deposition of HgSe in the liver. The process of the demethylation of MeHg and transformation of the released mercury into an inert compound such as HgSe, appears to be a strategy adopted by the animals to counteract the potentially damaging action of MeHg.

Differences in toxicity between organic and inorganic mercury compounds and the transferability of some mercury species from mother to foetus (Julshamn *et al.* 1987, Wagemann *et al.* 1988, Smith and Smith 1975) make it importance to determine mercury species in tissues used as food sources. Determination of the various mercury species such as MeHg and HgSe and not just total mercury will allow a more accurate assessment of the health risk to animals and to humans from the consumption of contaminated animal tissues. In view of concerns expressed by Native people about the toxicity of mercury in animal organs, this work lays the basis for the promulgation of more realistic consumption guidelines.

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Northern Contaminants Workshop, June 12–14, 1995, Inuvik. The purpose of this workshop was to make direct presentation of findings to the Native community, followed by round-table discussion to hear concerns of Native people, obtain their input and cooperation on future research, and answer any questions pertaining to contaminants.

Wagemann, R. 1995. Status and trends of metal contaminants in marine mammals of the Canadian Arctic. NAMCO conference on marine mammals and the marine environment. April, 20-21, Lerwick, Shetland, Isle. UK. The focus of the conference was to explore effects of pollutants on marine mammals and the marine environment, and to contribute through regional cooperation of current signatories to the NAMCO Agreement to research, conservation and management of whales, seals and walrus in the North Atlantic.

Wagemann, R. 1995. Mercury levels in marine mammals with particular reference to spatial and temporal trends. Canadian Mercury Network Symposium (September 29-30, 1995, York University, Toronto. The objective of the workshop was to identify the information base that is required by those charged with the responsibility of resource management and policy development in Canada and to establish a link between science and management procedures. Policy issues identified and discussed were : 1) The relative contribution to the mercury pool of anthropogenic vs. Natural sources, 2) The effects of anthropogenic loading and the definition of "critical loads", 3) The identification of groups at risk and the rationale for the 0.5 ppm consumption limit.

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CONTAMINANTS IN ARCTIC SEADUCKS

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OBJECTIVES

1. to examine heavy metal levels in eider tissues at different localities in the Arctic and to assess whether geographic variation occurs in levels of these contaminants and whether there are sub-lethal health effects in the birds associated with exposure to these contaminants.

2. to determine whether these contaminants may pose a risk to people who eat them, to pinpoint areas where the risk (if any) may be highest, to postulate potential sources of these contaminants and to assess whether these they may be contributing to the apparent population declines in these species.

DESCRIPTION

It is believed that for duck species in the Arctic, contaminants exposure occurs mainly during the winter in non-Arctic environments (Henny *et al.* 1991). Trace elements, including mercury, cadmium and selenium in the livers and kidneys of certain sea duck species from Alaska are quite high and, depending on their relative importance in a consumer's overall diet, may pose a risk to people who eat these tissues (Henny *et al.* 1995). For example liver mercury in seaducks from Alaska often exceeds 2 $\mu g \cdot g^{-1}$ dry weight (dry wt.) while cadmium and selenium often exceed 20 ppm. For mercury, consumption of as little as 46 g of liver containing 2 $\mu g \cdot g^{-1}$ dry wt. (@ 0.6 $\mu g \cdot g^{-1}$ wet wt.) would equal the Tolerable Daily Intake of mercury for a 60 kg person. In the case of cadmium, a 60 kg person's TDI would be met by consuming only 10 g of tissue containing Cd at 20 $\mu g \cdot g^{-1}$ dry wt. These contaminants are quite low in breast muscle of eiders from the Canadian Arctic (B. Braune, *pers. comm.*); however they do not normally concentrate in breast muscle. Rather they occur in their highest concentrations in liver and kidney, organs that are eaten by residents of several Arctic communities. Concentrations of these contaminants in liver and kidney of sea ducks in the Canadian Arctic are not known. There is also some concern for the health of the ducks with high levels of these contaminants, particularly whether the apparent population declines these species have been experiencing (Turner *et al.* 1996) may be attributable to high levels of trace element contamination.

In the western Arctic, approximately 20,000 king eiders and 2500 common eiders are harvested annually (Turner *et al.* 1996). In the Inuvialuit Settlement Region, 2000 – 5000 eiders are harvested each year (Fabijan *et al.* 1997). In the eastern Arctic, it is estimated that approximately 14,000 eiders are harvested per year with the communities of Pangnirtung, Cape Dorset, Iqaluit and Lake Harbour harvesting the bulk of the birds (Turner *et al.* 1996). It is likely that some families in these communities are eating many eider meals each year. These meals include liver and kidneys, organs where mercury, cadmium and selenium accumulate.

Population declines in arctic eiders have been documented. The number of king and Pacific common eiders migrating past Point Barrow, Alaska during spring migration apparently declined by more than 50% between 1976 and 1994 (Turner *et al.* 1996, Suydam *et al.* 1997) Some researchers have estimated declines in these species of up to 75% (summarized by Turner *et al.* 1996). Recent information from the Rasmussen Basin indicating that king eider populations have declined by around 75% (Cheri Gratto-Trevor, CWS, *pers. comm.*) supports the above estimates. In the eastern Arctic, the population status of king and common eiders is unknown, although it is possible that the king eiders from the Rasmussen Basin referred to above are of eastern Arctic origin. The problem of seaduck decline is not restricted to eiders. In Alaska, scoter populations declined 30% between 1957-93 (cited in Henny *et al.* 1995). In Canada, such estimates are unavailable. Declines of scoters in the western Pacific rim have also been alluded to by Goudie *et al.* (1994). The reasons for seaduck population declines are unclear. Overhunting, oil spills, increased nest predation, contaminants and nutritional or physiological factors have been cited as possible factors (Goudie *et al.* 1994, Environment Canada 1996, Turner *et al.* 1996). While overhunting is a major concern for king and common eiders, other factors are probably also important in regulating populations of these species (Turner *et al.* 1996).

Worldwide, there is growing suspicion that population declines or massive dieoffs of several species are related indirectly to pollution. The growing list includes several species of birds and marine mammals, for example striped dolphins from the Mediterranean Sea, bottlenose dolphins from the eastern seaboard of the USA, harbour seals from the North and Baltic Seas, bald eagles on the Great Lakes (Colborn *et al.* 1996). The central tenet of this study is that contaminants could be interacting with other physiological stressors in the environment to exert population level effects on eiders in the Canadian Arctic. Henny *et al.* (1995) have speculated that exposure of Alaskan seaducks to high levels of cadmium, selenium and mercury may be contributing to these declines. However, toxicological effects in seaducks exposed to high levels of heavy metals have not been documented.

Distinct populations of eiders are recognized in the Canadian Arctic. Western Arctic populations of king and common eiders winter in the Bering and Chukchi Seas while eastern Arctic eiders winter along the Atlantic coast and off the coast of Greenland while a subpopulation of common eiders winters in Hudson Bay. Contaminants exposure which is thought to occur primarily during winter may differ widely between these distinct populations.

This study is providing information about the geographic distribution of mercury, organic mercury, cadmium and selenium in livers and kidneys of eiders from different regions in the Canadian Arctic. The data complement similar data collected in the early 1990s on levels of these contaminants in breast muscles. It is also providing comparative information for two species of eiders harvested at the same locations and for three races (subpopulations) of common eiders. Finally, it is providing information about physiological condition and health status of these animals as they relate to contaminants exposure as a first step towards addressing the role of these contaminants in population declines in these species.

ACTIVITIES IN 1997/98

King and common eiders were collected at three locations in the Canadian Arctic during June and July, 1997. The locations were at Holman on Victoria Island, at East Bay on Southampton Island and in the Belcher Islands (Figure 1). Samples of liver and kidney were preserved for metals analysis. Morphometric, organ weight and body weight information also were collected so that a measure of body condition could be determined for each bird. At Holman and East Bay, subsamples of liver and kidney were preserved for histological examination. At East Bay, blood samples were collected from 12 common eiders for metals and hormone analyses. In addition, parasites of the gastrointestinal tract are being examined in birds collected from all locations by C. James at Guelph University.

All analyses of metals have been done at the National Wildlife Research Centre in Hull. Mercury and selenium analyses in liver and blood and cadmium analyses in kidney have been completed. Organic mercury analyses in liver have not been completed yet. Cadmium in blood will be done in July or August, 1998.

Morphometric and body and organ weight data were entered in a data base and will be examined in relation to metal concentrations in the birds.

Slides of liver and kidney have been prepared for histological examination. These examinations will be done during the summer and autumn of 1998. Hormone analyses are scheduled to be done during autumn 1998 after the collection of new samples in summer, 1998. Examination of gastrointestinal helminths is ongoing.

RESULTS

Fifty-three eider ducks were collected at the three locations. Hepatic mercury concentrations ranged from < 1 to 3 $\mu g \cdot g^{-1}$ dry wt. and Se concentrations from 7 to 60 $\mu g \cdot g^{-1}$. Renal cadmium concentrations ranged from 30 to 232 $\mu g \cdot g^{-1}$. Mean values are shown in Table 1. Mean concentrations of metals in king eiders were approximately equal to or higher than those in common eiders. In general, eiders from East Bay had higher concentrations of mercury and cadmium than their counterparts from the other sites while the opposite was true for selenium.

Concentrations of selenium and total mercury in 12 blood samples ranged from 1 to 6 and 0.2 to 0.4 $\mu g \cdot mL^{-1}$, respectively. Concentrations of selenium in blood were correlated with those in liver (r = 0.68, P = 0.02).

Table 1. Mean ± 1SE concentrations ($\mu g \cdot g^{-1}$ dry wt.) of total and organic mercury and selenium in liver and cadmium in kidney of common and king eiders at three Arctic locations.

Location	Species	Total Hg	Org. Hg	Se	Cd
Holman	King eider (n=10)	1.71 ± 0.14	—	37.4 ± 3.9	125.3 ± 18.7
	Common eider (n=10)	1.50 ± 0.11	—	31.1 ± 3.8	121.4 ± 10.3
East Bay	King eider (n=10)	2.80 ± 0.30	2.40 ± 0.30 (n=7)	20.2 ± 2.3	165.3 ± 11.5
	Common eider (n=13)	1.72 ± 0.19	1.20 ± 0.10 (n=2)	20.6 ± 2.0	70.6 ± 5.6
Belchers	Common eider (n=10)	1.46 ± 0.25	—	10.4 ± 0.8	91.6 ± 20.1

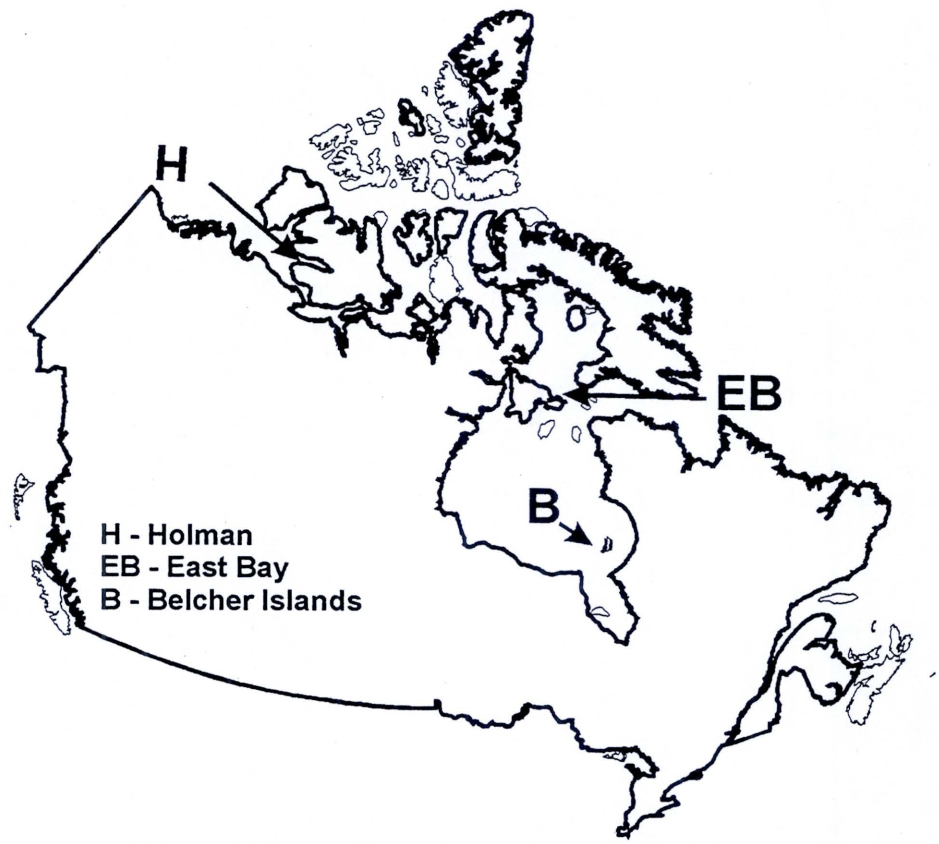

Figure 1. Map showing locations eider collections.

However, such was not the case for total mercury (r = 0.44, P = 0.15). The correlation between blood and renal cadmium will be done when cadmium analysis in blood is completed.

DISCUSSION

Hepatic mercury concentrations reported in this study are similar to those reported in seaducks from the west coast of Alaska (Henny *et al.* 1995) but were much lower than those in seaducks from the California coast (Ohlendorf *et al.* 1986, Hoffman *et al.* 1998). Selenium concentrations in eiders in this study were slightly lower than those in seaducks from Alaska and some areas of California (Henny *et al.* 1995, Hoffman *et al.* 1998) but were similar to those in seaducks from San Francisco Bay (Ohlendorf *et al.* 1986). However, Cd concentrations, were higher , especially in king eiders from East Bay. Cd concentrations reported in East Bay king eiders are among the highest reported in seaducks from several locations (Frank 1986, Ohlendorf *et al.* 1986, Hontelez *et al.* 1992, Henny *et al.* 1995).

The high concentrations of Cd in East Bay king eiders need to be further investigated by examining more samples and by identifying the geographic source of this contamination. In addition, efforts will be made to determine whether there are any discernible effects of these metals on the health of these species. Intensive investigations have begun examining the health of colonial-nesting common eiders at East Bay. After field protocols have been properly developed, an attempt will be made to use the same techniques to investigate the health of king eiders, a more sparsely-distributed species during the nesting period.

Expected Project Completion Date: For funding received in 1997/98, the project should be completed by May, 1999. For related funding, received in 1998/99, the project should be completed by May 2000.

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III HUMAN HEALTH

ENDOCRINE DISRUPTING EFFECTS OF COMPLEX ORGANOCHLORINE MIXTURES FOUND IN THE ARCTIC

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Project Team: É. Dewailly, S. Giroux, Québec Public Health Centre, CHUQ Research Centre (CHUL Pavilion); J.-P. Weber, Québec Toxicology Centre

OBJECTIVES

1. to develop and validate *in vitro* tests for measuring the endocrine disrupting potential of complex organochlorine mixtures found in the arctic environment and in humans.

2. to provide integrated measures of endocrine disrupter concentrations in plasma samples of women and infants participating in the Infant Developmental Study presently ongoing in Nunavik.

DESCRIPTION

The development and maintenance of reproductive tissues is to a large extent controlled by steroid hormones. Some environmental chemicals mimic, while others antagonize natural hormone activity when tested with *in vitro* assays or in whole animal models. Studies dating back to the late sixties identified 1-[2-chlorophenyl]-1-[4-chlorophenyl]-2,2,2-trichloroethane (*o,p'*-DDT), a minor constituent of technical DDT, as a weak estrogenic compound capable of causing an augmentation of rat uterine weight in the classic immature female rat model (Bitman *et al.* 1969). This compound and a few others sharing estrogenic properties have been implicated in abnormal sexual development in reptiles (Guillette Jr. *et al.* 1994, Guillette Jr. *et al.* 1995) and birds (Fry 1981) as well as feminized responses in male fish (Jobling *et al.* 1995).

Certain male reproductive tract disorders (cryptorchidism, hypospadias, testicular cancer) have been reported to be increasing in parallel with the introduction of xenoestrogens such as DDT into the environment. Furthermore, a decrease of semen quality was also reported in certain regions of the world during the last half of the century (Carlsen *et al.* 1992, Auger *et al.* 1995). Although these alterations are thought to be mediated by the estrogen receptor, they are also consistent with inhibition of androgen receptor-mediated events. Kelce and coworkers (1995) identified the major and persistent DDT metabolite, 1,1-*bis*[4-chlorophenyl]-2,2-dichloroethylene (*p,p'*-DDE), as a potent anti-androgenic agent in male rats. In addition to inhibiting androgen binding to the androgen receptor, this compound when administered to pregnant dams also induced characteristic antiandrogenic effects in male pups (reduced anogenital distance; presence of thoracic nipples). Treatment with *p,p'*-DDE at weaning delayed the onset of puberty, while treatment of adult rats resulted in reduced seminal vesicle and ventral prostate weights.

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is yet another organochlorine which has been shown to alter sexual development in male rats (Mably *et al.* 1992). Decreases in epididymis and cauda epididymis weights, daily sperm production and cauda epididymal sperm number were observed at day 120 and at most earlier times, when a dose as little as 64 ng/kg was administered to dams on day 15 of gestation. A number of compounds structurally related to TCDD, including other 2,3,7,8- chloro- substituted dibenzo-*p*-dioxins, dibenzofurans, as well as non ortho and mono ortho substituted polychlorinated biphenyl (PCB) congeners, bind to the Ah receptor and display similar toxicological properties, albeit with varying potency (Safe 1990). Results of the cancer bioassay conducted by Kociba and co-workers (1978) showed that TCDD possesses anti-estrogenic properties, as revealed by the striking decrease in the incidence of mammary tumors observed in females rats treated over two years with daily doses of 10 ng/kg body weight. Moore and co-workers (1997) recently produced data suggesting that hydroxy metabolites of several PCB congeners also possess anti-estrogenic properties, using two estrogen responsive *in vitro* bioassays.

Typical organochlorine mixtures found in highly exposed human populations such as the Inuit from Nunavik contain a large variety of organochlorine compounds, including substances with estrogenic, anti-estrogenic or anti-androgenic capacities. One may therefore anticipate that complex real life mixtures, composed of numerous compounds which can interact with different receptors involved in cell differentiation and growth, could generate disproportionate biological stimuli.

The proposed study aims at investigating complex organochlorine mixtures found in highly-exposed human populations, using *in vitro* assays designed to measure the activation or inhibition of estrogen, androgen and AH receptors. After the initial phase of development and validation, these assay systems will be used to analyse plasma samples collected during the course of various exposure surveys in Nunavik and epidemiological studies (breast cancer, endometriosis, male fertility), in order to obtain integrated biomarkers of exposure to estrogenic, anti-androgenic and dioxin-like compounds.

ACTIVITIES IN 1997/98

In order to establish our *in vitro* transcription assays, we obtained from different laboratories the expression vector for the four receptors under study as well as plasmids containing the responsive elements linked to the luciferase gene. These plasmids were amplified in E. coli and carefully purified to yield clean transfections. Three different cell lines are currently being used and conditions for transfections have been optimized for each one. Cell lysates are prepared with an efficient triton lysis buffer compatible with the luciferase assay. The enzymatic activity of luciferase is measured by adding ATP and luciferin and the light emitted is measured with a Minilumat LB9506 EG&G Berthold.

To assess the dioxin-like potency of xenobiotics (AH receptor agonists), the HepG2 cell line, a human hepatoma expressing a functional AH receptor, is transiently transfected with a reporter plasmid expressing the luciferase gene under the control of a promoter containing the dioxin-responsive element. In order to quantify estrogenic potency, the MCF7 cell line, a human breast cell line expressing a functional estrogen receptor, is transiently transfected with a reporter plasmid expressing the luciferase gene, under the control of a promoter containing the estrogen responsive element. To assess the activity via the androgenic receptor, the HeLa cell line, a human cervix carcinoma cell line not expressing the receptor, is transiently transfected with an androgen receptor expression vector and a reporter plasmid expressing the luciferase gene, under the control of MMTV (mouse mammary tumor virus) promoter containing the androgen responsive element. Finally, quantification of retinoic acid like activity will be effected using the HeLa cell line transfected with different receptor genes; the RARα, RARβ, RARγ and RXRα. Each RAR subunit can heterodimerize with RXRα to give a functional receptor; the receptor-retinoic acid complex interacts with its responsive element which is linked to a luciferase gene on our reporter plasmid. This system is still under development.

Preliminary experiments were conducted to measure the endocrine disrupting capacity of organochlorine mixtures extracted from four pooled samples, each made up of individual plasma samples collected in 1992 from fish eaters from the Lower-North-Shore of the Gulf of St. Lawrence. Individual samples were selected on the basis of their concentration of *p,p'*-DDE previously determined (Dewailly *et al.* 1992) in order to constitute "high organochlorine" and "low organochlorine" pooled samples for both men and women. A 10-ml aliquot of these pooled samples was extracted with an ether hexane mixture and the resulting extract purified on Florisil columns. An aliquot of the fraction eluted with hexane was analysed using dual capillary column gas chromatography with electron capture detector, while the rest of the extract was taken up in DMSO. Plasma extracts dissolved in DMSO were placed in the incubation milieu together with the transfected cells, the final DMSO concentration not exceeding 0.1%.

RESULTS

Figure 1 illustrates a dose-response curve obtained when increasing concentrations of 2,3,7,8-TCDD, the most potent substance of the dioxin family, are placed in the incubation milieu, in the presence of HepG2 cells transiently transfected with the dioxin-responsive elements coupled with the luciferase gene. Because day-to-day variability was important with all systems, results are presented in percent of the maximum fold induction obtained on the day of the experiment. Fold-induction is the ratio of the luminescence induced by the test sample over that of the blank. The lowest concentration producing a statistically significant increase of luminescence over that of the blank sample was 10 pM, with a mean value of 3.8 % of the maximum response (95%-CI = 2.8-4.7); compared to 1.7 % of the maximum response (95%-CI = 0.9-2.6) for the blank.

Figure 2 displays the dose-response curve obtained when introducing increasing concentrations of estradiol in the incubation milieu, in the presence of MCF-7 cells transiently transfected with the estrogen response elements coupled with the luciferase gene. Also shown are the dose-response curves corresponding to different DDT analogues that were obtained in the same estrogen system. The lowest concentration of estradiol tested, 0.01 nM, produced a statistically significant increase of luminescence over that of the blank sample, with a mean value of 20.1 % of the maximum response (95%-CI = 16.2-24.1); compared to 8.2 % of the maximum response (95%-CI = 4.0-12.4) for the blank. The weakly estrogenic compound *o,p'*-DDT was at least 1000-fold less potent than estradiol, while displaying the same efficacy (ability

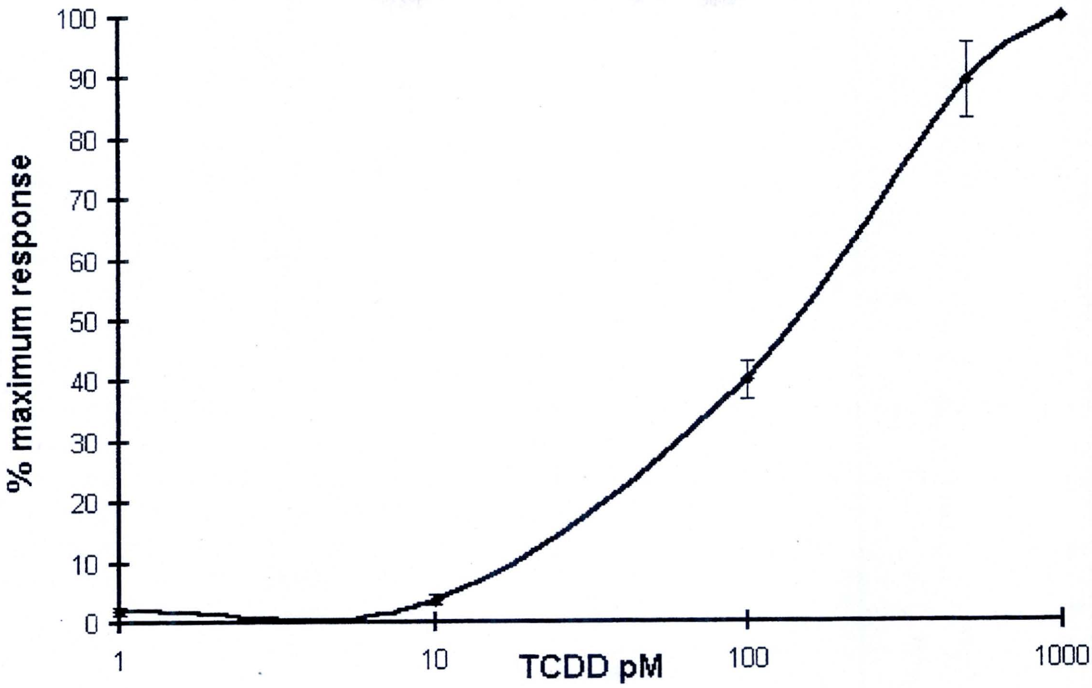

Figure 1. Dose-response curve obtained when adding increasing concentration of 2,3,7,8-TCDD in the incubation medium with transiently transfected HepG2 cells (dioxin system) Each point represents the mean 95%-CI for 3 to 5 experiments of three replicates.

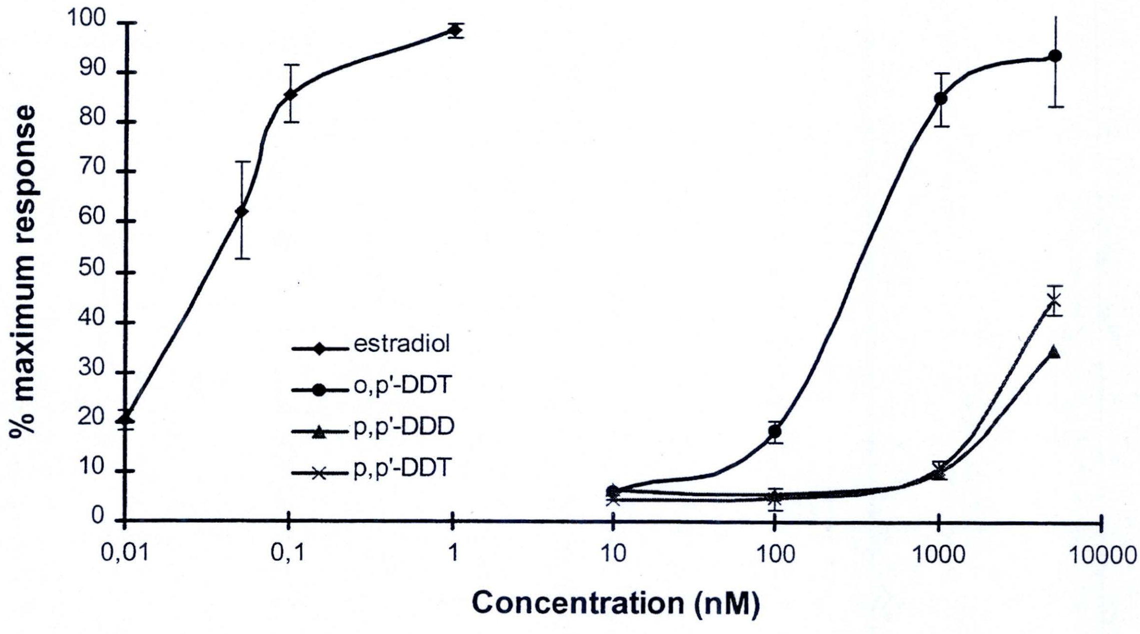

Figure 2. Dose response curves obtained when placing increasing concentrations of DDT analogues in the incubation milieu in the estrogen system. Each point represents the mean ± SEM for 3 to 5 experiments of three replicates.

Table 1. Concentration of selected organochlorines in pooled plasma samples (µg/L) from adult fishermen living on the Lower-North-Shore of the Gulf of St.Lawrence.

Pooled plasma sample	ΣPCBs[a]	*p,p'*-DDE	β-HCH	Hexachloro-benzene	Oxychlor dane	*Trans-* nonachlor
Men/High	57	15.0	0.20	0.63	0.50	0.62
Men/Low	15	2.3	0.07	0.23	0.18	0.26
Women/High	44	14.0	0.13	0.52	0.31	0.42
Women/Low	13	2.3	0.08	0.27	0.14	0.17
Control plasma	0.22	0.12	ND	0.02	ND	ND

[a] ΣPCBs = Total PCB concentration expressed as Aroclor 1260, calculated by multiplying the sum of congener 138 and congener 1153 concentrations by 5.2

to trigger the maximum response) as the natural estrogen. The other two DDT analogues tested showed a lower efficacy than estradiol or *o,p'*-DDT, the 5 µm being the maximum concentration tested.

Figure 3 presents the inducing effect of dihydrotestosterone (DHT) in the androgen system, consisting of HeLa cells transiently transfected with the human androgen receptor gene and the androgen response elements coupled with the luciferase gene. The maximum response was induced by 1 nM DHT, while 0.1 nM DHT produced an induction corresponding to 23.7% of the maximal induction. The latter concentration was the lowest to induce a statistically significant increase of luminescence over the bank (0.1 nM DHT: $\bar{x}$ = 23.7%; 95%-CI = 22.0-25.4; blank: $\bar{x}$ = 8.0%; 95%-CI = 1.6-14.5). The 0.1 nM concentration was used to test the antagonistic properties of *p,p'*-DDE. Concentrations of 100, 200, 500 and 1000 nM lowered the induction of 0.1 nM DHT by 15%, 30%, 52% and 55%, respectively. The lowest concentration of *p,p'*-DDE giving rise to a significant inhibition was 200 nM.

A preliminary experiment was conducted to evaluate the capacity of an organochlorine mixture found in human plasma extracts to induce (or inhibit) an estrogenic, an androgenic or a dioxin-like response. "High organochlorine" and a "low organochlorine" pooled samples were constituted for men and women. Results of OC analysis for these pooled samples are presented in Table 1. Mean plasma *p,p'*-DDE concentrations were 6-7 fold higher in the "high organochlorine" samples than in the "low organochlorine" samples. Smaller ratios were noted for the other OCs (2-4 fold).

Results of the preliminary tests with the estrogen system are presented in Figure 4. The left part of the figure presents the dose/response relationship obtained with increasing doses of estradiol. None of the samples tested (final concentration in the incubation medium equal to 1/10 of the plasma concentration) had any significant inducing effect in this system. Plasma extracts ("high organochlorine samples") in the presence of 0.1 nM estradiol caused a slight inhibition of E_2-induced response. Additional experiments were conducted to further substantiate this observation, using a final concentration in the incubation milieu equal to that in the pooled plasma samples. This time, no inhibition of estradiol response was noted. No activity was noted, whether agonistic or antagonistic, in the dioxin system or the androgen system (data not shown).

DISCUSSION/CONCLUSIONS

During the first year of this project, cell systems were constructed to measure the agonistic and antagonistic properties of xenobiotics and their complex mixtures. Results obtained during the validation phase with pure substances indicate that these cell systems perform similarly to those previously described in the literature. In particular, the dose-response curve obtained with the dioxin system is similar to those obtained using other systems designed for this purpose (Garrison *et al.* 1996). The EC_{50} was 0.16 nM with our assay, compared to 0.02-0.35 with other systems. The detection limit was approximately 10 pM, when this limit was defined as the lowest concentration producing a response significantly greater than the blank (no overlap between the 95-% confidence intervals on the means). Garrison and colleagues (1996) reported a minimal detection limit (MDL) between 0.1 and 1 pM, but their definition of the MDL was not provided.

Using the cell system for estrogenic compounds, the 10 pM estradiol concentration elicited a low but measurable response over the blank, while a near maximal response was obtained with 100 pM estradiol. Similar results were obtained by Klotz and colleagues using MCF-7 cells transiently transfected with the estrogen responsive element coupled to the luciferase gene (Klotz *et al.* 1996). However, our results differed markedly with regard to the potency and efficacy of DDT analogues. While Klotz and colleagues noted similar potencies and efficacies for *o,p'*-DDT and *p,p'*-DDD, both inducing the maximum response, only *o,p'*-DDT was a full agonist in our system. *p,p'*-DDD at a 5-µM concentration in the

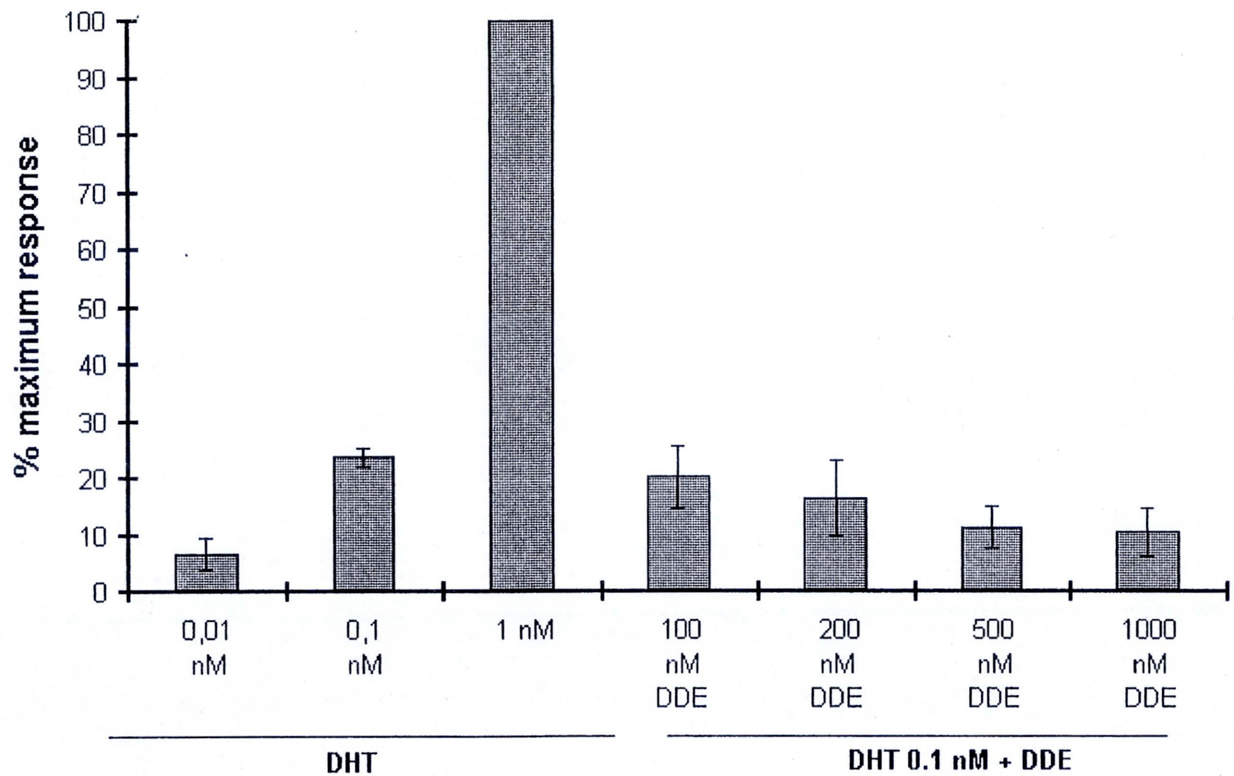

Figure 3. Luminescence induced by increasing concentrations of dihydrotestosterone (DHT) in the androgen system and antagonistic effects of *p,p'*-DDE. Each bar represents the mean 95%CI for 4-5 experiments of three replicates.

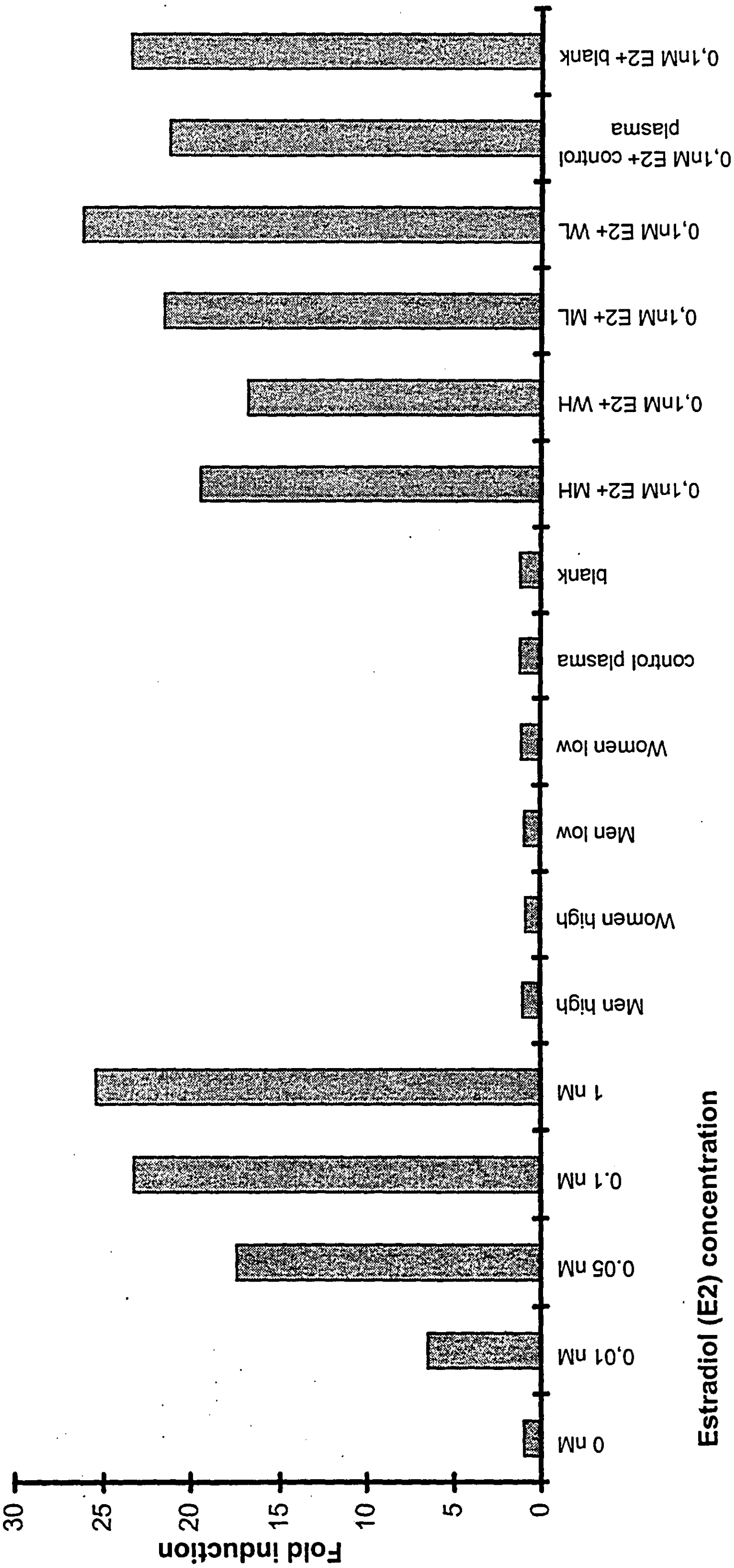

Figure 4. Agonistic and antagonistic effects of human pooled plasma sample extracts in the estrogen system. Each bar represents the mean of three replicates.

incubation medium elicited a response lower than 50% of the maximum response. The reason for this discrepancy is not clear, but as discussed by Klotz, it has been shown that different stocks of MCF-7 cells respond uniquely to estradiol and environmental estrogens in proliferation assays, and this may also be the case for luciferase activity in transiently transfected MCF-7 cells. The sensitivity of our system was better than that of the E-SCREEN test which is a proliferation assay (Soto *et al.* 1997).

The dose-response curve obtained with DHT in the androgenic system is similar to that reported by Kelce and co-workers using CV1 cells (Kelce *et al.* 1995). The antagonistic properties of *p,p'*-DDE were also noted in the present work. The lowest concentration producing a significant inhibition of DHT response was 200nM, corresponding to 63 µg/L. A similar sensitivity for detecting the antagonistic activity of *p,p'*-DDE was reported by Kelce and collaborators.

Using the same procedure to extract and purify OCs than that currently used by the *Centre de Toxicologie du Québec* to measure these substances in plasma by gas chromatography, endogenous hormones were separated from OCs and their metabolites. Indeed, this fraction contained PCB congeners and most chlorinated pesticides but no sex steroid hormones, as shown by the lack of response produced by the extracts in the estrogen or androgen systems. The highest concentration tested corresponds to that found in the original plasma sample (10 mL of plasma extracted, the resulting extract dissolved in 10 µL of DMSO and 2 µL of this solution placed in the 2-mL incubation medium).

While the performance of the separation procedure is encouraging, the fact that plasma extracts induced neither agonistic nor antagonistic effects in the three systems was disappointing. However, considering the limit of detection for individual compounds in these assays, these results may be rationalized. For the dioxin system, the lowest TCDD concentration that could be detected was 10 pM. This concentration corresponds to a 304 ng/L whole plasma concentration. Assuming the total lipid concentration in plasma is 6g/L, the minimum TEQ concentration that could be detected with our system is 500 ng/kg plasma lipids. Based on results published by Ryan and colleagues (1997), one can estimate that the total concentration of dioxin-like compounds (PCDD/Fs, non-ortho, mono-ortho and di-ortho PCBs) in the "high organochlorine" pooled samples was in the order of 400 ng TEQ/kg plasma lipids. Hence, unless a greater plasma volume is extracted or a larger extract volume is added to the cells, this concentration in plasma lipids cannot be detected with our dioxin system. Using a larger volume of plasma (i.e. more than 10 mL) would not be practical in epidemiological studies, whereas adding a greater volume of DMSO to the incubation medium may lead cell toxicity. Alternatively, another dioxin system with greater sensitivity could be used. We are presently evaluating the CALUX (Chemical Activated Luciferase Expression) assay developed by A. Brouwer and M. Denison which was used with success to quantify TEQ concentration in plasma sample extracts (with fat or not) from eider ducks treated with PCBs (Murk *et al.* 1997). The detection limit of this assay is currently 0.1 fmol (32 fg) TEQ (Murk *et al.* 1997), enabling the detection of concentrations ranging from 5 to 50 ng TEQ/kg lipids. This sensitivity would be sufficient to quantify dioxin-like compound concentration in plasma samples from the Inuit population (50-450 ng TEQ/kg lipids) and even from the general southern Québec population (20-30 ng TEQ/kg lipids) (Ayotte *et al.* 1997). Cells for the CALUX assay were kindly provided by Dr. Brouwer from the Department of Toxicology at Agricultural University of Wageningen (Netherlands).

As regards the estrogen system, the concentration of compounds which have been identified as estrogenic (*o,p'*-DDT) are so low compared to their detectable concentration in the estrogen system that this research avenue does not appear worthwhile. Indeed, the lowest concentration of *o,p'*-DDT that could be detected with our system was 0.1 µM, corresponding to a 35 µg/L plasma concentration. While this DDT analogue is the most potent estrogenic OC yet identified, it is only a minor constituent of the OC mixture and a 35-µg/L plasma concentration is totally unrealistic for environmentally (and occupationally) exposed population. Although anti-estrogenic effects were not demonstrated in the present study, they are nevertheless of interest because some HO-PCBs metabolites have been shown to blocked estrogen-induced responses (Moore *et al.* 1997). However, we cannot at the present time calculate the limit of detection of these compounds in our system. The current theory with regard to breast cancer is that the risk of this disease is proportional to the estrogenic stimulus. In order to estimate a total estrogenic index for women enrolled in epidemiologic studies on hormone-related diseases, it may be worthwhile measuring the estrogenic response induced by whole plasma (serum), including the contribution of endogenous and xenohormones, instead of measuring the effect of partial extracts. In order to correctly interpret the results though, the concentration of estradiol and estrone as well as that of the sex-hormone-binding globulin should be determined concurrently.

Finally, with regard to the androgen system, no xenobiotic has been to our knowledge identified as an androgenic substance. All attention is focused on antiandrogenic molecules since the discovery of the antiandrogenic properties of *p,p'*-DDE. The highest concentration of *p,p'*-DDE achieved in the incubation milieu was 15 µg/L (see Table 1), a concentration 4 times lower than the smallest concentration of *p,p'*-DDE (63 µg/L) that elicited an inhibitory effect (in the presence of 0.1 nM DHT). Similarly to the earlier proposition for estrogens, it may also be preferable to measure the androgenic response induced by whole plasma (serum), including the contribution of endogenous and xenohormones. Again, in order to correctly interpret the results, the concentration of testosterone, dihydrotestosterone and that of the sex-hormone-binding globulin must also be measured.

During the next year, we will proceed to analyse artificial mixtures similar in composition to that found in high rank predator from the arctic aquatic biota. Mixtures will be tested with and without metabolic activation. We will also analyse plasma samples collected during the course of various epidemiological studies investigating health effects possibly linked to exposure to endocrine disrupting chemicals (breast cancer study and endometriosis study in the Quebec City region; neurodevelopmental study in Nunavik and Greenland). Measurements with the androgen system will also be performed on plasma samples obtained from farmers in Mexico who are heavily exposed to DDT.

Expected project completion date: March 31, 1999

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ADVERSE DEVELOPMENTAL EFFECTS IN PIGS FOLLOWING *IN UTERO* AND LACTATIONAL EXPOSURE TO ORGANOCHLORINES: EFFECTS ON MALE REPRODUCTIVE FUNCTION

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Project Team: J.L. Bailey, B. Bérubé, J.-P. Laforest, M.-A. Sirard, R. Sullivan, Centre of Research in Biology of Reproduction (CRBR), Laval University; É. Dewailly, Québec Public Health Centre

OBJECTIVES

1. to assess the impact of pre- and postnatal exposure to organochlorine (OC) mixtures found in the Arctic on the development and function of the male reproductive system, using the pig as the animal model.

DESCRIPTION

The development and maintenance of reproductive tissues is to a large extent controlled by steroid hormones. Some environmental chemicals mimic, while others antagonize natural hormone activity when tested with *in vitro* assays or in whole animal models. Studies dating back to the late sixties identified 1-[2-chlorophenyl]-1-[4-chlorophenyl]-2,2,2-trichloroethane (*o,p'*-DDT), a minor constituent of technical DDT, as a weak estrogenic compound capable of causing an augmentation of rat uterine weight in the classic immature female rat model (Bitman *et al.* 1969). This compound and a few others sharing estrogenic properties have been implicated in abnormal sexual development in reptiles (Guillette *et al.* 1994, 1995) and birds (Fry 1981) as well as feminized responses in male fish (Jobling *et al.* 1995).

Certain male reproductive tract disorders (cryptorchidism, hypospadias, testicular cancer) have been reported to be increasing in parallel with the introduction of xenoestrogens such as DDT into the environment. Furthermore, a decrease of semen quality was also reported certain regions of the world during the last half of the century (Carlsen *et al.* 1992, Auger *et al.* 1995). Although these alterations are thought to be mediated by the estrogen receptor, they are also consistent with inhibition of androgen receptor-mediated events. Kelce and coworkers (1995) identified the major and persistent DDT metabolite, 1,1-*bis*[4-chlorophenyl]-2,2-dichloroethylene (*p,p'*-DDE), as a potent antiandrogenic agent in male rats. In addition to inhibiting androgen binding to the androgen receptor, this compound when administered to pregnant dams also induced characteristic antiandrogenic effects in male pups (reduced anogenital distance; presence of thoracic nipples). Treatment with *p,p'*-DDE at weaning delayed the onset of puberty, while treatment of adult rats resulted in reduced seminal vesicle and ventral prostate weights.

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is yet another organochlorine which has been shown to alter sexual development in male rats (Mably *et al.* 1992). Decreases in epididymis and cauda epididymis weights, daily sperm production and cauda epididymal sperm number were observed at day 120 and at most earlier times, when a dose as little as 64 ng/kg was administered to dams on day 15 of gestation. A number of compounds structurally related to TCDD, including other 2,3,7,8- chloro- substituted dibenzo-*p*-dioxins, dibenzofurans, as well as non ortho and mono ortho substituted polychlorinated biphenyl (PCB) congeners, bind to the Ah receptor and display similar toxicological properties, albeit with varying potency (Safe 1990). Results of the cancer bioassay conducted by Kociba and co-workers (1978) showed that TCDD possesses anti-estrogenic properties, as revealed by the striking decrease in the incidence of mammary tumors observed in females rats treated over two years with daily doses of 10 ng/kg body weight. Moore and co-workers (1997) recently produced data suggesting that hydroxy metabolites of several PCB congeners also possess anti-estrogenic properties, using two estrogen responsive *in vitro* bioassays.

Typical organochlorine mixtures found in highly exposed human populations contain a large variety of organochlorine compounds, including substances with estrogenic, anti-estrogenic or anti-androgenic capacities. One may therefore anticipate that complex real life mixtures, composed of numerous compounds which can interact with different receptors involved in cell differentiation and growth, could also generate disproportionate biological stimuli. This in turn may interfere with the normal development of the male reproductive system and result in impaired male fertility in adulthood. The proposed study aims to investigate the effect of a complex organochlorine mixture similar to that found in highly exposed human population on the development of the male reproductive system, using the pig as the experimental model.

The pig has been selected as the experimental model in the proposed study for numerous reasons. The team members have considerable experience with this species and are experts in porcine physiology. Moreover, there are many advantages of a porcine model: Pigs reach puberty early (6 months), have a short gestation period (~ 15 weeks) and are litter-bearing animals (~10 piglets). The Animal Science Department at Laval University will provide the infrastructure necessary to house the animals and perform the experiments. With respect to the digestive, reproductive, endocrine and other systems, porcine physiology is very similar to human physiology (Newman 1996). Furthermore, all tests commonly used to evaluate male fertility can be easily performed on boar, which is not the case for usual laboratories species. For example, it is essentially impossible to obtain ejaculated semen from rodents, hence many parameters cannot be assessed (e.g., semen volume, seminal plasma characteristics). Furthermore, rodents are sacrificed in order to collect epididymal sperm, so multiple analyses on the same individual would be impossible. In fact, certain tests can be more easily performed in pigs than in humans (e.g., the zona pellucida-induced acrosome reaction and *in vitro* fertilization).

ACTIVITIES IN 1997/1998

This project was funded as a mid-year proposal in 1996/1997 and this study is still at an early stage. Final adjustments on the protocol were made, mainly with regard to the dosing regimen and the exact composition of the organochlorine mixture. Following negotiations with Laval University and the Québec Ministry of the Environment, arrangements were made for the disposal of contaminated carcasses and faeces. Animals have been purchased, acclimated to their quarters and dosing began during the first week of June. We are now in the 12th week of dosing and weekly blood samples were collected for OC analysis. Additional protocols were elaborated to study the impact of the *in utero* and lactational exposure to OCs on the immune system function and the neurodevelopment in the F1 generation.

OVERVIEW OF THE RESEARCH PROTOCOL AND LABORATORY METHODS

Animal Treatment

Sixteen Landrace-Yorkshire-Duroc sows were randomly allocated to four treatment groups. Animals in each group are receiving by the oral route different doses of an organochlorine mixture from four months of age until the weaning of their first litter (sows will be approximately 12 months old). The composition of the organochlorine mixture is described in Table 1 and was designed to approximate that found in the blubber of ringed seal from Inukjuak (Derek Muir, personal communication). OCs were dissolved in corn oil to reach the appropriate concentration and the resulting solution was placed in 2-mL gelatin capsules. Animals are treated on Mondays, Wednesdays and Fridays. The first group receives 1 μg PCB/kg body weight/day, the second group 10 μg PCB/kg/day and the third group 100 μg PCB/kg body weight/day. Animals in the fourth group (control group) are administered corn oil only. Animals are weighed each week and the plasma concentrations of the various OCs is being monitored by monthly blood sampling that will be performed throughout the study.

At puberty, females will be inseminated with semen from an untreated boar (Duroc). Ten male piglets from each of the four treatment groups will be nursed by their sow, such that the offspring will also be exposed to organochlorines present in maternal milk. At weaning, the juvenile male pigs will receive the standard diet and will not be treated with OCs. Again, blood samples will be collected monthly for organochlorine determination. At puberty, the semen parameters of the young boars from each treatment group will be evaluated to assess the status of their reproductive system. Parameters of male reproductive function to be assessed include: Sperm concentration and total sperm number/ejaculate; sperm morphology (Mortimer 1985), motility, and viability (deLamirande 1991) sophisticated computer-assessments of sperm motion (Bailey *et al.* 1994, Lapointe *et al.* 1995); nuclear integrity and chromatin structure (Evenson 1991); functional assays of capacitation and the acrosome reaction (Tardif *et al.* 1996); the hypo-osmotic test (Jeyendran *et al.* 1984); quantification of a known fertility protein of epididymal origin (Boué 1996). Details on these tests are provided below. Results obtained from the treated boars will be compared to controls using analyses of variance. In addition, tissue samples will be collected at slaughter to investigate the histology of the reproductive system. A tissue banking system will be establish in order to allow for future analysis on tissue/organ samples.

Table 1. Composition of the organochlorine mixture.

Compound	CAS number	% weight
PCB mixture[a]		**32.59**
technical chlordane	57-74-9	21.3
p,p'-DDE	72-55-9	19.24
p,p'-DDT	50-29-3	6,79
technical toxaphene	8001-35-2	6.54
α-HCH	319-84-6	6.17
aldrin	309-00-2	2.52
dieldrin	60-57-1	2.09
1,2,4,5-tetrachlorobenzene	95-94-3	0.86
p,p'-DDD	72-54-8	0.49
β- HCH	319-85-7	0.46
hexachlorobenzene	118-74-1	0.35
mirex	2385-85-5	0.23
γ- HCH	58-89-9	0.20
pentachlorobenzene	608-93-5	0.18

a mixture containing 2,4,4'-trichlorobiphenyl (320 mg), 2,2',4,4'-tetrachlorobiphenyl (256 mg), 3,3',4,4'-tetrachlorobiphenyl (1.4 mg), 3,3',4,4', 5-pentachlorobiphenyl (6.7 mg), Aroclor 1254 (12.8 g) and Aroclor 1260 (19.2 g).

Semen Analyses

The volume and the pH of each fresh semen sample will be measured. To evaluate ejaculate viscosity and consistency, a semi-quantitative scale will be used. Concentration will be determined by hemocytometer counts after an appropriate dilution of a small aliquot of the fresh sample. The presence of leukocytes, erythrocytes and spontaneous agglutinates will be noted. Sperm motility will be evaluated with a Hamilton-Thorne sperm motion analyser. This apparatus is available in our Centre and is used regularly by the CRBR. Moreover, the CRBR's Hamilton-Thorne analyser is semi-mobile such that motility analyses can be performed locally. The percentage of motile sperm, progressive motility, linear velocity and curvilinear velocity will all be analysed in duplicates (deLamirande 1991). For each sample, eight fields and a minimum of 150 sperm will be selected and automatically analysed. The percentage of living sperm will be determined by exclusion staining. Eosin-nigrosin coloration will be performed systematically on all sperm samples (Eliasson 1977). A minimum of 100 sperm will be evaluated for each sample. This viability parameter is very different from the motility analysis, as sperm can be motionless but not dead. This technique will permit the distinction between asthenospermy (immobility) and necrospermy (dead), two situations that have different etiologies. A significant proportion of sperm in each sample may be morphologically abnormal (teratospermy). Analysis of these abnormalities can provide information regarding defective spermatogenesis, which often involves the gonadotrophin-sensitive Sertoli cells of the testicle. In order to determine the percentage of abnormal sperm and classify the teratospermy, semen smears of each sample will be stained by the Papanicolaou method. This coloration facilitates the description of sperm morphology and the identification of immature cells (Mortimer 1985).

All analyses will be performed by the same person in order to reduce experimental and subjective variability. The results obtained will permit the evaluation of testicular function in the boars. The parameters to be assessed reflect the integrity of the germinal line of the seminiferous tubules, which produce the male gametes, and will thus provide information on the effectiveness of spermatogenesis. The production of functional male gametes is dependent of a series of complex modifications that can not be completely analysed by these andrological tests (Mortimer 1995). However, other andrological tests will be performed to evaluate the biochemical, physico-chemical and physiological characteristics of the sperm and post-testicular male reproductive tract.

Hypo-Osmotic Test

The sperm plasma membrane, like the membrane of all intact cells, is semi-permeable. If the membrane is intact, it will inflate should the sperm be placed in a hypo-osmotic medium. The inflation pattern of the sperm plasma membrane is a reflection of the integrity of the cell (Jeyendran *et al.* 1984). Sperm from each ejaculate will be isolated by centrifugation and suspended in a hypo-osmotic solution. The percentage of cells that inflate under these conditions will be monitored in function of their pattern of inflation. These observations will permit investigation of the physical chemistry of the sperm plasma membrane during exposure to small concentrations of toxic products.

Evaluation of Sperm Maturity

After spermiation, which is the release of the sperm in the seminiferous tubules, the male gamete must undertake a considerable voyage to the site of fertilization in the oviduct of the female. These newly formed sperm are morphologically mature; however, they remain non-fertile. The sperm acquire the potential to fertilize within the male reproductive tract, particularly at the epididymal level where they undergo numerous modifications (Bedford 1967, Orgebin-Crist 1967). These post-testicular modifications can be affected by toxic substances and have no repercussion on the andrological parameters described heretofore. It is, therefore, necessary to use other tests to identify post-testicular damage that can affect the subsequent fertility of the sperm.

Nuclear Integrity

During spermatogenesis, the chromatin of the male gamete condenses. Since chromatin condensation occurs during this phase of maturation, it is a good indicator of sperm maturity. Chromatin stability is evaluated by coloration with acridine orange. This stain reacts with native double helix DNA to provide a green fluorescence and fluoresces red when bound to denatured DNA (Ballachey *et al.* 1988, Evenson 1991). Furthermore, any changes in the oxidation state of the sperm chromatin thiols can be measured with monobromobinane (Seligman *et al.* 1992). The sperm chromatin structure assay has been shown to be a sensitive measure of reproductive toxicology. Sperm obtained from males exposed to reproductive toxins that have effected spermatogenesis show an increased susceptibility to sperm DNA denaturation (Evenson 1986). This evaluation will be performed using flow cytometric analysis (FACS). This apparatus is available in our Centre and is used regularly by the CRBR.

Protein Marker of Epididymal Maturity

We have recently identified a protein, P34H, that is synthesized by the proximal part of the human epididymis and integrated on the sperm surface during post-testicular maturation (Boué *et al.* 1994). Moreover, we have demonstrated that this protein, which is a marker of epididymal function, is a good indicator of the sperm's capacity to interact with the oocyte. We have also shown that certain cases of male infertility are associated with low levels of P34H on the sperm membrane (Boué 1996). The epididymis is an androgen-dependent tissue that is extremely sensitive to toxins. Therefore, as a measure of epididymal function, and possibly as an indicator of male reproductive tract toxicity, the quantity of P34H will be routinely assessed from a constant number of sperm for each semen sample obtained. P34H and other proteins will be extracted from the sperm and separated by gel electrophoresis (SDS-PAGE). The gels will be probed using Western blotting with an anti-P34H antibody in order to identify the presence of the P34H protein. Densitometry will then be used to quantify the P34H present in the sperm from each animal (Boué 1996).

Ability of Sperm Capacitate and Acrosome React

In the male reproductive tract, sperm undergo modifications that provide them the *potential* to be fertile. Before the sperm reaches the oocyte, however, it must experience further biochemical and molecular modifications that ensure its ability to recognize and penetrate that egg. During their transit along the female reproductive tract, sperm undergo these other physiological modifications in response to specific extracellular signals present in the female. The ability of the male gamete to respond to these stimuli is a deciding factor for successful fertilization (Yanagimachi 1994). Several assays will be performed on each sperm sample to evaluate its capacity to carry these physiological alterations necessary for fertilization.

Capacitation

Sperm capacitation is an essential step leading to fertilization. This process occur in the female reproductive tract and is characterized by a series of modifications to the sperm surface: the negative surface charges decreases; the plasma membrane cholesterol/phospholipid ratio decreases; there is the modification, reorganization and loss of surface proteins (Langlais *et al.* 1988). These changes increase the fluidity of the sperm plasma membrane, and permit further physiological maturational events leading to the acquisition of fertilizing ability. Only functional gametes should be able to undergo the sequence of events leading to capacitation. The presence of toxic products in the body may well affect the ability of the sperm to undergo capacitation. In order to detect such damage, we will assay the ability of the subjects' sperm to appropriately undergo capacitation *in vitro*. Sperm will be suspended in a capacitating buffer supplemented with serum albumin, which is essential for human sperm capacitation. The time course of capacitation for each sample and the changes in sperm motility patterns will be evaluated. For capacitation evaluation, we will used a fluorescent image analysing microscope. Sperm will be fixed at different times during capacitation and the calcium influx of the sperms will be analysed by adding ionophore A23187. This experiment is routinely carried out in our laboratory.

Acrosome Reaction

Successful capacitation permits the sperm to undergo the acrosome reaction, which is an obligatory event for

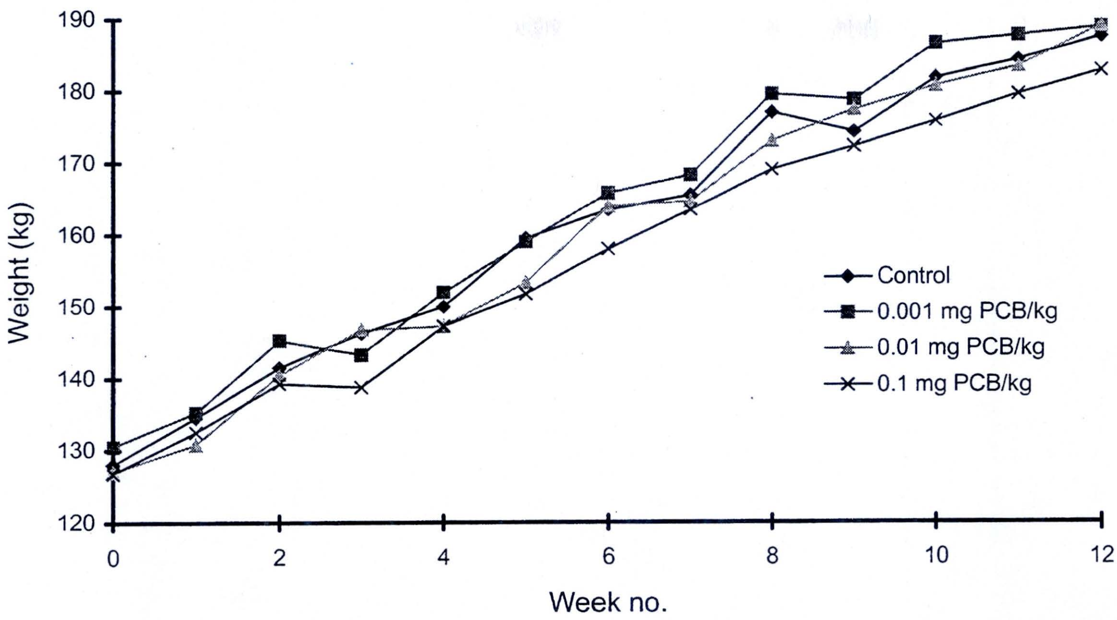

Figure 1. Body weight gain during the first 12 weeks of dosing with the organo-chlorine mixture. Each point represents the mean of four animals, except for the group receiving the 0.01 mg/kg dose for which N = 3 starting on the 8th week.

fertilization. The acrosome reaction is an exocytotic process during which proteolytic enzymes from the sperm are released, and occurs in capacitated sperm only as they bind to the outer layers of the oocyte (Barros 1967, Yanagimachi 1994). These sperm enzymes help the male gamete to traverse the natural barriers surrounding the oocyte. The acrosome reaction should occur at the appropriate location and at the appropriate moment for successful penetration of the oocyte and fertilization. Sperm can frequently undergo spontaneous acrosome reactions prematurely or be unable to do so in response to the appropriate stimulus, which reduces the fertilizing ability of the ejaculate (Kopf 1991). To assess the approximate fertilizing potential of the sperm, the percentage of cells undergoing spontaneous acrosome reactions will be determined by a *pisum sativum* lectin coupled to a fluorescent molecule, fluorescein. This lectin binds to sperm with an intact acrosomes (i.e. not acrosome reacted) and does not bind sperm that have completed the acrosome reaction (Graham *et al.* 1990). A second angle to this assay will be to observe the ability of capacitated sperm to undergo the acrosome reaction in response to a known inducer, lysophosphatidylcholine (LPC). A total of 100 sperm per treatment will be evaluated for acrosomal status. Capacitated sperm acrosome react in response to LPC, but noncapacitated sperm do not (Parrish *et al.* 1989).

Testosterone analysis

The concentration of free and bioavailable testosterone will be determined, in order to monitor the effects of OC exposure on sexual hormone production (Wingfield *et al.* 1997).

Organochlorine Analysis

Forty ml of blood are collected in two 10-ml blue lavender vials containing EDTA and two 10-ml green vials. Centrifugation (10 min., 5 000 rpm) is carried out within less than one hour from sampling. After centrifugation, plasma (serum) is transferred in a glass vial prewashed with hexane and stored frozen at 80C. Vials containing plasma will be thawed overnight at 4C in order to collect a 5 mL aliquot of plasma for OC analyses, and the remaining plasma will be frozen again at -80C immediately after for future analyses of OC metabolites. PCB congeners IUPAC No. 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187; aldrin, ß-BHC, *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, hexachlorobenzene, mirex, oxychlordane, *trans*-nonachlor, α-HCH, dieldrin, heptachlor, heptachlor epoxide, lindane, penta-chlorobenzene, toxaphene congeners- Parlar nos. 26 (T2), 32, 50 (T12), 62 (T20) and 69) are being measured by high-resolution capillary gas chroma-tography using an electron capture detector (HRGC-ECD). Detection limits are 0.02µg/L for PCB congeners and most chlorinated pesticides, 0.03 µg/L for *p,p'*-DDT and β-HCH, and 0.08 µg/L for heptachlor epoxide, dieldrin and Parlar nos. 62 and 69.

In order to adjust OC concentrations on a lipid basis, plasma concentrations of total and free cholesterol, triglycerides as well as phospholipids will be determined and total plasma lipid concentration estimated according to Phillips (1989).

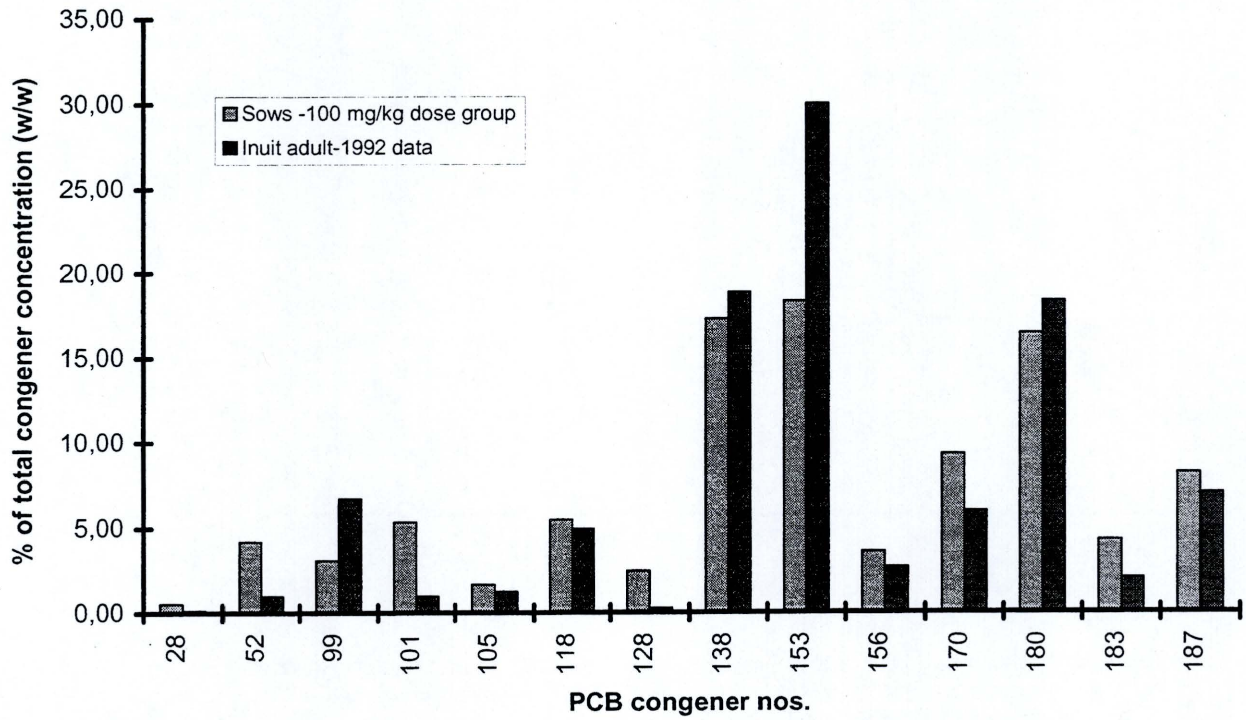

Figure 2. Comparison between PCB congener profiles in plasma lipids of sows receiving the highest dose of the organochlorine mixture in Inuit adults (Santé Québec 1994).

RESULTS

Figure 1 shows the mean weight gain of animals belonging to the four groups during the first 12 weeks of dosing. Animals in the highest dose group appeared to gain less weight than those in the other groups starting on the fourth week of dosing. At 12 weeks, the mean weight in the high-dose group was lower than that in other groups by 4-5 kg. This represents a 2.5% weight gain deficit compared to the other groups, but this difference was not statistically significant. During the 7th week, one sow from the mid-dose group (10 µg/kg) died of hemorrhagic enteritis, likely of allergic origin. All other animals were examined by a veterinarian who has a long experience with this animal species and they were all found to be in good health.

Tables 2 and 3 presents mean concentrations of organochlorines in plasma samples collected after 4 weeks of treatment. Organochlorine compounds were not found in plasma samples from animals belonging to the control group, whereas only *p,p'*-DDE was detected in samples from animals receiving the 1-µg/kg dose. Several compounds were detected in the groups receiving the highest doses; concentrations in samples from sows in the 100 µg/kg dose group being 7- to 10-fold greater than those in samples from animals in the 10 µg/kg group. Congeners nos. 138, 153 and 180 were the most abundant PCBs, the sum of their concentration representing 52% of the total concentration of the 14 PCBs quantified. These three congeners represented a greater proportion (67%) of the total PCB concentration (same 14 congeners) in plasma lipids from Inuit adults (Santé Québec 1994). In particular, the proportion of the total PCB concentration represented by congener no. 153 in plasma samples from Inuit adults was twice that found in sows from the high-dose group. Notwithstanding these differences the relative abun-dance of several congeners was similar in treated animals and in adults form the Inuit population (Figure 2).

DISCUSSION/CONCLUSIONS

This male reproductive study is now well underway and results from OC determination in plasma samples collected after one month of dosing seems to indicate that the profile of PCBs in sows is similar to that found in the Inuit population. Animals are gaining weight normally and there are no signs of overt toxicity. Insemination will be performed early in October 1998 and piglets are expected in January 1999. Evaluation of the male reproductive function will be conducted in 7-month-old boars starting September 1999.

Expected Project Completion Date: December 31, 1999.

Table 2. Concentration (µg/L) of various PCB congeners in plasma samples collected from sows treated during four weeks with the organochlorine mixture and from control animals.

	Controls	**1 µg/kg**	**10 µg/kg**	**100 µg/kg**
PCB congener				
28	ND	ND	ND	0.03
52	ND	ND	0.03	0.21
99	ND	ND	ND	0.15
101	ND	ND	0.04	0.26
105	ND	ND	0.03	0.08
118	ND	ND	0.03	0.27
128	ND	ND	ND	0.12
138	ND	ND	0.11	0.85
153	ND	ND	0.11	0.90
156	ND	ND	0.02	0.18
170	ND	ND	0.06	0.46
180	ND	ND	0.10	0.81
183	ND	ND	0.03	0.21
187	ND	ND	0.05	0.40
ΣPCBs[a]	ND	ND	0.61	4.91

[a] total concentration of all PCB congeners

Table 3. Concentration (µg/L) of various chlorinated pesticides and metabolites in plasma samples collected from sows treated during 4 weeks with the organochlorine mixture and from control animals.

	Controls	1 µg/kg	10 µg/kg	100 µg/kg
Aldrin	ND	ND	ND	ND
ß-HCH	ND	ND	ND	0.11
cis-chlordane	ND	ND	ND	ND
trans-chlordane	ND	ND	ND	ND
cis-nonachlor	ND	ND	ND	0.06
p,p'-DDE	ND	0.06	0.55	4.55
p,p'-DDT	ND	ND	0.21	1.94
hexachlorobenzene	ND	ND	0.02	0.15
mirex	ND	ND	0.02	0.20
oxychlordane	ND	ND	0.02	0.22
trans-nonachlor	ND	ND	0.04	0.35
α-HCH	ND	ND	0.12	0.83
p,p'-DDD	ND	ND	ND	0.07
dieldrin	ND	ND	0.13	1.05
heptachlor	ND	ND	ND	ND
heptachlor epoxide	ND	ND	ND	ND
lindane	ND	ND	ND	ND
pentachlorobenzene	ND	ND	ND	0.06
toxaphene congeners				
Parlar no. 26 (T2)	ND	ND	ND	ND
Parlar no. 32	ND	ND	ND	ND
Parlar no. 50 (T12)	ND	ND	ND	ND
Parlar no. 62 (t20)	ND	ND	ND	ND
Parlar no. 69	ND	ND	ND	ND

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TOXICOLOGICAL STUDIES OF *CIS*- AND *TRANS*-NONACHLOR IN RATS.

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Project Team (all from Toxicology Research Division unless otherwise indicated): M. Barker: pathology; G. Cooke: reproductive toxicology; I. Curran, molecular toxicology; Dr. M. Feeley (*Chemical Health Hazard Assessment Division*); Warren Foster (*Environmental Health Directorate*): reproductive toxicology; S. Gill: neurotoxicology; E. Lok: immunohistochemistry and behavioral toxicology; R. Mehta: carcinogenesis and immunohistochemistry; H. Newsome (*Food Research Division*): tissue residue analyses; O. Pulido: neuropathology; P. Rowsell: molecular toxicology; C. Suzuki: biochemical toxicology; H. Tryphonas: immunotoxicology; Technical staff: Toxicology Research Division, Food Research Division, Animal Resources Division.

OBJECTIVES

General:

1. to determine and compare the toxicological effects of *cis*-nonachlor and *trans*-nonachlor in male and female rats.

1997/98:

1. to complete the dosing phase of the study and begin analyses of tissues and biological samples.

DESCRIPTION

The pesticide chlordane is a mixture of structurally related chlorinated compounds, two of which are cis- and trans-nonachlor. Residue data indicate that these chemicals, particularly trans-nonachlor, are present in the fat and flesh of Arctic marine mammals (Muir *et al.* 1988) and in human fat (Dearth and Hites 1991). Although environmental contaminants occur as mixtures, the availability of toxicological data for individual components of a mixture is an invaluable tool in the preparation of a realistic health hazard assessment for food and environmental contaminants. This study addresses the lack of toxicological data for two major chlordane isomers.

Sprague-Dawley rats were divided randomly into treatment groups, as indicated in Table 1.

Rats were administered cis-nonachlor, trans-nonachlor or the parent mixture. technical chlordane, by gavage for 28 consecutive days. Control rats received an equivalent volume of corn oil vehicle. Behavioral, neuromuscular and sensorimotor observations were recorded for high dose rats (25 mg/kg) and controls at three time points: before dosing, after 1 week of dosing and after 3 weeks of dosing. At necropsy, 24 hours after the final dose, rats were exsanguinated via the abdominal aorta. Blood was collected for hematology, clinical chemistry and residue analyses. Tissues were collected for biochemical and histopathological assessment.

ACTIVITIES IN 1997/98

The animal phase of the study extended from mid-October to mid-December, finishing on December 11, 1997 with the necropsy of the final test group. Analyses of tissues and biological samples began at the end of December 1997 and are still in progress.

RESULTS

*Note: Statistical analyses have not been completed on all of the data outlined below. These results are to be taken as **preliminary only.***

General Observations

Female rats treated with trans-nonachlor at the highest dose level were the only test animals to show signs of overt toxicity. 3/7 rats in this group died before receiving all 28 doses (19, 22 and 22 doses). The three rats that

Table 1. Study groups

Group	Test chemical	Sex	Group size and dose			
			Control (0 mg/kg)	Dose 1 (0.25 mg/kg)	Dose 2 (2.5 mg/kg)	Dose 3 (25 mg/kg)
A	cis-nonachlor	female	n=7	n=7	n=7	n=7
B	trans-nonachlor	female	n=7	n=7	n=7	n=7
C	technical chlordane	female	n=7	n=7	n=7	n=7
D	cis-nonachlor	male	n=7	n=7	n=7	n=7
E	trans-nonachlor	male	n=7	n=7	n=7	n=7
F	technical chlordane	male	n=7	n=7	n=7	n=7

died lost weight for 3 consecutive days before death, sat quietly in a hunched position, and showed signs of abdominal tenderness when handled. The remaining 4 rats in the female, high dose, trans-nonachlor group were necropsied after 23 doses. At necropsy final body weight for this group was significantly lower than controls. All other treatment groups survived to the end of the 28-day dosing period, with no signs of illness and no significant loss of body weight.

Histopathology
Assessment in progress.

Hematology and clinical chemistry
There were no consistent or dramatic hematological changes for any of the test chemicals.

Rats treated with trans-nonachlor (male and female) and technical chlordane (male only) showed clinical changes in more parameters than the other test groups. These changes included elevated serum cholesterol (potential hepatotoxicity), elevated serum amylase (potential pancreatic toxicity), reduced thyroid hormone uptake and elevated serum proteins.

Urinalysis and organic ion transport assays indicated that kidney function was not compromised by any of the test chemicals.

Hepatotoxicity
To date the liver appears to be the most affected organ in rats treated with all three test chemicals. At necropsy hepatomegaly was observed in all of the 25 mg/kg dose groups. Increased liver weights were the most pronounced in male and female rats treated with trans-nonachlor (approximately 2x larger than control livers).

Standard histopathological assessment of liver sections are not complete, but immunohistochemical analyses indicate that the livers of all treated rats have single hepatocytes or foci displaying elevated glutathione S-transferase Π form (GSTΠ) expression. Female livers appear to exhibit higher numbers of GSTΠ positive hepatocytes than males. Enhanced expression of GSTΠ in single hepatocytes and foci in rat liver during chemical carcinogenesis has shown GSTΠ to be a reliable marker for preneoplasia (Mehta *et al.* 1994).

Molecular and enzymatic endpoints indicated that liver metabolic enzymes were induced by the test chemicals. Enzyme assays indicated that the cytochrome P450 enzymes as a group were induced, and specifically the isoforms CYP1A1 and CYP1A. The extent of enzyme induction appeared to vary between sexes as well as between test chemicals. Western blots indicated that CYP2B1/2 and CYP3A1 levels were increased to varying degrees for each test chemical, also with potential sex-related differences to test chemical potency. RT-PCR was used to measure changes in transcription for P450 isoforms. This confirmed the increases in CYP2B1/2 and CYP3A1.

Immunotoxicity
Data analyses in progress. Specimens were processed for three assays: (1) lymphocyte transformation; (2) natural killer cell assay; (3) flow cytometric analyses of lymphocyte subsets in peripheral blood.

Neurotoxicity
Of the parameters measured, the only notable observation was a decrease in foot splay in cis-and trans-nonachlor treated female rats only. There were no behavioral differences detected from a videotaped observation period of each rats (open field testing). There were no consistent changes in hind and forelimb grip strength.

Histopathological assessment of brain tissues is in progress.

Brains from rats in each group were dissected into five areas and are being probed for changes in the expression of a number of genes that serve as markers for neurotoxicity. Although these results are incomplete it appears that all of the test chemicals were able to induce changes in gene expression in the brains of treated rats. For example, two of the markers being examined are for the cell cycle genes cyclin D1 and cdk45. Both were reduced in groups A-D (tested so far). Other markers that are being examined include genes for microtubule- and growth-associated proteins (MAP2 and GP-43) and GABA and dopamine receptors.

Reproductive toxicology

Analyses in progress.

Residue analyses

Sample analyses are still in progress. Whole blood (males only), adipose and liver are being analysed for heptachlor, oxychlordane, γ-chlordane, α-chlordane, trans- nonachlor and cis-nonachlor. Adipose samples from groups B, C and D are completed. In adipose from females treated with trans-nonachlor (group B), the only contaminants were trans-nonachlor and oxychlordane. Both accumulated in a dose-dependent manner, and oxychlordane levels were approximately 3 to 7x lower than trans-nonachlor levels. In adipose from males treated with cis-nonachlor (group D), trace amounts of trans-nonachlor were present in addition to the primary and secondary contaminants, cis-nonachlor and oxychlordane. In adipose from technical chlordane-treated females, oxychlordane was the predominant contaminant, followed by trans-nonachlor, cis-nonachlor, -chlordane, heptachlor and γ-chlordane, respectively.

DISCUSSION

The available data indicate that trans-nonachlor is in general more toxic than cis-nonachlor and the parent mixture, technical chlordane. Female rats appear to be more sensitive to trans-nonachlor than male rats. Without histopathology data, the most sensitive target organ appears to be the liver. Residue analyses to date indicate that the primary metabolite of both cis- and trans-nonachlor is oxychlordane. In the case of technical chlordane the clinical and biochemical observations recorded for this study so far confirm the extensive toxicological literature available for chlordane (US Department of Health and Human Services 1994).

Expected Project Completion Date: Completion of each component of the study will vary according to the schedules of the labs involved. The majority of analyses should be completed by 1998/99. Manuscript preparation will begin as study components are completed.

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USE OF PHYSIOLOGICALLY-BASED-TOXICOKINETIC (PBTK) MODEL FOR RISK ASSESSMENT OF EXPOSURE TO MIXTURES OF ORGANOCHLORINES IN TRADITIONAL FOOD

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OBJECTIVES

The overall objective of this project is to develop a framework for assessing the potential health risks to the Arctic Inuit communities, associated with the dietary intake of mixtures of chemical contaminants in traditional food.

Specific objectives of this project are:

1. to characterize the health risk to Arctic Inuit populations associated with the dietary exposure to a mixture of organochlorines that are typically found in their diet.

2. to conduct experimental and modelling studies for improving the scientific basis of the currently used guideline levels for organochlorine compound exposure among the Arctic Inuit populations.

DESCRIPTION

Risk assessment should ideally be based on detailed knowledge of the relationships between external and internal dose, organ levels, and their relation to toxic symptoms in humans. However, human data on these toxicokinetic parameters for environmental pollutants originated mainly from individuals or small populations accidentally exposed for short periods to relatively high contaminant levels, but with an unknown total body burden. Therefore, assessment of the risk associated with exposure to low levels of environmental pollutants has had to depend largely on data from animal experiments.

The use of physiologically based toxicokinetic (PBTK) model is a scientifically-sound, mechanistic tool that has increasingly been used in health risk assessment procedures for the conduct of extrapolations essential for reducing the uncertainties (Krishnan and Andersen 1994). Moreover, the recent validation of the usefulness of physiological modelling approach in simulating the kinetics and dynamics of chemical mixtures, by accounting for the multiple chemical interactions (Pelekis and Krishnan 1995, 1997, Tardif *et al.* 1997) has given way to the development of an interaction-based risk assessment approach.

ACTIVITIES IN 1997/98

The first phase of this project was funded by NCP in November, 1997. Phase 2 of the project was approved for funding in May, 1998. Based on the dietary intake data collected from Broughton Island in 1988 (Chan *et al.* 1997) (Table 1), a mixture of organochlorines was designed to contain hexachlorobenzene, α-,β-, γ-HCH, *oxy, cis, trans*-chlordane, *cis* and *trans*-nonachlor, dieldrin, DDE, DDT, mirex, toxaphene) and PCB congeners (28,32, 101,99,118,105,153,128, 138,156,187,183,180,199). Based on the toxicological dose equivalency of human studies and the LOEL and NOEL levels, the dosages were decided to be 10X, 100X, and 1000X the mean daily intake level. Chemicals of the highest purity were purchased and the mixture was prepared in hexane at the CINE lab and shipped to Health Canada for the feeding experiment. The mixture in hexane was added to corn oil to make up the desired dosage. Concentrations of OC dose in the corn oil was confirmed by chemical analysis using GC-MS. Four groups of 12 female rats were administered the mixture in corn oil by gavage (three dose levels plus controls) for 28 days. The animals were necropsied at the end of the experiment and OC levels in blood and liver and adipose tissue are being measured to fit in the PBTK model. Selected tissues were collected for the following toxicological and histopathological assessment:

Table 1. Inuit Dietary Intake (μg/kg/d) of OC as estimated from the data collected from Broughton Island. Assuming 65 kg bw

OC	mean	PCB	mean
HBZ	0.092	28	0.012
α-HCH	0.108	32	0.046
β-HCH	0.011	101	0.062
γ-HCH	0.006	99	0.046
OXYCHL	0.154	118	0.062
CCHL	0.009	105	0.008
TCHL	0.005	153	0.123
CNONA	0.046	128	0.003
TNONA	0.108	138	0.092
DIELD	0.092	156	0.003
DDE	0.338	187	0.015
DDT	0.092	183	0.012
MIREX	0.005	180	0.031
TOX	1.108	199	0.003

a) General Toxicology - daily body weight, food and water consumption, clinical serum chemistry profile (indicators for liver and kidney functions), and organ weight.
b) Liver Toxicology Endpoints - microsomal liver enzyme induction assays, cytochrome P450, western blot analysis of specific P450 and protein kinase C (PKC) gene products, molecular markers of enzyme induction: P450 and PKC mRNA levels, immunohistochemical detection of preneoplastic foci in liver.
c) Histopathology - liver, kidney, spleen, adrenals, thymus and brain

The animal experimental protocol was approved by the Animal Care Committee of Health Canada.

A physiologically based toxicokinetic (PBTK) modeling framework for organochlorine mixture has been developed. In this framework, the animal is described as a composite of several tissue compartments interconnected by systemic circulation. This animal description file is connected to a file containing chemical-specific information, namely partition coefficients and biochemical rate constants. By referring to any of the subsections of the file, simulations of the kinetics and tissue dose of several organochlorine substances (e.g., PCBs, HCB, dioxins) can be generated at the present time. Alternatively, the kinetics of these substances in mixture can also be simulated simultaneously. The partition coefficients for the various substances in the mixture used in the feeding study have been computed as the ratio of neutral lipid content in tissues and blood, based on an algorithm developed by Poulin and Krishnan (1995). The metabolic rate constants for some substances have been derived from previous pharmacokinetic modeling studies, whereas for others the physiological limit of hepatic clearance is being considered for conducting simulations. The latter approach also allows to consider the presence of interactions and inter-individual differences in metabolism. Further, a description of oral absorption of chemicals has been developed and validated. With the inclusion of this oral absorption constant, the organochlorine mixture model can be used to simulate the tissue dose during exposure scenarios identical to the feeding studies.

The PBTK model will be used to simulate the area under the concentration vs. time curve (AUC) of parent chemical in rat liver (alternatively the amount metabolized), and this dose surrogate will be related to the severity of hepatic damage observed during the experimental studies. Two alternative strategies will be used: (i) identification of AUC_{liver} that corresponds to the NOAEL, and (ii) mathematical modeling (fitting exercise) to determine the AUC_{liver} that corresponds to a benchmark dose (BMD; a pre-determined level of response).

Expected project completion date: March 31, 1999.

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HUMAN CONTAMINANT TRENDS IN ARCTIC CANADA

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OBJECTIVES

1. To establish a baseline for selected organochlorine and metal contaminants in some residents in the NWT
2. To investigate the relationship between contaminant levels in maternal blood with those in umbilical cord blood
3. To assess the need for, and feasibility of, additional monitoring activities for environmental contaminants in NWT residents
4. To compare the magnitude and range of these contaminant concentrations with those of other territorial, national and international jurisdictions
5. To contribute to territorial, national and international data bases.

DESCRIPTION

This project was initiated at the beginning of the Northern Contaminants Program to establish a contaminants exposure baseline, and to put in context existing contaminants data, for NWT residents. It was (and still is) also important to the ongoing efforts of the federal government in their international negotiations to reduce the use of chlorinated organics and metals elsewhere in the world to be able to prove the presence of these contaminants in Northerners.

The course of establishing this exposure baseline has been long and expensive. There has been careful attention to comprehensive communications and consultations on the part of the regional health agencies, the territorial government, the federal government and the aboriginal partners. This has resulted in the production of a total of 12 workshops that have been related in some way to this project and organized by the DHSS and/or a regional health board, between 1991 and 1998. Altogether, these workshops have included a total of 556 people (223 women and 233 men). This does not include trips to communities made by regional health agency staff specifically to communicate contaminants monitoring program results.

This report summarizes the maternal and cord blood monitoring programs completed in the Baffin and Keewatin regions. Work done in the Inuvik Region has been summarized and submitted separately.

ACTIVITIES IN 1997/98

During this period, work begun the previous year was completed in the Baffin and Keewatin Regions, and a program was established in the Inuvik Region.

Table 1. Geometric mean and range of maternal and cord blood results from the Baffin Region (Moss 1997, pp. 25, 28)

Contaminant	Maternal blood (n=34)		Cord blood (n=66)	
	range	G. mean	Range	G. mean
Mercury (total) ppb	0.40-33.9	6.09	0.60-75.8	10.4
Cadmium ppb	0.03-6.30	1.43	0.01-7.45	0.08
Lead ppb	4.14-120	38.9	10.4-132	33.7
PCBs (Aroclor 1260) ppb	1.60-27.4	6.82	0.43-28.3	1.72

Table 2. Health Canada blood guidelines used for maternal results (Moss 1997).

Contaminant	Level of Concern (ppb)	Level of Action (ppb)
Mercury	20	100
Cadmium	5	N/A
Lead	N/A	100
PCBs (as Aroclor 1260)	5	100

Additionally, the Final Report from the Mackenzie and Kitikmeot Regions' Maternal and Cord Blood Monitoring for Environmental Contaminants was revised to correct errors in the original report, and redistributed.

RESULTS AND DISCUSSION

Baffin Regional Health and Social Services Board

The focus of work done in this fiscal year was the communication of contaminants results, and the production of the report *Environment and Lifestyle Assessment Project – Baffin Region Blood Monitoring Program Results*, which was released in September 1997. The following information is excerpted from this Report.

The Environment and Lifestyle Assessment Project recruited and sampled participants from January to December 1996. There were 99 pregnant women from the Baffin Region that gave informed consent to voluntarily participate in the program. This resulted in a total of 102 blood samples and 81 completed Lifestyle and Assessment Surveys. Of the 102 samples, 64 were from 32 mother/cord pairs, 35 were from umbilical cords and 3 were from mothers.

These samples were analysed for a suite of organochlorines including: PCBs (total as Aroclor 1260), congeners #28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187), aldrin, dieldrin, α-chlordane, γ-chlordane, β-HCH, oxychlordane, cis-nonachlor, transnonachlor, *p,p'*DDE, *p,p'*DDT, heptachlorepoxide, HCB, mirex, and toxaphene; heavy metals, including cadmium, lead, mercury (total and inorganic); trace metals, including copper, selenium and zinc; as well as lipids. Individual results for the four contaminants which have human health guidelines, mercury, cadmium, lead and (total) PCBs as Aroclor 1260, were made available to participants, and general results were made available to communities in the spring and summer of 1997.

Table 2 shows the Health Canada blood guidelines that were used in communicating maternal results (Moss 1997, p. 15).

The Level of Concern was exceeded by 3 participants for mercury, by 3 participants for cadmium and by 22 participants for PCBs. Three maternal samples and 1 cord sample exceeded the Level of Action for lead. Information was given to participants along with their results about ways to reduce their intake of contaminants if they were concerned, and repeat samples were taken for those participants with elevated lead levels.

Throughout the implementation of this program there was considerable emphasis placed on lifestyle choices as part of the 'health environment' of participants. Posters produced in English and Inuktitut that provided information about contaminants contained in cigarettes were well received. Since information collected from the Assessment Survey revealed that 90% of participants smoked at the time the survey was administered, this was timely and pertinent information. Traditional foods were consumed by many participants, with ringed seal, caribou, fish and berries reportedly being eaten the most. Store-bought foods were also eaten, with nearly all respondents consuming meat, junk food, and pop, and all respondents eating bannock or bread.

Table 3. Geometric mean and range of maternal and cord blood results from the Keewatin Region (Demmer and Schultz 1998)

Contaminant	Maternal blood (n=17)		Cord blood (n=16)	
	Range	G. mean	Range	G. mean
Mercury (total) ppb	0.60-11.5	3.66	1.00-26.9	8.00
Cadmium ppb	0.11-7.72	1.43	0.01-0.11	0.09
Lead ppb	12.4-64.2	28.6	8.29-74.6	24.4
PCBs (Aroclor 1260) ppb	0.41-60.1	5.58	0.10-11.0 (n=15)	1.53

Recommendations from this project include:

- a detailed statistical analysis be completed on the regional data as part of the Territorial analyses to investigate the relationship between routes of exposure and observed contaminant levels;
- a follow-up be carried out for project participants with elevated levels of lead in their blood;
- all future contaminants research in the Baffin Region include informational resources that are targeted for community use, such as this project has;
- residents in the Baffin Region are fully consulted as part of any future human health contaminants research;
- that clear communications with regional authorities take place before any sampling occurs regarding the limitations, evaluation criteria, and interventions relevant to possible sampling results; and
- future contaminants research in the Baffin Region include investigating issues of local contamination, contaminants in wildlife that are consumed, detailed dietary assessments, and the effects of food preparation on contaminant levels (Moss 1997).

Keewatin Regional Health and Social Services Board

This Board began "The Keewatin Environmental Health Project: Contaminants and People" in January 1996, after consultations with each community, and the communication of some results of contaminant levels in fish from the region. The following is excerpted from *The Keewatin Environmental Health Project: Contaminants and People Final Regional Report*, which was finalized in Spring 1998.

Participants were recruited from July 1996 to January 1997, with 38 women volunteering to participate who came from all but one community in the Keewatin Region. Participants delivered their babies at 1 of 4 possible locations: Rankin Inlet Birthing Centre; Churchill Health Centre, Manitoba; Stanton Regional Hospital, Yellowknife; or the Baffin Regional Hospital in Iqaluit.

Of the 38 participants, 53% did not contribute blood samples because they either delivered other than at the above 4 locations, sampling was missed, or they withdrew. Blood samples were taken from 17 mothers and 16 umbilical cords and analysed for the same suite of organochlorine and metal contaminants described above for the Baffin Region's project, with the following results for contaminants for which are human health guidelines exist.

Using the same Health Canada Guidelines for these contaminants as described above, there were no maternal samples that exceeded the Level of Action/At Risk Zone for lead, and no maternal samples exceeding the Level of Concern/Increasing Risk Zone for mercury, while 58.8% (10) and 17.6% (3) exceeded this level for PCBs and cadmium respectively.

Recommendations from this project include:

- ongoing communications occur with communities about health-related contaminants issues, including effects, as information becomes available;
- focussing on community based questions, which may improve participation rates in future contaminants and human health projects;
- collecting detailed food consumption data with the assistance of scientific expertise in this field in future projects of this nature;
- identifying/developing standard contaminant guidelines and health advice to assist with communication of results;
- collecting either maternal or cord blood in future monitoring projects.

The complete sets of results from both these programs have been contributed to the GNWT Department of Health and Social Services Territorial data base for the definition of a Territorial exposure baseline, which is underway.

Expected Project Completion Date: December 1999 for the complete NWT exposure baseline for environmental contaminants.

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EFFECTS OF OMEGA-3 TYPE FATTY ACIDS ON RISK FACTORS FOR CARDIOVASCULAR DISEASES AMONG JAMES BAY CREE

Project Leader: É. Dewailly, M.D., Ph.D., Public Health Centre of Quebec

Project Team: Carole Blanchet, Public Health Centre of Quebec Bruce Holub, Department of Nutrition Sciences, University of Guelph

OBJECTIVES

1. to describe the profile of plasma concentrations of omega-3 fatty acids on a representative samples of James Bay Cree.

2. to verify the relationship between plasma concentrations of omega-3 fatty acids and the prevalent risk factors of cardiovascular diseases (CVD).

This report presents results concerning the first objective of the project. The final report, which is scheduled for March 1999, will not be completed since this project was not funded by Northern Contaminant Program for 1998/1999.

DESCRIPTION

Numerous studies reported that the diet which is rich in fish and marine mammals could protect against cardiovascular diseases (CVD) (Dyerberg 1986, Holub 1989, Frolich 1992). Effectively, there is a low frequency of arterial thrombosis, cardiovascular diseases in populations who consume a lot of marine foods (Bang 1976, Dyerberg 1978, Kromhout 1985). There is also epidemiologic evidence of an inverse relation between fish consumption and death from coronary heart diseases. This beneficial effect was attributed to the omega-3 fatty acids and the main source of omega-3 type fatty acids for human is fish, shellfish, crustaceans and tissues of marine mammals. In particular, dietary fish oils are specifically rich in eicosapentanoic acid (EPA) and docosahexanoic acid (DHA), which are the major polyunsaturated fatty acids of the omega-3 serie.

Observed positive effects of omega-3 fatty acids include the lowering of blood lipid levels, especially of triglycerides, reduced platelet aggregation and inflammation (Beilin 1996, Harris 1990, Yamori 1985). It has also been suggested that these fish fatty acids could prevent the occurence of diabetes. Omega-3 fatty acids are believed to protect against some types of cancer. Some studies suggest a protective effect of fish oils, enriched with omega-3 fatty acids by inhibing cell proliferation (Frolich 1992, Borgeson 1989). Recent studies also tend to indicate that omega-3 type fatty acids especially DHA constitute an essential factor in child development (Olsen 1986, Olsen 1990, Carlson, 1993).

Fishing among Cree communities is an important activity and fish has a significant social, economic and nutritive value. Substantial literature supports the idea that omega-3 fatty acids measured in human tissues do reflect dietary intake (Willet 1990, Bjerve 1993). Our research project allowed to determine plasma concentrations of omega-3 type fatty acids on a representative sample of James Bay Crees. The hypothesis to be tested is that a moderate and long-term consumption of fish, the main source of omega-3 fatty acids, would positively associated with risk factors for cardiovascular disease among Cree population.

ACTIVITIES IN 1997/98

The Santé Québec Health Survey conducted in 1991 among James Bay Cree was to gather relevant information on physical, psychosocial and social health of the Cree population (Santé Québec 1994). In this survey, information on cardiovascular risk factors including blood samples, blood pressure, height, weight, waist and hip measures were collected. The remaining of the blood samples were kept frozen at the CHUL laboratory in Québec City. For the purpose of this project, plasma concentrations of fatty acids, in particular omega-3 fatty acids, were determined in the remaining of 917 blood samples at the Department of Human Biology and Nutritional Sciences, University of Guelph in Ontario on the supervision of Dr Bruce J. Holub. Information on the demographic portrait and the prevalent risk factors of cardiovascular diseases were obtained from the Santé

Table 1. Blood concentrations of fatty acids (expressed as % of phospholipids) among James Bay Cree and the Québec population (arithmetic mean).

Fatty acids	CREE	(95% CI) (n=917)	QUEBECER	(95% CI) (n=1460)
Eicosapentanoic Acid: EPA (C20:5, n-3)	0.860	(0.808-0.911)	0.518	(0.506-0.530)
Docosahexanoic Acid: DHA (C22:6, n-3)	3.017	(2.939-3.094)	1.275	(1.249-1.301)
EPA +DHA	3.876	(3.756-3.996)	1.793	(1.760-1.827)
Oleic Acid (C18:1, n-9)	13.04	(12.93-13.14)	12.31	(12.19-12.40)
Linoleic Acid (C18:2, n-6)	18.71	(18.52-18.91)	18.53	(18.40-18.65)
Linolenic Acid (C 18:3, n-3)	0.211	(0.205-0.217)	0.166	(0.161-0.168)
Arachidonic Acid: AA (C20:4, n-6)	9.157	(9.031-9.282)	6.397	(6.323-6.470)
Docosapentanoic Acid : DPA (C22: 5, n-3)	0.726	(0.711-0.741)	0.503	(0.496-0.511)
Saturated Fatty Acids [1]	47.63	(47.51-47.75)	53.18	(53.05-53.32)
Polyunsaturated Fatty Acids: N3 [2]	5.005	(4.873-5.136)	2.570	(2.531-2.609)
Polyunsaturated Fatty Acids: N6 [3]	30.99	(30.82-31.16)	28.52	(28.38-28.66)
Monounsaturated Fatty Acids: N9 [4]	16.46	(16.36-16.57)	15.73	(15.63-15.83)
Polyunsaturated / Saturated Ratio	0.758	(0.753-0.763)	0.588	(0.584-0.592)
N3 / N6 Ratio	0.166	(0.161-0.170)	0.090	(0.089-0.092)
EPA / AA Ratio	0.090	(0.085-0.094)	0.083	(0.081-0.085)
DHA / AA Ratio	0.327	(0.320-0.334)	0.200	(0.197-0.204)

1 Saturated Fatty Acids : ((C14:0, C15:0, C16:0, C18:0, C20:0, C22:0, C24:0).
2 Polyunsaturated Fatty Acids: N3 : ((C18:3-n3, C18:4-n3, C20:3-n3,C20:4-n3, C20:5-n3, C22:5-n3, C22:6-n3).
3 Polyunsaturated Fatty Acids: N6 : ((C18:2-n6, C18:3-n6, C20:2-n6, C20:3-n6, C20:4-n6, C22:2-n6, C22:4-N6, C22:5-n6).
4 Monounsaturated Fatty Acids: N9 : ((C14:1-n9, C16:1-n9, C18:1-n9, C20:1-n9, C22:1-n9, C24:1-n9).

Québec data files. Finally, for comparative purposes, plasma concentrations of omega-3 fatty acids of James Bay Cree were compared to those than we measured in 1997 among a representative sample of Quebecers (Dewailly 1998, Project ongoing - MRCC)

The statistical analysis sought to provide a preliminary description of the concentrations of fatty acids in the blood of James Bay Cree population. We conducted statistical analysis which involved calculating arithmetic means according to sex and age groups. We used also confidence interval at 95% of the arithmetic mean. To calculate means and confidence intervals, we used weighted samples. Thus, all the data presented in the following report were weighted, and representative of the entire James Bay Cree. All statistical analysis were conducted with the SAS software.

RESULTS

Table 1 shows fatty acids composition of plasma phospholipids measured among Cree and Quebecer populations, concentrations being expressed as a percentage of phospholipids. For the two main omega-3 fatty acids, namely eicosapentanoic acid (EPA) and docosahexanoic acid (DHA), the respective means stood at 0.86 and 3.02 and their sum (EPA+DHA) was twice greater than those observed among Quebecers. Similar results were observed for the sum of omega-3 fatty acids (N3). Arachidonic acid (AA) and the sum of omega-3 fatty acids (N6) respectively accounted for 9% and 31% of total fatty acids among Cree and these concentrations were also higher than those observed among Quebecers. However, when calculating the N3/N6 ratio, the Cree population showed the highest ratio. Concentrations of saturated fatty acids were higher among Quebecers whereas those of total mono-unsaturated fatty acids (N9) appeared to be slightly higher among Cree population. EPA/AA ratio, deemed an indicator of the level risk of contracting ischaemic disease (EPA/AA ratio less than 0.1) was found to be similar among Cree and Quebece populations.

Concentrations of omega-3 fatty acids did not vary according to sex (Table 2). Although means of arachidonic acid, docosapentanoic acid, total omega-6 fatty acids (N6) and polyunsaturated/saturated ratio were statistically higher among men, and that those of linolenic acid and DHA/AA ratio were statistically higher among women, we observed very slight differences between the means.

Table 2. Blood concentrations of fatty acids (expressed as % of phospholipids) according to sex among James Bay Cree.

Sex / Fatty Acids	Men	(N=422)	Women	(n=495)
	Arithmetic mean	(95% CI)	Arithmetic mean	(95% CI)
EPA (C20:5, n-3) ** p= 0.23*	0.888	(0.806-0.969)	0.832	(0.766-0.898)
DHA (C22:6, n-3) ** p= 0.68*	2.992	(2.878-3.105)	3.042	(2.935-3.149)
EPA +DHA ** p= 0.80*	3.879	(3.698-4.060)	3.874	(3.713-4.034)
Oleic Acid (C18:1, n-9) ** p= 0.08*	12.949	(12.80-13.10)	13.12	(12.97-13.28)
Linoleic Acid (C18:2, n-6) ** p= 0.67*	18.77	(18.47-19.07)	18.66	(18.40-18.91)
Linolenic Acid (C 18:3, n-3) ** p= 0.0003*	0.199	(0.191-0.208)	0.222	(0.213-0.231)
Arachidonic Acid (C20:4, n-6) ** p= 0.0001*	9.461	(9.272-9.651)	8.854	(8.692-9.016)
Docosapentanoic Acid (C22:5, n-3) ** p= 0.0001*	0.755	(0.733-0.777)	0.697	(0.677-0.718)
Saturated Fatty Acids [1] ** p= 0.008*	47.46	(47.28-47.64)	47.80	(47.64-47.97)
Polyunsaturated Fatty Acids: N3 [2] ** p= 0.70*	5.016	(4.817-5.215)	4.993	(4.817-5.169)
Polyunsaturated Fatty Acids: N6 [3] ** p= 0.005*	31.25	(30.99-31.50)	30.73	(30.50-30.96)
Monounsaturated Fatty Acids: N9 [4] ** p= 0.07*	16.37	(16.22-16.52)	16.56	(16.40-16.71)
Polyunsaturated / Saturated Ratio ** p= 0.0005*	0.767	(0.760-0.773)	0.750	(0.743-0.756)
N3/ N6 Ratio ** p= 0.565*	0.165	(0.157-0.174)	0.166	(0.159-0.174)
EPA / AA Ratio ** p= 0.97*	0.089	(0.082-0.097)	0.090	(0.084-0.096)
DHA / AA Ratio ** p= 0.0001*	0.314	(0.304-0.323)	0.340	(0.331-0.350)

** p-value obtained by Student's t-test.*

Furthermore, concentrations of EPA and DHA varied statistically according to age groups (Table 3), with figures for the 55-74 age group respectively three times and twice greater than those observed to the 18-24 age group. As total omega-3 fatty acids (N3) increased with age, total omega-6 (N6) and omega-9 (N9) fatty acids decreased and, as expected, the N3/N6, EPA/AA and DHA/AA ratios increased . As regards concentrations of saturated fatty acids, a slight increase was observed according to age group, in particular among the 45-54 age group. Finally, no age trend was observed for the linolenic acid and the polyunsaturated/saturated fatty acids ratio.

Table 4 shows the prevalence of risk factors for cardiovascular diseases (CVD) according to sex among James Bay Cree. Except for triglycerides levels which are similar among men and women, cholesterol (total) and LDL levels, and cholesterol/HDL ratio were significantly higher among men, whereas HDL values were greater among women. Compared to Quebecers, the prevalence of high cholesterol, triglycerides, LDL and cholesterol/HDL ratio levels were lower in the Cree population. However, almost half of the Cree population showed ponderal obesity compared to 13% of Quebecers and more than 80% displayed abdominal (or troncal) obesity compared to 42% among of Quebecers. The prevalence of both obesity types was

Table 3. Blood Concentrations of Fatty Acids (expressed as % of phospholipids) according to Age Group among James Bay Cree.

Age Group / Fatty Acids	**18-24**	**(n= 251)**	**25-34**	**(n= 285)**	**35-44**	**(n= 146)**	**45-54**	**(n= 123)**	**55-74**	**(n= 112)**
	Mean	**(95% CI)**	**Mean**	**(95% CI)**	**Mean**	**(95% CI)**	**Mean**	**(95% CI)**	**Mean**	**(95% CI)**
EPA * *p= 0.0001*	0.526	(0.482-0.570)	0.656	(0.597-0.716)	0.883	(0.757-1.010)	1.188	(1.043-1.334)	1.614	(1.382-1.845)
DHA * *p= 0.0001*	2.338	(2.242-2.434)	2.720	(2.618-2.822)	3.035	(2.871-3.199)	3.733	(3.523-3.944)	4.278	(4.018-4.539)
EPA +DHA * *p= 0.0001*	2.864	(2.739-2.990)	3.377	(3.231-3.522)	3.919	(3.657-4.180)	4.922	(4.597-5.247)	5.892	(5.440-6.344)
Oleic Acid * *p= 0.0001*	13.83	(13.63-14.04)	13.29	(13.11-13.46)	12.69	(12.46-12.92)	12.27	(12.04-12.51)	12.07	(11.79-12.35)
Linoleic Acid * *p= 0.0001*	20.27	(19.98-20.56)	19.44	(19.15-19.73)	18.46	(18.00-18.93)	16.96	(16.46-17.46)	16.06	(15.46-16.65)
Linolenic Acid * *p= 0.80*	0.210	(0.200-0.221)	0.207	(0.196-0.218)	0.217	(0.199-0.234)	0.216	(0.196-0.236)	0.207	(0.190-0.224)
Arachidonic Acid * *p= 0.0001*	8.359	(8.139-8.579)	8.989	(8.778-9.200)	9.264	(8.965-9.564)	9.842	(9.508-10.18)	10.29	(9.927-10.64)
Docosapentanoic Acid * *p= 0.01*	0.643	(0.618-0.667)	0.670	(0.649-0.692)	0.741	(0.706-0.775)	0.813	(0.769-0.857)	0.910	(0.862-0.958)
Saturated Fatty Acids * *p= 0.0001*	47.10	(46.87-47.34)	47.32	(47.11-47.54)	47.98	(47.69-48.27)	48.44	(48.13-48.75)	48.17	(47.88-48.47)
Poly. Fatty Acids: N3 * *p= 0.0001*	3.884	(3.747-4.021)	4.430	(4.269-4.590)	5.082	(4.798-5.366)	6.181	(5.819-6.542)	7.231	(6.742-7.721)
Poly. Fatty Acids: N6 * *p= 0.0001*	31.93	(31.65-32.20)	31.65	(31.38-31.92)	30.99	(30.56-31.42)	29.75	(29.30-30.20)	28.90	(28.40-29.39)
Mono. Fatty Acids: N9 * *p= 0.0001*	17.19	(16.98-17.41)	16.69	(16.51-16.87)	16.04	(15.80-16.29)	15.71	(15.45-15.97)	15.77	(15.50-16.04)
Poly / Saturated Ratio * *p= 0.04*	0.763	(0.754-0.772)	0.765	(0.757-0.773)	0.754	(0.742-0.766)	0.744	(0.731-0.757)	0.752	(0.740-0.763)
N3 / N6 Ratio * *p= 0.0001*	0.123	(0.118-0.127)	0.142	(0.136-0.148)	0.167	(0.156-0.178)	0.212	(0.197-0.227)	0.259	(0.237-0.281)
EPA / AA Ratio * *p= 0.0001*	0.063	(0.058-0.067)	0.073	(0.066-0.079)	0.091	(0.081-0.102)	0.118	(0.105-0.130)	0.151	(0.132-0.170)
DHA / AA Ratio * *p= 0.0001*	0.280	(0.271-0.288)	0.304	(0.294-0.313)	0.329	(0.314-0.345)	0.381	(0.362-0.400)	0.416	(0.394-0.437)

* *p-value obtained by ANOVA.*

Table 4. Prevalence (weighted %) of risk factors for cardiovascular diseases according to sex among James Bay Cree and the Quebec population.

CVD Risk Factors (%)	Men (n=422) (%)	Women (n=495) (%)	Total (n=917) (%)	Quebec (n=2056)
Total Cholesterol:				
< 5.2 mmol/l	60.9	76.6	68.8	51.7
5.2-6.2 mmol/l	31.4	18.2	24.8	29.2
>= 6.2 mmol/l	7.7	5.2	6.4	19.1
* p = 0.001				
Triglycerides:				
< 2.3 mmol/l	90.2	90.5	90.3	83.2
≥ 2.3 mmol/l	9.8	9.5	9.7	16.8
* *p = 0.78*				
LDL:				
<3.4 mmol//	64.2	81.6	72.9	61.1
3.4-4.1 mmol/l	24.6	15.2	19.9	22.2
4.1-4.9 mmol/l	9.2	2.8	6.0	11.9
≥ 4.9 mmol/l	2.0	0.4	1.2	4.7
* *p = 0.001*				
HDL:				
< 0.9 mmol/l	11.2	8.7	10.0	7.7
≥ 0.9 mmol/l	88.8	91.3	90.0	92.3
* *p = 0.003*				
Cholesterol total / HDL Ratio:				
< 3.5	31.7	41.2	36.4	34.8
3.5 - 5.0	43.4	46.0	44.7	38.1
≥ 5.0	24.9	12.8	18.8	27.1
* *p = 0.001*				
Ponderal Obesity:				
BMI < 30	60.8	44.7	52.7	87.2
BMI ≥ 30	39.2	55.3	47.3	12.8
* *p = 0.001*				
Abdominal Obesity: waist/hip ratio				
< 0.9 (M) & < 0.8 (W)	22.4	8.5	15.5	58.9
≥0.9 (M) & ≥ 0.8 (W)	77.6	91.5	84.5	41.1
* *p = 0.001*				
High Blood Pressure:				
Diastolic < 90 mm Hg	86.6	86.9	86.8	86.2
Diastolic ≥ 90 or treatment	13.4	13.1	13.2	13.8
* *p = 0.73*				
Smoking:				
Non-smoking	44.7	53.6	49.2	68.2
Smoking	55.3	46.4	50.8	31.8
* *p = 0.001*				
Diabetes:				
No 96.1	88.6	92.5	94.1	
Yes 3.9	11.4	7.5	4.9	
* *p = 0.001*				
Sedentary:				
No	49.8	30.4	40.3	60.0
Yes	50.2	69.6	59.7	40.0
* *p = 0.001*				
Alcohol consumption:				
Abstainers	16.5	29.2	22.9	4.2
Former drinkers	28.3	31.3	29.8	7.4
Occasional & regular drinkers	55.2	39.5	47.3	88.4
* *p = 0.001*				

* p-value obtained by chi-square test

Table 5. Prevalence (weighted %) of risk factors for cardiovascular diseases according to age group among James Bay Cree.

CVD Risk Factors	18–24 (%)	25–34 (%)	35–44 (%)	45–54 (%)	55–74 (%)
Total Cholesterol:					
< 5.2 mmol/l	86.6	72.0	61.7	54.8	48.8
5.2–6.2 mmol/l	12.1	24.0	28.2	37.0	35.4
>= 6.2 mmol/l	1.3	4.0	10.1	8.2	15.8
* *p = 0.001*					
Triglycerides:					
< 2.3 mmol/l	93.9	89.8	83.8	88.8	93.6
≥ 2.3 mmol/l	6.1	10.2	16.2	11.2	6.4
* *p = 0.001*					
LDL:					
<3.4 mmol//	90.1	74.0	68.5	60.5	54.0
3.4–4.1 mmol/l	8.6	19.3	22.6	31.1	29.2
4.1–4.9 mmol/l	1.3	5.3	7.4	6.8	14.5
≥ 4.9 mmol/l	0.0	1.4	1.5	1.6	2.3
* *p = 0.001*					
HDL:					
< 0.9 mmol/l	8.1	14.0	10.7	7.5	6.0
≥ 0.9 mmol/l	91.9	86.0	89.3	92.5	94.0
* *p = 0.001*					
Cholesterol total / HDL Ratio:					
< 3.5 51.1	36.5	23.7	26.6	32.1	
3.5 – 5.0 38.3	42.1	49.4	52.2	50.7	
≥ 5.0 10.6	21.4	26.9	21.2	17.2	
* *p = 0.001*					
Ponderal Obesity:					
BMI < 30 68.2	59.9	39.1	31.6	42.9	
BMI ≥ 30 31.8	40.1	60.9	68.4	57.1	
* *p = 0.001*					
Abdominal Obesity: waist/hip ratio					
Normal:< 0.9 (M) & < 0.8 (W)	30.2	19.3	8.1	0.8	2.0
High: ≥ 0.9 (M) & ≥ 0.8 (W)	69.8	80.7	91.9	99.2	98.0
* *p = 0.001*					
High Blood Pressure:					
Diastolic < 90 mm Hg	95.5	92.9	84.2	69.0	76.0
Diastolic ≥ 90 or treatment	4.5	7.1	15.8	31.0	24.0
* *p = 0.001*					
Smoking:					
Non-smoking	23.5	41.8	63.5	73.5	76.6
Smoking 76.5	58.2	36.5	26.5	23.4	
* *p = 0.001*					
Diabetes:					
No 99.5	97.0	93.2	81.6	78.8	
Yes 0.5	3.0	6.8	18.4	21.2	
* *p = 0.001*					
Sedentary:					
No 43.0	40.7	35.4	38.0	42.5	
Yes 57.0	59.3	64.6	62.0	57.5	
* *p = 0.01*					
Alcohol consumption:					
Abstainers 10.3	19.4	27.8	31.8	41.4	
Former drinkers	15.5	28.3	40.7	38.0	41.0
Occasional & regular drinkers	74.2	52.3	31.5	30.2	17.6
* *p = 0.001*					

* p-value obtained by chi-square test

significantly much higher among women. The prevalence of high blood pressure did not vary according to sex and the overall prevalence was comparable to that found in Québec. The prevalence of diabetes was significantly higher among Cree women and than that reported by other Québec women (Santé Québec 1994). Overall, 51% of Cree population reported that they regularly or occasionally smoked compared to 32% of Quebecers and there were more men than women smokers. Sedentarity was more prevalent among Cree population and particularly among women. Besides, the prevalence of alcohol consumption was higher in men than in women but was less frequent in the Cree than Quebecers.

Table 5 shows that in general, the prevalence of risk factors for CVD observed among James Bay Cree increased significantly with age, in particular for cholesterol and LDL levels, abdominal obesity and diabetes. We observe also for the 34-44 age group, a jump in some prevalences of CVD risk factors such as blood lipids, obesity and blood pressure. Among the individuals aged over 45 years, high cholesterol levels, obesity and diabetes were particularly prevalent among them.

CONCLUSION

This project allowed to know the profile of plasma omega-3 fatty acids on a representative samples of James Bay Cree and to describe the prevalence of risk factors for cardiovascular disease in this population. The steady advances have shown that the major risk factors for cardiovascular disease are either preventable or controllable. Several studies conducted over the past 30 years have consistently shown that smoking, high blood pressure, elevated serum cholesterol and diabetes increase the risk of cardiovascular disease. In turn, these risk factors are strongly linked to abdominal obesity, diets high in saturated fat, and inadequate physical activity (IHHC 1992). According to the Santé Québec Health Survey, two thirds (66%) of the Cree population had one of the major risk factors for cardiovascular disease, i.e. smoking, high cholesterol or high blood pressure (Santé Québec 1994). Although diabetes is a relatively recent condition among the Cree, it is more prevalent than elsewhere in Québec. Moreover, obesity, particularly abdominal obesity, is reaching epidemic proportions in the Cree population.

Several epidemiological and experimental studies showed association between the omega-3 fatty acids and a low mortality of cardiovascular disease and a reduced tendency to development of atherosclerotic and thrombotic lesions. As mentioned before, omega-3 fatty acids are derived essentially from the consumption of marine products. In Nunavik, the arithmetic mean of omega-3 fatty acids (EPA+DHA) for Inuit, expressed as percentages of phospholipids, was found to be 8% whereas that of Quebecers was found to be 1.8% (Dewailly 1994, Dewailly 1998). Thus, the mean concentration of omega-3 fatty acids found in James Bay Cree represents about the halfway point between that of Inuit and Quebecers. Omega-3 fatty acids measured in the bloodstream of Inuit were associated with a significant increase in HDL cholesterol and a decrease in triglycerides (Dewailly 1994). Additional data analysis demonstrated also that high levels of EPA+DHA were associated with low levels of insulinemia. Moreover, a negative correlation was observed between blood pressure and omega-3 fatty acids levels. Among obese men showing high omega-3 fatty acids levels, high blood HDL-cholesterol were associated to low triglycerides and insulinemia levels. These results could indicate a protective effect of omega-3 fatty acids against some risk factors for cardiovascular disease.

Over the past years, emphasis was put on health risks related to the consumption of mercury-contaminated fish. Very little information was given to the Cree population about the nutritional values of fish consumption. The results from the project will allow to elaborate recommendations for James Bay Cree about health benefits of fish consumption.

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THE INFLUENCE OF EXPERTS' KNOWLEDGE ON THE SOCIAL REPRESENTATION OF RISKS AND ON THE MODIFICATION OF HEALTH RELATED BEHAVIOUR: A PILOT PROJECT

Project Leader: É. Dewailly, Director, Environmental Health Service, Québec Public Health Centre.

Project Team: S. Bruneau, G. Muckle, Environmental Health Service, Québec Public Health Centre, M. Grey, Chairperson Nunavik Nutrition, and Health Committee.

OBJECTIVES

General:

1. to determine if the communication of expert knowledge is influencing the social representations of risks and benefits, linked to food chain contamination, and health related behaviours.

Specific:

1. to assess to what extent risk data is interpreted and adapted among participants of the Infant and Health Development Study (Dr. Gina Muckle).

DESCRIPTION

The accumulation and biomagnification of potentially toxic substances in the fauna and the physical environment of the Eastern Canadian Arctic, including Nunavik, has been clearly demonstrated during the last decades (Barrie *et al.* 1992, Lockhart *et al.* 1992). Since 1987, the studies undertaken in Nunavik (risk identification, external dose assessment, biological exposure, health impact evaluation) have all clearly stated that unusual quantities of contaminants are present in the food chain, that there is potential health risk relating to contaminant intake.

Paradoxically, these studies also showed that there are very important benefits from eating relatively large quantities of marine mammals and fish (Dewailly *et al.* 1989, 1992, 1994). This situation (potential risks vs. real benefits) allow scientists to transmit to the populations under study very confusing messages. In this context, it has been observed that community residents tend to generate their own information and explanations through a process of "contaminants gossip" (Usher *et al.* 1994). It is well recognized in the literature that individuals who do not have the technical expertise needed to interpret scientific data will counteract this situation by putting in place a set of heuristic rules that can create a dissonance between perceived risk and real risk identified by scientists (Grondin and Larue 1995). For many authors lay knowledge derives from what people experience and is of great worth (Brown 1993, Stacey 1994, Phillimore and Moffat 1994). For Stacey, lay knowledge can be quite complex. It is the essence of people's experience, and it can be modified and passed on, mostly by word of mouth. Its crucial characteristics are that it is informal, experiential and mostly unwritten.

It has been observed that in the Eastern Arctic, communication activities related to environmental topics have induced a great variety of social effects. Thus, the notification of the population of PCB contamination in Broughton Island and the Northwest Territories (Allen 1991), or by mercury in Salluit (Wheatley and Wheatley 1981), is a good example of psychosocial repercussions linked to environmental contamination. Furthermore, the Santé Québec Inuit Health Survey (1992) showed that risk communication on PCBs in Nunavik seems to affect perceptions of food quality and life habits (imported food is better for your health, decrease in consumption of marine mammals and fish during breast-feeding) (Dewailly *et al.* 1993). However, these repercussions have not been adequately characterized and one can ask how do the Nunavimiut perceive interpret and adapt the risks they are exposed to.

It seems that the range of induced behaviours can vary according to the type of environmental stress experienced, the personality of each individual, the availability of a natural support network and the community context (Elliott *et al.* 1993). Meanwhile it is quite surprising to observe that few studies raise the question of modification of behaviour adopted to cope with perceived environmental risks.

ACTIVITIES IN 1997/98

The budget initially requested for the realization of this study was $44,500 and the amount granted by the Northern Contaminants Program was $19,500. Since no co-funding was found, this grant allowed the main researcher to work part-time (1.5 days/week) on the realization of the preliminary phase of the study. The main activities consisted of a literature review and the observation of the ongoing process of the Infant Health and Development study

Proposed methodology

For the purpose of the pilot project, a sub-sample of 7 women in prenatal period and 7 women at twelve months post-partum will be solicited to participate in semi-structured interviews. These interviews will include questionnaires and directed open-ended questions. With the authorization of all participants, the semi-structured interviews will be recorded.

For the final phase of the study, 50 participants will be recruited from the Infant Health and Development Study that consists of all women who gave birth in Kuujuarapik, Inukjuak and Puvirnituq and agreed to participate.

The Infant Health and Development study

Observations on the implementation and the ongoing process of the study has allowed to realize that an important dimension has been taken into account in the 1997-1998 project: Information has been disseminated on a community basis as well as at the individual level. For example, at the first interview with a participating mother, background information, objectives of the study and future steps are discussed with the scientific team members. Meanwhile, the main researcher and members of the Nunavik, Nutrition and health Committee have done some phone-in shows during which the population raised questions on this particular project but also questions on contamination of the food chain and interpretation of other study results. These communication activities are creating a situation where not only participants to the study but all community members are aware of the Infant Health and Development study and have their own opinion about it and about the overall context of risk and benefits linked with the food chain contamination. This context is outlining, the fact that a social dynamic of risk communication exists and that it is essential to take it into account. One can ask: How will the participants of the study adapt and interpret scientific data? Will the participants be influenced by "contaminants gossip"? Can it have an impact on their health related behaviour?

Finally, the Infant Health and Development study procedures include samples of hair from the participants (when first interviewed), blood (just before delivery), milk, babies cord blood (at delivery) and first meconium. When the baby is 6.5, 9.5, and 12 months, its neurobehavioural and cognitive development, as well as its neuromotor and neurologic functions, are assessed in the presence of the mother. A blood sample is also taken from the baby at 6.5 months.

Given this information we realized that a medical framework (interventions such as hair, milk and blood samples) is used to clarify the question of *in utero* exposure to contaminants creating a situation of medical control. Could the fact of medicalizing a situation that has not yet been declared as a medical problem have an impact on health related behaviours of the participants? This indeed, adds a new dimension to our study and has to be documented.

CONCLUSION

It has been decided to broaden the objectives of the study in order to propose a conceptual framework that is more appropriate to include this new preoccupation: the social representation of risks. The social representation framework includes a society's values, ideas, beliefs and practices as rules systems structuring social life and as codes facilitating communications (Moscovici 1990). This field of study gives great importance to social interactions and cognitive process. It is now recognized that social representations are governing our relations with the world and with others and are orienting and organizing social conducts and communications (Moscovicci 1989, Jodelet 1989).

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INTEGRATION OF 12 YEARS OF DATA IN A RISK AND BENEFIT ASSESSMENT OF TRADITIONAL FOOD IN NUNAVIK

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Project Team: P. Ayotte, Ph.D.; C. Blanchet, M.Sc.; S.Bruneau, M.Sc.; G. Muckle, Ph.D., S. Gingras, M.Sc.; Centre de Santé Publique de Québec

Collaborators: J.-F. Proulx, Nunavik, Nutrition and Health Committee-Kuujjuak, Québec; A. Gilman, Health Canada, Ottawa; P. Bjerregaard, DICE Copenhagen - Denmark.

OBJECTIVES

The general objective of this study is to review all data generated by our research group over the past 12 years in a risk/benefit assessment framework, taking into consideration the current health status of the Inuit population, in order to better advise communities about the safety of traditional food.

The specific objectives are to:

1. identify, using current data bases, major causes of morbidity and mortality for the Inuit population and study their relationship with dietary and/or environmental determinants
2. identify major causes of morbidity and mortality in industrialized countries which are rare in Nunavik and study their relationship with dietary determinants
3. determine etiologic and prevented fractions resulting respectively from an increase in prevalence of positive risk factors (Hg, PCB) and from an increase in prevalence of negative risk factors (omega-3 fatty acids)
4. summarize all health risks and benefits related to the consumption of traditional foods.

DESCRIPTION

Over the past decade, we have conducted various studies and programs in Nunavik in order to assess which contaminants are potentially harmful to health, what are the levels of exposure of Inuit people (breast-fed babies, foetus and adults) and which effects could be linked to this exposure (breast-fed infants and forthcoming, foetus) (Dewailly *et al.* 1989, 1991, 1992a, 1993a, 1993b, 1996). In particular, we have gathered numerous data on biological exposure of pregnant women and their offspring to organochlorines and heavy metals using blood and breast milk samples. More recently, pilot studies were conducted regarding early effects of prenatal exposure to food chain contaminants, at the biological level and at the clinical level (Ayotte 1994, Muckle 1994). We also started risk characterization by comparing the exposure with safety levels recommended by various health organizations (Ayotte 1995, 1996). In reviewing the literature regarding possible health effects induced by low-level environmental exposure to four major food-chain contaminants (mercury, lead, PCBs and DDE), adverse effects on reproduction and development were identified as the main public health concern. Therefore, our evaluation of the health risks associated with food-chain contaminants in Inuit from Nunavik was mainly focused on these possible health issues (Dewailly *et al.* 1996).

In parallel to this work, dietary surveys were conducted in various age groups and regions. Nutrient and contaminant concentrations were measured and used to estimate average daily intakes. Results from these projects allowed us to answer the following important questions: What are the main contaminants of concern? What is the level of exposure compared to other populations? Which food items are the major source of exposure? Which subgroups of the population are more exposed or susceptible to contaminants? What kind of health effects could be due to contaminants? In 1995-1996, we evaluated the effectiveness of different food restriction scenarios designed to reduce contaminant intake while maintaining nutritional benefits in the event that exposure to contaminants exceeded tolerable daily intakes (Dewailly *et al.* 1996). However, this project was not elaborated to orient public health authorities regarding the need for such dietary restriction advisories to be forwarded to the population. Furthermore, our report focussed on specific health endpoints associated with four contaminants (PCBs, DDE, mercury, lead), not on all health aspects relevant to northern communities. Northerners are entitled to receive the most complete and precise information on both risks and benefits of traditional food. Because of the large uncertainty surrounding traditional risk assessment, ambiguous messages have been provided to Arctic populations with regard to the contamination of traditional food, which led to confusion, anxiety and likely lifestyle modifications, in particular moving away from the traditional diet. In doing so however, the intake of important nutrients are reduced, which may have deleterious effects on the health status of this population. There is need to examine risk and benefits from traditional foods globally, taking into consideration the current health status of the population, in addition to theoretical calculations of risks and benefits.

ACTIVITIES IN 1997/98

Sources of Data

The main data bases that we selected are (all developed at CHUL) are listed below:

For the major causes of mortality and morbidity in Nunavik:

- "Fichier des Décès au Québec (K-26)" [1]
- "Fichier des Tumeurs au Québec"[1]
- "Fichier des naissances et des mortinaissances au Québec"[2]
- "Santé Québec Health Survey conducted among Inuit of Nunavik in 1992"[3]
- "Santé Québec Cardiovascular Survey conducted among Quebecers in 1990"[3]
- "National Cancer Incidence Reporting System"[4].

[1]Ministère de la Santé et des Services Sociaux du Québec; [2]Bureau de la Statistique du Québec; [3]Santé Quebec Administration; [4]Statistics Canada

To characterize the biological exposure of contaminants:

Prenatal exposure to contaminants:

- "Cord Blood Monitoring Program 1993-1996"

Postnatal exposure to contaminants:

- Study on "Breast milk contamination by PCDDs, PCDFs and PCBs in Arctic Québec".

For health effects induced by exposure to food contaminants:

Prenatal and early effects:

- "Cord Blood Monitoring Program: Physical growth at birth and thyroid hormone status;
- "Infant Development Study: Physical growth at birth, development at 6 month of age"
- Study on "Susceptibility to infections and immune status in Inuit infants exposed to organochlorines"

Exposure of Inuit adults:

- "The Santé Québec Health Survey among the Inuit of Nunavik"
- "Organochlorine exposure of Inuit women giving birth in Arctic Quebec"
- "Exposure of remote maritime populations to coplanar PCBs"
- "PCBs and dioxin-like compounds in plasma of adult Inuit living in Nunavik"

To document the contamination of traditional foods:

- "The Northern Contaminant Database"
- "La contamination du milieu et des ressources fauniques de la zone d'étude du Complexe Grande-Baleine et du Complexe Nottaway-Broadback-Rupert", developed by Hydro-Québec.

To characterize the nutrient content of traditional foods:

- Data obtained from nutrient content analysis of fishes, wildfowl and marine mammals of Northern Québec (data base developed by our team and from Kuhnlein 1991).

To perform the risk/benefit analysis of traditional food consumption:

- "Health risk assessment and elaboration of public health advisories concerning food contaminants in Nunavik"
- "Arctic Air pollution and human health: what effects should be expected?

Data analysis

The major causes of morbidity and mortality for adults and infants were identified from available data bases. Only those that have known or suspected dietary and/or environmental determinants were included in this study.

Considering the health endpoints identified during the first phase, contaminants and nutrients of interest were selected. Exposure assessment of the Inuit population to selected contaminants was performed using biological exposure data (pending on the availability of a biological exposure index (i.e. PCBs, dioxin-like compounds, DDE, lead, mercury) (Santé Québec 1994a, Dewailly 1996, Ayotte *et al.* 1997). Biological samples that have been analysed for organochlorines in the Inuit population include breast milk samples collected in 1989-1990 from 107 Inuit women (Dewailly *et al.* 1992b, 1993a, 1994a), blood samples collected from 492 Inuit adults in 1992 (Dewailly *et al.* 1996) and cord blood samples collected in the course of the "Cord blood surveillance program", which took place in Nunavik from 1993 to 1996 (Muckle 1998). Daily intakes were either determined from food questionnaire data and food contamination data (Santé Québec 1994a, Dewailly *et al.* 1996), or estimated using concentration in biological samples and toxicokinetic modelling (Ayotte 1995, 1996, Dewailly 1996).

Estimates of relative and attributable risks for the various health outcomes were derived from epidemiologic or toxicological data and available dose-response models. Similarly, we estimated the relative protective effects of nutrients on the incidence or prognosis of these health outcomes (Kleinbaum 1987). Whenever possible, prevented fraction (PF) in the exposed population was also measured by generalized impact fraction, which reflects a reduction in the disease rates in the Inuit population as a result of a change in the distribution of exposure. This reduction could result either from a decrease in the prevalence of a positive risk factor or from an increase in the prevalence of the negative risk factors.

Finally, we synthesized for each major health problem the relative impact of contaminants and nutrients in the incidence and/or the prognosis of these health conditions.

RESULTS

1. The causes of mortality and diseases in excess in Nunavik and their relationship with Inuit diet

1.1 Mortality rates among Inuit adults

In Nunavik, the standardized mortality rate per 100,000 person-years from all causes was 1239 between 1987 and 1996, compared to 649 for Quebec as a whole. In all regions of Quebec, the mortality rate has been decreasing by 24% since 1975. In Nunavik, the reduction among men and women was respectively of 22% and 53%. For the period 1993-95, life expectancy in Nunavik differed markedly from other regions of Quebec (Choinière *et al.* 1998). It was approximately 10 years less than in Quebec as a whole.

- Diseases of the respiratory system

During the 1987/1996 period, diseases of the respiratory system were the leading cause of mortality in Nunavik with a mortality rate of 232 compared to 56.5 in Quebec as a whole (Table 1). Infectious diseases, pneumonia, influenza, chronic obstructive pulmonary disease and bronchiectasis which are also more prevalent in Nunavik explain this high rate. Extreme cold, smoking and passive smoking, poor indoor air quality, crowding are all factors which can have a detrimental effect on respiratory system and these risk factors are much more common in Nunavik (Hodgins 1997). It has been suggested that infectious diseases of the respiratory system could be associated at least in part, to a deficient vitamin A intake (see section 3 on nutrition).

- Lung cancer

The standardized mortality rate from lung cancer is also much higher in Nunavik compared to that observed in Quebec and this observation is in agreement with the standardized incidence rate (SIR) reported among Canadian Inuit (Tables 1 and 2). According to Miller and Gaudette, the smoking pattern among Inuit, possibly combined with co-factors related to environment and diet, are believed to be the relevant causal factors for lung cancer (Miller 1996b). Possible co-factors include extreme cold, insufficient vitamin A intake and exposure to irritants such as carving dust. Alternatively, there could be some genetic factor that might explain the high incidence and mortality rate of lung cancer in the Inuit population.

- Nasopharynx and salivary gland cancer

This type of cancer is classically recognized to be in excess in Nunavik (Tables 1 and 2). According to the Nunavik Cancer Registry, the nasopharynx cancer represented 13% of all cancers occurring from 1969 to 1989 (Hodgins 1997). Genetic predisposition, Epstein-Barr virus (EBV virus), smoking and diet have a role in the etiology of this cancer (Lanier 1996a). Intake of large amounts of salted fish could activate nitroso-compound formation and thus could contribute to nasopharynx carcinogenesis (Goodhart 1980). Moreover, the low consumption of fresh fruits and vegetables (thus low vitamin C intake) by the Inuit population, which can inhibit nitroso-compound formation, could explain in part the increased nasopharynx cancer incidence.

- Colon and rectum cancers

Colon cancer seems to be in excess in Nunavik (Table 1). There is a significant difference between mortality rates observed in Nunavik and in Québec. In addition to differences in diet, access to health care, availability of specialized diagnostic procedures, methods used to record and classify must all be considered (Storm 1996). It has been suggested that low consumption of dietary fibres including whole grain sources, fruits and vegetables could contribute to colon cancer and the Inuit population does not consume enough of these foods. Also, a diet rich in total fat and/or animal proteins, or low in vitamin C could be a risk factor for this type of cancer.

Table 1. Causes of mortality (1987-1996): Standardized Mortality Rates per 100,000 person-years.

Causes of mortality (CIM-9)	Gender	Nunavik	Québec
All causes	Males	1568	935.6
	Females	1070	521.9
	Total	1239	694.3
Lung cancer (162)	Males	141.1	99.7
	Females	134.8 *	30.1
	Total	143.0 *	59.1
Naso-pharynx and salivary glands cancers (140-149)	Males	5.4	7.3
	Females	10.1 * †	1.5
	Total	7.5	4.0
Colon and rectum cancers (153)	Males	52.0	21.9
	Females	32.7	16.3
	Total	40.1 * †	18.6
Liver cancer (155)	Males	0.0	5.1
	Females	0.0	2.4
	Total	0.0	3.6
Breast cancer (174)	Females	17.9	31.3
Corpus uteri cancer (182)	Females	0.0	2.3
Ovary cancer (183)	Females	0.0	7.4
Prostate cancer (185)	Males	0.0	28.7
Testis cancer (186)	Males	0.0	0.4
Bladder cancer (188)	Males	0.0	8.1
	Females	0.0	2.2
	Total	0.0	4.4
Kidney cancer (189)	Males	8.4	6.3
	Females	0.0	3.0
	Total	5.1	4.4
Ischaemic heart disease (410-414)	Males	118.7	216.4
	Females	50.7	106.9
	Total	72.3 *	153.5
Myocardial infarction (410)	Males	29.7 * †	132.1
	Females	25.8	63.0
	Total	24.2 * †	92.7
Hypertensive diseases (401-405)	Males	0.0	4.3
	Females	9.6	4.6
	Total	4.8	4.6
Cerebrovascular diseases (433-438)	Males	81.9 *	39.7
	Females	43.8	30.4
	Total	70.2 *	34.3
Diseases of respiratory system (460-519)	Males	229.3 *	90.2
	Females	253.1 *	37.1
	Total	232.2 *	56.5
Infections diseases of respiratory system (460-487)	Males	31.5	23.1
	Females	37.8	13.3
	Total	34.6	16.8
Pneumonia and influenza (480-487)	Males	31.5	22.6
	Females	37.8	13.0
	Total	34.6 * †	16.5
Bronchitis, emphysema, and asthma (490-493)	Males	7.9	16.3
	Females	5.3	6.1
	Total	7.6	9.9
Bonchectasis and chronic obstructive pulmonary diseases (494-496)	Males	184.2 *	b41.8
	Females	151.8 *	12.5
	Total	155.9 *	23.1
Other diseases of respiratory system (510-519)	Males	5.7	6.9
	Females	58.2 * †	4.1
	Total	34.1 * †	5.2

* Statistically significant difference ($p \leq 0.05$)
† C.V. > 33 %

Table 2. Incidence of cancer in Canadian Inuit: Standardized Incidence Ratio (SIR)*

Cancer site	Gender	1984 - 1988 SIR (95 % CI)	1969 - 1988 SIR (95 % CI)
Total cancer	Males	1.2 (1.0 - 1.4)	1.1 (0.9 - 1.2)
	Females	1.0 (0.9 - 1.3)	1.0 (0.9 - 1.1)
Lung cancer	Males	2.6 (2.0 - 3.4)	2.3 (1.9 - 2.7)
	Females	3.8 (2.6 - 5.3)	5.1 (4.1 - 6.3)
Naso-pharynx cancer	Males	34.5 (17.8 - 60.4)	24.0 (15.7 - 35.1)
	Females	49.0 (19.6 - 101)	25.1 (12.5 - 45.0)
Colon cancer	Males	0.9 (0.4 - 1.8)	0.8 (0.5 - 1.3)
	Females	0.5 (0.1 - 1.3)	0.7 (0.4 - 1.2)
Rectum cancer	Males	0.0 (—)	0.5 (0.2 - 0.9)
	Females	1.8 (0.6 - 3.9)	1.4 (0.8 - 2.4)
Liver cancer	Males	0.0 (—)	0.4 (0.0 - 2.1)
	Females	0.0 (—)	2.3 (0.5 - 6.9)
Gall bladder and biliary tract cancers	Males	1.8 (0.0 - 9.7)	1.7 (0.3 - 5.1)
	Females	1.3 (0.0 - 7.4)	2.3 (0.7 - 5.3)
Breast cancer	Females	0.3 (0.1 - 0.5)	0.2 (0.1 - 0.3)
Corpus uteri cancer	Females	0.2 (0.0 - 1.1)	0.2 (0.0 - 0.5)
Ovary cancer	Females	0.9 (0.2 - 2.3)	0.5 (0.2 - 1.1)
Prostate cancer	Males	0.3 (0.1 - 0.7)	0.2 (0.1 - 0.4)
Testis cancer	Males	0.9 (0.1 - 3.1)	1.0 (0.3 - 2.1)
Bladder cancer	Males	0.2 (0.0 - 0.9)	0.1 (0.0 - 0.4)
	Females	0.0 (—)	0.2 (0.0 - 1.0)
Kidney cancer	Males	1.2 (0.3 - 3.0)	1.1 (0.5 - 2.0)
	Females	1.4 (0.3 - 4.2)	1.4 (0.6 - 2.8)
Leukemia	Males	1.4 (0.6 - 2.9)	1.0 (0.6 - 1.7)
	Females	0.6 (0.1 - 2.1)	0.4 (0.1 - 1.0)
Thyroid cancer	Males	0.0 (—)	0.5 (0.0 - 2.5)
	Females	0.4 (0.0 - 2.5)	0.3 (0.0 - 1.2)

* Reference population is the Canadian population (Census years: 1970, 1980, 1990).

Table 3. Prevalence (%) of main health problems

Health problems	Nunavik	Québec
< 15 years		
Hearing problems	9.1	na[1]
Diseases of respiratory system	7.6	9.9
Cutaneous allergies and other infections	4.5 *	8.4
Allergies	4.0 *	8.9
Thyroid problems	1.9*	0.2
Anemia	1.8 *	0.4
15 to 24 years		
Hearing problems	14.8	0.6
Diseases of respiratory system	4.7	6.1
Allergies	4.6	15.7
Thyroid problems	2.7 *	0.2
Cutaneous allergies and other infections	2.8	8.7
Anemia	2.3	0.9
25 to 44 years		
Hearing problems	9.9	0.6
Allergies	8.0	13.1
Diseases of respiratory system	6.0	4.7
Arthritis and rheumatism	5.7	6.4
Cutaneous allergies and other infections	5.2	8.6
≥ 45 years		
Hearing problems	23.1	na
Diseases of respiratory system	19.8	8.1
Arthritis and rheumatism	16.9	24.6
Bone and joint diseases	11.8	4.4

* Statistically significant difference ($p \leq 0.05$)

[1] data not available

Table 4. Infant mortality: 1992-1996

Infant mortality	Nunavik	Québec
Mortinatality (per 1000 births)	5.9	4.1
Perinatal mortality (mortinatality + death < 7 days per 1000 births)	15.4	7.2
Total neonatal mortality (Death < 28 days per 1000 live births)	11.1	3.7

• Cerebrovascular diseases

Cerebrovascular diseases (stroke) including stenosis and obstruction of precebral and cerebral arteries, and cerebral transitory ischemia are in excess in Nunavik compared to Québec, particularly among Inuit men (Table 1). It appears that the main causes for cerebral diseases in Nunavik differ from those in southern Québec. In the South, most cerebrovascular diseases are due to atherosclerosis and to high blood pressure; these causes are less prevalent in Nunavik (Hodgins 1997). The pathogenesis of cerebrovascular diseases has not been investigated enough in Inuit populations. According to Burgess (personal communication), this high rate could be explained by residual valvulopathogenesis of post-streptococcus infection that took place in Nunavik 50 years ago, which in turn is a risk factor for cerebrovascular diseases. The bleeding time among Inuit is known to be too long and strokes seem to be more of hemorrhagic origins among Inuit. Excessive bleeding time is possibly related to omega-3 fatty acid intake. Only an autopsy study looking at brain tissues in patient who died from stroke will be able to confirm this hypothesis.

1.2 Prevalence of main diseases among Inuit adults

Morbidity indicators such as hospitalization rates and statistics of dispensary consultation are difficult to obtain in Nunavik and often, may be somewhat inaccurate. Of the numerous means of measuring a population's state of health, subjective evaluation is widely used today (Santé Québec 1994a). The increasing popularity of this method since the 1960s has been amply justified (Goldstein *et al.* 1984). Previous studies have generally shown that the state of health of the Inuit population is poorer than that of the Québec population as a whole. In the *Santé Québec Health Survey*, Inuit people were asked to describe their perceived state of health and 44% reported at least one health problem during the two week period prior to the survey. This occurred more frequently among women than among men (49% vs. 40%) and women reported more health problems than men. According to the *Santé Québec Health Survey*, the perceived state of health appeared closely linked with the presence of health problems.

• Hearing problems

The majority of the studies showed that the most prevalent health problems among the Inuit were hearing problems (Hodgins 1997). In the *Santé Québec Survey*, apart from specific hearing problems such as otitis or deafness, hearing impairments represented the most frequently occurring health problems reported by the Inuit and 12% of the population was affected. Table 3 presents the prevalence of main health problems reported by Inuit. Hearing problems were the most common health problems reported by Inuit of all age groups. Repeated infections during childhood, perforation and scarring could result in permanent hearing loss (Hodgins 1997). The contributing factors are described in section 1.4 (otitis media).

• Diseases of the respiratory system

In the *Santé Québec Health Survey*, diseases of the respiratory system represented the second health problem reported by Inuit adults (Table 3) and this perception was closely linked with the high mortality rate by respiratory diseases observed in Nunavik. In this survey, one Inuit out of eight mentioned that respiratory diseases were the reason for the most recent health professional consultation. The risk factors for respiratory problems are quite prevalent in Nunavik and their prevention should constitute a priority, since they have a considerable impact upon the Inuit quality of life.

• Other diseases

Among other health problems declared by Inuit adults, headaches, mental health problems, thyroid problems and anemia were more frequently reported by the Inuit than by Quebecers (Santé Québec 1994a).

1.3 Mortality rates among Inuit infants/children

Infant mortality dropped dramatically through the 1960s, with the improvement of living conditions and accessibility to appropriate health care services. However, infant mortality rate in Nunavik remains by far the highest in Québec. For the years 1992 to 1996, the infant mortality rate in Nunavik was 23.6/1000 live births, compared to 5.4/1000 in Québec (Table 4). Neonatal death (under 28 days of life) and post-neonatal mortality rates (death from 28 to 365 days) in Nunavik are respectively 3 and 6 times higher than the rates observed for Québec. According to Hodgins, main causes of infant mortality in Nunavik are congenital anomalies (33%), infections (28%) and sudden infant death syndrome (28%) (Table 5) (Hodgins 1997). During the time period 1987–1996, mortality rates for congenital anomalies (per

100,000 person-years) were significantly higher than those observed in Québec, particularly among male babies (Table 6). Data suggest that congenital heart anomalies are more frequent in Nunavik compared to Québec but the difference is not significant. Other congenital anomalies may also be more common in Nunavik, including: a defect of the nerves of the large bowel (Hirsprung's disease), brain abnormalities and intra-cerebral aneurysms (genetic origin). According to Hodgins, reasons for higher rates of congenital anomalies could include nutritional deficiencies early in pregnancy, genetic predisposition and toxic exposures (alcohol, environmental contaminants).

Table 5. Main causes of infant mortality in Nunavik

Main causes of infant mortality	%
Congenital causes (Birth defects)	33
Infections	28
Sudden Infant Death Syndrome: SIDS	28
Other causes	11

1.4 Prevalence of main diseases among Inuit infants/children

• Respiratory diseases

Bronchiolitis and pneumonia are the most important causes of hospitalization during the first year of life in Nunavik. In 1994 and 1995, 32% of babies born required one hospitalization episode. According to Hodgins, most cases of bronchiolitis (and many cases of pneumonia) are caused by the Respiratory Syncytial Virus. A recent study revealed that 72% of children in grades four to six showed at least one episode of lower respiratory tract infection before the age of two years (Ernst, unpublished data). Children with a history of lower respiratory tract infection are more likely to show signs of chronic airway abnormalities, a situation contributing to the development of chronic obstructive pulmonary disease in adult life. Chronic airway abnormalities were also associated with passive smoking among Inuit children (Hodgins 1997). However, several studies confirmed the increased risk of respiratory diseases in children with nutritional deficiencies such as preexisting vitamin A deficiency (Sommer 1996). In effect, clinical and histopathologic studies of vitamin A-deficient children revealed early metaplasia of the tracheobronchial tree.

• Otitis media

Otitis media (ear infection) is a major problem among Inuit children. In the study that we conducted among Inuit infants in 1989-1990, 80% had experienced at least one otitis media episode during the first year of life (Dewailly, submitted). Moreover, in a study conducted during 1987 among pre-school children in Inukjuak, we observed that the ear condition was normal in only 24% of children; 63% of children showed past history of otitis media and 13% showed current incidence of the disease (Bruneau *et al.* 1987). Genetically determined IgG2 deficiency, anatomy, physiology, diet, passive smoking and crowded housing are all factors that can contribute to otitis media among Inuit children. Breast-feeding for a long period of time with contaminated milk may be a risk factor to this disease (Dewailly, submitted). According to Sommer, otitis media was one of the first infections to be associated with vitamin A deficiency in humans and reported to respond to vitamin A therapy (Sommer 1996). Squamous metaplasia of the middle ear occurs early in vitamin A deficiency and greatly increases the risk of otitis media.

2. Contaminants in Nunavik

2.1 Overview of health effects possibly induced by exposure to organochlorines and heavy metals

In reviewing the literature regarding the possible health effects induced by low-level environmental exposure to the major food chain contaminants of the Arctic aquatic food chain (heavy metals and organochlorines), adverse effects on reproduction and development were identified as the main public health concern. Therefore, our evaluation of the health risk associated with food-chain contaminants in Inuit from Nunavik was mainly focused on these possible health issues. In addition, since several OCs have been identified as endocrine disrupters, it is pertinent to review their possible involvement in hormone-dependent diseases.

2.1.1 Lead

There is no official recommendation in Canada regarding acceptable concentrations of lead in blood of adults. In the United States, authorities recommend avoiding lead concentrations in the bloodstream in excess of 1 to 1.2 µmol/L (Landrigan 1990). In 1991, the Centers for Disease Control (CDC) published a statement regarding the prevention of lead poisoning in young children, in which it is stated that blood levels as low as 0.5 µmol/L, which do not cause distinctive symptoms, are associated with decreased intelligence and impaired neurobehavioural development (CDC 1991). Many other effects begin at these low levels including decreased stature or growth, decreased acuity and decreased ability to maintain a steady posture. Lead's impairment of vitamin D metabolism is detectable at blood lead levels of 0.5-0.75 µmol/L. Maternal and cord blood lead levels in the same range appear to be associated with reduced gestational age and reduced weight at birth. The CDC further adds that although researchers have not yet completely defined the impact of blood lead concentrations below 0.5 µmol/L on central nervous system function, it may be that these levels are associated with adverse effects that will be clearer with more defined research. The role of prenatal exposure to lead on the neurodevelopment of infants is still debated. However, since there is a close correspondence between maternal and cord blood levels and because lead may be transferred to the infant through breast feeding, it is prudent to apply the same limit to infants and women of reproductive age. Therefore, the reference level for lead in blood was set at 0.5 µmol/L. Data from the *Santé Québec Health Survey* conducted in 1992 (Table 7) indicate that 24% of women aged 18 to 39 years had a blood concentration exceeding the 0.5 -mmol/L limit. Seven percent of cord blood samples collected between 1993 and 1996 in Nunavik (33 out of 475) contained lead in excess of the reference value (Table 8).

2.1.2 Mercury

According to the World Health Organization, the levels of methylmercury associated with a low (5%) risk of neurological damage to adults are approximately 1000 nmol/L, corresponding to 50 µg/g of hair (WHO 1990). For pregnant women or women of reproductive age, the recommendation is 400 nmol/L. However, WHO cautioned that a 5% risk of neurological disorder in the offspring (subtle effects) may be associated with a peak mercury level of 10-20 µg/g in maternal hair (roughly 200-400 nmol/L in blood).

Studies involving children of fish eaters have been conducted in many countries: Quebec (the Cree First Nations), New Zealand, Peru, Seychelles and the Faroe Islands. These studies documented the effects of a maternal hair mercury concentration below 20 µg/g on childhood development. In Cree children aged 12 to 30 months, abnormality of muscle tone or reflexes was positively associated with mercury exposure to an average maternal hair concentration of 6 µg/g; this effect was seen in boys only (McKeown-Eyssen 1983). In Peru, anthropometric characteristics at birth (weight, head circumference and length) and postnatal neurological examination were not significantly correlated with peak hair methylmercury concentration (mean = 8.3 µg/g, values ranging from 1.2 to 30 µg/g) (Marsh *et al.* 1995). In the Seychelles Islands study, the neurological examination, the Denver Comprehensive Development Test, the Fagan's visual recognition test and the visual attention index developed by Rose were all administered at 6.5 months of age. No significant associations were found between exposure and the effects studied (Myers *et al.* 1995a). In this study, maternal hair mercury ranged from 0.5 to 26.7 µg/g with a median peak of 5.9 µg/g. Nevertheless, in a pilot study conducted within the same population, Myers found a negative correlation between exposure and the results of the Denver Test during the period from 5 to 109 weeks of age (Myers *et al.* 1995b). Until recently, since no significant correlation had been identified between maternal hair mercury concentration during pregnancy and developmental parameters in infants from the Seychelles and from Peru, a 300 nmol/L mercury blood level (corresponding approximately to 15 µg/g of hair) was considered as the critical biological exposure limit for methyl mercury in women of reproductive age.

However, the recent release of results from the Faroe Islands study renewed the debate concerning the neurotoxicity of prenatal exposure to low doses of methylmercury. In this cohort, the average maternal hair mercury concentration was 4.27 µg/g at parturition and ranged from 2.6 to 7.7µg/g. Clinical examination and neurophysiological testing did not reveal any clear-cut mercury-related abnormalities but the neuro-psychological testing showed subtle negative effects in the domains of language, attention, and memory, and to a lesser extent in visuospatial and motor functions in 7-year-old children (Grandjean *et al.* 1997). These negative effects in the domains of cognitive, language and visuo-motor functions were not observed in 711 children from the Seychelles Islands who were tested at 66 months of age (unpublished data).

Results from the *Santé Québec Health Survey* (Table 7) indicate that only 1.7% of Inuit women aged between 18 and 39 years had a mercury concentration above the 300-nmol/L biological exposure index, all concentrations being inferior to 360 nmol/L. Since cord blood mercury levels are usually 1.5 time greater than those found in maternal blood, the reference value applicable to cord blood mercury level is 450 nmol/L. Only two out of the 475 cord blood samples analysed for Hg between 1993 and 1996 (0.4%) displayed a concentration exceeding this reference value. Moreover, the reference limit derived from the above studies may not apply to the Inuit population, because selenium which is present in marine food consumed by Inuit may afford protection against methylmercury toxicity (WHO 1990).

2.1.3 Organochlorines

- Immunological effects and susceptibility to infectious diseases

Several OCs display immunotoxic properties in both laboratory animals and humans, the most potent being substances structurally related to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) such as non - and mono-ortho chloro-substituted PCBs as well as 2,3,7,8-chloro-substituted PCDD/Fs. These molecules can bind to the AH (aryl hydrocarbon) receptor (Safe 1990) and the ligand-receptor complex triggers the expression of genes which are involved in cell proliferation and differentiation (Whitlock 1991). In almost all animal species tested, including primates, PCDD/Fs and PCBs produce myelosuppression, immunosuppression, thymic atrophy, and inhibition of immune complement system components (NRC 1992). Exposure to TCDD during pre and/or postnatal life results in more severe effects than if the chemical is administered during adult life and in some species may be a prerequisite for immunosuppression (Hoffman *et al.* 1986, Vos 1989). In fact, available evidence in laboratory animals suggests that the maturation of the immune system is especially vulnerable to the adverse effects of dioxin-like compounds, chlordane, hexachlorobenzene, polycyclic aromatic hydrocarbons and possibly endocrine disrupting compounds such as DDT and kepone (Barnett *et al.* 1987, Holladay 1996).

In children and young adults accidentally exposed to PCBs and PCDFs in Taiwan ("Yu-Cheng disease"), serum IgA and IgM concentrations as well as percentages of total T cells, active T cells and suppressor T cells were decreased compared to values in age and sex matched controls (Chang *et al.* 1981). The investigation of delayed type hypersensitivity responses further indicated that cell mediated immune system dysfunction was more frequent among patients than controls. Infants born to Yu-Cheng mothers had more episodes of bronchitis or pneumonia during their first 6 months of life than unexposed infants from the same neighborhoods (Rogan *et al.* 1988). The authors speculated that the increased frequency of pulmonary diseases could result from a generalized immune disorder induced by transplacental or breast milk exposure to dioxin-like compounds, more likely PCDFs (Rogan 1988). Eight to 14 year old children born to Yu-Cheng mothers were recently shown to be more prone to middle-ear diseases than matched controls (Chao 1997).

The high incidence of infectious diseases in young native children from Nunavik has been known for many years, in particular meningitis, broncho-pulmonary and middle ear infections (Duval 1982, Dufour 1988, Proulx 1988). Otitis media and the damage it can cause to hearing is a major problem of Inuit children and adults. In fact, Inuit in Nunavik report hearing loss as their most common chronic health problem (Santé Québec 1994a). In 1984, 78% of Inuit school children in Kuujjuarapik were found to have had current or previous ear infections and 23% of the children had a significant hearing loss in one or both ears (Julien *et al.* 1987). The prevalence of hearing loss among 74 students tested in Inukjuak in 1988 was 24% (Proulx 1988). In 1995/1996, screenings performed on the coast of Ungava found a 28% rate of hearing loss in students (unpublished data).

In view of the immunotoxic properties displayed by some OCs, in particular following perinatal exposure, we hypothesized that part of the high infection incidence among Inuit infants could be related to the relatively high maternal body burden of these contaminants, and its partial transfer to the newborn during breast feeding. Hence, a cohort study was set up in Nunavik to investigate the relationship between gestational or lactational exposure to OCs and 1) the occurrence of infectious diseases and 2) the immune status in Inuit infants during the first year of life. The number of infectious disease episodes in 70 breast-fed and 48 bottle-fed infants was compiled during the first year of life. Concentrations of organochlorines were measured in breast milk and immune system parameters determined in venous blood samples collected from infants at 3, 7 and 12 months of age. The risk of otitis media among breast fed infants appeared lower than in bottle-fed infants during the first trimester but not thereafter. During the second and third follow-up periods, the risk increased with terciles of cumulative exposure to several organochlorines among breast-fed infants (e.g. for PCBs at 4-7 months: RR = 1.88, 95%-CI = 1.01 - 3.51). Furthermore, a negative association was found between CD4/CD8 ratio and either cumulative PCB exposure or breast feeding duration during this period. We concluded that organochlorine exposure through breast feeding can modulate the immune system function and may be a risk factor for acute otitis media in Inuit infants. However, data from this study cannot be used to derive a dose/response relationship. Therefore the risk of otitis attributable to OC exposure cannot be computed.

- Reproductive and developmental effects - PCBs

At low exposure doses, PCBs induced adverse effects on reproduction and development in rhesus monkeys and there is some evidence that humans are also affected, although this issue is highly controversial (for a literature review on the subject, see Swain, 1991). In the rhesus monkey, it affected the foetus (abortions, resorptions, reduced weights at birth and stillbirths) and the reproduction (longer menstrual cycles, reduced progesterone levels in the blood). These effects were observed at the lowest dose of Aroclor 1248 administered, about 100 µg/kg/day (Allen 1980, Barsotti 1975). However polychlorinated furans were detected in the mixture given to monkeys (1.7 ppm) which could explain, partly or entirely, the toxic effects observed. In another study, where furan-free Aroclor 1016 was administered, less severe effects were observed (Barsotti 1984). In the group receiving 40 µg/kg/day, the average weight of newborns was significantly lower than in the control group. The NOAEL identified in this study was 10 µg/kg/day. These studies helped in establishing the

Table 6. Standardized mortality rates for different causes of infant mortality: 1987-1996 (per 100,000 person-years)

Causes of mortality (CIM-9)	Gender	Nunavik	Québec
Congenital causes (740-759)	Males	13.6 *	4.5
	Females	9.3 * †	3.8
	Total	11.5 *	4.2
Congenital cardiac causes (745-746)	Males	3.6	1.7
	Females	1.3	1.2
	Total	2.5	1.5

* Statistically significant difference ($p \leq 0.05$)
† C.V. > 33 %

Table 7. Concentrations of food contaminants in blood samples from Inuit adult

Contaminant			Arithmetic mean	Geometric mean
Mercury (nmol/L)	Adult population		109.3	79.60 (73.77 - 85.89)
Gender	Men		113.5	74.96 (65.24 - 86.12)
	Women		106.3	83.21 (76.56 - 90.44)
Gender / Age	Men:	18 - 39 years	75.82	53.67 (45.69 - 63.04)
		40 - 74 years	162.3	115.6 (93.63 - 142.7)
	Women:	18 - 39 years	80.15	64.21 (58.14 - 70.91)
		40 - 74 years	148.6	126.7 (113.7 - 141.2)
Plomb (nmol/L)	Adult population		0.496	0.422 (0.401 - 0.445)
Gender	Men		0.536	0.479 (0.448 - 0.512)
	Women		0.467	0.385 (0.358 - 0.414)
Gender / Age	Men:	18 - 39 years	0.479	0.429 (0.394 - 0.468)
		40 - 74 years	0.610	0.553 (0.502 - 0.608)
	Women:	18 - 39 years	0.397	0.333 (0.304 - 0.364)
		40 - 74 years	0.580	0.486 (0.435 - 0.543)
PCB (Aroclor 1260)(µg/L)	Adult population		29.68	17.82 (16.20 - 19.61)
Gender	Men		33.87	20.55 (17.68 - 23.89)
	Women		26.55	16.02 (14.19 - 18.09)
Gender / Age	Men:	18 - 39 years	18.34	12.42 (10.47 - 14.72)
		40 - 74 years	54.18	39.71 (32.57 - 48.42)
	Women:	18 - 39 years	12.56	9.265 (8.229 - 10.43)
		40 - 74 years	48.95	38.54 (33.54 - 44.27)
p,p,'-DDE (µg/L)	Adult population		12.40	7.594 (6.934 - 8.316)
Gender	Men		13.47	8.469 (7.379 - 9.720)
	Women		11.59	7.001 (6.208 - 7.896)
Gender / Age	Men:	18 - 39 years	7.319	5.224 (4.494 - 6.071)
		40 - 74 years	21.52	15.93 (13.29 - 19.10)
	Women:	18 - 39 years	5.419	4.093 (3.643 - 4.597)
		40 - 74 years	21.39	16.41 (14.19 - 18.98)

Table 8. Newborn exposure (geometric mean): Cord blood study (1993-1996)

Contaminant	Nunavik	Québec
BPC (Aroclor 1260) (µg/Kg)	831	211
DDE + DDT (µg/Kg)	397	na[1]
Mercury (nmol/L)	71.0	4.3
Plomb (µmol/L)	0.191	0.09

[1] data not available

reference dose for PCBs. The reference dose proposed by the USEPA (1998) is 0.07 µg/kg/day (US EPA 1998).

Epidemiological studies conducted with children from North Carolina, Michigan and Taiwan who had been exposed to PCBs, showed diminished learning abilities (Jacobson 1990, Gladen *et al.* 1988, Rogan *et al.* 1988). Such effects have also been observed in monkeys and could be related with the capacity of certain congeners to decrease dopamine neurone concentrations in the caudate, nucleus putamen, substantia nigra and hypothalamus (Shain 1991, Seegal 1990).

On the basis of results from epidemiological studies on child development, a "NOAEL" of 1 mg/kg in milk fat was identified for the most sensitive effect, i.e. a decrease of the visual cognitive memory (Tilson 1990). However, Schwartz and coworkers (1983) who conducted the PCB analysis in the Michigan study used a different quantification method than that used by the *Centre de Toxicologie*, which conducted the analysis in the *Santé Québec Survey* (Schwartz *et al.* 1983) . In view of these differences the 1-ppm NOAEL identified by Tilson and coworkers (1990) likely corresponds to a 2-ppm concentration in the *Santé Québec Survey*. Considering the total lipid concentration in plasma, then the 2-ppm NOAEL corresponds to 12 µg/L and 5 µg/L for women of reproductive age and newborns, respectively. In the *Santé Québec Health Survey*, the mean concentration in Inuit women aged between 18-39 years was 12.6 µg/L, with 33% of them above the reference level (Table 7). Results from the Cord Blood Surveillance Program in Nunavik revealed that 10.1% (48) of the 475 plasma samples analysed contained PCBs in excess of the 2 ppm NOAEL. An epidemiological study is presently underway to investigate the role of contaminant exposure and other lifestyle factors in modulating neurodevelopment in Nunavik.

In the North Carolina cohort, suppression of reflexes, as determined by the Brazelton Neonatal Behavioural Assessment Scale, appeared to be associated ($p < 0.06$) with levels of DDE in breast milk exceeding 4 mg/kg (fat basis) (Rogan *et al.* 1986). Given the mean total plasma lipid concentration of 6.0 g/L determined among women aged 18-39 years, the DDE concentration expressed on a fat basis translates into a 24-µg/L whole plasma concentration. However, other organochlorines could be involved, as PCBs (a mean concentration of 3.5 mg/kg fat) and other organochlorines were also present in the environmental mixture to which the foetus was exposed.

- Organochlorine mediated endocrine disruption and hormone-dependent diseases

Some environmental chemicals mimic, while others antagonize natural hormone activity when tested with *in vitro* assays or in whole animal models. Studies dating back to the late sixties identified *o,p'* -DDT, a minor constituent of technical DDT, as a weak estrogenic compound, capable of causing an augmentation of rat uterine weight in the classic immature female rat model (Bitman 1969). This substance and a few others sharing estrogenic properties have been implicated in abnormal sexual development in reptiles (Guillette Jr. *et al.* 1994, 1995) and birds (Fry 1981) as well as feminized responses in male fish (Jobling *et al.* 1995). More recently, toxaphene (Bonefeld Jrrgensen 1997), β-hexachlorocyclohexane (Coosen 1989, Steinmetz 1996) have been identified as estrogenic in various *in vitro* bioassays. While these compounds have yet to be causally related to adverse responses in humans, their possible involvement in reproductive disorders has been hypothesized based on studies with the synthetic estrogen diethylstilbestrol in animals and humans (Davis *et al.* 1993).

- Male fertility and reproductive tract disorders

The quality of male sperm have been reported to be declining in some parts of the world (Auger *et al.* 1995, Carlsen *et al.* 1992, Cheek 1998). In addition, certain male reproductive tract disorders (cryptorchidism, hypospadias, testicular cancer) have been reported to be increasing in parallel with the introduction of xenoestrogens such as DDT into the environment (Cheek 1998). Although these alterations are thought to be mediated by the estrogen receptor, they are also consistent with inhibition of androgen receptor-mediated events. Kelce and coworkers identified the major and persistent DDT metabolite, 1,1-*bis*[4-chlorophenyl]-2,2-dichloroethylene (*p,p'*-DDE), as a potent antiandrogenic agent in male rats (Kelce *et al.* 1995). In addition to inhibiting androgen binding to the androgen receptor, this compound when administered to pregnant dams also induced characteristic antiandrogenic effects in male pups (reduced anogenital distance; presence of thoracic nipples). Treatment with *p,p'*-DDE at weaning delayed the onset of puberty, while treatment of adult rats resulted in reduced seminal vesicle and ventral prostate weights. Their results suggest that as little as 65 µg/L could antagonize androgen-induced biological events, such as androgen-driven sexual maturation in the foetus. Table 7 shows that average concentration in Inuit adults are well below this level. Only 2 women and 3 men aged over 40 years showed concentrations above 65 mg/L. No women aged 18 to 39 years exceeded this limit. Similarly, no cord blood samples collected between 1993 and 1996 in Nunavik contained concentrations of *p,p'*-DDE over this reference limit.

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is yet another organochlorine which has been shown to alter sexual development in male rats (Mably *et al.* 1992). Decreases in epididymis and cauda epididymis weights, daily sperm production and cauda epididymal sperm number were observed at day 120 and at most earlier times, when a dose as little as 64 ng/kg was administered to dams on day 15 of gestation. We previously calculated that this dose should result in a 525 ng/kg lipid concentration in dams (Ayotte *et al.* 1996). A number of compounds structurally related to TCDD referred to as *dioxin-like compounds*, including other 2,3,7,8-chloro- substituted dibenzo-*p*-dioxins, dibenzofurans, as well as non-ortho, mono-ortho and some di-ortho substituted polychlorinated biphenyl (PCB) congeners, bind to the AH receptor and display similar toxicological properties, albeit with varying potency (Safe 1990). Pooled samples made up of individual samples collected in the course of the *Santé Québec Health Survey* were analysed for dioxin-like compounds (Ayotte *et al.* 1997). The mean total dioxin-like compound concentrations for the two pooled samples comprising individual samples from Inuit women aged 18-39 years was 83 ng TEQ/kg lipids, a concentration more than 6-fold lower than that shown to induce reproductive dysfunction in male offspring by Mably and colleagues.

- Cancer

Several organochlorines have induced cancer in laboratory animals which lead IARC and US EPA to classify these compounds as either possible or probable carcinogens in humans (IARC 1978, 1979, 1991, 1997, US EPA 1998). Epidemiologic evidence suggesting a carcinogenic effect of OCs is however scarce.

Key and Reeves summarized all the evidence from epidemiology available on the relationship between exposure to PCBs or DDT analogues and breast cancer (Key 1994). They concluded that it is unlikely that DDT in the environment increases the risk of breast cancer. However, they pointed out that all published epidemiological evidence at that time came from six studies comprising a total of 301 women with breast cancer and 412 women without. They further mentioned that the question is important and still deserves additional studies to be conducted. For PCBs, they concluded that there is no evidence for an association with breast cancer risk and that there was no need to pursue this question further. Their argumentation was based in part on that fact that PCBs have been classified as "probably carcinogenic" to humans by the International Agency for Research on Cancer, with a possible association with cancer of the liver and biliary passages. There is no strong reason to expect PCBs to cause breast cancer rather than any other cancer.

It is noteworthy that while there is some evidence that PCBs are estrogenic (Bitman 1969). Moore and co-workers recently produced data suggesting that hydroxy metabolites of several PCB congeners also possess anti-estrogenic properties, using two estrogen responsive *in vitro* bioassays (Moore *et al.* 1997). Similarly, while 2,3,7,8-TCDD has been classified as *carcinogenic to humans* by IARC (1997), in the cancer bioassay conducted by Kociba and co-workers, a striking decrease in the incidence of mammary tumors was observed in females rats treated over two years with daily doses of 10 ng/kg bw, in line with the anti-estrogenic properties of TCDD (Kociba *et al.* 1978, Safe 1991).

Mortality and morbidity data indicate that the incidence and mortality rates of hormone-dependent cancers (breast, corpus uteri, ovary and prostate) are lower in the Inuit population than the general Canadian population (Tables 1 and 2).

As already discussed above, it has been recently suggested that the recent rise in the incidence of testicular anomalies, including testicular cancer, could be attributable to *in utero* exposure to endocrine-disrupting chemicals (Kelce *et al.* 1995, Sharpe *et al.* 1993, 1995). However, this hypothesis has not been supported by any epidemiological data. Interestingly, the incidence and mortality rates of testicular cancer in Inuit do not differ from those in the general Canadian population (Tables 1 and 2).

Dioxin-like compounds are suspected of causing cancer in humans based on evidence form epidemiological and animal studies. In evaluating the carcinogenic potential of 2,3,7,8-TCDD, IARC (1997) noted that four epidemiological studies of high-exposure industrial cohorts in Germany, the Netherlands and the United States found an increase in overall cancer mortality (IARC 1997). In these cohorts, the blood lipid 2,3,7,8-TCDD levels estimated to the last time of exposure were 2000 ng/kg (mean) (up to 32 000 ng/kg) in the United States cohort, 1434 ng/kg geometric mean (range, 301-3683 ng/kg) among accident workers in the Dutch cohort, 1008 ng/kg geometric mean in the group of workers with severe chloracne in the BASF accident cohort in Germany and measurements up to 2252 ng/kg in the Boehringer cohort in Germany. These calculated blood 2,3,7,8-TCDD levels in workers at time of exposure were in the same range as the estimated blood levels in a two-year rat carcinogenicity study (Kociba 1978). In rats exposed to 100 ng/kg bw 2,3,7,8-TCDD per day, hepatocellular carcinomas and squamous-cell carcinomas of the lung were observed. Estimated blood lipid levels were 5000-10 000 ng/kg 2,3,7,8-TCDD. In the same study, in rats exposed to 10 ng/kg bw 2,3,7,8-

TCDD per day, hepatocellular nodules and focal alveolar hyperplasia were observed. Estimated blood lipid levels were 1500-2000 ng/kg 2,3,7,8-TCDD. The NOEL in this study was 1 ng/kg/day, corresponding to 540 ng/kg blood lipid at the end of the study. These results indicate parallel tumorigenic responses to high exposure to 2,3,7,8-TCDD in both humans and rats.

Since body burden of 2,3,7,8-TCDD have been estimated in studies described above, it is of interest to compare the body burden of dioxin-like compounds to those associated with a carcinogenic effect. The mean total TEQ concentration of dioxin-like compound (plasma lipids) in Inuit people aged 50 years and over was 281 ng/kg (Ayotte *et al.* 1997). This concentration is two-fold lower than the NOAEL in the study Kociba and colleagues and well under those associated with excess cancer in epidemiological studies in occupational settings. Total cancer incidence in Canadian Inuit is quite similar to that for the general Canadian population in both men and women (Table 2).

Liver cancer is of special interest in relation with organochlorine exposure. In addition to 2,3,7,8-TCDD, PCBs have been associated with an increased risk of liver cancer, as mentioned previously. Moreover, several OCs have been shown to be liver carcinogens in laboratory animals. Therefore, one might expect that liver cancer incidence might be increased in populations receiving an unusually high exposure to organochlorines. One way of looking at this question is through inspection of mortality and morbidity data (section 1). Mortality data indicate that no death from liver cancer occurred in Nunavik Inuit from 1987 to 1996 (Table 1). Incidence data for Canadian Inuit do not show an excess in liver cancer incidence between 1969 and 1988, compared to the general Canadian population (Table 2).

- Endometriosis

As mentioned previously, some organochlorines display estrogenic properties, even though their estrogenic potencies are substantially lower than that of estradiol. In addition, PCBs as well as PCDDs and PCDFs can also interfere with immune system functions (Vos 1989). This constitutes the basis for the hypothesis of a link between endometriosis and organochlorine exposure (Ahlborg et al. 1995). Two experimental studies involving rhesus monkeys studied this association. In a recent investigation during which rhesus monkeys were chronically exposed to 2,3,7,8,-tetrachlorodibenzo-p-dioxin (TCDD) through the diet (5 or 25 ppt), Rier *et al.* reported a dose-response relationship between TCDD exposure and the incidence and severity of endometriosis (Rier *et al.* 1993, 1995). Initial observations reported by Campbell *et al.* also suggested a possible link between PCB (Aroclor 1254) exposure and the occurrence of endometriosis in the rhesus monkey (Campbell 1985). More recently, after a thorough review of the data, the same research group concluded, however, that there was no evidence to support an association between PCB exposure and the incidence and severity of endometriosis (Arnold *et al.* 1996).

In the study by Rier and coworkers, females in the 5-ppt group had 2,3,7,8-TCDD concentrations in adipose tissues of approximately 100 ng/kg near the end of the 3.5-year treatment period. This concentration fell to around 50 ng/kg at 18 months post-treatment (Bowman 1989). We previously showed that a typical Inuit female receiving the median exposure through breast feeding would have a 125 ng TEQ/kg fat concentration at weaning (total dioxin-like compounds), gradually declining thereafter to reach a concentration exceeding 50 ng/kg during adulthood. We concluded that it is likely that a substantial proportion of Inuit women would have, during most of their lifetime, adipose tissue concentrations of dioxin-like compounds close to or higher than those associated with increased incidence of endometriosis in the rhesus monkey (Ayotte 1996). Results from a study recently conducted by our group among women from the Québec City area indicated that organochlorine exposure was not associated to endometriosis in women from the general population receiving a low dose of organochlorine (Lebel *et al.* 1998). However, the relationship has not been investigated in the Inuit population which shows a higher exposure to organochlorines than the general southern Québec population.

3. Nutrition

3.1 Overview of nutritional deficiencies in Nunavik and effects of deficiency

• Vitamin A deficiency

The most important function of vitamin A is related to the maintenance of normal vision. Vitamin A is also required for healthy epithelium, reproduction, normal skeletal and tooth development. Moreover, vitamin A plays an essential role in maintaining the integrity of anatomic barriers to infection and has an adjutant action in both humoral and cellular immunity (Sommer 1996). Vitamin A intakes in the Inuit population are insufficient. The vitamin A content of some Inuit traditional foods such as liver of marine and land mammals is elevated (Table 9) but these foods are seasonally consumed, such that they might not provide the necessary vitamin A requirement (Dewailly *et al.* 1996). Milk and margarine that are fortified with vitamin A are not frequently consumed by the Inuit (Santé Québec 1994a). As observed at Table 10a, median vitamin A intakes of Inuit men and women represented respectively 50% and 33% of the recommended intake in Canada (particularly among older adults). β-carotene intake of Inuit adults was also lower than that found in the Quebec population, reflecting their insufficient consumption of fruits and vegetables, including certain yellow and green ones that contain provitamin A carotene (Table 10b). The deficient vitamin A intake could play a role in the high prevalence of some diseases in Nunavik such as infectious diseases (respiratory system, otitis) and also the iron-deficiency anemia (Sommer 1996).

• Iron-deficiency anemia

Iron deficiency (anemia) is the most common nutritional deficiency and results from one or a combination of the following: inadequate diet, impaired absorption, blood loss or repeated pregnancies (Goodhart 1981). Anemia is also recognized as a potential consequence of vitamin A deficiency (Sommer 1996). In populations similar to Nunavik, there is evidence that *Helicobacter pylori* may play a role in rendering a significant proportion of the population iron deficient, even when iron intake seems to be adequate (Hodgins *et al.* 1996). Iron deficiency anemia is a medical and public health problem of prime importance, contributing seriously to weakness and ill health. It may also result in impaired cell-mediated immunity and may increase susceptibility to infection. Iron is widely distributed in meat groups including marine mammals and wildfowl (Dewailly *et al.* 1996), in liver and in whole-grain or enriched cereals and breads, legumes and some deep-green leafy vegetables. In a study conducted in Nunavik among Inuit women and infants, the prevalence of anemia (Hb < 115 g/L) was 40% among full term pregnant women (Hodgins 1996 *et al.*). Fifty-eight percent of the infants aged between 9-14 months were anemic (Hb < 110 g/L), while another 18% had depleted iron stores. In that study, 27% of Inuit women had positive or equivocal *Helicobacter pylori* serologies compared to 10% in the comparison group. In addition, the *Santé Québec Health Survey* revealed that recommended daily intakes for iron were partly reached by Inuit women aged between 18-34 years while those of men and older women were reached (Table 10c) (Santé Québec 1994a). As regards infants, their iron intake could be also deficient. According to Hodgins *et al.*, whole cow's milk is widely used for Inuit infants instead of fortified milk formulas, and iron-fortified cereals are little used in Nunavik (Hodgins 1997).

• Vitamin C deficiency

Vitamin C (ascorbic acid) is involved in several hydroxylation metabolic reactions such as formation of the collagen, an abundant protein that forms the intercellular substance in cartilage, bone matrices, dentin and the vascular epithelium. This hydroxylation function helps to explain the importance of vitamin C in wound healing and the ability to withstand the stresses of injury and infection. It is also an hydrosoluble antioxydant. Vitamin C shows a stimulant effect on dietary non-hemic iron absorption. Moreover, it has been demonstrated that vitamin C inhibits the growth of *Helicobacter pylori*, a risk factor for anemia and gastric carcinogenesis (Zhang *et al.* 1997). Almost all of the daily intake of vitamin C is generally obtained from the vegetable-fruit group. Some plants and berries found in Nunavik are excellent sources of vitamin C. The *Santé Québec Health Survey* revealed that mean vitamin C intakes of Inuit men and women were low, reaching only 25% of the recommended daily intake among Inuit aged 50 years and over (Table 10d) (Santé Québec 1994a). Moreover, it has been established that requirements among smokers are increased by 50% (Health and Welfare Canada 1990). This is of interest in Nunavik, since 68% of the Inuit population is smoking.

• Calcium deficiency

Of the approximately 1200 grams of calcium in the adult body, 99% are found as the salts forming the matrix of bones and teeth. The remaining 1% is distributed throughout the extracellular and intracellular fluids and it fulfills important functions: it regulates the contraction and relaxation of muscles, including the heartbeat, aids in the absorption of vitamin B_{12} and catalyzes two steps in the clotting of blood (Robinson 1981). The *Santé Québec Health Survey* revealed that all Inuit adults displayed low calcium intakes (Table 10e). Moreover, calcium median intakes represented less than half the recommended daily intake for Canadian adults.

Table 9. Nutrient content of Nunavik traditional foods

Species	Energy (kcal)	Proteins (g)	Lipids (g)	Vit. A (U.I.)	Vit. D[1] (U.I.)	Fe (mg)	Ca (mg)	Mg (mg)	P (mg)	Se (mg)	Zn (mg)	EPA[2] (mg)	DHA[3] (mg)
FISH:													
Longnose Sucker	89.0	18.4	1.49	2.59	65.1	0.24	19.6	17.4	186	0.04	0.52	82.9	179
White Sucker	83.0	17.7	1.15	4.35	263	0.26	63.1	21.8	203	0.05	0.30	75.2	212
Lake Whitefish	107	23.3	1.30	4.88	445	0.32	25.7	17.2	237	0.05	0.38	59.1	251
Northern Pike	95.5	21.8	0.67	6.70	77.0	0.21	32.6	17.3	209	0.04	0.41	44.4	165
Arctic Cod	111	24.8	1.04	2.49	198	0.59	20.2	18.1	194	0.07	0.47	165	329
Fourhon Sculpin	111	20.6	2.93	15.3	356	2.50	96.5	18.5	460	0.05	0.79	198	324
Brook Trout	113	23.5	1.78	2.40	335	0.30	9.30	21.0	230	0.04	0.46	112	322
Lake Trout	98.0	20.9	1.35	3.94	890	0.25	6.11	20.8	209	0.08	0.38	72.7	232
Ouananiche	138	24.3	4.25	2.10	629	0.38	11.6	22.9	240	0.05	0.57	269	612
Walleye	88.9	20.1	0.71	7.70	521	0.20	31.0	21.2	216	0.04	0.32	52.2	156
Red Charr	141	20.2	7.20	2.40	335	0.70	7.20	21.0	257	0.04	0.60	780	690
Atlantic Salmon	139	19.8	6.40	40.0	335	0.80	12.0	29.0	200	0.04	0.64	300	900
WILDFOWL:													
Northern Pintail	130	26.4	2.36	14.3	na[4]	7.10	2.10	13.5	275	0.04	1.14	58.7	54.0
Green-winged Teal	133	26.0	2.94	13.2	na	5.37	9.93	15.3	260	0.04	0.84	79.1	51.4
American Black Duck	127	25.7	2.42	21.5	na	6.18	6.24	17.3	215	0.05	0.96	71.9	40.2
Canada Goose	121	23.9	2.52	36.5	na	5.63	8.07	13.3	250	0.02	1.33	12.9	27.9
Common Loon	120	24.1	2.37	8.70	na	7.35	5.8	19.5	260	0.06	2.40	76.8	32.0
Herring Gull	150	26.3	4.64	154	na	7.38	14.3	17.3	233	0.07	1.60	126	119
Willow Ptarmigan	123	25.6	1.98	14.8	na	5.03	8.04	18.2	252	0.01	0.67	17.8	28.8
Black Scoter	136	25.1	3.68	29.4	na	7.05	27.1	15.5	311	0.06	1.20	116	103
MARINE MAMMAL:													
White Whale													
meat	110	24.2	1.17	na	na	16.1	4.30	13.0	180	0.17	3.00	80.1	79.4
skin	185	24.2	9.40	na	na	0.18	10.0	14.0	140	0.55	3.00	326	340
fat	898	0	98.7	1556	372	0.28	3.30	0.10	14.0	na	0.20	4303	4974
liver	na	na	na	na	na	na	na	na	na	2.11	3.22	na	na
Ringed Seal													
meat	184	29.3	7.01	3.20	36.2	26.3	3.4	22.5	205	0.05	2.54	88.3	118
fat	790	0	86.8	2221	3012	2.10	2.10	1.90	25.0	na	0.30	6277	12285
liver	138	25.1	3.83	160661	938	15.5	15.5	15.0	275	0.61	4.12	189	140

[1] The vitamin D content could not be determined in all species due to the small amount of tissue available.
[2] EPA = Eicosapentanoic acid: C20:5N3.
[3] DHA = Docosahexanoic acid: C22:6N3.
[4] na = data not available.

Traditional food showed low calcium concentrations and market food such as milk and dairy products, which are important sources of this mineral, are not consumed enough by the Inuit people (Santé Québec 1994a). Kinloch *et al.* found surprisingly high amounts of calcium in the skin of Red Charr (268 mg/100g) (Kinloch 1992). Moreover, according to Kinloch, bone (cooked in soups) and bone marrow (e.g. from caribou) are other potential sources of calcium in the Inuit diet. Osteoporosis was never measured among Inuit adults and according to Hodgins, there is no evidence that it is prevalent in Nunavik (Hodgins 1997). However, in the *Santé Québec Survey*, 11.8% of Inuit aged 45 years and over declared suffering from osteoarticular diseases (Table 3). Osteoarticular diseases were also the leading cause of long-term disability, as perceived by Inuit adults in the survey.

4. The causes of mortality and the diseases in deficit in Nunavik and their relationship with the Inuit diet

4.1 The causes of mortality in deficit in Nunavik

In Nunavik, cancer incidence and mortality rates of cardiovascular diseases (CVD) are reduced compared to Québec, Canada and other industrialized countries. The low incidence could be explained by genetic factors, Inuit diet, lifestyle factors or by the absence of some risk factors.

- Cardiovascular diseases

Even though cardiovascular diseases appear to be a significant cause of death in Nunavik, they are in deficit compared to Québec as a whole. From 1987 to 1996, the mortality rate (per 100,000 person-years) from ischaemic heart disease amounted to 72.3 in Nunavik

Table 10a. Median daily intakes of vitamin A (μg ER)

		RNI*	Nunavik	Québec
Men				
	18 - 34 years	1000	390	905
	35 - 49 years	1000	372	1000
	50 - 74 years	1000	186	1015
Women				
	18 - 34 years	800	299	743
	35 - 49 years	800	402	762
	50 - 74 years	800	202	829

* Recommended nutrient intake in Canada

Table 10b. Median daily intakes of β-carotene (μg ER)

		RNI*	Nunavik	Québec
Men				
	18 - 34 years		134	—
	35 - 49 years		137	—
	50 - 74 years		151	—
Women				
	18 - 34 years		122	—
	35 - 49 years		138	—
	50 - 74 years		110	—

* There is no recommended nutrient intake for β-carotene (provitamin A) but it contributes to vitamin A intake

Table 10c. Median daily intakes of iron (mg)

		RNI*	Nunavik	Québec
Men				
	18 - 34 years	9	13.0	16.3
	35 - 49 years	9	12.8	15.7
	50 - 74 years	9	15.8	14.4
Women				
	18 - 34 years	13	10.1	11.0
	35 - 49 years	13	13.7	10.8
	50 - 74 years	8	13.2	10.1

* Recommended nutrient intake in Canada

Table 10d. Median daily intakes of Vitamin C (mg)

		RNI*!	Nunavik	Québec
Men				
	18 - 34 years	40	37.0	81.8
	35 - 49 years	40	20.9	74.1
	50 - 74 years	40	7.8	72.0
Women				
	18 - 34 years	30	29.9	74.7
	35 - 49 years	30	17.5	60.8
	50 - 74 years	30	7.6	81.0

* Recommended nutrient intake in Canada
! Smokers should increase by 50% their vitamin C intake

Table 10e. Mean daily intakes of calcium (mg)

		RNI*	Nunavik	Québec
Men				
	18 - 34 years	800	341	984
	35 - 49 years	800	325	769
	50 - 74 years	800	398	673
Women				
	18 - 34 years	700	347	688
	35 - 49 years	700	309	555
	50 - 74 years	800	265	532

* Recommended nutrient intake in Canada

compared to 153.4 for Québec as a whole and this difference was statistically significant (Table 1). Furthermore, for the same period, the mortality rate from myocardial infarction was 24.2 in Nunavik, compared to 92.7 for Québec.

The steady advances in identifying the major contributing factors have shown that CVD are preventable or controllable. Smoking, high blood pressure, elevated serum lipids and diabetes increase the risk of CVD. In turn, these risk factors are strongly linked to abdominal obesity, diets high in saturated fat and inadequate physical activity (sedentary). In Nunavik, prevalences of high blood pressure and elevated blood lipids such as cholesterol, triglycerides, LDL-cholesterol and cholesterol/HDL ratio are significantly lower than those in Québec (Table 11) (Blanchet 1994, Santé Québec 1994b). However, prevalences of smoking and ponderal and/or abdominal obesity are higher in Nunavik than those observed in Québec while prevalences of diabetes are approximately equal. Considering the deleterious effects of tabagism and obesity on blood pressure, blood lipids and diabetes, one would expect higher prevalences of these cardiovascular risk factors in Nunavik and consequently, higher mortality rates from ischaemic heart diseases, but this is not the case.

Protection afforded by omega-3 fatty acids: Numerous studies reported that the Inuit traditional diet which is rich in fish and marine mammals could protect against cardiovascular diseases (CVD) (Dyerberg *et al.* 1978, Holub 1989, Frolich 1992). Effectively, Bang and Dyerberg observed in 1970 a low incidence of cardiovascular diseases in Greenland Eskimos and showed a strong association between this deficit of heart disease and a marine-based diet (Bang 1972, Bang 1976, Dyerberg *et al.* 1978). This beneficial effect was attributed to the omega-3 fatty acids obtained from seafood. Dietary fish oils are specifically rich in eicosapentanoic acid (EPA) and docosahexanoic acid (DHA) which are polyunsaturated fatty acids of the omega-3 series. Several epidemiological and experimental studies showed an association between omega-3 fatty acid intake and a low mortality of CVD and a reduced tendency to develop atherosclerotic and thrombotic lesions. A series of physiological events induced by omega-3 fatty acid intake have been linked to the beneficial effects of these fatty acids on established CVD risks factors. These effects are mainly related to blood lipids and platelet vessel wall interaction (Harris 1989, Zhu 1991, Bjerve *et al.* 1993).

Although total fat intakes of Inuit adults seem to be higher than those of Quebecers, the *Santé Québec Health Survey* revealed that saturated fatty acids contributed less to the Inuit fat intake compared to Quebecers (Santé Québec 1994a). The *Santé Québec Survey* demonstrated also that monounsaturated fatty acids intakes of Inuit were higher than those of Quebecers. Omega-3 fatty acids (EPA+DHA) intakes of Inuit were not assessed by the survey but our team has estimated these daily intakes from 1200 to 2000 mg (Dewailly 1996). Information about EPA and DHA intakes of Quebecers is not available but as Quebecer's fish consumption amounts to a daily average of 18 to 20 grams, we can assume that their EPA and DHA intakes are much lower than those of Inuit (Santé Québec 1994b).

This last ascertainment can be verified by comparing omega-3 fatty acids concentrations that our team measured in the bloodstream of Inuit and the general Québec population (Dewailly *et al.* 1994a, Dewailly *et al.* 1998). Indeed, since EPA and DHA are derived essentially from the consumption of marine products, they are good markers of this consumption when measured in blood phospholipids. Thus, the arithmetic average of omega-3 fatty acid concentration (expressed as % of plasma phospholipids) in Inuit adults was 8.00 (95% CI: 7.62-8.39) compared to 1.79 (95% CI: 1.76-1.83) in Quebecers (Table 12). Omega-3 fatty acid concentrations of Inuit adults varied significantly according to sex, as the average concentration was found to be higher in women than in men. Concentrations varied also according to age, Inuit aged 45 to 74 years showing concentrations twice as high as those in the 18-24 age group.

Blood concentration of EPA/AA (arachidonic acid) ratio is deemed to be an indicator of the risk to develop ischaemic diseases. Effectively, a low EPA/AA ratio (less than 0.1) was found to be one of the risk indicators in patients with angina and suspected coronary disease (Kondo *et al.* 1986). Among Inuit, the EPA/AA ratio was 0.53 compared to 0.083 for Quebecers (Table 13). Moreover, only 12.6% of Inuit adults showed an EPA/AA ratio less than 0.1 in comparison to 69.1% among Quebecers. The EPA/AA ratio varied also according to age group, Inuit aged between 45 to 74 years showing concentrations three times greater than those aged 18 to 24 years.

Prevented Fraction for Cardiovascular Diseases in the Inuit population:
Prevented fraction for CVD in the Inuit population was calculated since omega-3 fatty acids exposure is a protective factor. Thus, the prevented fraction is the proportion of potential cases that are prevented by high blood levels of omega-3 fatty acids. Among Inuit of Nunavik, the proportion of prevented CVD cases (for an EPA/AA ratio ≥ 0.1) was 43.7% compared to 15.4% among Quebecers and this, in accordance with the respective mortality rates observed in these populations.

Table 11. Prevalence (%) of cardiovascular risk factors in Nunavik

Risk factors	Gender	Nunavik	Québec
Diabetes (Glycaemia ≥ 7.8 mmol/L)	Males	2.0	2.9
	Females	2.4	2.1
	Total	2.1	2.5
High blood pressure	Males	7.1 *	14.9
(diastolic pressure ≥ 90 mmHg or treatment)	Females	4.8 *	12.8
	Total	6.0 *	13.8
Smoking	Males	64.6 *	32.4
	Females	70.9 *	31.2
	Total	67.7 *	31.8
Ponderal obesity (BMI ≥ 30)	Males	14.8	12.6
	Females	23.9 *	12.9
	Total	19.0 *	12.8
Abdominal obesity	Males	8.2	7.3
	Females	50.8 *	15.2
	Total	27.7 *	11.2
Blood Lipids			
HDL ≤ 0.9 mmol/L	Males	10.1	12.4
	Females	3.5	3.2
	Total	6.8	7.7
Triglycerides ≥ 2.3 mmol/L	Males	8.1 *	22.6
	Females	4.9 *	11.1
	Total	6.5 *	16.8
Cholesterol ≥ 6.2 mmol/L	Males	13.7 *	20.6
	Females	14.6	17.7
	Total	14.2 *	19.1
LDL ≥ 3.4 mmol/L	Males	34.9 *	41.6
	Females	29.5 *	36.4
	Total	32.2 *	38.9
Cholesterol / HDL Ratio ≥ 5.0	Males	19.2 *	38.0
	Females	8.5 *	16.6
	Total	13.9 *	27.1

* Statistically significant difference ($p \leq 0.05$)

Table 12. Arithmetic means (95 % CI) of Omega-3 fatty acids exposure (% of phospholipids)

	Nunavik	Québec
Adult population	8.00 (7.62 - 8.39)	1.79 (1.76 - 1.83)
Gender		
Men	7.49 (6.90 - 8.08)	1.77 (1.72 - 1.81)
Women	8.55 (8.06 - 9.05)	1.82 (1.77 - 1.87)
Age		
18 - 24 years	5.46 (4.98 - 5.95)	1.60 (1.54 - 1.66)
25 - 44 years	7.93 (7.39 - 8.46)	1.75 (1.70 - 1.79)
45 - 74 years	11.07 (10.36 - 11.78)	1.93 (1.87 - 1.99)

Table 13. Arithmetic means (95 % CI) of EPA/AA Ratio

	Nunavik	Québec
Adult population	0.527 (0.482 - 0.573)	0.083 (0.081 - 0.085)
Gender		
Men	0.492 (0.421 - 0.563)	0.082 (0.080 - 0.085)
Women	0.564 (0.505 - 0.623)	0.084 (0.081 - 0.087)
Age		
18 - 24 years	0.310 (0.255 - 0.364)	0.072 (0.068 - 0.076)
25 - 44 years	0.499 (0.434 - 0.563)	0.083 (0.080 - 0.086)
45 - 74 years	0.832 (0.738 - 0.926)	0.087 (0.084 - 0.090)

Table 14. Effects of Omega-3 fatty acids on blood lipids of Inuit adults

	Arithmetic mean	Geometric mean
HDL		
Omega-3 $\leq$ 6.931	1.357	1.295 (1.229 - 1.366)
6.931 < Omega-3 $\leq$ 11.460	1.455	1.400 (1.337 - 1.466)
Omega-3 $\geq$ 11.461	1.693	1.621 (1.549 - 1.696)
Triglycerides		
Omega-3 $\leq$ 6.931	1.201	1.091 (1.010 - 1.178)
6.931 < Omega-3 $\leq$ 11.460	1.247	1.059 (0.970 - 1.155)
Omega-3 $\geq$ 11.461	1.049	0.932 (0.868 - 1.002)

There is scientific evidence that omega-3 fatty acids play an important role in reducing blood triglycerides, LDL and cholesterol levels and in increasing HDL cholesterol levels (the good cholesterol) (Leaf 1998, Frolich 1992). Also these fatty acids could have anti-hypertensive and hypoglycemic effects (Beilin *et al.* 1993, Frolich 1992). The association between terciles of omega-3 fatty acid concentrations and both HDL and triglycerides is presented in Table 14. As concentrations of omega-3 fatty acids increase, the HDL-cholesterol levels increase to 1.36 and 1.69 mmol/L. Inversely, triglycerides levels decrease from 1.20 to 1.05 mmol/L. Additional data analysis demonstrated also that high levels of EPA+DHA were associated with low levels of insulinemia (Dewailly, unpublished data). Moreover, a negative correlation was observed between blood pressure and omega-3 fatty acids levels. Among obese men showing high omega-3 fatty acids levels, high blood HDL-cholesterol were associated to low triglycerides and insulinemia levels. These results could indicate a protective effect of omega-3 fatty acids against some CVD risk factors in the Inuit population.

Protection by selenium: Selenium is another key nutrient of the traditional Inuit diet that was also extensively studied during the last decade. Fish and marine mammals, especially mattak (beluga whale skin), are rich in this element (Table 9) (Svensson *et al.* 1992). It is currently believed that selenium has a role of antioxydant in the prevention of atherosclerotic diseases since selenium is an integral part of the antioxydant enzyme glutathione peroxidase. In the *Santé Québec Health Survey*, the mean concentration of selenium found in Inuit blood was 1.96 µmol/L, ranging from 1.11 to 3.74 µmol/L (Dewailly *et al.* 1994a). These concentrations are high compared to those found in southern Québec (0.4 to 1.5 µmol/L). The survey revealed also that selenium concentrations of individuals who consumed mattak weekly were high (2.25 µmol/L) compared to those who consumed mattak less than once a month (1.76 µmol/L). There was no extensive study conducted on the protective effects of selenium in the Inuit population. Selenium intake in combination with omega-3 fatty acid intake may be responsible for the reduced occurrence of CVD in Nunavik.

- Cancer

Omega-3 fatty acids are also believed to protect against some types of cancer. Studies on the effects of omega-3 fatty acids on human cancer are limited. However, some epidemiological studies conducted in Greenland populations and Alaskan Eskimos, known to have a diet rich in omega-3 fatty acids showed very low breast cancer rates (Lanier 1989, Lanier 1976, Bang 1976). Comparisons of breast cancer mortality between Japan and Iceland and between Inuit and Danes suggest that a low-fat diet in combination with a high omega-3/omega-6 fatty acid ratio (around 0.5) could be associated with low mortality rates from breast cancer (Kromhout 1990). Some studies suggest a protective effect of fish oils enriched with omega-3 fatty acids by inhibiting cell proliferation (Frolich 1992). We conducted a pilot study among Quebec women to compare the lipid profile in plasma phospholipids of 20 breast cancer cases and 20 population controls (Dewailly *et al.* 1994b). EPA levels were lower among cases than controls. Moreover, EPA/AA ratio was significantly lower among breast cancer cases compared to controls. Similar metabolic processes could be involved in prostate, corpus uteri and ovary cancers since these types of cancer show some common risk factors. In effect, a number of common risk factors such as genetic factors, hormonal factors, lifestyle factors and dietary risk factors have been identified for breast, ovary, corpus uteri and prostate cancers. The international comparisons support evidence that diet high in animal saturated fat is a major dietary influence for these types of cancer (Miller 1986, Prener 1996, Kjaer 1996).

We observed in Nunavik lower incidences and cancer mortality rates of some type of cancers compared to Québec, Canada and other industrialized countries. In fact, from 1987 to 1996, no death from corpus uteri, ovary and prostate cancers occurred in Nunavik, while notable mortality rates of 2.3, 7.4 and 28.7 (per 100,000 person-years) were observed in Québec (Table 1). Moreover, the SIRs observed in Canadian Inuit for the same cancers were also low (Table 2). As regards breast cancer, it occurs at lower rates among Inuit women (both Nunavik and Canadian Inuit women) compared to Québec women (Miller 1996a). For the year 1997 only, based on the latest statistics, it is expected that more than 4000 new cases will be diagnosed in Québec (Institute National du Cancer du Canada 1997). Finally, Tables 1 and 2 show that the incidence and mortality rate of bladder cancer is also very low.

Protection afforded by omega-3 fatty acids: The previously described relationship between low CVD rates and omega-3 fatty acid blood concentrations in the Inuit population is striking and based on clinical and epidemiologic studies, these nutrients may also explain the Inuit cancer rates that are in deficit compared to those of Québec. According to Kromhout, a high ratio of omega-3/omega-6 fatty acids (N3/N6 $\geq$ 0.5) would be associated with low mortality rates of breast cancer (Kromhout 1990). The previous comparison of omega-3 concentrations observed among Inuit women and Quebec women could explain at least in part, differences in mortality rates from breast cancer. Moreover, the prevalence of N3/N6 ratio $\geq$ 0.5 (preventive ratio) was 31% among Inuit women compared to 0% among Quebecers. These observations may apply to ovary, corpus uteri and prostate cancers since these types of cancer are also associated to fat intake (Miller 1986, Kjaer 1996). As regards bladder cancer, according to Lanier *et al.*, the low rates of bladder cancer observed among Inuit are surprising considering the high prevalence of smoking in Circumpolar communities (smoking is an important risk factor of bladder cancer) (Lanier 1996b). It may reflect the absence of other risk factors (occupational factors) or a protective effect afforded by genetic or dietary factors.

Prevented Fraction for Breast Cancer in the Inuit population:
A prevented fraction for breast cancer in Inuit women was calculated since omega-3 fatty acid intake is a protective factor. The prevented fraction is the proportion of potential cases that are prevented by high blood levels of omega-3 fatty acids. Among Inuit women, the proportion of prevented breast cancer cases (for an N3/N6 ratio $\geq$ 0.5) was 43.0% compared to 0% among Quebecers and this, in accordance with the respective mortality rates observed in these populations.

Protection by selenium: Studies have shown that blood concentration of selenium is inversely associated with human cancer risk (Clark 1986, Salonen 1986). By virtue of its antioxidant properties, selenium may protect against free radical mediated carcinogenesis. Currently, it is believed that selenium may have an antagonist effect upon mercury toxicity (WHO 1990). This protective effect could explain the absence of any signs of intoxication among populations showing concentrations of mercury in the blood in excess of 1000 nmol/L (Kershaw 1980, Turner *et al.* 1980). Selenium intakes in the Inuit population are high and blood concentrations were found to be elevated compared to those found in southern Québec. However, further epidemiological and clinical studies are needed to firmly establish selenium as a protective factor from carcinogenesis.

4.2 The diseases in deficit in Nunavik

- Arthritis and rheumatism

Several clinical trials have been carried out to evaluate the effects of dietary supplements of omega-3 fatty acids on human inflammatory diseases (Robinson *et al.* 1994). Although alterations in the production of inflammatory eicosanoids by omega-3 fatty acids, such as the inhibition of leucotriene B_4 synthesis, could contribute to the anti-inflammatory effects induced by omega-3 fatty acids, other factors may be important, and the mechanisms of the anti-inflammatory response triggered by these fatty acids remain unknown. However, some trials have found statistically significant, though modest, beneficial effects in patients with rheumatic arthritis. The apparent beneficial effects of dietary omega-3 fatty acids in rheumatic arthritis are promising for the treatment for this disease (Geusens *et al.* 1994).

Table 15. Characteristics of birth outcomes (1986-1995)

Birth outcomes	Nunavik	Québec
Prematurity		
Prematurity (< 37 weeks)	10.4 % *	6.7 %
Mean length of pregnancy (sd)	38.7 (2.1)	39.1 (1.9)
Birth weight		
Low birth weight (< 2500 g)	5.4 %	6.0 %
Average weight (sd)	3407.2 (562.6)	3330.1 (556.9)
Teen pregnancies		
Mother's age < 18 years	12.0 % *	1.1 %
Average age of mothers (sd)	23.7 (5.5)	27.7 (4.8)

* Statistically significant difference ($p \leq 0.05$)

On the whole, the prevalence of arthritis and rheumatism reported by Inuit adults in the *Santé Québec Health Survey* appeared to be lower than that observed in Québec (comparative index Inuit/Quebecers: 0.71; Table 3). However, one should interpret with caution this reported problem since cultural differences and improper translation may have impeded the Inuit from understanding the medical concepts of these diseases (Santé Québec 1994a). Nevertheless, it was suggested that omega-3 fatty acids would have a protective effect in patients with rheumatic arthritis (Kremer 1987, Frolich 1992). Since we know that the Inuit population show high blood omega-3 fatty acid concentrations, it is tempting to speculate that these fatty acids could explain, at least in part, the lower prevalence of this disease in Nunavik compared to Québec as a whole.

- High blood pressure and hyperlipemia (see section on cardiovascular diseases)

4.3 Birth outcomes

High birthweights have been associated with fish consumption during pregnancy (Olsen 1986, 1990). In 1986, Olsen observed among Faroes women which mainly consumed fish and marine mammals (average intake = 91 grams/day), prolonged gestation (+3.6 days) and higher newborn birthweight (+194 grams) compared to Danish women whom consumed an average of 22 grams of seafood per day. Olsen also demonstrated that plasma omega-3 fatty acid concentrations were significantly higher among Faroes women than among Danish women. Summarily, studies showed an average increase of 100-110 grams in birthweight when seafood consumption is important among pregnant women and this, particularly during the third trimester of pregnancy. Omega-3 fatty acids are the predominant structural fatty acid in the human brain and retina. An adequate supply of these fatty acids during the period of their most rapid accumulation (the last trimester of the gestation and the first months of postnatal life) is believed to be of major importance for appropriate growth and development of these organs.

In Nunavik, despite the high rates of teen pregnancy (mothers aged under 18 years), the widespread use of tobacco (over 80% of women smoke during pregnancy) and exposure to PCBs, all of which have been associated to small birthweights, the average birthweight of Inuit newborns was 3407 grams, compared to 3330 grams for newborns from the rest of the province, and this for the 1986-1995 period (Table 15). As described before (Table 12), the average concentrations of EPA+DHA of Inuit women are much higher (8.55, 95% CI:8.06-9.05) than those observed among southern Québec women (1.82, 95% CI: 1.77-1.87). It is reasonable to assume that concentrations of pregnant women could approach those of women from the general population. Moreover, the comparison of blood omega-3 fatty acid concentrations between Inuit and Quebec newborns revealed that Inuit newborns levels (average: 4.3) were significantly higher than those of southern Québec newborns (average: 2.0).

DISCUSSION AND CONCLUSION

In the present project, we summarized the major causes of diseases and mortality in Nunavik which could be related to the Inuit diet and/or the environmental contaminants. For the 1986-1995 period, the standardized mortality rate per 100, 000 person-years from all causes was 1239 compared to 649 for Quebec as a whole. The leading causes of death in Nunavik were diseases of respiratory system and lung cancer. Smoking and passive smoking are the major risk factors, but some co-factors related to environment and diet are also suspected. Colon, nasopharynx and salivary gland cancers are also in excess in Nunavik compared with Québec and the Inuit diet could be involved in their pathogenesis. As regards the prevalence of main diseases among Inuit, the *Santé Québec Health Survey* revealed that besides specific hearing problems such as otitis or deafness, hearing impairments represent the most frequently occurring Inuit health problems, diseases of respiratory system representing the second health problem.

For the years 1992 to 1996, infant mortality rate in Nunavik was 23.6/1000 live births, compared to 5.4/1000 in Québec. The main causes of infant mortality in Nunavik are congenital anomalies, infections and sudden infant death syndrome. Between 1987 and 1996, mortality rates for congenital anomalies were significantly higher than those observed in Québec, particularly among male babies. Reasons for higher rates of congenital anomalies could include nutritional deficiencies early in pregnancy, genetic predisposition and toxic exposures (alcohol, environmental contaminants) (Hodgins 1997). Regarding the main diseases observed among Inuit infants and children, respiratory diseases and otitis media are the major health problems. Genetically determined IgG2 deficiency, anatomy, physiology, diet, passive smoking and crowded housing are all factors that can contribute to these illnesses among Inuit children. Results from an infant cohort study in Nunavik suggest that exposure through breast feeding may also be a risk factor for otitis media.

The relationship between the Inuit diet and diseases which are not prevalent in Nunavik but which are particularly frequent in Quebec and/or Canada, was also described. Deaths owing to cardiovascular diseases and breast, endometrial, ovary and prostate cancers are rare events in Nunavik, whereas these illnesses are a major cause of mortality in industrialized countries. Moreover, despite the fact that smoking and obesity are widely prevalent among Inuit, the prevalence of other risk factors leading to cardiovascular diseases such as diabetes, high blood pressure and hyperlipemia is low in Nunavik. This suggests that the seafood based Inuit diet which is rich in omega-3 fatty acids prevents risk factors predisposing to cardiovascular diseases and also, the incidence of some type of cancers. Estimation of the relative protective effects of omega-3 fatty acids on cardiovascular disease and breast cancer mortality rates, revealed a large protective effect afforded by omega-3 fatty acids. The high dietary intake of these fatty acids could also afford beneficial effects on birth outcomes. Despite high rates of teen pregnancy, the widespread use of tobacco use and the exposure to PCBs, all of which has been associated to small birthweight and are much prevalent in Nunavik, average birthweight of Inuit newborns was higher than that of Quebec newborns for the 1986-1995 period. One explanation could be that the high consumption of foods rich in omega-3 fatty acids counter these risk factors and contribute to high birthweight. Recent studies also indicate that omega-3 fatty acids, in particular DHA, constitute an essential factor in child development. Thus, the consumption of fish and marine mammal by pregnant Inuit women permit to increase their fat stores in omega-3 fatty acids, thereby ensuring adequate supply of DHA to promote optimal retina and brain development of the fetus.

In parallel to these beneficial effects, the *Santé Québec Health Survey* revealed that the Inuit population presents some nutritional deficiencies. Vitamin A intakes of Inuit population are insufficient and this may play a role in the high prevalence of some diseases in Nunavik, such as infectious diseases (respiratory system, otitis) and also the iron-deficiency anemia. Concentrations of vitamin A in blood of Inuit adults should be analyzed in order to assess their vitamin A status and also to propose effective and preventive treatment if needed. The prevention of vitamin A deficiency should be considered along with iron supplementation, as a potentially important approach to the control of nutritional anemia. Iron-fortified cereals should be given to the infant as early as two-three months of life and when breast-feeding is not applied, and the use from birth to six months of infant fortified milk formulas should be encouraged (Hodgins, 1997). The Inuit population showed a low consumption of fresh fruits and vegetables which are main sources of vitamin C. This is compounded by the fact that 68% of the Inuit population are smokers, which require higher daily intake of vitamin C (two-fold) than non-smokers. Because numerous effects due to a deficient vitamin C intake appears to be prevalent in Nunavik, the consumption of more vitamin C sources by the Inuit population should be encouraged. Finally, considering the very weak calcium intake of Inuit, efforts should be made to promote the consumption of food items that are good sources of calcium. Moreover, increasing vitamin A fortified milk and dairy products consumption would also increase the intake of vitamin A.

At the present time, it is not clear whether or not the contaminant body burden carried by the Inuit is responsible for any adverse health effect. Of recent interest is the possibility that exposure to organochlorines, some of them having been identified as endocrine disrupting agents, could be associated with the incidence of hormone-dependent diseases. However, incidence of breast, endometrial, ovary, prostate and testicular cancers are lower than those reported in Quebec and Canada in recent years. Reproductive function and development could also be altered by in utero exposure to hormonal mimics. There are however no epidemioligical data to support this hypothesis in Nunavik. A neurodevelopmental study is presently underway to address this question. Analysis of data obtained during the course of the *Santé Québec Inuit Health Survey* conducted in 1992 revealed that respectively 24% and 33% of women aged 18 to 39 years had blood lead and plasma PCB concentrations above the threshold concentration associated with cognitive deficits in infants. Scenarios of risk abatement were elaborated to reduce PCB exposure in women aged 18-39 years (Dewailly *et al.* 1996). A 46% reduction in PCB exposure would lower from 33% to 10% the percentage of women of reproductive age displaying a PCB concentration greater than 12 µg/L (the threshold PCB concentration in plasma). This would be achieved by eliminating beluga skin and fat from the diet, which would also result in a 19% decrease in omega-3 fatty acid intake. The elimination of Ringed seal fat from the diet, in addition to beluga tissues, would further reduce the proportion of women at risk below 3%, with a concomitant decrease of more than 40% in omega-3 fatty acid intake. Hence, the reduction of PCB associated health risk would be effected at the expense of nutritional benefits, which may adversely affect the cardiovascular health, the breast cancer risk and the development of the newborn.

Since the scientific community cannot at the present time reliably assess the health impacts of PCB exposure on the Inuit population, and because nothing can be done to eliminate this potential health hazard without creating new problems, it is concluded that dietary advice is not warranted at the present time. Moreover, this assessment was based on data obtained during 1992, and there is some evidence to suggest that exposure of women of reproductive age to organochlorines (as well as dietary omega-3 fatty acid intake) has declined over the recent years. The decision to propose or not dietary advice on the basis of the scientific evidence lies with the Inuit population.

The real challenge that supersedes contaminant issues is to apply gained knowledge to education programs on nutrition. The adoption of safe nutritional habits present a two-fold challenge: to maintain aspects of the traditional diet which have afforded the Inuit population a comparative advantage (such as a low prevalence of cardiovascular disease associated with high omega-3 fatty acids intake) and to include in the diet a greater variety of healthy market food. Availability of market food will certainly increase from year to year. Quality control in food supply plus healthy market food choices must be made available and accessible for the Inuit population. The promotion of a healthy nutrition among the Inuit population must take into account societal values of the Inuit traditional diet.

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LEAD POISONING AMONG INUIT CHILDREN: IDENTIFICATION OF SOURCES OF EXPOSURE

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OBJECTIVES

1. to characterize blood lead isotopes in Inuit newborns' cord blood samples
2. to compare results of lead isotopes in two groups of Inuit newborns: those with cord blood lead levels equal to or higher than 9.6 μg/dl (0.48 μmol/l) to those with cord blood levels lower than 9.6 μg/dl
3. to compare results of lead isotopes in Inuit newborns to those of newborns from the southern part of Québec.

DESCRIPTION

The problem of lead contamination has been the subject of many scientific publications. In the past, the relation between lead exposure and human health was mostly examined in an occupational context. Since the beginning of the 1980s, lead contamination of the environment has progressively become a major public health preoccupation, mainly with regard to neuro-behavioural effects on foetuses and young children (Davis *et al.* 1993, Goyer 1993, Needleman and Bellinger 1991).

The results of studies on cord blood lead done between 1993 and 1995 show that 7.6% (n = 238) of Nunavik newborns had blood lead levels of 9.6 μg/dl and higher (Dewailly 1995), compared with 0.2% (n = 955), 0.7% (n = 149) and 0% (n = 154) of babies from the southern part of Québec (Rhainds *et al.* 1995), the Québec Northern Shore (Dewailly *et al.* 1994), and the Gaspésie region (Levallois *et al.* 1995). Subjects with high concentrations were uniformly distributed across the territory. Moreover, 2.1% of the samples from Nunavik showed blood lead levels higher than 15 μg/dl. These data, added to those collected in Nunavik during the 1992 Santé Québec survey, revealed that 24% of women aged between 18 and 39 years had blood lead levels higher than 9.6 μg/dl (Dewailly *et al.* 1996).

In Inuit communities of Nunavik, lead exposure through fallout from industrial activities, from fragments of old paint or through drinking water is unlikely. However, the consumption of game seems to be a source of exposure that should not go unnoticed. In fact, relatively high levels of lead in caribou and many species of waterfowl – key-elements of the traditional Inuit diet – were observed. Caribou is contaminated by airborne lead found in the lichen they eat (Crête *et al.* 1990, 1992) and lead levels observed in waterfowl (Scheuhammer and Templeton 1998, Langlois and Langis 1995) may be due to the ingestion of shot shell used by hunters (Scheuhammer and Templeton 1998). Lead shot fragments left in the meat of waterfowl and ingested by consumers may also be a source of contamination for Nunavik community members (Tsuji and Nieboer 1997).

Lead has an isotopic structure typical of the ore from which it comes (Sturges and Barrie 1987). In the presence of a limited number of sources, it is possible to identify the origin of the exposure by determining lead isotopic ratios (204, 206, 207, 208). This technique has frequently been used in studies on animals and plants (Scheuhammer and Templeton 1998, Carignan and Gariépy 1995, Keinonen 1992) as well as on humans (Angle *et al.* 1995, Gulson *et al.* 1995, Rabinowitz 1995a, 1995b, Gulson and Wilson 1994, Alexander *et al.* 1993, Al-Saleh *et al.* 1993, Keinonen 1992, Manton 1985, Tera *et al* 1985, Yaffe *et al.* 1983, Manton 1973,1977).

ACTIVITIES IN 1997/98

All blood samples needed for the project were already available, having been collected previously in other studies (Dewailly 1995, Levallois *et al.* 1995, Rhainds *et al.* 1995). In all, 61 cord blood samples from Inuit

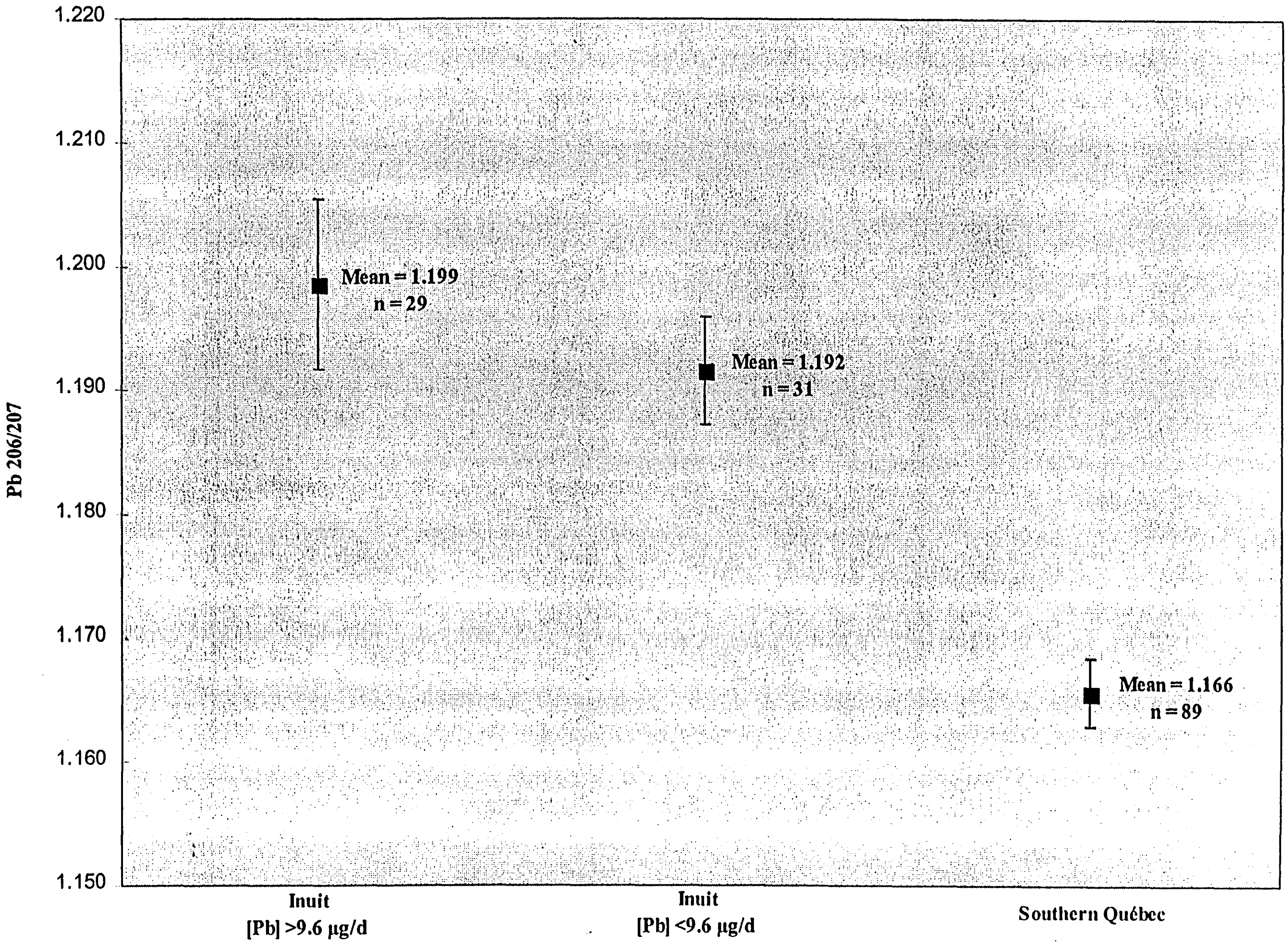

Figure 1. Mean and confidence interval (95%) of 206/207 isotopic lead ratios for Inuit newborns highly contaminated, slightly contaminated, and for newborns from the southern part of Québec.

newborns of 11 Nunavik communities were taken. Of this number of samples, 29 showed lead concentrations equal to or higher than 9.6 μg/dl and 31 showed concentrations below 9.6 μg/dl. At the same time, 89 samples were taken from newborns showing under 9.6 μg/dl of lead and coming from 10 administrative regions of the southern part of Québec. Each Inuit newborn blood sample over 9.6 μg/dl was paired to at least one other sample from a newborn of the same community, as well as to 3 samples from southern Québec. A few additional analyses were also performed: Two for Inuit controls and two for southern Québec controls. Analyses were conducted at the Québec Toxicology Centre. The lead isotopic ratios were determined by ICP-MS on a Perkin Elmer Sciex Elan 5000 A. Results were expressed as relative abundance of 206/204, 206/207, and 208/206. The Pb Standard NIST SRM-981 (common PB isotopic standard was used to evaluate the analytical precision during runs and the mass bias of the instrument. An overall precision of 0.3% was obtained by this method.

RESULTS

For practical reasons, interpretation of results will only be done according to the 206/207 isotopic ratio. The use of the 206/207 isotopic ratio provides us with a greater analytical precision and furthermore, it is also the ratio for which we find the most data in the literature.

The mean $Pb^{206/207}$ isotopic ratio found in Inuit newborns most contaminated (1.199; $n = 29$; range of distribution: 1.166–1.230) seems slightly higher than that of Inuit newborns less contaminated (1.192; $n = 31$; range of distribution: 1,174–1.212), although the difference observed is not statistically significant (Student T-Test; $p = 0.0910$) (Figure 1). Overall Inuit newborns have a mean $Pb^{206/207}$ ratio (1.195; $n = 60$; range of distribution: 1.166–1.230) significantly higher than that found in southern Québec newborns (1.167; $n = 89$; range of distribution: 1.126–1.230) (Student T-Test; $p \leq 0.0001$).

DISCUSSION/CONCLUSION

Results obtained on isotopic lead ratios found in cord blood show no statistical difference between Inuit newborns presenting a blood lead level ≥ 9.6 μg/dl ($Pb^{206/207} = 1.199$) and newborns with a level < 9.6 μg/dl ($Pb^{206/207} = 1.192$). Therefore, we an presume that sources of lead are probably the same for the two groups, but the level of exposure is different, thus explaining the trend towards a slightly lower ratio in less contaminated Inuit. In this case, background exposure could be a proportionately more important factor contributing to explain exposure. However, differences observed as regards isotopic ratios between Nunavik populations and southern Québec populations show that sources in Nunavik are distinct from those found in southern Québec.

As discussed, among the sources of lead found in Nunavik, the consumption of game, particularly waterfowl and caribou, is clearly the most probable source of exposure, by primary contamination of animals (natural body burden) or by secondary contamination (by lead shot pellets after being shot down). A research team from the Canadian Wildlife Service (CWS) analysed the skeletal structure of waterfowl to determine their lead concentration as well as their $Pb^{206/207}$ isotopic ratio (Scheuhammer 1998). These analyses performed on 122 ducks sampled in Québec at the end of the 1980s and at the beginning of the 1990s, and for which their migration zone includes Northern Québec, resulted in a mean isotopic ratio of 1.093. This value is very far from the one obtained for Inuit newborns (1.195). Furthermore, caribou contamination by lead is most probably caused by its consumption of lichen, which in turn is contaminated by atmospheric pollution (Crête 1992). Based on data available on lichen contamination in Québec, we can presume that the $Pb^{206/207}$ isotopic ratio in caribou should be around 1.15 (Carignan and Gariépy 1995, Sturges and Barrie 1987). These results tend to show that primary contamination of game is not the preponderant factor for the lead body burden found in Nunavik Inuit newborns.

Analyses conducted on lead shot from four brands of shotgun cartridges used by Nunavik hunters (FEDERAL, WINCHESTER, REMINGTON, IMPERIAL) (Scheuhammer 1998) revealed that the mean $Pb^{206/207}$ isotopic ratios of these bullets (1.193; $n = 10$; range of distribution 1.125 – 1.233) were comparable to the isotopic ratio of the lead found in Inuit newborns (1.195). Consequently, it appears that the ingestion of lead shot or lead residue (fragments, dust), found in game that was shot down, is responsible for lead levels found in Nunavik Inuit. Furthermore, recent data on lead contamination of ptarmigan from Northern Québec (Rodrigue 1998) showed that 90% (n - 31) of birds shot in the head had lead concentrations (found in flesh) below the threshold of detection (<0.04 μg/g).

X-rays of the abdomen conducted on Nunavik Inuit reveal the presence of lead shot in the digestive system (Tremblay 1998), thus supporting the hypothesis that lead shot ingestion is the main source of contamination. This problem was also observed in Cree communities from northern Ontario (Tsuji and Nieboer 1997). Many studies show that the ingestion of lead shot (or lead objects) can not only cause problems related to the accumulation of shot in the digestive system (perforation, abscess, peritonitis) (Reddy 1985, Carey 1977, Balch and Silver 1971) but can also cause an increase in lead body burden (Madsen *et al.* 1988, Greensher *et al.* 1974, Biehusen and Pulaski 1956).

It is well documented that the use of lead shot has had a negative impact on certain animal species, such as waterfowl. Many countries have banned the use of lead-containing cartridges to protect fauna. The results of our study support such a measure, but in this case to prevent human health problems.

We recommend the abandonment of the use of lead cartridges in favour of a non-toxic alternative steel shot as the best option from the perspective of public health protection.

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POSTNATAL EXPOSURE TO ORGANOCHLORINES AS A RISK FACTOR FOR OTITIS MEDIA IN NUNAVIK.

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OBJECTIVE

1. to investigate the impact of exposure to organochlorines (OCs) on the risk of otitis media among Inuit children.

DESCRIPTION

Otitis media (ear infection) and the damage it can cause to hearing is a major problem of Inuit children and adults. In fact, Inuit in Nunavik report hearing loss as their most common chronic health problem (Santé Québec 1992). Early in the 1980s, parents and teachers expressed their concerns to health services because of the problems students with hearing loss were experiencing at school. The detrimental effect of otitis media on school performance is mostly due to the hearing loss experienced by the student causing difficulties in language comprehension and acquisition, and subsequently in reading.

In 1984, 78% of Inuit school children in Kuujjuarapik were found to have had current or previous ear infections and 23% of the children had a significant hearing loss in one or both ears (Julien *et al.* 1987). Furthermore, prevalence of hearing loss of 74 students tested in Inukjuak in 1988 was 24% (Proulx *et al.* 1988). In 1995/1996, screenings performed on the coast of Ungava found a 28% rate of hearing loss in students.

It is known that otitis media becomes a chronic situation at a very young age. In 1987, an epidemiologic study was conducted in children of 2 to 6 years of age in two communities of Nunavik (Bruneau *et al.* 1987). The ear condition revealed the seriousness of the problem: 12.1% of ears examined had either serous or chronic otitis; 55% of ears had scarring evidence of past ototis outbreaks, and 33% of ears were normal. This study also included a medical file review and a questionnaire which examined environmental and lifestyle factors associated with otitis media. With these findings in mind, schools and health organizations united their efforts to build an intervention program on otitis and its most concerning impact, hearing loss. This program has three phases: prevention (knowledge and intervention on risk factors); treatment (early screening and standardized treatment) and rehabilitation (hearing evaluation and if needed, fitting of a hearing prosthesis).

A number of risk factors have been tentatively associated with acute otitis in previous studies (summarized by Infante-Rivard 1993), including day care, passive smoking and bottle feeding. It is unlikely that these factors could be the only explanation for the high rates of otitis observed in Nunavik. Previous studies conducted by our group have shown that Inuit newborns receive a relatively high dose of several OCs both *in utero* and through lactation (Dewailly *et al.* 1992, 1993, Ayotte *et al.* 1996). Available evidence in laboratory animals suggests that the maturation of the immune system is especially vulnerable to the adverse effects of dioxin/like compounds, chlordane, hexachlorobenzene, polycyclic aromatic hydrocarbons and possibly endocrine disrupting compounds such as DDT and kepone (Barnett *et al.* 1987, Holiday and Luster 1996).

A cohort study conducted in 1989–1991 revealed a significant relationship between postnatal exposure to organochlorines and the incidence of otitis media during the first year of life, among Inuit infants of Nunavik. A total of 181 mother-infant pairs were studied during the entire follow up period (12 months), of which 105 were breast fed and 76 bottle fed. Concentrations of selected organochlorines (DDE, dieldrin, hexachlorobenzene, mirex, PCBs) in breast milk fat were used as prenatal exposure surrogates. Postnatal exposure was approximated by multiplying organochlorine levels in milk fat by breast feeding duration. The number of episodes of ORL, lung and skin infections were compiled during the first year of life. White blood cell counts (granulocytes, lymphocytes, monocytes), immunologic marker analyses ($CD3^+$ lymphocytes, $CD20^+$ B-lymphocytes, $CD4^+$ T-lymphocytes, $CD8^+$ T-lymphocytes) and immunoglobulin determinations (IgA, IgG, IgM) were performed in venous blood at 3, 7 and 12 months of age. Frequency of otitis media among breast fed infants was lower in breast-fed than in bottle-fed infants during the first follow up period (0 – 3 months) ($p < 0.05$), but not later during the first year of life. During the second and third follow up periods, statistically significant dose response relationships were observed between postnatal exposure to organochlorines and the frequency of acute otitis media. During the third period, this infection was more frequent among breast fed infants receiving the highest organochlorine dose than in bottle fed infants ($p < 0.005$). Concomitantly, breast fed infants had a lower $CD4^+$/ $CD8^+$ T-lymphocyte ratio than bottle fed infants ($p < 0.05$). Cumulative PCB exposure through breast feeding ($r = -0.27$; $p = 0.05$) and breast feeding duration ($r = -0.29$; $p < 0.05$) were inversely correlated to the $CD4^+$/ $CD8^+$ ratio during the second follow up period. No other infectious disease was related to organochlorine exposure. We concluded that organochlorine exposure through breast feeding can modulate immune system function and may be a risk factor for acute otitis media in Inuit infants. The proposed case-control study aims to confirm results described above, using a more valid measurement of postnatal OC exposure, i.e. OC concentration in ear wax collected at six months.

ACTIVITIES IN 1997/98

A new study designed to evaluate the prevalence of otitis media among pre-school children from Inukjuak gave us a unique opportunity to reassess the relation between OC exposure and the risk of otitis. For 2- to 6-year-old children living in Inukjuak (N = 150), an ENT exam was performed (which includes observation of ear, nose and throat conditions, and a photograph of the eardrum) and an earwax sample was collected using a disposable plastic ear curette. Finally, a questionnaire was administered to the parents regarding environmental and lifestyle conditions.

The data collection phase was carried out from November 18th through the 23rd. 1997. All young residents of Inukjuaq, born between January 1st 1991 and December 31st 1994 (n=160) were invited to participate. The parents were also invited to complete a questionnaire regarding environmental and lifestyles factors. The participation rate, if we do not count the young people out of town during the study, was of 81% (n=130). The proportion of children for which we obtained an earwax sample was 51%, the younger ones generally presenting to small amounts to have a sample taken.

At the beginning of the ENT exam, an earwax sample was collected using a disposable plastic ear curette (Bionix 9555 or 4888). The earwax sample and the curette&|ip was transferred into a 15 ml polycarbonate vial and kept frozen at –20°C until analysis. Preliminary studies conducted on subjects from our research staff have demonstrated the feasibility of using this biological sample to assess organochlorine body burden. A 40 mg sample is sufficient to allow the detection of most organochlorine compounds usually determined in blood lipids. Other have also used earwax measurements and showed a good correlation with blood lipid levels (To-Figueras *et al.* 1995, Xu-Qing *et al.* 1988). Lipids will be extracted from the earwax sample using dichloromethane, while mixing with a Polytron. The lipid extract will be purified by gel permeation chromatography and a deactivated (0.5%) florisil column. Organochlorines (PCB congeners IUPAC No. 138, 153, 180, 187; *p,p'*-DDE, *p,p'*-DDT) were determined in the concentrated eluate by high-resolution capillary gas chromatography using an electron capture detector (HRGC-ECD). Lipid concentration in earwax samples were assessed gravimetrically.

RESULTS

At first look, when compared with the results obtained for children of the same age in 1987, preliminary results obtained from the otologic examination show the evolution of chronic otitis media in the last 10 years. On one hand, the proportion of children from two to six years of age presenting a perforation of the eardrum seems unchanged (17% versus 16%). On the other hand, in 1997, more young children (74%) have two normal or near normal eardrums (minimal scarring), compared to 52% in 1987. These gains are essentially noted by the clearly lower frequency of scarring of the eardrum (maximal scarring), that decreased from 22% to 3%. A final evaluation report should be presented to the community of Inukjuaq in this coming fall.

As previously mentioned, earwax samples were not easy to obtain because of the small amounts found in the ear. Of the 66 samples available results are available for only 33 samples, because of insufficient sampling quantity (Appendix 1). The results presented in Annex 1 indicate that for Aroclor 1260, levels vary between 0.30 mg/kg and 3.1 mg/kg. As for congener # 138, levels vary between 21 µg/kg and 906 µg/kg; levels of congener # 153 vary between 36 µg/kg to 2092 µg/kg; levels of congener # 180 vary from 14 µg/kg to 717µg/kg and levels of congener # 187 vary from 27 µg/kg to 276 µg/kg. Finally, results for pesticides shows that *p,p'*-DDE vary from 126 µg/kg to 3072µg/kg and *pp'*-DDT varies from 65 to 969 µg/kg.

The main objective of this study was to investigate the impact of exposure to organochlorines (OCs) on the risk of otitis media among Inuit children. The ear status has

Table 1. Organochlorine and pesticide concentrations by ear status at the otologic examination

Contaminants	Ear status	n	geometric mean (μg/kg)	confidence interval 95 %
Aroclor 1260				
	Normal	9	1,300	730 - 2,320
	Normal/Minimal	12	760	460 - 1,240
	Maximal/Chronic	10	1,340	780 - 2,290
	Total	31	1,160	830 - 1,610
Congener 138				
	Normal	9	99.96	59.64 - 167.53
	Normal/Minimal	12	54.13	34,07 - 85.99
	Maximal/Chronic	10	98.19	56.69 - 170.07
	Total	31	84.61	61.92 - 115.61
Congener 153				
	Normal	9	149,41	80.21 - 278.33
	Normal/Minimal	12	90,80	54.36 - 151.67
	Maximal/Chronic	10	158,39	92.41 - 271.48
	Total	31	137,09	97.76 - 192.24
Congener 187				
	Normal	9	93.24	64.39 - 135.01
	Normal/Minimal	12	55.88	37.94 - 82.30
	Maximal/Chronic	10	91.88	60.37 - 139.84
	Total	31	78.90	62.93 - 98.91
p,p' DDE				
	Normal	9	449,22	288.96 - 698.35
	Normal/Minimal	12	301,13	207.72 - 436.55
	Maximal/Chronic	10	505,12	348.08 - 733.01
	Total	31	425,92	332.86 - 545.00

been divided in 3 categories: Normal means that both ears examined are normal; the normal/minimal status means that at least one ear has a minimal scarring; maximal/chronic means that at least one of the ear as either a maximal scarring or a chronic otitis. Two individuals were excluded of the analysis because the examination chart was not completed adequately. Thus, preliminary results presented in Table 1 show that there is no statistical association between ear status and contaminants levels.

Unfortunately, the small number of samples available will not allow us, at this point, to present clear conclusions on the possible links between OCs and otitis media. Furthermore, the surprising difference of results between the normal and normal/maximal category could be explained by the breast-feeding status of the children. Further data analysis is necessary in order to make consistent conclusions.

CONCLUSION/DISCUSSION

In more than 10 years of assessing organochlorine body burden in Nunavik we always used breast-milk and blood sample analysis. It is the first time that earwax samples were used and for individuals participating in studies such samples were necessary – it is clearly a much more acceptable way than venous puncture. Nevertheless, it was observed that the younger the child is, the less earwax is available which, in this case where a 40 mg sample was needed, decreased the possibility of getting a sample from 130 to 66 and finally to 33. It was observed during the field work phase that teenagers had sufficient earwax to do such an analysis. Therefore this approach is not recommended for children under 10 years of age.

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A SYNTHESIS OF CONTEMPORARY INUIT DIETS: ASSESSING NUTRIENT SOURCES AND FOOD SAFETY

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OBJECTIVE

1. to review and compile recent international data concerning Inuit foods and to assess the importance of regional variations or similarities regarding nutrient intakes and food quality, considering country food versus store-bought food consumption.

   This report presents results on consumption of country food versus store-bought food. Only preliminary results are presented. This project was not funded by the Northern Contaminants Program for 1998/1999.

DESCRIPTION

Various nutrition surveys have been conducted in different regions of the Arctic (Kuhnlein *et al.* 1996, Santé Québec 1995, Nobmann 1989 and 1996). They indicate major regional variations, just as important differences have been found in contaminant intakes (Dewailly *et al.* 1996a). However, no comprehensive study has been done to evaluate the importance of regional differences and similarities in terms of nutrient intakes and food safety requirements. To provide the basis for comparison between the different regions of the Arctic, a prerequisite is the establishment of a uniform database summarizing and listing Inuit food consumption patterns as well as all food items with their respective nutrient contents.

Comparisons will help formulate interpretations of the health consequences and assess the different factors that should ideally be brought together regionally to attain an optimal diet from a public health standpoint. This will also make it possible to define some health limitations which can hinder the development of the economic base underlying the production and consumption of country food.

ACTIVITIES IN 1997/1998

Four countries were included in the Circumpolar study: Alaska, Greenland, Siberia and Canada. To start, we conducted an inventory of the studies on food consumption and nutritional intakes among Inuit populations. Approximately 40 studies that were done after 1950 were itemized. For the comparison between regions, we selected more recent, completed and available studies.

1. Alaska

For Alaska, two studies were selected:

- Dietary Intake of Alaska Adults 1987 /1988 (Nobmann 1989)
- Diet Among Siberian Yup'iks of Alaska and the Implications for cardiovascular Disease (Nobmann 1996)

1.1 Dietary Intake of Alaska Adults 1987 /1988 (Nobmann 1989)

This study was conducted in 1987/88. Eleven communities were selected: Anchorage, Sitka, Kake, Mt. Village, Kwigillingok, Bethel, Pedro Bay, Pilot Bay, Dillingham, Kotzebue and Selawik. Three hundred and fifty one Alaska native men and women (Inuits (53%), Indians (34%) and Aleuts (13%)) aged between 21 and 60 years were interviewed using a 24-hour dietary recall. To determine seasonal differences in food intakes, each participant was asked to recall all foods consumed in the previous 24-hour period during five seasons over an 18 month period. The participants completed between one and five recalls.

1.2 Diet Among Siberian Yup'iks of Alaska and the Implications for cardiovascular Disease (Nobmann 1996)

The study was conducted in 1992; 65 Siberian Yup'ik aged between 40 and 89 years were interviewed using a 24-hour dietary recall and a food frequency questionnaire. The subjects were selected from the community of Gambell on St. Lawrence Island.

2. Canada

For Canada, five studies were selected:

- Santé Québec; A Health Profile of the Inuit. (Santé Québec 1992)
- Air Stage Subsidy Monitoring Programme; Final Report: Volume 2: Food Consumption Survey (Lawn and Langner 1994)
- Nutritional and Toxicological Components of Inuit Diets in Broughton Island, Northwest Territories (Kuhnlein 1989)
- Sanikiluaq Traditional Food Study Report (Wein 1995)
- Inuvialuit Food Use and Food Preferences in Aklavik, Northwest Territories, Canada (Wein and Freeman 1992)

2.1 Santé Québec; A Health Profile of the Inuit (Santé Québec 1992)

The study was conducted in Nunavik in 1992; 433 Inuit (men and women) aged between 40 and 89 years were interviewed using a 24-hour dietary recall. A food frequency questionnaire was aimed at women aged 18 to 74 years who were neither pregnant nor lactating and who had completed the 24-hour recall (N=228). The subjects were selected from the communities of Akulivik, Aupaluk, Inukjuak, Ivujivik, Kangiqsualujjuaq, Kangiqsujuaq, Kangirsuk, Kuujjuaq, Kuujjuapik, Povungnituk, Quaqtaq, Salluit, Tasiujaq and Umiujaq in Nunavik.

2.2 Air Stage Subsidy Monitoring Programme; Final Report: Volume 2: Food Consumption Survey (Lawn and Langner 1994)

The study was conducted between 1992/1993, Inuit women, aged between 15 and 44 years (N=397 in 1992, N=396 in 1993), were interviewed using a 24-hour dietary recall and a food frequency questionnaire. In this sample, pregnant or lactating women were included. The subjects were selected from the communities of Pond Inlet, Repulse Bay, Nain, Arctic Bay, Gjoa Haven and Coral Harbour. Two Indian communities were also selected for this study but they were not used in this report. Data analysis for this study is not completed yet and is not included in the report.

2.3 Nutritional and Toxicological Components of Inuit Diets in Broughton Island, Northwest Territories (Kuhnlein 1989)

The study was conducted between 1987 and 1988, 369 Inuit (men and women), aged between 3 and 85 years, were interviewed using a 24-hour dietary recall and a food frequency questionnaire. To determine seasonal differences in food intakes, each participant was asked to recall all foods consumed in the previous 24-hour period for six seasons over a 12-month period. The participant completed between one and six recalls. The subjects were selected from the community of Broughton Island on Baffin Island. In this sample, pregnant or lactating women were included.

2.4 Sanikiluaq Traditional Food Study Report (Wein 1995)

The study was conducted between 1992 and 1993, 102 Inuit households were interviewed using a traditional food frequency questionnaire. The questionnaire asked respondents to estimate their consumption for each season of the preceding year (December 1992–November 1993). Forty-eight adults completed two 24-hour dietary recalls, one in Winter (February–March 1993) and the other in Fall (October– November 1993). The subjects were selected from the community of Sanikiluaq, Belcher Island.

2.5 Inuvialuit Food Use and Food Preferences in Aklavik, Northwest Territories, Canada (Wein and Freeman 1992)

The study was conducted between 1990 and 1991, 36 Inuit households were interviewed using a traditional food frequency questionnaire. The questionnaire asked respondents to estimate their consumption for each season of the preceding year (Fall 1990 – Summer 1991). The subjects were selected from the community of Aklavik (Inuvik).

3. Greenland

For Greenland, two studies were selected:

- Cardiovascular Risk Factors in Greenland Inuit (Bjeeregaard *et al.* 1997)
- Greenland (Bjeeregaard *et al.* 1998)

3.1 Cardiovascular Risk Factors in Greenland Inuit (Bjeeregaard et al. 1997)

This study was conducted between 1993 and 1994; 1728 Greenland residents (1580 Inuit), aged from 18 to more 60 years, were interviewed using a short food frequency questionnaire (17 food items). The subjects were selected from all 17 towns and 21 villages. Danish as well as East and North Greenlanders were excluded.

3.2 Greenland (Bjeeregaard et al. 1998)

The study was conducted in 1995, 450 Inuit were interviewed using a 24-hour dietary recall and a food frequency questionnaire. The subjects were selected from two communities: Ilulissat and Aasiaat. Data for this study was not analysed and is not available for the report.

4. Siberia

For Siberia, only one study was selected:

- Comparison of Diets in Two Native Chukotka Populations and Prevalence of Ischemic Heart Disease Risk Factors (Nikitin *et al.* 1991)

The study was conducted among 277 native males, aged 30–59 years. They were interviewed using a 24-hour dietary recall. The subjects were selected from coastal or tundra regions of Chukotka.

5. Limits of data

We had some limits for comparing between the different studies. All methods used to survey food consumption have their own limitations and all studies included in the report were not the same. A single 24-hour recall is rarely representative of an individual's usual intake. The frequency questionnaire is used to measure long-term intakes, thus providing a more representative idea of usual intakes (Gibson 1990, Willett 1990). The major limitation of the food frequency questionnaire is its list of foods. However, the food list may be extensive enough to enable estimates of total food intake. In general, longer food frequency lists overestimate intake, whereas shorter lists underestimate intake (Thompson and Byers 1994, Gibsons 1990).

RESULTS

Results from Alaska

1. Nobmann study, 1989

This study revealed that traditional foods most frequently consumed by Alaskan Inuit were salmon and other fish, crustaceans, caribou, reindeer, berries, duck and moose. Intakes in traditional foods increased with age. Imported foods most frequently consumed were coffee, tea, sugar, white bread and crackers.

2. Nobmann study, 1996

This recent study revealed that the most popular traditional foods consumed by Alaskan Inuit were seal meat, walrus meat and liver, seal fat, skin and fat mallu, fish and seafood, mallu meat and berries.

Results from Nunavik (Santé Québec Health Survey 1992)

According to the Santé Québec Health Survey conducted in 1992 among the Inuit population of Nunavik, imported food consumption was greater than that of traditional foods among all age groups and sex. However, traditional food intakes increased with age whereas the contribution of imported foods decreased. According to data collected from the 24-hour dietary recall, traditional foods most frequently consumed were caribou, red char (arctic char), misirak, white whale blubber, seal and lake whitefish. According to data collected from the food frequency questionnaire, similar results were observed although the Inuit population showed a higher consumption of wildfowl whereas traditional food consumption varied seasonally.

According to data collected from the 24-hour dietary recall, the most popular imported foods were sugar and sweets, pasta and rice, tea and coffee, bannock, sweetened beverages, butter and shortening and white bread. Intakes of perishable imported foods such as milk and dairy milk products appeared to be related to availability of foods in the Nunavik communities. We observed a greater consumption of milk, dairy products and white bread, and a lower consumption of bannock in Kuujjuaq compared to other remote communities.

Results from Baffin Island (Kuhnlein et al. 1989)

Consumption of imported food was higher than that of traditional foods among all age groups and sex. Traditional food intakes increased with age, in particular as regards seal intake. Besides, imported food intakes decreased with age. According to data collected from the food frequency questionnaire, traditional foods most frequently consumed were seal (meat, fat and liver), caribou (meat and fat), red char (flesh and skin), walrus (fat, skin and meat), seaweed, berries, duck and other wildfowl, crustaceans and wild eggs. Data collected from the 24-hour dietary recall showed similar results. Traditional food consumption varied seasonally. Imported foods most frequently consumed were tea, sugar, bannock, cookies, fruit drinks, crackers, evaporated milk and white bread.

Results from Sanikiluaq (Wein 1995)

Even if there was no information on the quantity of foods consumed in the food frequency questionnaire, the frequency of consumption of main traditional food was in order of importance: Fish and mollusc, wildfowl and eggs, marine mammals (particularly seal), and berries. Traditional food consumption varied very little according to seasons but the consumption was higher from

September to November. However, Wein suggested that there may be overestimation of some traditional foods in the food frequency questionnaire such as fish and mollusc intakes. As regards information collected with the 24-hour dietary recall, imported foods were more often mentioned than traditional foods. However, traditional foods were consumed in higher amounts, in particular among men and elders. Traditional food intakes were higher in the winter and the most popular consumed were reindeer and seal. As regards imported foods, tea, sugar, bannock, evaporated milk and white bread were imported foods that were most frequently consumed.

Results from Akalavik (Wein and Freeman 1992)
According to the food frequency questionnaire, mammals (in particular caribou and white whale), fish (particularly lake whitefish), wildfowl, berries and other plants were the most popular traditional foods. Traditional foods were consumed daily on an average of 1.85 times by each family and were more often consumed in fall and winter.

Results from Greenland (Bjerregaard et al. 1997)
According to the food frequency questionnaire, traditional foods most frequently consumed by Greenland Inuit were seal meat, fish and wildfowl. Average traditional food meals amounted to 28 per month and consumption was higher among men and elders. Moreover, we found a higher consumption rate in small northern communities than in larger towns.

Results from Siberia (Nikitin et al. 1991)
Nikitin *et al.* observed that Inuit living in the tundra mainly consumed caribou meat, bread, sugar, river fish and butter. As regards coastal Inuit, they showed greater intakes of walrus, whale, seal, mutton, bread and sugar.

DISCUSSION AND CONCLUSION

Traditional food consumption varied according to regions. This variation may be attributed to territorial availability of species; populations of coastal regions consuming more marine mammals and fish that populations of central regions. Traditional foods such as caribou and red char were frequently consumed in Baffin Island and Nunavik. Moreover, compared to Nunavik and Alaska regions, seal, narwhal, molluscs and walrus were more consumed in Baffin Island. Salmon and other fish intakes (except for red char) were higher in Alaska and reindeer and venison intakes were also higher in Alaska. As regards amounts consumed, traditional foods appeared to be higher for mammals such as caribou, seal, walrus and also mollusc in Sanikiluaq, Baffin Island in comparison to Nunavik. Moreover, Wein (1995) reported that traditional food consumption was 1.7 times higher in Sanikiluaq than in Akalavik and that traditional food intakes in Sanikiluaq were similar to those observed by Kuhnlein *et al.* in Baffin Island. Traditional food intakes of Alaskan Inuit appeared to also be comparable to those of these last two mentioned regions. Intakes of the most perishable imported foods such as milk, fruit juices and fruit were lower in Baffin Island than in Nunavik and Alaska. Moreover, intakes of Alaska Inuit for these foods were higher than those of Nunavik Inuit. Alaska appeared to be better supplied in imported foods than other regions and this last ascertainment could explain, at least in part, why Alaska showed the highest imported food intakes.

Finally at this time, since we don't have detailed dietary data for all circumpolar regions, we have to limit our interpretation. Nevertheless, our project provided additional information on the traditional and imported food intakes of circumpolar Inuit populations, this information being essential to promote healthy nutrition among Inuit populations.

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CIRCUMPOLAR MATERNAL BLOOD CONTAMINANT SURVEY

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OBJECTIVE

1. To assess the geographical variation of contaminant levels among circumpolar peoples of the Arctic.

INTRODUCTION

All circumpolar countries agreed to monitoring of specific human tissues for contaminants in the Arctic under the Arctic Monitoring and Assessment Program (AMAP) monitoring plan. During the AMAP meeting of the Human Health Group held in Copenhagen on September 26 – 27, 1994 Canada offered to coordinate and lead a special project for the monitoring of maternal blood in the circumpolar region, using a standardized collection procedure. Seven circumpolar countries were able to participate in this protocol, Denmark/Greenland, Canada, Sweden, Norway, Russia, Iceland and Finland. The United States (Alaska) was able to join the protocol at a later date. Each participating country agreed to send a minimum of 30 maternal blood samples (plasma and whole blood). Maternal blood was selected instead of cord blood because it could provide enough blood for duplicate analyses (one for the national and one for the international laboratory).

Methods

For each mother, 40 ml of blood was drawn by venous puncture into 4 X 10 ml vacutainers. Each sample was analysed for 14 PCB congeners (IUPAC No. 28, 52, 99, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187) 13 organochlorine pesticides (aldrin, beta-hexachlorocyclohexane (HCH), alpha-chlordane, gamma-chlordane, cis-nonachlor, *p,p'*-DDT, *p,p'*-DDE, dieldrin, heptachlorepoxide, hexachlorobenzene, mirex, oxychlordane and transnonachlor) and 4 elements (mercury, lead, cadmium and selenium). All organochlorine analyses reported here were analysed in the Quebec Toxicology Center but not all metals and selenium analyses were performed in the same laboratory.

PCBs and pesticides were measured in plasma using gas chromatography (GC) with electronic capture detectors according to the method of Ferron (1994). Briefly, two mL of plasma are extracted, cleaned upon a Florisil column, taken to a final volume of 100 µL and analysed on a HP5890 series II GC with dual capillary columns and dual Ni-63 electron capture detectors. PCBs and pesticides are identified by their relative retention times obtained on the two columns, using a computer based program developed in house. Quantitation is mainly done on the Ultra-1 column. The limit of detection, based on 3 times the standard deviation of noise is 0.02 µg/L for PCB congeners and chlorinated pesticides except for heptachlorepoxide and dieldrin for which the detection limit is 0.1 µg/L.

Quality assurance/quality control was assessed though addition of three standards, one plasma blank and one quality control to each batch of twelve samples. The control used was the SRM#1589, PCB as Aroclor 1260 in human serum (NIST) diluted ten-fold with distilled water in which 0.4 µg/L of each chlorinated pesticide have been added. The between day precision (n=50) ranged 2.7 to 10% NS 4.5 to 10% for PCB congeners and chlorinated pesticides, respectively. For Aroclor 1260 the precision was 2.4%. The average percentage recoveries were greater than 95% for PCB congeners and ranged from 90 to 103% for chlorinated pesticides.

Lead, cadmium and selenium were also measured in plasma using atomic absorption with a graphite furnace (Stoeppler and Brandt 1980, Parsons and Slavin 1993). Mercury (both total and inorganic mercury) were measured in whole blood samples using flameless atomic absorption according to the method of Ebbstadt *et al.* (1975).

Table 1. Persistent Organic Pollutants in Maternal Blood (Geometric Means, µg/L plasma)

	n[1]	PCBs[2]	β-HCH[3]	HCB[4]	DDE	DDT	DDE/DDT
Canada							
Nunavik, Quebec	30	2.15	0.04	0.30	2.00	0.13	15.5
Kitikmeot, NWT	67	1.62	0.09	0.54	1.29	0.08	16.1
Finland	13[5]	1.45	0.07	0.19	0.57	0.02	24.6
Greenland	30	4.54	0.18	0.77	3.93	0.25	16.0
Iceland	40	1.80	0.25	0.32	0.87	0.03	28.4
Norway	60	1.36	0.06	0.18	0.62	0.02	26.2
Russia	51	1.75	1.62	0.47	3.06	0.36	8.5
Sweden	40	2.26	0.09	0.16	0.84	0.02	35.1
United States - Alaska	20	0.65	0.08	0.26	1.03	0.03	29.4

1 maximum number of mothers analysed, not availabe for all analytes
2 polychlorinated biphenyls as total of 14 congeners
3 β-hexachlorocyclohexane
4 hexachlorobenzene
5 made up of nine composites (n=129) and four individual analyses

Each participating country obtained patient consent for the sampling and attempted to complete a questionnaire for each mother covering at a minimum, date of sampling, country/region of residence and age of the mother.

RESULTS AND DISCUSSION

The results presented here are those of the Canadian reference laboratory. The results for PCBs (as sum of 14 congeners), beta-hexachlorocyclohexane (β-HCH), hexachlorobenzene (HCB), DDT and DDE are outlined in Table 1 for Canada, Finland, Greenland, Iceland, Norway, Russia, Sweden and the United States -Alaska. Further results for all analytes are available in Appendix 1. Results for metal analyses are not presented here as they involve analyses from a number of national laboratories and will be available in a separate report.

In Table 1 the concentration of HCB and DDE are 25% to 700% higher in maternal plasma from Greenland than in maternal samples from any other country. PCB levels were also 200% to 700% higher in the Greenland maternal samples. The highest levels of DDT, the parent compound of DDE were found in the maternal samples from Russia. Maternal plasma samples from Russia had the second highest levels of DDE. The DDE to DDT ratio for the Russian maternal samples is less than 9 while all other nations had ratios of 15 to 35 (Table 1). β-HCH levels were also 600% to 2000% higher in the Russian maternal samples.

In Canada higher levels for PCBs, DDE and DDT were found in Nunavik maternal samples compared to maternal samples from Kitikmeot in the west central Arctic (Table 1). In contrast to this the maternal samples from Nunavik had lower levels of HCB. Levels of DDE and various other organochlorine pesticides (Appendix 1) were not as high as those seen in Greenland but higher than levels seen in Norway, Sweden, Iceland and Finland.

With the exception of β-HCH and DDE/DDT levels in the Russian samples, the pattern of persistent organic pollutants are consistent with the relative amounts of traditional food consumed, especially where marine mammals make up a large part of the diet. The greatest reliance of Indigenous peoples on marine species and the highest concentrations in the species consumed occurs in Greenland followed by Nunavik in Canada. Mothers sampled in Norway, Sweden, Iceland, and Finland consume marine fish species and terrestrial mammals such as reindeer, sheep and cattle but very few marine mammals. Hence, levels in these countries are very similar to, and virtually indistinguishable from, subarctic values.

The pattern of DDE/DDT and β-HCH in Russian maternal samples suggests that there are either significant uses of the both DDT and HCH (technical Lindane) in northwestern Russia or that there are significant amounts of these pesticides in their food supply.

CONCLUSIONS

The levels of persistent organic pollutants and metals observed are generally consistent with long-range transport of pollutants into the Arctic and the relative amount of traditional food consumed by those sampled. DDT and β-HCH levels found in Russian suggest significant local use of these pesticides or importation of food containing those pesticides.

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APPENDIX 1

Table 1. "Maternal Blood - Canada, Nunavik"

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	30	5.64	4.19	7.59	100
Σ14 congeners	30	2.15	1.63	2.83	
Congener #28	30	0.01	0.01	0.01	83
Congener #52	30	0.04	0.03	0.05	100
Congener #99	30	0.13	0.10	0.18	100
Congener #101	30	0.03	0.03	0.04	100
Congener #105	30	0.03	0.02	0.04	97
Congener #118	30	0.10	0.08	0.14	100
Congener #128	30	0.01	0.01	0.02	77
Congener #138	30	0.39	0.29	0.53	100
Congener #153	30	0.64	0.46	0.90	100
Congener #156	30	0.04	0.03	0.05	93
Congener #170	30	0.11	0.08	0.16	100
Congener #180	30	0.26	0.19	0.36	100
Congener #183	29	0.06	0.05	0.08	100
Congener #187	29	0.16	0.12	0.20	100
Aldrin	29	0.01	0.01	0.01	72
β-HCH	29	0.04	0.03	0.05	100
DDT	29	0.13	0.10	0.16	100
DDE	29	2.00	1.50	2.66	100
ΣDDE + DDT	29	2.14	1.62	2.83	
Ratio DDE / DDT	29	15.50	12.96	18.54	
α-Chlordane	29	0.01	0.01	0.01	72
γ-Chlordane	29	0.01	0.01	0.01	72
ΣChlordanes	29	0.87	0.65	1.16	
Cisnonachlor	29	0.10	0.07	0.12	100
Hexachlorobenzene	29	0.30	0.23	0.38	100
Mirex	29	0.06	0.05	0.09	97
Oxychlordane	29	0.27	0.20	0.38	100
Transnonachlor	29	0.46	0.34	0.62	100

APPENDIX 1

Table 2. Maternal Blood - Finland

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. μg/L					
Aroclor 1260	13	3.74	3.40	4.13	100
Σ14 congeners	13	1.45	1.33	1.58	
Congener #28	13	0.02	0.01	0.02	62
Congener #52	13	0.01	0.01	0.01	15
Congener #99	13	0.04	0.03	0.04	100
Congener #101	13	0.01	0.01	0.01	0
Congener #105	13	0.03	0.02	0.03	77
Congener #118	13	0.07	0.06	0.08	100
Congener #128	13	0.01	0.01	0.01	0
Congener #138	13	0.29	0.27	0.32	100
Congener #153	13	0.43	0.39	0.47	100
Congener #156	13	0.05	0.05	0.06	100
Congener #170	13	0.13	0.12	0.15	100
Congener #180	13	0.24	0.22	0.26	100
Congener #183	13	0.04	0.03	0.04	100
Congener #187	13	0.08	0.07	0.09	100
Aldrin	13	0.01	0.01	0.01	0
β–HCH	13	0.07	0.06	0.08	92
DDT	13	0.02	0.02	0.03	46
DDE	13	0.57	0.50	0.65	100
ΣDDE + DDT	13	0.59	0.52	0.67	
Ratio DDE / DDT	13	24.55	20.14	29.92	
α-Chlordane	13	0.01	0.01	0.01	0
γ-Chlordane	13	0.01	0.01	0.01	0
ΣChlordanes	13	0.11	0.10	0.11	
Cisnonachlor	13	0.01	0.01	0.01	31
Hexachlorobenzene	13	0.19	0.17	0.21	100
Mirex	13	0.01	0.01	0.01	0
Oxychlordane	13	0.03	0.02	0.03	85
Transnonachlor	13	0.05	0.04	0.05	100

APPENDIX 1

Table 3. Maternal Blood - Greenland

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	30	12.15	9.24	15.96	100
Σ14 congeners	30	4.54	3.49	5.91	
Congener #28	30	0.02	0.02	0.03	90
Congener #52	30	0.03	0.02	0.04	80
Congener #99	30	0.22	0.16	0.31	100
Congener #101	30	0.05	0.04	0.06	93
Congener #105	30	0.06	0.04	0.08	93
Congener #118	30	0.28	0.21	0.37	100
Congener #128	12	0.01	0.01	0.01	17
Congener #138	30	0.97	0.74	1.26	100
Congener #153	30	1.37	1.04	1.81	100
Congener #156	30	0.12	0.10	0.16	100
Congener #170	30	0.26	0.20	0.34	100
Congener #180	30	0.67	0.51	0.87	100
Congener #183	28	0.10	0.08	0.13	100
Congener #187	30	0.32	0.24	0.42	100
Aldrin	30	0.01	0.01	0.01	0
β–HCH	30	0.18	0.15	0.21	100
DDT	30	0.25	0.20	0.30	100
DDE	30	3.93	3.02	5.12	100
ΣDDE + DDT	30	4.19	3.24	5.43	
Ratio DDE / DDT	30	15.97	14.06	18.15	
α–Chlordane	30	0.01	0.01	0.01	0
γ–Chlordane	30	0.01	0.01	0.01	7
Σ–Chlordanes	30	1.57	1.00	2.49	
Cisnonachlor	30	0.14	0.09	0.21	93
Hexachlorobenzene	30	0.77	0.57	1.04	100
Mirex	30	0.08	0.05	0.11	87
Oxychlordane	30	0.50	0.30	0.82	97
Transnonachlor	30	0.87	0.54	1.41	100

APPENDIX 1

Table 4. Maternal Blood - Iceland

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	40	4.56	4.04	5.14	100
14 congeners	40	1.80	1.61	2.02	
Congener #28	40	0.03	0.03	0.04	93
Congener #52	40	0.02	0.01	0.02	55
Congener #99	40	0.07	0.07	0.08	100
Congener #101	40	0.01	0.01	0.02	43
Congener #105	40	0.03	0.03	0.03	98
Congener #118	40	0.13	0.11	0.14	100
Congener #128	40	0.01	0.01	0.01	8
Congener #138	40	0.35	0.31	0.40	100
Congener #153	40	0.52	0.46	0.59	100
Congener #156	40	0.06	0.05	0.07	100
Congener #170	40	0.13	0.11	0.14	100
Congener #180	40	0.26	0.23	0.30	100
Congener #183	40	0.04	0.04	0.05	98
Congener #187	40	0.10	0.09	0.12	100
Aldrin	40	0.01	0.01	0.01	0
β-HCH	40	0.25	0.20	0.30	100
DDT	40	0.03	0.02	0.04	55
DDE	40	0.87	0.74	1.03	100
ΣDDE + DDT	40	0.91	0.77	1.08	
Ratio DDE / DDT	40	28.35	24.05	33.43	
α–Chlordane	40	0.01	0.01	0.01	0
γ–Chlordane	40	0.01	0.01	0.01	0
ΣChlordanes	40	0.19	0.16	0.22	
Cisnonachlor	40	0.02	0.02	0.03	70
Hexachlorobenzene	40	0.32	0.28	0.37	100
Mirex	40	0.01	0.01	0.02	35
Oxychlordane	40	0.05	0.04	0.06	100
Transnonachlor	40	0.09	0.08	0.11	100

APPENDIX 1

Table 5. Maternal Blood - Norway

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	60	3.58	3.23	3.96	100
Σ14 congeners	60	1.36	1.24	1.51	
Congener #28	60	0.02	0.02	0.03	85
Congener #52	60	0.01	0.01	0.02	58
Congener #99	60	0.05	0.05	0.06	100
Congener #101	60	0.01	0.01	0.01	15
Congener #105	60	0.02	0.02	0.02	58
Congener #118	60	0.08	0.07	0.09	100
Congener #128	60	0.01	0.01	0.01	3
Congener #138	60	0.27	0.25	0.30	100
Congener #153	60	0.41	0.37	0.46	100
Congener #156	60	0.05	0.04	0.05	100
Congener #170	60	0.09	0.08	0.11	100
Congener #180	60	0.20	0.18	0.22	100
Congener #183	60	0.03	0.03	0.03	97
Congener #187	60	0.08	0.07	0.09	100
Aldrin	60	0.01	0.01	0.01	0
β–HCH	60	0.06	0.05	0.07	97
DDT	60	0.02	0.02	0.03	42
DDE	60	0.62	0.52	0.73	100
ΣDDE + DDT	60	0.65	0.55	0.77	
Ratio DDE / DDT	60	26.24	22.45	30.67	
α–Chlordane	60	0.01	0.01	0.01	0
γ–Chlordane	60	0.01	0.01	0.01	2
ΣChlordanes	60	0.12	0.11	0.13	
Cisnonachlor	60	0.01	0.01	0.02	43
Hexachlorobenzene	60	0.18	0.15	0.21	100
Mirex	60	0.01	0.01	0.01	15
Oxychlordane	60	0.03	0.03	0.03	92
Transnonachlor	60	0.05	0.05	0.06	100

APPENDIX 1

Table 6. Maternal Blood - Russia

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	51	4.24	3.82	4.70	100
Σ14 congeners	51	1.75	1.58	1.93	
Congener #28	51	0.03	0.02	0.03	90
Congener #52	51	0.02	0.02	0.02	59
Congener #99	51	0.15	0.14	0.17	100
Congener #101	51	0.02	0.02	0.02	63
Congener #105	51	0.06	0.05	0.07	100
Congener #118	51	0.23	0.21	0.26	100
Congener #128	51	0.01	0.01	0.01	14
Congener #138	51	0.37	0.33	0.41	100
Congener #153	51	0.44	0.40	0.49	100
Congener #156	51	0.07	0.06	0.08	100
Congener #170	51	0.07	0.07	0.08	100
Congener #180	51	0.15	0.14	0.17	100
Congener #183	51	0.03	0.02	0.03	92
Congener #187	51	0.06	0.05	0.07	100
Aldrin	51	0.01	0.01	0.01	0
β-HCH	51	1.65	1.44	1.90	100
DDT	51	0.36	0.30	0.43	100
DDE	51	3.06	2.65	3.53	100
ΣDDE + DDT	51	3.45	2.99	3.98	
Ratio DDE / DDT	51	8.52	7.59	9.56	
α-Chlordane	51	0.01	0.01	0.01	0
γ-Chlordane	51	0.01	0.01	0.01	0
ΣChlordanes	51	0.18	0.16	0.20	
Cisnonachlor	51	0.04	0.03	0.05	96
Hexachlorobenzene	51	0.47	0.41	0.53	100
Mirex	51	0.01	0.01	0.01	6
Oxychlordane	51	0.02	0.02	0.03	84
Transnonachlor	51	0.09	0.07	0.10	100

APPENDIX 1

Table 7. Maternal Blood - Sweden

Contaminants	N	Geom. Mean	95% CI		Prop. of detected value (%)
a. µg/L					
Aroclor 1260	40	6.09	5.37	6.91	100
Σ14 congeners	40	2.26	2.00	2.55	
Congener #28	40	0.03	0.02	0.03	88
Congener #52	40	0.02	0.02	0.02	85
Congener #99	40	0.06	0.06	0.07	100
Congener #101	40	0.02	0.01	0.02	65
Congener #105	40	0.02	0.02	0.02	68
Congener #118	40	0.11	0.10	0.13	100
Congener #128	40	0.01	0.01	0.01	3
Congener #138	40	0.48	0.42	0.54	100
Congener #153	40	0.70	0.61	0.79	100
Congener #156	40	0.09	0.08	0.10	100
Congener #170	40	0.19	0.16	0.21	100
Congener #180	40	0.34	0.30	0.39	100
Congener #183	40	0.06	0.05	0.07	100
Congener #187	40	0.11	0.10	0.13	100
Aldrin	40	0.01	0.01	0.01	0
β–HCH	40	0.09	0.08	0.11	95
DDT	40	0.02	0.02	0.03	43
DDE	40	0.84	0.70	1.01	100
ΣDDE + DDT	40	0.87	0.73	1.05	
Ratio DDE / DDT	40	35.07	28.02	43.88	
α–Chlordane	40	0.01	0.01	0.01	0
γ–Chlordane	40	0.01	0.01	0.01	0
ΣChlordanes	40	0.09	0.08	0.10	
Cisnonachlor	40	0.01	0.01	0.01	25
Hexachlorobenzene	40	0.16	0.14	0.18	100
Mirex	40	0.01	0.01	0.01	8
Oxychlordane	40	0.02	0.02	0.02	70
Transnonachlor	40	0.04	0.03	0.04	98

APPENDIX 1

Table 8. Maternal Blood - Alaska

Contaminants	N	Geom. Mean	95% CI		Prop. of detected Value (%)
a. µg/L					
Aroclor 1260	20	1.63	1.09	2.43	100
Σ14 congeners	20	0.65	0.45	0.93	
Congener #28	0				
Congener #52	20	0.02	0.02	0.03	65
Congener #99	20	0.04	0.03	0.06	85
Congener #101	20	0.01	0.01	0.01	10
Congener #105	20	0.02	0.01	0.02	45
Congener #118	20	0.06	0.04	0.08	100
Congener #128	20	0.01	0.01	0.01	0
Congener #138	20	0.12	0.08	0.17	100
Congener #153	20	0.20	0.13	0.29	100
Congener #156	20	0.02	0.01	0.02	30
Congener #170	20	0.03	0.02	0.04	75
Congener #180	20	0.07	0.05	0.10	100
Congener #183	20	0.01	0.01	0.02	30
Congener #187	20	0.03	0.02	0.05	90
Aldrin	20	0.01	0.01	0.01	0
β-HCH	20	0.08	0.05	0.13	100
DDT	20	0.03	0.02	0.05	100
DDE	20	1.03	0.78	1.36	100
ΣDDE + DDT	20	1.06	0.81	1.41	
Ratio DDE / DDT	20	29.37	24.30	35.51	
α-Chlordane	20	0.01	0.01	0.01	0
γ-Chlordane	20	0.01	0.01	0.01	0
ΣChlordanes	20	0.26	0.18	0.40	
Cisnonachlor	20	0.02	0.01	0.03	50
Hexachlorobenzene	20	0.26	0.18	0.37	100
Mirex	20	0.02	0.01	0.03	35
Oxychlordane	20	0.11	0.07	0.16	100
Transnonachlor	20	0.11	0.07	0.17	100

NORTHERN HEALTH INITIATIVE WORKSHOP

Project Leader: A. Gilman, Chief, Environmental Health Effects Division, Health Canada

Project Team: J. Van Oostdam, D. Riedel (Health Canada); S. Neve; D. Gibeault (workshop reporter, contractor); D. Gibeault (facilitator, contractor)

OBJECTIVES

1. to propose research that will provide information upon which to base practical and up-to-date advice for Northerners on the significance to health, well-being and lifestyle of exposure to contaminants through traditional foods, water and air.

2. to provide information which will allow the development a Northern Health Initiative to guide Northern/Arctic human health contaminants research being undertaken by the Northern Contaminants Program, and by other federal, provincial and territorial health agencies.

DESCRIPTION

Health Canada was asked by the Northern Contaminants Program to host a workshop that would address the human health contaminant research needs over the next five years. Health Canada invited a wide range of people from federal, provincial and territorial health agencies plus university researchers and representatives from various aboriginal communities (Invitees/attendees in Appendix 1). The workshop was held in Ottawa on 26 and 27 of June 1997 to address the above objectives. A complete workshop report is available from Dr. Jay Van Oostdam, Environmental Health Effects Division, Health Canada, Rm 1139 Main Bldg., Tunney's Pasture, AL0301A1, Ottawa, ON, K1A 0K9.

WORKSHOP FORMAT

To keep the workshop firmly focussed on actual research proposals all attendees were asked to submit research proposals that they felt should be undertaken to address the key research needs. These were to form the basis of the discussions in the workshop. The workshop started with a series of plenary talks on Exposure Studies, Toxicology Studies, Epidemiology Studies, Risks and Benefits and Development of Advice. The workshop then involved a series of discussion groups on these topics with each group reporting back in plenary. The research proposals submitted were rated by workshop participants and are a significant part of the workshop proceedings. A copy of the agenda is in Appendix 2.

PRESENTATIONS

The purpose of the presentations was to situate the plenary discussions in terms of what is currently known about human health in the Arctic and to identify some of the major gaps in the research. Because some of this information is pertinent to the evaluation of the proposals, some of the highlights are reviewed briefly.

Exposure Studies – ***Harriet Kuhnlein***

To date, the assessment of contaminants in the North has not provided evidence to suggest that exposure is severe enough to impose food restrictions. However, there is a need for dietary/food information to allow individuals to make personal food choices.

What is *not* known about the effects of dietary exposure:

- sustained efficacy of TDIs
- effects from contaminant mixtures
- effects from chronic low levels of contaminants
- effects from short term/long term exposure
- effects from combined contaminants and low nutrient risks
- effects from combined contaminants and nutrient/ cultural benefits
- effects on chronic disease incidence
- how to change dietary exposure to reduce contaminants and optimize nutrients

Toxicology Studies – ***Frank Iverson***

What *is* known:

- major intake of contaminants appears to be through food
- the major food source is associated with marine mammals

- terrestrial sources of food are less heavily contaminated

What is *not* known:

- contaminants for which little is known are toxaphene, chlordane, and nonachlor

Epidemiology Studies – ***Eric Dewailly***

Dr. Dewailly discussed the type of epidemiological research that could be undertaken in Arctic Canada. Research should involve:

- study biological or subtle clinical modifications (early response) more than disease (e.g. biomarker studies, neurobehavioural, immunotoxicity, sperm quality). Continuum of abnormalities, no case-control design
- if studying specific diseases, focus on cancer (case control design) and infections (nested in immunotoxic-epi study)
- clinical studies of subtle effects
  - neurobehavioral – infants (cohort)
  - neurologic disorders in adults exposed to high levels of mercury (cross sectional)
  - sperm quality in exposed and non-exposed males (cross sectional)
- biomarker studies – should focus these around delivery places (i.e. hospitals – availability of placenta, etc.)
  - immunotoxicology – functional tests (nested in neurobehavioral cohort)
  - enzyme induction in placenta

Risks and Benefits – ***Lori Chan***

- The majority of the information currently available has to do with acute toxicity and mutagenicity with very little information regarding long-term toxicity, carcinogenicity and reproductive toxicity.

Development of Advice/Guidelines – ***Jody Walker & Mark Palmer***

Gaps/Needs

- lack of toxicological data
- lack of mixtures data
- (often) lack of dietary data
- lack of process for preliminary assessment of data – does it all need to go to Health Canada for all contaminants analysed?
- co-operative approach is essential
- research not necessarily done to answer community questions [see expectations]
- getting information back takes a long time
- not all organizations have the same focus or time lines
- complicated answers are given to straight forward questions such as Where to go with health hazard assessments?
- continued open communications between all stakeholders
- sampling driven by questions from communities *or* make it clear from the beginning when sampling is not being done from a human health standpoint
- need a process for re-evaluating advisories that have already been communicated
- "sentinel" contaminants need to be identified
- "hot spots" identified and monitoring plan in place
- benefits characterized and integrated as part of risk assessment process
- science of communications incorporated into the risk management process
- clear communications for individual and community exposure/risk reduction
- evidence of decreasing levels of contaminants
- cultural and nutritional integrity of North maintained

PROPOSALS – EVALUATION

Evaluation Methods and Rationale

As outlined in the workshop format, the main objective of the conference was to discuss the health related activities underway or required in the Arctic regions by the NCP partners. To this end, all workshop attendees were asked to submit proposals for projects they planned to do or saw a need for in Arctic Canada. These proposals were discussed in the plenary sessions and prioritized based on well-defined evaluation criteria. The proposals were considered and rated based on:

- the rationale
- whether or not the projects involved the community
- the priority rating (as provided by the group)
- cost:
  - What is the project likely to cost?/Is the budget inflated?
  - Are organizations already doing this?
  - What could you/your organization contribute?

The groups also discussed whether some of the projects need to be combined and potential partnerships (are the partners identified the right ones?).

Highlights of the comments made and priorities set during the plenary sessions, as well as the results of the priority rating that was done by all workshop participants, follows. More complete information about the ratings for each project is provided in the workshop report including total scores, the sample size (number of people who rated the proposal), the average score, and the rating relative to the other projects in the given category.

SESSION A – EXPOSURE STUDIES

General Comments

Prior to a specific evaluation of the proposals, the group discussed the gaps in the knowledge as they saw them. It should be noted that many of the gaps identified here were similar to those brought up by Jody Walker in her presentation. The following gaps were identified:

- there is a need for re-testing in communities – to determine whether contaminant levels in individuals have: (i) increased; (ii) decreased; or, (iii) stayed the same. A new proposal was submitted to fill this gap (A11).
- effects of exposure to mixtures of contaminants. Need more information about the cumulative impacts of many contaminants.
- when/how chemicals are added to the list; when/how they are removed. Do all of the old chemicals still need to be on the list – should new chemicals be added?
- there is little information regarding speciation of contaminants (OCs, mercury, arsenic).
- information regarding exposure to mercury identified as a gap.
- lead exposure in children in Nunavut. This remains an important issue as acute exposures continue to occur in the North.
- insufficient information regarding exposure to radionuclides was identified – most importantly with respect to caribou. Communities' understanding of radionuclides is also very low.
- little information re. UV-B exposure. This is a known community concern.
- the lack of Inuit dietary studies was identified as a big gap.
- the information with respect to the nutrient benefits of foods is incomplete (i.e. exposure to beneficial elements of foods). For example, the information regarding the anti-oxidants and other mitigants of exposure/intake in some foods is lacking. In general, better food composition data is needed.
- re-analysis of the Yellowknife Dene dietary study is a priority (see proposal A4). Survey of other (remaining) Dene/Métis communities' diets is not a priority.
- one of the most significant gaps, according to this group, was information regarding what the community perceived as the biggest concerns and how to find out what these concerns are.

General themes in the setting of priorities

In general, the group thought all of the projects, with the exceptions of A1 and A3, were important. The points that were commonly mentioned regarding why a project was supported were:

- the project was already underway and needed relatively minor work to complete it
- the results of the study would be comparable with other northern communities and/or with other countries
- there was an interest in seeing how things had changed over time and in continuous monitoring of communities. Project A5, for example, would provide an indication as to the impact of media attention on dietary choices.
- the project complemented another one –e.g., project A5 complement the CINE NCP Inuit diet studies
- the project had the support of the community

Interestingly both projects that were rated as being "low priority" were relatively technical in nature. The low ratings also likely reflect the fact that neither project has definitive community support. It is also apparent that the higher priorities were assigned to those projects that looked at dietary exposures, most notably those that also considered the beneficial aspects of the diets (i.e. A10 and A5).

SESSION B - TOXICOLOGY

General Comments

Areas of concern in toxicology:

- the toxaphene/chlordane projects are a priority as they fill a gap in the knowledge and will reduce the uncertainty in the risk estimates.
- complex mixtures have to be addressed.
- mercury research projects have to be focussed and integrated (upcoming workshop will possibly assist in doing this).
- research on radionuclides is not required from a toxicological point of view.
- cancer risk questions are a community-based priority that should be reflected in research projects being carried out – this may be an education issue and not necessarily toxicological but this needs to be looked into nonetheless.
- human contaminant guideline values should be revised/reviewed or developed if none exist (i.e. toxaphene). In addition, the levels of concern need to be explained with respect to what kinds of endpoints they have been associated with. This point was made in several of the plenary sessions.
- health hazard assessment advice should be more simplistic (see sessions D and E). Need to provide an interpretation of the numbers given – i.e. provide interpretation of maternal/cord blood guidelines.

The group developed the schematic shown in diagram A.

Dietary Studies → **TDI** → **Information to Communities** ← **Human Contaminant Guidelines** ← **Biomonitoring**

Health Significance of (exceeding) values

DIAGRAM A

General themes in the setting of priorities

- The top two rated projects were both studies based on mixtures of contaminants, a gap that was identified by many of the participants and was also identified in the CACAR report as a significant gap in the research.
- Projects rated 3 through 6 all had to do with toxaphene and chlordane, the contaminants identified consistently as being those for which information is lacking.
- Similar to what was seen in session A, the lowest two rated projects were those of a highly technical nature involving in vitro tests of very specific endpoints.
- Given that there was considerable emphasis placed on international controls as well as on the establishment of time trends (are levels going up, down, staying the same?), it is somewhat surprising that B2 did not receive higher priority ratings.

SESSION C - EPIDEMIOLOGY STUDIES

General Comments

The groups considered the general scope of the NHI. There was a lengthy discussion in this session in which the group considered:

- What would be the goals of the studies done in the Arctic? What kinds of questions can be *meaningfully* answered in the Arctic and which ones are best answered elsewhere (e.g. in the "South")? What are meaningful health effects from a public health perspective? What are the unique health characteristics of the population?
- Subsequent to an elaborate discussion regarding the suggested process to follow in doing epidemiological studies in the Arctic, the following process was suggested:
  1. determine the risk outcome (e.g. diabetes, cancer, etc.)
  2. identify the communities where the outcome is prevalent (high risk groups)
  3. look at factors that could lead to the elevated outcome (i.e. what are the attributable risk factors from contaminants?)
  4. implement preventative measures

[It was noted that the outcome in question may not be in sufficient amounts/severity that they would become a public health concern but subtle effects need to be looked at nonetheless.]

- there was some concern about the focus on *only* contaminants and it was suggested that we should move beyond contaminants alone; others suggested that we must remain within the mandate of the program.
- many of the communities in the North are asking questions about the rising incidence of many diseases, especially cancer, and are concerned about the possible association between the increased incidence and exposure to environmental contaminants.
- the potential for spin-off information was also identified – i.e. epidemiological studies also involve looking for associations between lifestyle and other potential confounders – this could provide information about risk factors other than contaminants.
- need for registries was identified such as the ones that exist in the Great Lakes Basin (cancer, birth defects, morbidity). These serve to identify "hot spots" and would be a good starting point for research. They would also serve to reconcile the perceptions with actual incidence data.
- also a need for more information on the nutritional benefits (possible protective effects of selenium for example) in order to discuss the benefits of continued consumption.

General themes in the setting of priorities

- there was an overall agreement in the groups that the lower ratings of proposals were either not highly relevant, or reflected research questions that may be better answered in another population, or as part of another project category. For example, C14 is toxicology rather than epidemiology.
- projects that will provide a clearer picture of the current situation in the north with respect to the impacts of contaminants on health were rated highly (i.e. C6 and C17)
- projects that filled identified gaps in the current knowledge such as cancer and effects on reproduction were also highly rated (C4, C1, C11).

- although C10 was rated quite low by the overall group (G3), discussions in the plenary sessions seem to place a higher priority on this project. Given that it is a sub-component of project C11 the higher rating may need to be considered.

SESSION D - RISKS AND BENEFITS

General Comments

- the group discussed the need for permanent working groups to coordinate:
  - the scientific information
  - understanding of needs
  - priorities
  - development of options
  - ways/approach in communicating with the community

This approach also offers continuity to com-munity members – familiarity with people providing health advice– and fosters trust.

- there is a need for harmonization within the region as well as on a large scale (i.e. international).
- need for guidelines on communications to avoid confusing or contradictory messages. Messages need to be simple.
- more education is also needed to allow communities to control their lives; they need to hear both sides.
- the importance of two way communications was emphasized.
- need new money to train community representatives on data interpretation – Possibly reallocate money from science to communications or find more money.
- need health reps. and renewable resource people

  [Many of these same comments were echoed in session E.]

General themes in the setting of priorities

- the top two rated projects in this category both have to do with strengthening the risk assessment process and allowing more information regarding benefits to be incorporated into the process.
- the projects involving modelling were rated less highly, likely representing the uncertainty surrounding the feasibility of representing benefits in this format.
- it should be noted, however, that the average ratings in this category were quite high with the lowest project rating an average of 3.4 reflecting a strong interest in projects focusing on the risks and benefits of diets and other activities.

SESSION E - DEVELOPMENT OF ADVICE/GUIDE-LINES

General Comments

- there is a need for a balanced message. There was some confusion about who has the overall health responsibility in the territories. GNWT health has the main responsibility for delivering health services in the NWT. Health Canada was perceived as the sole information provider with respect to health advice despite the fact that (in the Northwest Territories) GNWT then packages that advice the way they think is most appropriate. It was unclear who had the mandate to provide health advice. There was a need for a team approach (see also section D). Other groups that were identified as sources of information included CINE and Santé Public. Access to a variety of experts was identified as having been very valuable and it was important to people that the various parties continue to be available and work together.
- the group discussed the fact that there are no consistent guidelines (especially blood guidelines) being used in the North. Because the communities all receive the same media, when different guidelines are quoted it becomes confusing for people and makes communications very difficult. The packaging of advice makes it appear contradictory leading to difficulties in risk communication. Need for a standardized approach in the provision of advise. More information about what the guidelines represent in terms of real health outcomes is needed – especially in the increasing risk range; people want to know what types of health outcomes the different guidelines or blood levels may be associated with. There was an urgent request for guidelines (and clear description of potential health effects associated with them) for newborns (identified as a major knowledge gap in the CACAR report).
- the evaluation of communications was discussed and while it was agreed that informal evaluations occur all the time, there is a need for a more formal evaluation. It was stressed however that any evaluation should be done by the communicators themselves rather than an outside party.
- a problem that has often been encountered in the dilemma surrounding what to say/advise when no guidelines are available. The group discussed the need for a more flexible tool to use to help people understand the risks associated with various activities or the effects associated with various guidelines.

General themes in the setting of priorities

- as in several of the other sessions, priority is placed on projects which will provide more information about risks and improving the system by which advice is arrived at and disseminated.

- the interest in international agreements to control the release of pollutants is also reflected in the high priority placed on proposal E4.
- it should be noted that category E proposals (similar to category D) had high average ratings compared to the other categories (- range in average scores of 3 - 4.8) likely reflecting an interest in the communications and guidelines development aspect of the research despite the fact that information gaps do remain.

SUMMARY

The knowledge gained to date in Canadian Arctic human health research was discussed. Knowledge gaps in considering the effects of environmental contaminants on human health in the Arctic are similar to other areas of Canada but exposures are significantly higher than in more southern areas of Canada. The higher exposures in Arctic Canada make the knowledge gaps identified particularly important to Canada's northern peoples.

Each of the discussion groups pointed out a number of areas where more research is needed to fill significant knowledge gaps. The workshop attendees rated individual projects in all topic areas and this overall evaluation is useful in helping agencies/departments/ universities participating in Arctic research. A more complete discussion of all proposals discussed and their specific ratings can be obtained in the workshop report. The priorities for Arctic human health research identified allows each agency to assess where it can best contribute to addressing the question of human health impacts of Arctic environmental contaminants.

APPENDIX 1 LIST OF INVITEES

ATTENDING	NAMES	ORGANIZATION
No	Ayotte, Pierre	DEPARTMENT DE SANTE COMMUNAUTAIRE DU CENTRE
Yes	Band, Pierre	HEALTH CANADA
Yes	Baweja, Anar	HEALTH CANADA
Yes	Benzing-Purdie, Laure	HEALTH CANADA
No response	Boljkovac, Craig	INUIT TAPIRISAT OF CANADA
Yes (for Minnie Grey)	Bruneau, Suzanne	NUNAVIK NUTRITION AND HEALTH COMMITTEE
No response	Carpenter, Bill	MÉTIS NATION
Yes	Chan, Laurie	CENTRE FOR ABORIGINAL PEOPLES
No	Corriveau, André	GOVERNMENT OF NORTH WEST TERRITORIES
Yes	Demers, Marianne	KEEWATIN REGIONAL HEALTH BOARD
Yes	Dewailly, Eric	CENTRE DE SANTE PUBLIQUE DE QUEBEC
Yes	Dickson, Cindy	COUNCIL OF YUKON FIRST NATIONS
Yes	Feeley, Mark	HEALTH CANADA
Yes	Gaudette, Leslie	STATISTICS CANADA
Yes	Gilman, Andy	HEALTH CANADA
No	Grey, Minnie	(Suzanne Bruneau is attending on her behalf)
Yes	Grey, Roda	PAUKTUUTIT INUIT WOMEN'S ASSOCIATION
Yes	Han, Siu Ling	DEPT. OF INDIAN AND NORTHERN DEVELOPMENT
Yes	Harris, Katie	LABRADOR INUIT ASSOCIATION
Yes	Iverson, Frank	HEALTH CANADA
Yes	Jerome, Vicki	HEALTH CANADA
Yes	Kuhnlein, Harriet	CENTRE FOR ABORIGINAL PEOPLES
Yes	Mao, Yang (for Ray Edwards)	HEALTH CANADA
Yes	Meakin, Stephanie	INUIT CIRCUMPOLAR CONFERENCE
Yes	Mills, Carol	DIAND
Yes	Moore, Jeff	HEALTH CANADA
Yes	Mori, Brian	HEALTH CANADA
No	Moss, Siobhan	BAFFIN REGIONAL HEALTH BOARD
Yes	Nutall, Richard	GOVERNMETN OF NORTHWEST TERRITORIES
Yes	Ogina, Julia	KITIKWAT WORKING GROUP
Yes	Palmer, Mark	YUKON CONTAMINANTS COMMITTEE
Yes	Papik, Stephanie	DENE NATION
No	Paradis, Sylvain	HEALTH CANADA
No	Pearson, Ron	YUKON HEALTH
Yes	Receveur, Olivier	CENTRE FOR ABORIGINAL PEOPLES
Yes	Riedel, Dieter	HEALTH CANADA
Yes	Shearer, Russ (or Jill Jensen)	DEPT OF INDIAN AND NORTHERN AFFAIRS
Yes	Shortreed, John	UNIVERSITY OF WATERLOO
Yes	Shulz, Sharon	KEEWATIN REGIONAL HEALTH BOARD
Yes	Sims, Jackie	DEPT OF INDIAN AND NORTHERN DEVELOPMENT
Yes	Tracy, Bliss	HEALTH CANADA
Yes	Van Oostdam, Jay	HEALTH CANADA
Yes	Walker, Jody	GOVERNMENT OF NORTHWEST TERRITORIES
Yes	Wein, Eleanor	UNIVERSITY OF ALBERTA
No	Wheatley, Brian	CONSULTANT
Yes	Whitby, Leslie	DEPT. OF INDIAN AND NORTHERN AFFAIRS
Yes	Young T. Kue	UNIVERSITY OF MANITOBA

APPENDIX 2

NORTHERN HEALTH INITIATIVE (1997 - 2002)
WORKSHOP AGENDA
June 26 and 27, 1997
Room C301
Banting Building, Tunney's Pasture, Ottawa, ON

THURSDAY JUNE 26, 1997

9:00 Coffee/Tea/Juice and Greetings

10:00 Welcome/ Introduction

10:30 Northern Health Initiative – Risk Assessment Needs

- Presentations
  - A. Exposure Studies — H. Kuhnlein
  - B. Toxicology Studies — F. Iverson
  - C. Epidemiology Studies — E. Dewailly
- Discussion to define future directions

12:00 Lunch (provided) - project room
- Facilitator

1:00 Northern Health Initiative – Risk Management Needs

- Presentations
  - D. Risks and Benefits — L. Chan
  - E. Development of Advice/Guidelines — J. Walker/M. Palmer
- Discussion to define future directions

2:00 Plenary-Session– Northern Health Initiative – Risk Assessment Needs

- Charge to Groups A, B and C
- Breakout Groups

Coffee/Tea/Juice Available

4:00 Plenary Discussion of Results of Breakout Session

- Presentations
  Groups A to C, 10 minutes each.
- Discussion

5:00 Close Day 1 – Instructions for Day

****Dinner - Invitation to Bar-B-Q, 571 Hilson Ave., Ottawa****

FRIDAY JUNE 27, 1997

8:30 Review of Needs for Risk Assessment
- Dieter Riedel

8:45 Plenary-Session – Northern Health Initiative – Risk Management Needs

- Charge to Groups D and E
- Breakout Groups

Coffee/Tea/Juice available

11:00 Plenary Discussion of Results of Breakout Session

- Presentations Groups D and E, 10 minutes each
- Discussion

11:40 Evaluation of Priorities

- Fill out Priority Evaluation Sheets

12:00 Lunch

1:00 Plenary-Session – Reevaluation of Partners, Implementation/Timing, Budgets

- Results of Priority Evaluation
- Charge to Breakout Groups A, B, C, D and E
  - A. Exposure Studies
  - B. Toxicology Studies
  - C. Epidemiology Studies
  - D. Risks and Benefits
  - E. Guidelines/Development of Advice

3:00 Coffee/Tea/Juice

3:15 Roving among Breakout Groups (1–5)

3:45 Plenary Discussion: Overview of Workshop, Path Forward
- Jay Van Oostdam

4:00 Closing

Adjourn 4:15

A STUDY WITH CYNOMOLGUS MONKEYS *(MACACA FASICULARIS)* TO DETERMINE THE POTENTIAL TOXICOLOGICAL AND REPRODUCTIVE EFFECTS OF INGESTING TECHNICAL GRADE TOXAPHENE.

Project Leader: F. Iverson, Ph.D., Toxicology Research Division, Food Directorate, Health Protection Branch, Health Canada.

Project Team: **Toxicology Research Division:** D. Arnold and F. Bryce, Costudy Directors; H. Tryphonas, immunotoxicology; R. Mehta, carcinogenesis and immunohistochemistry; C. Suzuki, biochemical toxicology; I. Curan, molecular toxicology; T. Schrader, geno-toxicology; G. Cooke, reproductive toxicology; O. Pulido, neuropathology; M. Barker, pathology; and E. Lok, immunohistochemistry. **Food Research Division:** H. Newsome, tissue residue analysis. **Bureau of Biostatistics and Computer Applications:** S. Hayward, statistician.

OBJECTIVES

Overall:

1. A large monkey study was undertaken in May of 1996, to assess thoroughly the toxicological implications of toxaphene ingestion. The data from this study will assist in the assessment of toxaphene's potential risk to human health and will provide information to indicate whether the TDI for toxaphene, as set by Health Canada, is acceptable or warrants a review.

1997/98:

1. There were two objectives for the 1997/98 report period. The first was to evaluate the immunological effects of toxaphene administration to primates and the second was to initiate the reproduction component of the study to evaluate the effects of toxaphene on primate reproduction.

DESCRIPTION

Forty adult female monkeys were randomly distributed into four dose groups receiving 0.0, 0.1, 0.4, and 0.8 mg/kg body weight/day of technical grade toxaphene. Five adult male monkeys also received the high dose of 0.8 mg/kg b.w./day. As of March 31, 1998, 97 weeks of dosing have been completed.

ACTIVITIES IN 1997/98

A. The following immunologic parameters were investigated in the adult female cynomolgus monkeys:

- ▲ Lymphocyte transformation (tritiated thymidine incorporation) using three mitogens - Con A, PHA, and PWM.
- ▲ Natural Killer Cell Activity using the 4-hour ^{51}Cr release assay.
- ▲ Delayed Type Hypersensitivity using dinitrochlorobenzene as the sensitizer.
- ▲ Determination of antibody titers (IgG) to tetanus toxoid and pneumococcus antigens.
- ▲ Determination of antibody titers (primary IgM and secondary IgG) to sheep red blood cell antigens.
- ▲ Quantification of peripheral blood leukocytes and subsets using flow cytometry.
- ▲ Determination of total serum cortisol levels.

B. The following immunologic parameters were investigated in the adult male cynomolgus monkeys:

- ▼ Lymphocyte transformation (tritiated thymidine incorporation) using three mitogens - Con A, PHA, and PWM.
- ▼ Natural Killer Cell Activity using the 4-hour ^{51}Cr release assay.
- ▼ Determination of antibody titers (IgM and IgG) to sheep red blood cell antigens.
- ▼ Quantification of peripheral blood leukocytes and subsets using flow cytometry.

C. The breeding phase of the study in which all treated and control females were and still are being mated with non treated males was started on November 3, 1997. Ultrasound imagery procedures were and still are being used to ensure pregnancy diagnosis as early as possible and to monitor fetal growth.

RESULTS

Analysis of all immunology samples is completed. Data are currently collated and will be submitted to statistical analysis.

As of April 1, 1998, twenty-eight of the forty females are pregnant with the number of pregnancies relatively equal across dose groups (5 controls, 8 low dose, 9 middle dose, and 6 high dose).

DISCUSSION

After 75-80 weeks of treatment, menses duration appears to be longer in the high dosed females. Very few if any other clinical signs have developed in any of the treated monkeys.

Analysis of blood and adipose tissues collected prior to this reporting period are in progress. Two congeners, T2 (Parlar number 26) and T12(Parlar number 50), account for the majority of the residues observed in the blood and adipose.

Expected completion date: March 31, 2000.

ASSESSMENT OF DIETARY BENEFIT:RISK IN INUIT COMMUNITIES

Project Leader: H.V. Kuhnlein, Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University

Project Team: H.V. Kuhnlein, O. Receveur, L. Chan, P.R. Berti, (CINE); C. Boljkovac (ITC)

OBJECTIVES

1. To derive quantitative estimates of traditional and market food intake among Inuit in five regions (Inuvialuit, Kitikmeot, Keewatin, Baffin and Labrador), representing approximately 50 Inuit communities
2. To complete databases of nutrient and contaminant contents of traditional food as prepared and consumed for quantitative estimates of intake of these items
3. To define benefits of traditional food in terms of nutritional, socioeconomic and cultural significance
4. To define the levels of dietary exposure to contaminants (Hg, Cd, As, Pb, organochlorines)

DESCRIPTION

Policy objectives identify the need for dietary studies to define the levels of exposure to contaminants. The need for CINE to complete a dietary survey among Inuit communities was specifically identified by the Working Group on Health Risk Assessment at the Northern Contaminants Program Project Planning Workshop (AES 1996).

Dietary data suitable for assessment of benefits and risks have been collected by CINE in Denendeh and the Yukon in a total of 26 communities. Following similar methods, a member of each participating community will be employed by the project to conduct dietary interviews of one adult man and one adult woman from approximately 30 randomly selected households (or 10% of households whichever the largest) in both fall and winter. If an adolescent (15–20 years of age) is also present in the household s/he will also be invited to participate in the interview.

The dietary interview takes approximately one hour to administer, is confidential and voluntary. Questions are asked about the frequency of traditional food consumption, the dietary intake in the day preceding the interview, and a series of questions on the family and cultural attributes of traditional foods. In addition, the participant will also be asked to keep a seven-day traditional food record at any time during the season. Finally, if the respondent agrees, height and weight will be measured.

The interviewer, where appropriate, will also collect traditional food samples for laboratory analyses of nutrients and/or contaminants.

ACTIVITIES IN 1997/98

Databases of nutrients as well as contaminants in traditional food species are available at CINE. Information gaps are being identified and relevant analyses completed.

During the preparatory phase of this project (1997-98) five regional workshops were conducted; dates and number of communities represented at the workshops by a minimum of two delegates (usually one Community Health Representative and one wildlife specialist) were as follows:

- Inuvialuit (Inuvik, October 22-25, 1997): 6 communities
- Kitikmeot (Yellowknife, October 27-29, 1997): 8 communities
- Kivalik (Baker Lake, January 15-17, 1998): 7 communities
- Baffin (Iqaluit, January 21-23, 1998): 13 communities
- Labrador (Nain, February 6-8,1998): 5 communities

The methods and process of research were defined, and potential collaborators identified. Participation in the workshops was excellent with all communities represented, and the interest in this study was overwhelming since all communities expressed their desire to participate.

The communities selected at the workshop to participate in this study are: Aklavik, Tuktoyaktuk, Paulaktuk, Qutluktuuk, Holman, Cambridge Bay, Pelly Bay, Resolute Bay, Pond Inlet, Igloolik, Lake Harbour, Baker Lake, Chesterfield Inlet, Rankin Inlet, Nain, Hopedale, Makovik and Rigolet.

DISCUSSION/CONCLUSIONS

The first phase of this project was successful thanks to the cooperation between the ITC, CINE and regional Inuit associations. All Inuit communities participated in the preparatory workshops and all Inuit communities wanted to participate in the project.

Data collection methods were designed to provide the most reliable estimates of nutrients intake and contaminant exposure, as well as document the sociocultural dimensions of the traditional food system.

The following two phases of this project are:

Phase 2: Data collection (1998/99)
Data collection will build on methods previously used in Dene/Métis and Yukon First Nations communities whereby in each community a research-trained dietitian based with CINE works with a local researcher to administer the survey. Traditional food samples are collected if requested by community members or needed for nutrient or contaminant analysis.

In each community, a random 10% sample of the households will be drawn. Two adults and one adolescent from each household will be invited to participate and will be followed between the months of September 1998 and March 1999. Survey instruments will include 24-hr recalls (minimum of two and maximum of four per person), traditional food frequency targeted at the months of June-August 1998 and December-February 1999, seven-day traditional food records to be kept during the months of October 1998 and March 1999. A short socioeconomic questionnaire will complete the interview. Height and weight measures will be collected.

In addition one focus group will be conducted in each region to document the variety of perceptions and meanings surrounding the traditional food system.

Before starting data collection in September 1998, the methods will be pilot-tested in two communities and research agreements negotiated with each community.

Phase 3: Data analysis, discussion of results, and reporting (1999/2000)
Following methods of participatory research previously used at CINE, data analysis will proceed with input from the most interested community members. During that phase, food samples analyses will be completed. Draft reports will be circulated by March 2000. The process of discussing results with communities will be initiated and expected to carry over the year 2001.

Expected Project Completion Date: March 31, 2000

CINE FACT-FINDING AND STRATEGIC PLAN PROJECT, 1998

H.V. Kuhnlein

INTRODUCTION

CINE is a centre established at McGill University that is recognized for its unique expertise and understanding in Aboriginal diets and ecosystems and cultural sensitivities. Since it's establishment in 1992, CINE has worked in harmony with Aboriginal peoples in researching Native diets, ecosystems, nutrition and contaminants; and in conducting community-based education through newsletters, workshops and training courses.

CINE has an all-Aboriginal Governing Board that determines priorities and approves activities, and that works with McGill University to ensure the long-term success of the Centre. The board includes representatives from Assembly of First Nations, Council of Yukon First Nations, Dene Nation, Inuit Tapirisat of Canada, Inuit Circumpolar Conference, Métis Nation (NWT), and the Mohawk Council of Kahnawake. As a McGill Centre approved by the McGill Board of Governors within the Faculty of Agricultural and Environmental Sciences and the Faculty of Graduate Studies and Research, CINE has members who are a) Aboriginal leaders, b) academics, c) students, or d) Aboriginal community members. The Centre has established terms of reference for the Governing Board, and for operations within the university, as well as recognized mission, goals and objectives, and a six-year plan of activities.

The Centre has been successfully funded to date. DIAND provided McGill University the funds ($4.2 million) to establish CINE over the 1992-97 period. In addition, CINE has had several successful research initiatives funded through the AES/NCP of DIAND and other research agencies from 1993 to the present time (approximately $1.8 million, total). McGill has provided salary of key professors who contribute to centre operations, physical facilities, access to university programs and resources, and private sector fund-raising activities. To date, fund-raising has been successful for projects related to community education activities, with more than $700,000 being raised for these projects and student scholarships since 1993. The CINE Governing Board has directed CINE to secure an annual budget of $923,000. To date, this has been accomplished.

CINE has been a successful endeavor. We have worked exceedingly well with a wide variety of communities of Indigenous Peoples addressing issues of traditional food systems with well-recognized participatory research and education. We have been successful in providing a resource for Indigenous Peoples to address their concerns about their environment, traditional food systems, nutrition and health. We have made model research partnerships among Indigenous Peoples and non-native researchers with multidisciplinary activities in nutrition and toxicology. As well, meaningful connections have developed among those from the North and South, among those who are concerned about food as the link between nature and culture, and among those who recognize food as an expression of their faith and culture to provide good health. Thus, CINE with its members and supporting structures, is in a rare and privileged position to make unique contributions to new knowledge and to fulfil our mandate for research and education according to our mission. During the approximately five years since the opening of CINE in 1993, we have developed an international reputation for excellent academic and community-relevant work in this field.

During CINE Governing Board meetings of 21 August, and October 15, 1997, it was agreed that action should be taken to address issues of a strategic plan for CINE, including those of long-term funding and succession of leadership. Objectives of a strategic plan were made, and the basic process to be followed. These meetings followed on discussions about concerns facing CINE regarding reduced funding from DIAND/NCP toward meeting the target funding level, and lack of security for continued stable funding to CINE, both of which affect our abilities to fulfil the Governing Board mandate and give us a secure base of operations within the University. It was decided that the current director of CINE was in the best position to take a half-time leave from normal duties at the University to prepare a strategic long-term plan for CINE which takes into account perspectives from the various elements of CINE structure, the mandate and six-year plan from the Governing Board, and views from CINE staff, membership, and key knowledgeable individuals within the field. Thus, a proposal for preparation of a strategic plan was agreed upon by the CINE Governing Board, and funded by DIAND/NCP to take place over two fiscal years, from 1 January, 1998 - 31 December, 1998.

This is the report for this first phase of this project at the end of the 1997-98 fiscal year on 31 March.

What is a strategic plan?
The basic idea of strategic planning for CINE that generated this project was the realization that plans for the future need to be set. While CINE has been exceedingly successful as a university centre devoted to participatory research and education related to traditional food systems with Indigenous Peoples, our financial security and continuity/transition in leadership are of concern. Thus, there is a need to identify from the various perspectives in CINE structure:

- -where CINE is at this point in time
- where we want to go
- how we are going to get there

Clearly, the first step in this process is to get the views on these matters of key individuals on a) the CINE Governing Board, b) the McGill University administration, c) other academic leaders who have experience operating research/extension centres within universities, d) representatives from key government agencies and private sector funding agencies who have vested interests in CINE expertise, and e) a variety of CINE members who have positions of responsibility. To this end, a series of questions that address "where CINE is ... wants to go, ... how to get there" were created with input from the CINE Governing Board (attachment A). Following this, a list of key contributors to this thought process and time line of potential interviews with them from February through July was made (attachment B).

Key questions to be addressed and outline of project progression
The strategic plan questions (attachment A) were drafted in seven categories of CINE issues:

a) funding to meet CINE Governing Board-approved annual budget
b) CINE activities to meet the needs of Aboriginal communities
c) expansion to international activities with Indigenous Peoples
d) terms of office for CINE leadership
e) university contributions to CINE objectives
f) finding ways to work more effectively with government
g) maintaining or closing CINE

These categories, and the questions within them are thought to encompass the spectrum of issues needed in an effective plan for the future of CINE.

The timeline of project progression (attachment B) was created to consider one-half time of the Director-on-partial leave. Individuals to be contacted within specific months to conduct the interviews were considered, taking into account that the interviews require substantial planning and approximately 1-2 hours to conduct. All interviewees hold positions of responsibility and leadership in Aboriginal organizations, government, the University, or international centres relevant to Indigenous Peoples nutrition and/or environment. In short, their perspectives on centre funding, operations, objectives and goals can make valuable contributions to the planning process.

As of 31 March, 1998, twelve interviews have been conducted, yielding a diversity of opinions and many new ideas and perspectives in the categories noted above for the future of CINE.

Strategic plan workshop
In February 1998, the concept of having a strategic planning weekend workshop was advanced by Dr. Leslie Whitby, Director of DIAND/NCP. A potential facilitator for this workshop was identified by Dr. Whitby and meetings were held with key CINE staff. It became clear that other ideas for a strategic planning experience were developing, which included marketing/manage-ment by objectives-style planning and private-sector fund-raising external to McGill. Proposals and draft contracts for this initiative have been received by the CINE office.

The final concept was to conduct a CINE planning workshop to bring together key decision makers in CINE's complex structure (Governing Board, CINE executive, McGill administration, possible government funders). The timing, goals, participants, and facilitator(s) of the workshop were determined. Key to this process is agreement to proceed with specific objectives by the Dean of the Faculty of Agricultural and Environmental Sciences, and support from McGill's Faculty of Management, including the Centre for Strategic and Organizational Planning to ensure a state-of-the-art planning exercise. The costs of the workshop, including sufficient time available by existing CINE staff to prepare for it, completion of sufficient interviews noted above for input to the workshop, and funding potential were evaluated.

The workshop was held in early July. DIAND/NCP agreed to fund the workshop for $20,000. This figure did not cover expenses of travel of participants, including CINE board members, to attend the workshop.

SUMMARY

The initial plan for the project has been implemented and successfully completed to date as proposed. The project will proceed to gather critical information from knowledgeable individuals regarding long-term plans for CINE's future. The recent idea to conduct a CINE planning and resourcing workshop is being considered and developed with the various elements of CINE structure. The workshop will be designed with specific objectives, and will be a separate exercise from that discussed in this report, but its results will be incorporated into a long-term plan for CINE. The long-term plan will be a result of the renewal installment (Phase two) for this project. The continuation of this strategic planning project must be assured to guarantee a successful long-term plan.

EXPOSURE TO NUTRIENT BENEFITS: EXPANDING THE TRADITIONAL FOOD COMPOSITION DATABASE

Project Team: H. Kuhnlein, L. Chan, O. Receveur, and CINE Board members

OBJECTIVES

This project extends the capacity of the CINE laboratories for the analysis of nutrients in traditional food. The intent has been to more fully document the nutrient composition of traditional food in order to better understand the dietary benefits of this food as used by Indigenous Peoples in the Arctic.

The project was submitted for mid-year funding to the Northern Contaminants Program. While the term of the project was September, 1997, to March, 1998, in effect funds were transferred so late that the account was opened as of 10 February, 1998, leaving us little time to complete the work. Nevertheless, the laboratory staff made strides to develop methods for assay of several vitamins in food, which we look forward to using when food samples are collected in the study "Assessment of Dietary Benefit:Risk in Inuit Communities."

FINDINGS

Methods for the analysis of the water-soluble vitamins thiamin, riboflavin, niacin, folate, and ascorbate were considered. Methods for the fat soluble vitamin A (retinol and carotenoids), vitamin D, vitamin E (various tocopherols), and vitamin K were also determined. It is clear that HPLC is the instrumentation of choice for each vitamin. See Figure 1 for an outline of vitamin analyses, and Tables 1 and 2 for the description of the various analyses suggested.

Preparation of samples varies with the nutrient in question. For the water-soluble vitamins, the techniques involve homogenization and hydrolysis. For fat-soluble vitamins, it is critical to saponify the sample for analysis of total vitamins A, D, and E. Depending on the form of the nutrient, enzymatic hydrolysis or direct extraction are accomplished.

It was determined that internal standards are required , which varies with the nutrient being determined. Table 3 shows the internal standards recommended in the literature for the analysis of several nutrients.

Using the physical and chemical properties of the various water-soluble and fat-soluble nutrients, techniques were partially developed for nutrient analysis. The properties are shown in Tables 4 and 5.

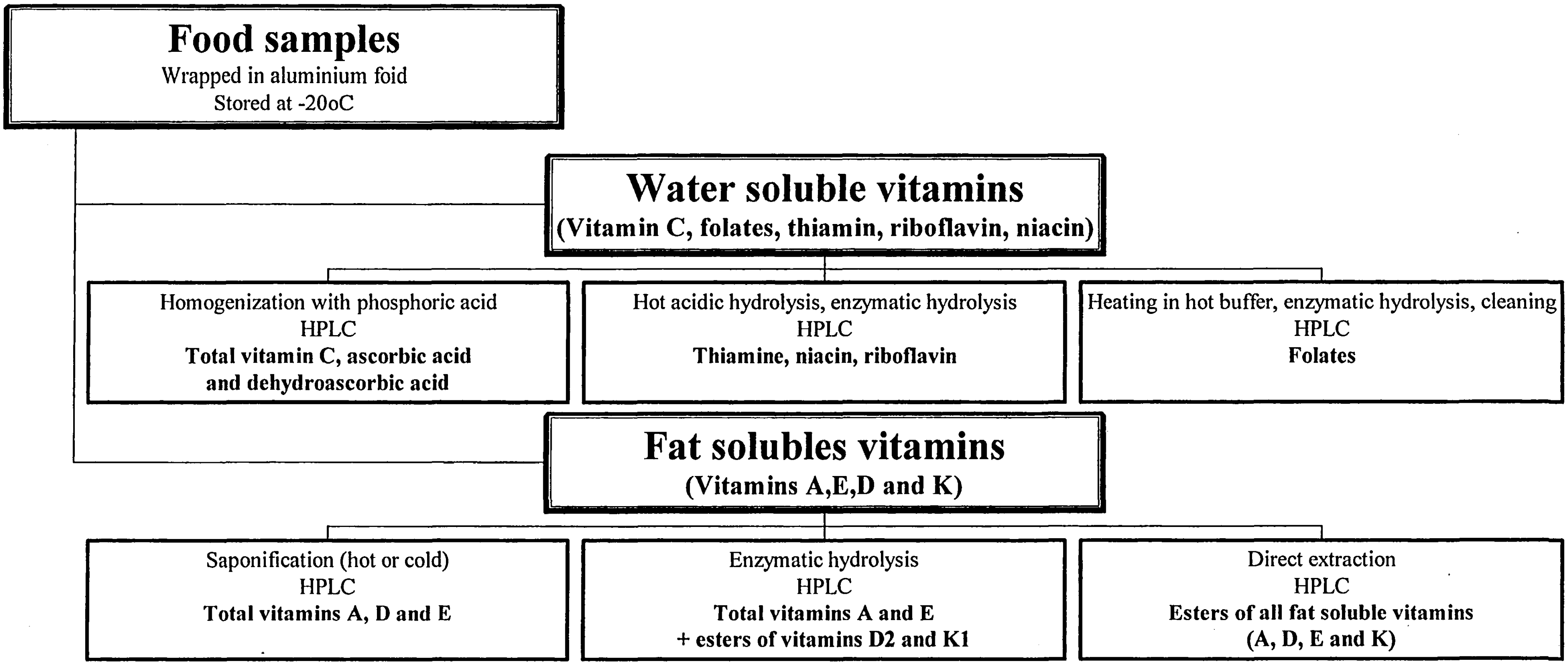

Figure 1. Outline of vitamin analysis in foods.

Table 1. Various HPLC methods to analyse water-soluble vitamins.

Vitamin	Source	Extraction method	HPLC conditions	References
Folate	Spinach, cabbage, freeze-dried pig liver, milk powder, whole wheat flour, beef liver, chanterelles	Homogenization in KPi buffer (75mM, pH6) containing ascorbic acid (52 mg) and 2-mercapto-ethanol (0.1%, v/v) (2-octanol used to reduce foaming) heating in microwave for 1 min heating in boiling water for 10 min centrifugation pH adjustment (4.9 with acetic acid) enzymatic hydrolysis (HK and CP) heating in boiling water cleaning with SAX cartridge (elution with sodium chloride 10% in 0.1M acetate)	Shandon Hypersil ODS column (30°C) Elution gradient: acetonitrile - KPi buffer (30 mM, pH 2.2) Flow rate: 0.8 mL/min Fluorescent detection (for TFH_4, 5-CH_3H_4-, 5-HCO-H_4folates $_{ex}$:290 nm, $_{em}$:356nm, for 10-HCO-folic acid $_{ex}$:360 nm, $_{em}$:460 nm)	Vahteristo *et al.* 1996
Folates			Nova-Pak phenyl column Elution: methanol (15%, v/v) in KPi buffer (0.05M, pH 3.5) Flow rate: 0.4 mL/min Detection: electrochemical, fluorometric ($_{ex}$:295 nm, $_{em}$:365 nm), UV (280 nm and scan 200-400 nm) UV detection no realistic for trace analysis of 5CH_3-H_4-Pte-Glu	Lucok *et al.* 1995
Folates	Vegetables, fruits and berries	Homogenization in cold buffer for samples rich in starch: treatment with -amylase, centrifugation and adjustment to pH 4.9 enzymatic hydrolysis with HK deconjugase purification SAX column (strong) anion exchanger) or SPE column	Two columns in series: Spherisorb ODS column in front of Hypersil ODS column Temperature: 30°C Elution gradient with Buffer A: KPi (30 mM, pH 2.2) and buffer B: acetonitrile Flow rate: 0.5 mL/min Fluorescent detection (for TFH_4, 5-CH_3H_4-, 5-HCO-H_4folates $_{ex}$:290 nm, $_{em}$:356nm, for 5,10-methenyl-H_4folate and 10-HCO-folic acid $_{ex}$:360 nm, $_{em}$:460 nm) UV detection (290 nm for folic acid and $PteGlu_3$)	Vaheteristo *et al.* 1997
Folates	Food products and biological samples (animal tissues)	Homogenization in Na acetate buffer (0.05M, pH 4.9) containing 1% ascorbic acid addition of 2-octanol to suppress foaming flushing with nitrogen heating in boiling water for 10 min	Bondapak phenyl column Elution gradient with buffer A NaPi (0.033M, pH 2.3) buffer B: acetonitrile Flow rate: 1mL/min Fluorescent detection ($_{ex}$:295 nm, $_{em}$:356nm) UV detection (290 nm for folic acid and	Gregory *et al.* 1984

Table 1. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Folates cont'd ...	Vegetables, fruits and berries	centrifugation enzymatic hydrolysis with HK deconjugase adjustment to pH 7.0 with NaOH purification DEAE-Sephadex A25 column exchanger) or SPE column	$PteGlu_3$)	
Folates	Rat liver	Heating 10 min at 100°C in Hepes-Ches (50mM, pH 7.85) containing 2-mercaptoethanol (0.2M) & Na ascorbate (2%) Homogenization Centrifugation Enzymatic hydrolysis with rat plasma deconjugase heating 10 min at 100°C centrifugation	Horne *et al.* (1981) modified by Wilson and Horne (1983) Buffers A and B containing 7mM tetrabutylammonium phosphate and 1mM sodium ascorbate	Wison and Horne 1984
Folates	Whole wheat bread, white rice, spaghetti, breakfast cereals	Heating 10 min in boiling water Hepes-Ches buffer (50 mM, pH 7.85)containing 2-mercaptoethanol (10mM) and Na ascorbate (2%) Homogenization Trienzymatic hydrolysis (rat plasma folate conjugase, -amylase and protease) heating 10 min in boiling water centrifugation cleaning by affinity chromatography with immobilized folate binding proteins	Ultremex C_{18} column Elution gradient with buffer A; phosphoric acid (33 mM, pH 2.3) and buffer B acetonitrile Flow rate: 1mL/min UV detection (280 nm)	Pfeiffer *et al.* 1997
Nicotinic acid Nicotinamide Ascorbic acid Sorbic acid	Fresh meat	Homogenization in water heating in boiling water	Partisil SCX column Elution buffer: Kpi buffer (50 mM, pH 3.0) UV detection (260 nm)	Hamano *et al.* 1988
Nicotinic acid (total niacin)	Beef, semolina, cottage cheese	Homogenization with water and $Ca(OH)_2$ at 121°C for 15 min pH adjustment to 6.5-7.0 with oxalic acid filtration cleaning with C18 Sep-Pak column	C_{18} LC-180DB column Elution buffer: MeCN (23%), H3PO4 (0.1%), sodium dodecylsulfate (0.1%) in water UV detection (254 nm)	Tyler and Genzale 1990

Table 1. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Riboflavin FMN	Flour, bread, raw beef, corned beef, milk, chicken liver, mushrooms, milk products and cereals	Remove fat for high fat content sample with hexane homogenization with HCl (0.1N) at 121°C for 30 min pH adjustment to 6.0 and then to 4.5 Centrifugation Filtration	Lichrosorb RP-8 column Elution buffer: methanol:water (40:60, v/v) containing 5 mMv sodium hexane sulfonate Fluorescent detection ($_{ex}$:440 nm, $_{em}$:565nm)	Reyes *et al.* 1988
Thiamin Riboflavin	Cereals and processed cereals	Fine grinding acidic hydrolysis (HCl 0.1N and autoclave for 30 min) centrifugation filtration	Bondapak C_{18} column Elution: 12.5% acetonitrile, 87.5% NaPi Buffer (0.01 M, pH 7.0) containing 0.005M sodium salt of heptane sulfonic acid Flow rate: 2.5 mL/min UV detection (254 nm)	Kamman *et al.* 1980
Thiamin Riboflavin	Freeze-dried chicken, chicken liver, non fat dry milk, whole wheat flour, enriched white flour, powdered split peas and powdered red kidney beans	Acidic hydrolysis (HCl 0.1N and 6N, autoclave for 10 min at 121°C) pH adjustment (4.0-4.5 with sodium acetate) enzymatic hydrolysis (takadiastase) deproteinization pH adjustment (3.5) filtration derivatization cleaning with C_{18} Sep-PAK cartridge	C_8- Radial-PAK column Elution:37% methanol in NaPi buffer, (0.01 M, pH 7) Flow rate: 1.5 and 3 mL/min Fluorescent detection (for thiochrome $_{ex}$:360 nm, $_{em}$: 415nm, for riboflavin $_{ex}$:450 nm, $_{em}$:530nm)	Fellman *et al.* 1982
Thiamin 1990	Liver	Homogenization with HCl (0.1N) at 95-100°C for 60 min pH adjustment to 4.5 enzymatic hydrolysis (takadiastase and papain) centrifugation	Lichrosorb Li60 column Elution buffer: chloroform: methanol (80:20, v/v) Fluorescent detection after derivatization with alkaline $K_3Fe(CN)_6$ ($_{ex}$:375 nm, $_{em}$:430 nm)	Bailey and Finglas
Vitamin B Thiamine Niacin Riboflavin	Cooked rice	Fine grounding acidic hydrolysis (H_2SO_4, 0.1N, autoclave for 30 min at 121°C) pH adjustment (4.5 with sodium acetate) enzymatic hydrolysis (takadiastase and papain) filtration	Micro Bondapak C_{18} column Elution: methanol:glacial acetic acid:water (39:1:60, v/v/v) containing PIC-5 and PIC-7 Flow rate 1 mL/min UV detection (254 nm)	Toma and Tabekhia 1979

Table 1. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Vitamin C	Wheat flour, bread dough conditioners	Homogenization with) dithiothreitol (0.7M centrifugation filtration	Two Bondapak-NH_2 columns in series Elution buffer NaPi (10mM, pH 4.46):MeOH:MeCN (30:35:35, v/v/v) UV Detection (254 nm)	Lookhart and Finney 1982
Vitamin C	Orange juice, soft drinks, protein-fortified drinks	For ascorbic acid: deproteinization (if necessary) with TCA (12.5%) centrifugation filtration For total vitamin C: pH adjustment to 7.0 with Kpi (45%) Addition homocyteine solution (0.8%) Filtration	Bondapak-NH_2 column Elution buffer MeOH:KPi (0.25%, pH 3.5) (50:50, v/v) UV Detection (244 nm)	Dennison *et al.* 1981
Vitamin C	Fresh apples, potatoes	For ascorbic acid: homogenization with HPO3 (2.5%) and MeCN:KPi (50 mM) (70:25, v/v) filtration through Celite cleaning with C_{18} Sep-Pak cartridge For total vitamin C: after filtration pH adjustment to 6 addition dithiotreitol cleaning with C_{18} Sep-Pak cartridge	Dynamax-60A-NH_2 column Elution buffer: MeCN: KPi (50mM) (70:25, v/v) UV detection (254 nm)	Sapers *et al.*1990
Vitamin C	Meat products	Homogenization with HPO_3 (6%)	Bondapak C_{18} column Elution buffer MeOH:water (1:1, v/v) containing trioctyl-methyl-ammonium chloride (3mM), final pH 5.05 UV detection (255 nm)	Parolari 1982
Vitamin C	Cured meats	Homogenization with HPO_3 (6%) filtration through glass wool cleaning with C_{18} Sep-Pak cartridge	Bondapak C_{18} column Elution buffer tetrabutyl-EA (5 mM) ammonium formate, final pH 4.77 UV detection (254 nm)	Lee and Marder 1983
Vitamin C	Canned food, frozen concentrated orange juice	Homogenization with cold HPO_3 (17%) centrifugation For ascorbic acid: adjustment to pH 7.1 with NaPi (pH 9.8) Waiting 30 min at 25°C Dilution with HPO_3 (0.85%) Dilution with acetate buffer (pH4.8) containing MeOH (15%) For total vitamin C: adjustment to pH 7.1 with homocysteine in NaPi buffer (pH 9.8)	RP C_{18} column Elution buffer: acetate buffer (80mM) containing n-octylamine (1mM), MeOH (15%) and HPO_3 (0.015%), final pH 4.6	Behrens and Madère 1990

Table 1. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Vitamin C	Cured meat	Homogenization with HPO_3 (5%) containing NaEDTA (0.1g/L) Centrifugation Dilution in mobile phase	Ultraspher ODS column Elution buffer: acetate buffer containing tetrabutyl ammonium phosphate (5mM) and NaEDTA (0.2g/L), final pH 5.25 Amperometric detection	Kutnink and Omaye 1987
Vitamin C (ascorbic acid and erythorbic acid)	Processed meat	Homogenization with HPO_3 (0.5%) Centrifugation Dilution with HPO_3 (0.5%) Addition of MeOH (up to final concentration 4%)	Hypersil ODS column Elution buffer: water:MeOH:acetate buffer:1,5-dimethyl-hexylamine (945:40:15:1.5, v/v/v/v) UV detection (254 nm)	Schüep and Keck 1990

Table 2. Various HPLC methods to analyse fat soluble vitamins.

Vitamin	Source	Extraction method	HPLC conditions	References
Vitamin A	Powdered infant formula Chicken feed Cereal Low fat milk	Saponification Extraction with petroleum ether	ODS-C18 column Elution buffer: MetOH:water (90:10, v/v) Flow rate: 1.5 mL/min UV detection (325 nm or 313nm)	Bueno 1997
Vitamin A palmitate and acetate	Fortified whole milk powder	Dispersion in non-aqueous solvent Hexane extraction (49.5:49.5:1, v/v/v) UV detection (313 nm)	μPorasil column Elution buffer: Hexane:chloroform:ethanol	Dennison and Kirk 1977
Vitamin D	Animal feeds milk products liver fortified food	Saponification Benzene extraction Evaporation Semi-preparative HPLC (Nucleosil C_{18}, MeOH:MeCN (1:1), UV detection 254 nm) Eluate evaporation	Zorbax SIL column Elution buffer: Propan-2-ol in hexane (0.4%) UV detection 254 nm	Takeuchi *et al.* 1984
Vitamin E	Fish or diphasic hexane-methanol (2:1, v/v)	Monophasic extraction MetOH Elution buffer: MetOH:water (96:4, v/v) (2:1, v/v)	Hypersil ODS column Flow rate: 1 mL/min Fluorescent detection (λ_{ex} 296nm, λ_{ex}340nm)	Huo *et al.* 1996
Vitamin E	Piglet liver & heart	Extraction with hexane-methanol (1:1, v/v)	Supelcosil LC-Diol column Elution buffer: Hex:PpOH (99:1, v/v) Fluorescent detection (λ_{ex} 296nm, λ_{ex} 330nm)	Kramer *et al.* 1997
Vitamin E	Beef carcass ascorbic acid)	Saponification (+250 mg Elution buffer: IsoOct:THF (96:4, v/v) Extraction with isooctane	Silica column (waters) Flow rate: 1 mL/min Fluorescent detection (λ_{ex} 296nm, λ_{ex} 325nm)	Liu *et al.* 1996
Vitamin E	Atlantic salmon *(Salmo salar)*	Extraction according to Bligh and Dyer (1959)	Normal phase Partisil-5 silica column Elution buffer: Fluorescent detection (λ_{ex} 290nm, λ_{ex}330nm)	Siguurgisladottir *et al.* 1994
Vitamin E	Channel catfish	Saponification Extraction with ethyl acetate:hexane (10:90, v/v)	Zorbax ODS column Elution buffer: Methanol:water (98:2, v/v) Flow rate 1 mL/min Electrochemical detection	Erikson 1993

Table 2. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Vitamin E	Whole milk powder Infant formula Freezed-dried liver Blood Fish Grain meal	Saponification (+ pyrogallol) Extraction with light petroleum: diisopropyl ether (3:1, v/v)	C18 Rad-Pak column Elution buffer: Methanol Flow rate: 1mL/min Fluorescent detection (λ_{ex} 295nm, λ_{ex}330nm)	Indyk 1988
Vitamin E	Meat and meat products Fish and fish products Evaporation	Cold saponification Hexane extraction (93:7, v/v) Fluorescent detection (λ_{ex} 292nm, λ_{ex}324nm)	LiChrosorb Si-60 column Elution buffer: Hexane:diisopropyl ether	Piironen *et al.* 1985 Syvaoja *et al.* 1985
Vitamin E (Total α-tocopherols)	Animal feeds Human food	Saponification Diethyl ether extraction Evaporation Fluorescent detection(λ_{ex} 293nm, λ_{ex}326nm)	LiChrosorb Si-60 column Elution buffer: Hexane:propan-2-ol (99.9:0.1, v/v)	Manz and Philipp 1981
Vitamin K	Oil	Lipase in NaPi buffer (pH 5.5) Extraction with pentane Addition KOH/EtOH Silica column for cleaning (elution with hexane:n-octanol (99.8:0.2, v/v)	Reverse phase column Elution buffer: MetOH:ACN: Water (88:10:2, v/v/v) Flow rate: 1.5 mL/min UV detection (280 nm)	Zonta and Stancher 1985
Vitamin K_1	Infant formula	Enzymatic hydrolysis Pentane extraction Evaporation	μ-Bondapak C18 Elution buffer: Methanol:MeCN:THF: water (39:39:16:6, v/v/v/v) UV detection (254 nm)	Bueno and Villalobos 1983
Vitamins A, D and E	Commercial multivitamin tablets Fish liver oil	Water + methysulfoxide Hexane extraction	Micropak MCH Gradient elution buffer: MetOH - water (80-100% at 1%/min) UV & fluorescent detection (λ_{ex} 296nm, λ_{ex}340 nm, UV 325 & 254 nm)	Wehr, Varian Instruments
Vitamins A, D and E	Fish	Saponification Extraction with diethylether:petroleum ether (1:1, v/v)	Lichrosorb Si 100 column Elution buffer: PpOH:Hex (1.5:97.5, v/v) Flow rate: 1 mL/min UV detection (264, 294 and 325 nm)	Pozo *et al.* 1990
Vitamins A, D, and E	Cod liver Pharmaceutical products Milk & soy bean infant formula	Saponification Trypsin digestion Lipase digestion Hexane extraction	Two C18 in series Gradient elution with Buffer A: MetOH:CAN (20:80, v/v), buffer B: water Temperature: 40°C UV detection (280, 260, 450 & 325 nm)	Zonta and Stancher 1982

Table 2. cont'd ...

Vitamin	Source	Extraction method	HPLC conditions	References
Vitamins D_3 or D_2	Fortified milk whole milk powder milk powder with soy bean chocolate milk powder diet food	Saponification Extraction with petroleum spirits Evaporation Sep-Pak silica (cleaned up for high fat samples only) Eluate evaporation	Two Hypersil ODS columns Elution buffer: Methanol:water (99.5:0.5, v/v) UV detection (265 nm)	Bui 1987

Table 3. Various internal standards used for vitamin analysis in food products.

Vitamin	Sample source	Internal standard	Reference
Carotenoids	Leaves	Echineone	Delisle *et al.* 1997
	Green vegetables	All-trans-Decapreno-β-carotene	Khachik *et al.* 1986
Folates	Vegetables	Pte-Glu_3	Vahteristo *et al.* 1997
Riboflavin	Food products	7-Ethyl-8-methyl-riboflavin	Russell and Vanderslice 1992
	Dairy products	Sorboflavin	Bilic and Sieber 1990
Vitamin C	Food products	Erythorbic acid	Ball 1994
	Citrus juice	Qunic acid	Lee and Coates 1987
	Fresh tomatoes	Pentanophenone	Russell 1986
Vitamin D_3	Eggs, butter, milk, cheese	Vitamin D_2	Jackson *et al.* 1982
Vitamin E	Garlic α-Tocopherol)	δ-Tocopherol	Malik *et al.* 1997
	Beef carcass	α-Tocopherol (n=1)	Liu *et al.* 1996
	Walnuts	β-Tocopherol	Lavedrine *et al.* 1997
	Heart and liver	α-Tocopheryl-succinate	Kramer *et al.* 1997
	Aquatic organisms	Tocol	Huo *et al.* 1996
	Whole milk powder, infant formula, freezed-dried liver, blood, fish, grain meal		α-Tocopherol Indyk 1988
Vitamins A, D, E and K1	Infant formula, dairy products	Cholesterol phenyl acetate	Barnett *et al.* 1980

Table 4. Physical and chemical properties of various water-soluble vitamins.

	Vitamin C	Thiamin	Riboflavin	Folic acid	Niacin
Solubility	Ascorbic acid: soluble in water, readily soluble in acetic acid and acetonitrile Sodium ascorbate: soluble in water Ascorbyl palmitate: soluble in ethanol	Soluble in water, readily soluble in glycerol		Insoluble in cold water, readily soluble in boiling water, warm dilute HCl (but instable), soluble and stable in dilute alkali	Nicotinic acid: readily soluble in water, ethanol Nicotinamide: soluble in water, ethanol Sodium salt: soluble in water
Major forms	Ascorbid acid dehydroascorbid acid	Meat: TPP, TMP & TTP Milk: free form, protein bound & TMP Cereals: non phosphate form Wheat germ: TPP	FMN, FAD, Riboflavin		Nicotinamide transformed into nicotinic with 1 N acid when autoclaved at 121-123°C
Oxygen	Sensitive		Stable	Sensitive (THF)	Stable
Light	Stable	Sensitive to UV	Sensitive to UV and visible	Sensitive to UV and visible	Stable
Alkali conditions		Sensitive	Sensitive when pH > 7	Stable (PGA pH 7–12)	Sensitive (NAD^+ & $NDAP^+$)
Acidic conditions		Stable in dilute acid	Stable in the pH range 2-5	Stable (PGA in pH 5–7) sensitive (PGA for pH<5)	Sensitive (NADH & NADP)
Heavy metals	Sensitive to (Fe^{3+} & Cu^{2+})			Sensitive to Fe^{3+} & Cu^{2+} (THF)	
Sulfite ion		Sensitive			
Reducing agents			Sensitive (reversible)		
Heat		Sensitive alkali environment Stable acidic environment	Sensitive (heating 95-100°C or autoclaving 121 -123°C convert FMN to riboflavin)	Stable (PGA 100°C for 10h, pH 5-12)	+ (dry state and aqueous solution)

Table 5. Physical and chemical properties of fat-soluble vitamins.

	Vitamin A	Vitamin D	Vitamin E	Vitamin K
Forms	Vitamin A (free or ester forms) and provitamin A (carotenoids)		.Tocopherols and tocotrienols (free or ester forms)	Philloquinone (K_1), menaquinone (K_2), menadione
Solubility	Soluble in alcohol, readily soluble in diethyl ether, petroleum spirits, chloroform, acetone, fats, oil	Soluble in 95% ethanol, acetone, fats, oils, readily soluble in benzene, chloroform and ether	Soluble in alcohol, acetone, chloroform and ether	Philloquinone sparingly soluble in alcohol and readily soluble in acetone, ether, chloroform, hexane, fats and oils Menaquinone soluble in organic solvents and slightly soluble in water Bisulfite derivatives of menadione
Oxygen	Esters more stable than alcohol form	Sensitive	Sensitive (quinone formation)	Stable
Light	Sensitive (wavelength lower than 500 nm)	Sensitive	Sensitive (quinone formation)	Sensitive (UV)
Alkali conditions	Stable	Stable	Sensitive	Sensitive
Acidic conditions	Sensitive	Sensitive (5,6-*trans*-isomerization)		Sensitive to strong acids
Heavy metals	Sensitive	Sensitive	Sensitive (Fe^{3+} and Cu^{2+})	
Water	Sensitive	Sensitive		
Reducing agents	Stable	Stable	Stable	Sensitive
Heat	Sensitive (inducing *cis-trans* isomerization)		Sensitive	Stable
Solvents to avoid	Chloroform, dichloromethane (inducing *cis-trans* isomerization)			

INUVIK REGIONAL HUMAN CONTAMINANTS MONITORING PROGRAM

Project Leader: C. MacNeil, Inuvik Regional Health and Social Services Board (IRHSSB)

Project Team: J. Houseman, Project Coordinator, IRHSSB; B. Wrathall, Senior Environmental Health Officer, IRHSSB; E. Wein, Scientific Advisor, Canadian Circumpolar Institute, University of Alberta, Edmonton; J. Walker, Environmental Contaminants Consultant, Health and Social Services, GNWT; V. Walker, Project Manager Research, Aurora Research Institute, Inuvik.

Collaborators: A. Corriveau, Health and Social Services, GNWT; O. Receveur, Centre for Indigenous Peoples' Nutrition and Environment, McGill University, Montreal; Stanton Regional Hospital, Yellowknife; Kitikmeot Consultation Working Group; J. VanOostdam, Health Canada, Health Protection Branch, Ottawa; S. Paradis, Health Canada, Medical Services Branch, Ottawa; B. Archie, Inuvialuit Regional Council, Aklavik, Inuvialuit, Sahtu & Gwichin Community Representatives.

OBJECTIVES

General:

1. to establish a baseline of data for specific heavy metal and organochlorine contaminants in the blood of women and their newborns from communities served by the Inuvik Regional Health and Social Services Board. Collection of such data from the Inuvik Region will complete the NWT data base, since this type of data has already been gathered from all other health board regions of the NWT.

Specific:

1. to identify types and concentrations of specific organochlorine and metal contaminants in maternal and umbilical cord blood samples to complete the NWT baseline.
2. to identify the concentration of mercury absorbed in maternal hair samples during the pregnancy term.
3. to assess the potential for exposure through the frequency of country food intake and certain other lifestyle factors.
4. to examine the relationship between contaminant levels in blood and hair samples and frequency of consumption of country foods and selected lifestyle factors.
5. to establish an effective communication network among the research team, participants, communities, and research collaborators.

DESCRIPTION

Contaminants in the north come from local and distant sources. A significant amount of pollution from distant sources is transported to the north by global circulation and becomes absorbed by marine and land plants. Contaminants then bioaccumulate in the country food chain. This is a concern for many northerners, as they are top consumers of many country foods. These issues have been well documented in Jensen *et al.* (1997).

Specific contaminants will be measured in the blood and hair of northerners. In conjunction with monitoring contaminant levels, an assessment of the frequency of country food intake and other lifestyle factors such as smoking and occupation will be examined in order to provide more specific risk management options.

Maternal and cord blood monitoring programs for contaminants have been completed in all other health board regions of the NWT. Program reports were reviewed and project team members involved in previous studies were consulted to provide this study with the best chance for success. The 'Program Implementation Guide' developed for the Maternal Cord Blood Monitoring for Environmental Contaminants program that took place in the Mackenzie and Kitikmeot Health Board Regions was used as a guide for modelling the blood sampling component of the study.

Participation is available to women who reside in the area served by the Inuvik Regional Health and Social

Services Board, and choose to deliver their babies at the Inuvik Hospital, or the Stanton Hospital in Yellowknife during the one year sampling period (June, 1998 to June, 1999). Community Health Centres are equipped to provide consultation and information packages to all pregnant woman. Those who choose to participate will sign a consent form acknowledging that they understand the program and their role.

Levels of organochlorines and heavy metals will be measured in maternal blood and the cord blood from their babies. Maternal blood samples will be collected with routine sampling during admission. If collection is missed at this time, a second opportunity exists to collect maternal blood before the mother is released. The umbilical cord samples will be collected during delivery. The samples are forwarded to the hospital lab for processing, then shipped to the Centre du Toxicologie de L'University de Laval at Laval University Hospital Centre for analysis. Results will be returned directly to the Project Coordinator for management and subsequent communication during the 1999/2000 fiscal year.

In addition to blood sampling, hair samples will be collected two weeks after delivery and analysed for mercury levels. The analysis will give a picture on the level of mercury exposure for most if not all of the pregnancy term (depending on the sample length). These samples will be collected at the community health centre from which the volunteer resides. Samples will then be shipped to the Project Coordinator, for preparation for shipment to Health Canada, Medical Services Branch, Indian and Northern Health Laboratory for analysis. The analytical results will be returned directly to the Project Coordinator for management during the 1999/2000 fiscal year. The information will build on work begun in the NWT by the Medical Services Branch, Health Canada, to assess current mercury exposure levels, and to examine temporal trends in the region.

In conjunction with this monitoring, the project team, in collaboration with the Centre for Indigenous Peoples' Nutrition and Environment (CINE), produced a food frequency questionnaire to measure the intake frequency of country foods, and assess other lifestyle factors which may influence the contaminant levels measured. The questionnaire, which takes about twenty-five minutes to complete, will be administered shortly before the delivery date. Part I lists a number of plant and animal species indicative of Sahtu, Gwichin and Inuvialuit country foods. The participant selects one of 10 frequency categories to represent consumption during the past year (three months before conception and during the term of pregnancy). Part II examines such factors as dietary changes made during pregnancy, breastfeeding previous babies, and exposure to tobacco and chemicals. This information will result in the ability to provide more specific risk management options than have previously been possible. Data from the questionnaire will be managed and analysed by CINE. The frequency questionnaire is designed to be integrated with portion size data from CINE's Dene/Métis and Inuit studies, for a more accurate analysis of population exposure.

This work is being done by the Inuvik Regional Health and Social Services Board in collaboration with the GNWT Department of Health and Social Services, and in consultation with a team of environmental contaminant research advisors, and regional advisors. The sampling and communication protocol was established and reviewed by members of the Inuvik Regional Health Board ethics committee, community and technical advisors, and the IRHSSB Community Health Representatives. This project has been awarded a Scientific Research Licence from the Aurora Research Institute.

ACTIVITIES IN 1997/98

Planning and Development

The focus of the 1997/98 fiscal year has been communication among communities, the project team and collaborators, and developing the tools to implement a solid program. Beginning June 1998, the focus will turn toward active recruitment and sampling, as well as ongoing consultation with participants and their communities.

The following activities have been completed in the 1997/98 fiscal year:

- Human Contaminants Monitoring - Inuvik Workshop, Inuvik, NT, April 30-May 2, 1997; provided community representatives with general information about contaminants in the north and an understanding of the purpose for measuring contaminant levels in humans. The workshop also provided researchers with prioritized concerns from northerners about contaminants. The group provided a summary of recommendations on how to implement the Human Contaminant Monitoring Program. A workshop report was completed by the Aurora Research Institute (Aurora Research Institute, 1997).
- January 1998, a Project Coordinator was hired to focus on the development and implementation of the program based from the Inuvik Regional Hospital.
- Project leaders, project team members, the working group and interested organizations were identified. The roles of the project team members, and the

working group were established, as well as the roles of Stanton Hospital, CINE, Health Canada, and the Laval University Hospital Centre.

- The project management team met with CINE, IRHSSB, and H&SS in Yellowknife to discuss program development and the dietary and lifestyle questionnaire.
- A NWT Scientific Research Licence was issued to the project leader. Obtaining the licence ensured many important steps were taken, including consultation with hamlets, community corporations, and aboriginal councils, and the review and approval of the IRHSSB Review Committee for Ethics in Human Health Research.
- The Coordinator met project team members, collaborators and advisors at the 1998 Northern Contaminants Program Results Workshop, Calgary, AB. She also gained much background knowledge on the issue of contaminants in the north from the scientific presentations.
- An article was submitted to community newspapers, the 'Drum' and 'Mackenzie Valley Viewer', about contaminants in the north and printed in January 1998. A second article focussed on the Inuvik Regional Human Contaminants Monitoring Program and printed in the same papers, February 1998.
- A presentation was delivered to the Inuvik Hospital staff introducing the Inuvik Regional Human Contaminants Monitoring Program. A second presentation focussing on blood sampling protocols, was delivered in June.
- Coordinator attended the Kitikmeot Contaminants Consultation Working Group Workshop in Yellowknife. Also in attendance was O. Receveur, CINE and R. Watt, Nunivik Nutrition and Health Committee. The Project Coordinator delivered a presentation and consulted with regions who have completed similar studies.
- Working Group training workshop held in Inuvik, NT, for community health representatives (CHRs) from each participating community. Guests speakers were J. Ogina, Kitikmeot Contaminants Consultation Working Group and CHR, and N. Cournoyea, Chair, IRHSSB.
- Sampling materials were ordered. Tracking forms, consent forms, registration forms, posters and information kits were reviewed and revised by various researchers and community representatives, then developed, printed and distributed in preparation for the recruitment and sampling phase of the program.

DISCUSSION/CONCLUSIONS

Baseline exposure assessments have been completed in the Kitikmeot, Mackenzie, Baffin and Keewatin Regions. Due to the increased awareness of contaminants, and concern for human health and traditional foods, it was in the interest of many northern residents to coordinate a similar study in the western NWT. It is expected that most contaminant levels will be within an acceptable range. This study will complete the Territorial baseline on contaminant level exposure in humans, and provide a baseline against which trends or changes can be measured in the future. In addition, the hair samples will provide insight on mercury exposure during pregnancy, a factor not measured in the other regions. Furthermore, the more detailed food frequency questionnaire used in the Inuvik region will permit more in-depth examination of the relationships between potential exposure through food and other lifestyle factors and contaminant levels in blood and hair.

Activities conducted during the 1997/98 successfully built a solid foundation to implement the recruitment and sampling protocols.

Expected completion date: March 31, 2000

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OVERVIEW OF THE RESEARCH PROTOCOL DEVELOPED TO STUDY THE NEUROPHYSIOLOGICAL AND NEUROLOGICAL EFFECTS OF PRENATAL EXPOSURE TO PCB AND HG DURING CHILDHOOD

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OBJECTIVES

1. to examine the long term consequences of prenatal exposure to polychlorinated pesticides (PCB) and mercury (Hg).

BACKGROUND

This study will support the health risk assessment process by providing dose-effect analysis for the neurophysiological and neurological domains of effects. It is driven by community concerns, adopts a holistic approach to health and is supported by the Nunavik Nutrition and Health Committee and the Medical Services Branch in Health Canada.

Children of preschool age from Nunavik represent the target group. Exposure to PCB and Hg is the result of Arctic ecosystem contamination. Of particular interest is the impact of exposure on neurophysiological and neurological endpoints that could be related to learning difficulties and disabilities. The proposed project is designed to extend previous findings by studying domains of effects that have been overlooked in most of the previous studies.

This study is made possible because of the existence of the Nunavik Cord Blood Surveillance Program funded under NCP since 1993. During the next four years, about 450 children for whom prenatal PCB and Hg exposure is documented will reach the age of four. Because the exposure data are already collected, there is an exceptional opportunity to realize a historical cohort study on the long term effects of being prenatally exposed to environmental contaminants present in the food web, and to get final results in a very short period of time. There is another cohort study going on in Nunavik, co-financed by the NCP and by the US National Institute of Health. However, this ongoing study does not focus on the endpoints proposed here and the infants' last assessment is at 11 months.

DESCRIPTION

Effects of prenatal exposure to background levels of PCB from environmental sources have been studied in four major cohort: Michigan, North Carolina, the Netherlands and Oswego. Effects of PCB poisoning from contaminated rice oil were studied in Taiwanese children. All these studies provided information about adverse developmental effects seen during infancy. However, only the Michigan and the North Carolina studies provided data for preschool children exposed to background levels of PCB, while the Taiwanese PCB poisoned children were assessed at age four. Unfortunately, neurophysiological effects of exposure to background concentrations of PCB have never been studied. Cognitive event-related potentials, pattern-visual evoked potentials and somatosensory evoked potentials are however well suited for pediatric neurotoxicity testing (Otto 1981). These measures are easily administered and interpreted, stable, reliable, sensitive to neurological insult, have culture-free nature and relative age independence. Few studies have looked at the neurological status from birth to 18 months. Furthermore, to date, a full neurological examination was never administered to preschool or school age children exposed *in utero* to background levels of PCB.

The effects of prenatal exposure to background levels of Hg were studied in fish eating populations from various countries – Canada, Peru, Republic of Seychelles, New-Zealand, Faroe Islands. However, children older than two years of age were tested only in the Canadian Cree Indian and the Faroe Island studies. Effects of fetal Hg poisoning were studied in Japan – Minamata and Niigata – and Iraq following the consumption of Hg contaminated fish and Hg contaminated seed grain. In the Faroe

Islands study (Grandjean 1997), neurophysiological testing such as PVEP was performed in 7-year-old children. Unfortunately, this study remained incomplete since only a few parameters of the pattern visual evoked potentials were used. A neurological examination was also performed with these children but very little is known regarding the sensitivity of the examination used to detect sub-clinical neurological signs. Moreover, this examination did not seem to assess neurological domains that have been associated with Hg exposure in the Canadian, Minamata and Iraq studies.

Neurological and Neuromotor Effects of PCB Exposure

Both the North Carolina and the Michigan studies found a significant negative effect on neonatal behavioural performance, assessed with the Brazelton Neonatal Behavioural Assessment Scale (Rogan *et al.* 1986, Jacobson *et al.* 1984). In 1995, Huisman *et al.* partly confirmed these results with a behavioural and an age-adequate neurological examination. These authors found that the combination of a high prenatal and a high lactational exposure was associated with an increase in the prevalence of neonatal neurological non-optimality and a higher incidence of hypotonia two weeks after birth as well as with a small negative effect on the neurological condition at 18 month of age (Huisman *et al.* 1995a, 1995b). In a group of 7- to 12-year-old children born to PCB poisoned Taiwanese mothers, Chen (1994) did not report abnormalities with the standard neurological examination. However, in three of the motor tasks, soft neurological signs consisting of mirror movements, mild to moderate degrees of poor finger-thumb opposition, and choreiform movements were observed. Their findings suggested that prenatal exposure to elevated concentrations of PCB tends to affect high cortical function.

Neurological and Neuromotor Effects of Mercury Exposure

In 1968, Harada reported that maternal consumption of Hg contaminated fish during pregnancy seemed to have caused severe psychomotor retardation in 22 children from Minamata. Motor retardation and abnormal neurological signs were related to maternal ingestion of Hg treated seed grain in the Minamata and Niigata populations (Marsh *et al.* 1980). In the Canadian Cree Indian population, the presence of abnormal muscle tone and deep tendon reflexes were positively associated with maternal Hg exposure in boys (McKeown-Eyssen *et al.* 1983). A neurological examination with an emphasis on motor coordination and perceptual-motor performance was performed in the Faroe Islands children exposed to background levels of Hg. The total number of tests completed with optimal performance as well as reciprocal motor coordination and simultaneous finger movement were unrelated to the Hg exposure (Grandjean *et al.* 1997). However, the neurological examination performed did not seem to assess the neurological domains associated to Hg exposure in poisoned populations previously studied.

Neurophysiological Effects of PCB Exposure

Using cognitive evoked potentials (event-related potentials) data, Chen and Hsu (1994) examined the long-term neurotoxicity of prenatal exposure to PCB with 54 children aged 7 to 12 years who had been born from the victims of the 1978-1979 Yu-Cheng poisoning in Taiwan. Results showed a significant difference in latencies and amplitudes of the P300 between PCB exposed children and their matched controls, PCB exposed children showing longer latencies and reduced amplitude. These results suggested that children exposed to PCB have a greater risk of cognitive impairment than do unexposed children. Overall, results from this study revealed that the effect of PCB exposure may persist for a long period and that the P300 may identify these subtle deficits in cognitive functions. In this study, there was no apparent conduction abnormality in pattern visual evoked potentials and sensory evoked potentials. However, the protocol used with the PVEP was based on a stimulus (50 min of arc) known to be too large to detect any subtle clinical effects.

Neurophysiological Effects of Mercury Exposure

In a recent study by Grandjean *et al.* (1997), visual evoked potentials with a smaller and more sensitive stimuli (15 and 30 min of arc) were used in children of seven years of age exposed to background levels of Hg. This study revealed that the peak latency of the pattern visual evoked potentials waves decreased with increased exposure to Hg. Surprisingly, these results were interpreted as the beneficial effects of marine product ingestion on elevated intake of Hg. Unfortunately, the authors did not obtain or examine the elements which may have explained their results. Moreover, only few parameters of the pattern visual evoked potentials were studied. The combine use of various contrasts with different spatial and temporal frequencies in their stimuli (known to examine the two main visual pathways), could have allowed to conclude on the integrity or not of the visual pathway in population exposed to this contaminant. In addition, the significant intake of nutritional elements such as omega-3 fatty acids in the patient's diet, elements which are known to play an important role in optimal visual development (Uauy *et al.* 1990), have not been adequately associated with the data obtained by the authors.

ACTIVITIES IN 1997/1998

During 1997/1998, we explored the possibility of using neurophysiological and neurological parameters when studying the effects of prenatal exposure to PCB and Hg among Inuit children of preschool age. We identified, in collaboration with experts in pediatric neurophysiology and neurology, instruments to be used as indicators of learning, memory, neurological and sensory deficits in preschool aged children. Discussion regarding confounding variables allowed us to specify exclusion criteria to be used as well as instruments to be used when conducting the maternal interview and the child evaluation. The examination of the cord blood surveillance program data base allowed to specify the number of four-year-old children available per year and per community as well as the PCB and Hg exposure range to be expected.

Research protocol

Design

This historical cohort study will involve testing children from Nunavik; the number of children will be determined after the statistical power analysis. Children will be four years of age when tested. Children's mothers will be interviewed in order to measure potential confounding factors.

Population

Results obtained during various surveys conducted in Nunavik demonstrated that Inuit are exposed to higher PCB concentrations than populations living in southern regions of the province of Québec (Dewailly *et al.* 1989, 1993, 1995, 1996, in progress; Rhainds *et al.* submit). The plasma concentration of Aroclor 1260 in Inuit women on reproductive age (15 µg/L) is higher than the Health Canada guideline (5 µg/L) (Dewailly *et al.* 1993) and exceeds concentrations measured in past cohort studies for which neurobehavioural and foetotoxic effects were observed during infancy and childhood. Available data have also confirmed that Inuit newborns are exposed to mercury. In Nunavik, the mercury concentration (geometric mean) found in cord blood was of 14.1 µg/L (n=475), as opposed to 1.0 µg/L (n=1109) in newborns from southern Québec (Muckle *et al.* 1998). According to the maternal blood/cord blood ratio of 1.31 found in the Northwest Territories (Seddon, under review), these cord blood concentrations should correspond to maternal blood concentrations of 10.8 µg/L and 0.8 µg/L, respectively. Furthermore, according to WHO (1990), these maternal blood concentrations should correspond to maternal hair concentrations of 2.7 µg/g and 0.2 µg/g, respectively.

Exclusion criteria

The following criteria will be applied to the population to be tested: Apgar below 5 at 5 minutes of life; evidence of birth trauma; gestation less than 37 weeks; birthweight less than 2500 grams; congenital or chromosomal anomalies; epilepsy; significant disease history; major neurological impairment; fetal alcohol syndrome; presence of facial dysmorphologies associated with fetal alcohol effects; less than 6/9 visual acuity in both eyes as per the "O" of Landolt, without a normal ocular alignment as determined by the corneal reflex; severe hearing impairments as determined by an auditory screening evaluation; under medication affecting the central nervous system (e.g., Ritalin).

Exposure assessment

Concentrations of polychlorinated pesticides and mercury were obtained at birth through cord serum analyses and will be used to characterized prenatal exposure. Current exposures to polychlorinated pesticides and mercury will be measured in the child's blood and a child's hair sample will also be collected to document Hg exposure.

Outcomes

This study will focus on neurological and neurophysiological endpoints. To be more specific, a neurological exam will be performed, the fine neuromotor function as well as the visual system and the cognitive and attentional functions will be assessed via highly sophisticated instruments, designed in neuroscience to be more sensitive and specific than neurobehavioural tests used in traditional neuropsychological testing.

The neurological examination (Amiel-Tison and Stewart 1989) consists of an objective neurological examination using standardized procedures that evaluates both posture and passive tone at rest, in addition to motor activity and postural reactions. Three signs, indicators of mild damage to the corticospinal tracts which normally supersede subcortical control of posture, mild impairment of higher motor control and early deficit of brain growth, will also be assessed. We believe that the proposed neurological assessment developed by Amiel-Tison and Stewart is prone to be the most sensitive tool to detect mild neurological deficits in toddlers whose mothers were exposed to environmental pollutants during their pregnancy. None of the other early neurodevelopmental examinations described so far have been able to detect anomalies concomitant with significant cognitive impairments as early or as confidently as this one in premature and/or children with perinatal asphyxia.

The fine neuromotor function refers to the microscopic involuntary components of gross motor skills and to the precision of voluntary movements executed repeatedly. An effort had been made to select tests which should be more sensitive to detect subtle changes in the fine neuromotor function that the traditional neurobehavioural tests used in neurophysological testing. As a result, new technologies from the field of cognitive neuroscience used with adults will be adapted for child testing. The instruments selected have been used in previous studies to detect effects that were smaller than classical clinical signs and sufficiently subtle to be ignored by most clinical examinations (Beuter *et al.* in press A, Beuter *et al.* in press B, Beuter *et al.* in press C). Moreover, in their recent works, Beuter and collaborators showed that the methodological approach used here is sufficiently sensitive and specific to characterize the performance of Cree subjects exposed to low levels of Hg, subjects with Parkinson's disease and subjects exposed to manganese (Beuter *et al.* under review). The administration of these tests will allow the measurement of tremor, rapid alternating movements, rapid pointing movements, postural sway, reaction time and possibly eye movements. Symmetry in time and space (or lack of), precision (or lack of), regularity also called harmonicity (or lack of), coherence between two signals (or lack of), center frequency and dispersion (or lack of), duration, speed-accuracy trade-off (Fitt's constant), amplitude, drift, fluctuations in time and space (or lack of), skewness, peakedness, proportional power, range, similarity in size or shape coefficient of variation and smoothness are the characteristics used to describe the motor performance.

Since the neurophysiological effects of prenatal and perinatal exposure to environmental contaminants can occur at the level of the central as well as the peripheral nervous system, the combination of pattern visual evoked potentials (PVEP) to other electrophysiological techniques such as the flash electroretinogram (ERG) and pattern ERG (PERG) should clarify the presence or absence of a visual deficit at both of these levels. The PVEP is a reflection of the neuronal mechanism responsible for the spatial integration of the visual information and allow an appropriate evaluation of the maturation and functional integrity of the visual pathway. The flash ERG and the pattern ERG, which respectively evaluate the photoreceptor and the ganglion cells of the retina, have been used to demonstrate subtle changes in the retina. The flash ERG represent the global electrical activity of the retina and allow the evaluation of cones and rods function. It gives information on the nature of various degenerative retinal disorders and provide an index of retinal sensitivity. The PERG will be used to detect central or subtle peripheral retinal damage. PERG amplitude is significantly reduced in many visual disease which afflict the optic nerve or the ganglion cells of the retina, and since the maturation of the PERG is already achieved at the age of our population, this test will contribute to evaluate various levels of the visual system in our investigation.

Using an oddball paradigm, the latency, amplitude as well as the topographical distribution of cognitive evoked potentials such as the P300 with a reaction time procedure (which involves decisional processes) and the mismatch negativity (MMN), which is closely linked to automatic attention, should reflect the extent of cognitive deficits that might be observed after Hg and PCB exposition. When correlated to neuropsychological measures, the MMN and the P300 of the evoked related potentials should be able to predict those children who will be more prone to achieve lower scholar performances, both in regards of deficits in attentional and memory updating/classification processing respectively.

Confounding factors

Four groups of potentially confounding variables will be measured:

- prenatal and postnatal exposure to lead and other environmental contaminants;
- nutritional elements (e.g., prenatal exposure to polyunsaturated fatty acids (PUFAs) and selenium, prenatal vitamin A deficiency, PUFAs in the child's diet during first year of life, anemia during childhood);
- maternal health related factors (e.g., number of previous abortions, number of previous stillbirths, gravidity, parity);
- socio-demographic and familial variables consistently found to be related to the development of preschool children (e.g., socio-economic status, highest grade attained by the primary caregiver, number of children and adults at home, quality of intellectual stimulation provided by the family, maternal mental well-being and intelligence, family violence).

Regarding marijuana and tobacco exposure through pregnancy, evidence has not been provided to support the existence of differences in long-term outcomes for children exposed compared to non-exposed children. There is a paucity of research on long-term outcomes of children exposed to cocaine, heroin and multiple drugs. However, our ongoing study with pregnant women from Nunavik revealed that this practice seemed to be of very low occurrence.

CONCLUSIONS

We anticipate that this is a four-year project: 12 months for the implementation phase, 30 months for data collection and 6 months for data analysis. Learning disability is a major concern for health authorities and community representatives in Nunavik. This study will not only clarify the impact of environmental contaminants on children's cognitive and learning abilities, but will also provide current information about visual, hearing and neurological problems seen in children from Nunavik.

The Nunavik Nutrition and Health Committee is a partner in this study. Results of this research will have implications for risk management by agencies and native groups, as well as Health Canada, NWT, Labrador and other circumpolar countries.

Expected project completion date: Year 2001/2002.

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TRANSPLACENTAL EXPOSURE TO PCBS AND INFANT DEVELOPMENT STUDY : PROGRESS REPORT FOR YEAR 1997/1998

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OBJECTIVES

1. to examine the consequences of *in utero* and lactational exposure to PCBs on Inuit infants, from birth to 12 months of age.

Of particular interest is the impact of exposure on newborn thyroid hormone levels and physical growth, on the infant's overall health, mental, psychomotor, and neurobehavioural development, and on visual and spatial information processing abilities.

DESCRIPTION

Results from several surveys have indicated that Inuit newborns from northern Québec (Nunavik) are exposed to doses of organochlorines which exceed acceptable (tolerable) daily intakes for several health endpoints. Dewailly *et al.* (1992) reported that the mean concentration of PCBs (Aroclor 1260) in breast milk fat was 2.9 mg/kg (n=107) for Inuit women, compared with 0.5 mg/kg (n=536) for women from southern Québec. This level among Inuit is 5.6 times greater than that of southern women and is higher than 1.5 mg/kg, the lipid concentration corresponding to the maximal acceptable concentration in breast milk of 50 µg/L established by Health Canada (1978). More recently, PCB concentrations were measured in Greenlandic new-borns. The average PCB (Aroclor 1260, fat basis) concentration measured in cord blood samples was 1.7 mg/kg (P. Bjerregaard, unpublished data), compared with 1.0 mg/kg in Nunavik (Dewailly *et al.* 1995) and 0.2 mg/kg in southern Quebec (Rhainds *et al.* in press).

The effects of prenatal exposure to background levels of PCBs from environmental sources have been examined in four major cohort studies: in Michigan, North Carolina, the Netherlands and New York. The effects of PCB/PCDF poisoning were also studied in Taiwanese children. In Michigan, higher cord serum PCB concentrations were associated with lower birth weight (Fein *et al.* 1984). This exposure was also associated with less optimal newborn behavioural function (e.g., reflexes, tonicity and activity levels) in all three studies that administered the Brazelton (1994) Neonatal Behavioural Assessment Scale (Jacobson *et al.* 1984, Lonkey *et al.* 1995, Rogan *et al.* 1986). The Netherlands study found that elevated levels of PCBs can alter the thyroid hormone status in early infancy; higher TSH, and lower FT_4 and TT_4 levels were found to be significantly correlated to PCBs measured in maternal milk (Koopman-Esseboom *et al.* 1994). In North Carolina, dose-response analysis indicated deficits in psychomotor development at 6, 12 and 24 months in highly exposed children: those whose mothers' milk PCB levels exceeded 1.75 mg/kg (Gladen *et al.* 1988, Rogan and Gladen 1991). At higher levels of PCB/PCDF exposure in Taiwan, deficits were seen in infant mental and psychomotor development (Yu *et al.* 1991). The principal finding in Michigan was an association with poorer visual information processing ability, which indicated a deficit in visual memory and/or attention (Jacobson *et al.* 1985, 1990, 1992).

ACTIVITIES IN 1997/1998

The data collection is continuing. To date, 146 pregnant women have agreed to participate in our study. The activities carried out since April 1, 1997 involve the following: 1) data collection; 2) reinforcement of the links with the Inuit communities involved in the study; 3) finalizing the research procedures; 4) training a new research assistant to perform the maternal interviews and the infant testing at 6.5 and 11 months of age.

Since women from Inukjuaq are now delivering in their own community (previously all babies were born in

Puvirnituk hospital), the Inukjuaq midwifes were trained to perform the newborn assessment. This training aimed to ensure reliability for the anthropometric measurement and the evaluation of neurological and physical maturity at birth. These midwives were also trained to collect biological samples (cord and maternal blood, placenta and meconium) that will be used to document prenatal exposure to environmental contaminants, tobacco and drugs.

In Puvirnituk and Inukjuaq, Dr. Muckle did a phone-in radio program at the FM local station (English-Inuktituk). This allowed us to update the population on the research activities; more specifically, what was accomplished since September 1996 and what was to be done during year 1997/1998 in their communities. In Kuujjuarapik, we were invited by the head nurse to meet with a group of pregnant women to answer their questions about their diet during a pregnancy, environmental contaminants, and infant development.

We also met with new hospital and nursing station nurses, midwives and laboratory technicians directly involved in the data collection process to present the objectives of the research and the research procedures in which they are involved during the data collection phase. In addition, we met with medical professionals in each village to identify any problems and difficulties that have emerged since the beginning of the data collection, to find ways to facilitate their work, and to ensure the quality of the data collected.

OVERVIEW OF THE RESEARCH PROTOCOL AND THE LABORATORY METHODS

This prospective cohort study will involve approximately 300 Inuit infants; 200 from Nunavik and 100 from Greenland. Mothers are recruited during pregnancy, at their first or second prenatal medical exam. They are met again during the second trimester of their pregnancy and one month after delivery. Their infants are assessed at 6.5 and 11 months of age. At these infant testing sessions, an interview with the mothers is also carried out. Concentrations of PCBs, chlorinated pesticides and heavy metals are obtained at birth from umbilical cord and maternal serum analyses; and postnatally from breast milk analysis. A hair sample was collected one month after the delivery to document prenatal mercury exposure by trimester of pregnancy. Anthropometric characteristics are measured in newborns. Thyroid hormone levels are measured in maternal and cord blood as well as in infants' blood. Five groups of potentially confounding variables are measured: exposure to other toxic substances, polyunsaturated fatty acids, perinatal medical complications, socio-demographic status, and psychosocial risk. Exposure to other toxic substances and nutritional effects are evaluated through cord serum analyses. Prenatal exposure to DDE and other organochlorine pesticides, mercury, lead, and polyunsaturated fatty acids is assessed in cord blood. Prenatal exposures to alcohol, drugs and nicotine are measured during pregnancy and after delivery through a structured maternal interview. Fetal exposure to illicit drugs is also documented through meconium analysis. Information about pregnancy and delivery complications is obtained from medical records, and socio-demographic status from maternal reports. Socio-demographic data include maternal age, education, employment, marital status, gravidity, and the number of children in the family. Psychosocial variables that can affect infant development are measured at 6.5 and 11 months postpartum. These include quality of intellectual stimulation provided by the mother, maternal depression and intelligence, and family violence.

Blood samples collected to date have been assessed for PCBs, mercury, selenium and lead. Blood samples containing EDTA as the anticoagulant are centrifuged and the plasma collected in glass vials prewashed with hexane. Plasma samples are frozen at -20°C and analysed at the Québec Toxicology Center for PCB, Hg, Pb and Se determinations. For PCB analyses, a 1/1/3 mixture of ammonium sulfate/ethanol/hexane is first added to the plasma to extract organochlorines. The extracts are then concentrated and purified on two Florisil columns. The 14 most prevalent PCB congeners (IUPAC nos. 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187) are measured in the purified extracts by dual capillary column high-resolution gas chromatography (HP-1, HP-2) coupled with an electron capture detector. Lipids are also measured in an aliquot of plasma in order to express PCB congener concentrations per lipid weight. Total plasma lipid concentration is calculated from total cholesterol, free cholesterol, triglyceride and phospholipid concentrations using the formula of Phillips *et al.* (1989). A sample of whole blood was also analysed for total mercury, lead and selenium. Total mercury concentrations are determined by cold vapor atomic absorption spectrometry. The blood (or hair) sample is first digested with nitric acid, and reduction of mercury is performed using $SnCl_2$, in the presence of $CdCl_2$. Metallic mercury volatilizes and is detected by atomic absorption. Blood lead concentrations are determined by graphite furnace atomic absorption spectrometry using the Zeeman graphic furnace method. Selenium is also quantified in whole blood by atomic absorption spectrometry. Detection limits are 0.02 μg/L for PCB congeners and other chlorinated pesticides, 0.03 μg/L for *p,p'*-DDT and β-

BHC, 0.05 μmol/L for lead and 0.5 μmol/L for selenium and 1.0 nmol/L for total mercury (0.2 μg/g in hair samples).

PCB congeners in milk samples were determined by high-resolution gas chromatography. Milk samples were mixed with an aqueous solution of sodium oxalate, ethyl ether, and ethanol and then extracted with hexane. The hexane extracts were washed with reagent water and concentrated to constant weight, and the percentage of lipids was determined gravimetrically. The lipid residue was diluted in hexane and cleaned using a sulfuric acid-silica gel slurry, followed by elution through a neutral acid-silica gel chromatographic column. The analysis was performed by dual-column gas chromatography with a Hewlett-Packard 5890 gas chromatograph equipped with two capillary columns (HP-1, HP-2). Twin electron capture detectors were used. The specific PCB congeners and chlorinated pesticides (see above) were identified and quantified by comparing the responses and retention times with calibration standards for each analyte of interest. The detection limits are 0.3 μg/kg lipids for PCB congeners and other chlorinated pesticides.

RESULTS AND DISCUSSION

Participation and Retention Rates

From November 1995 to March 1998, 146 mothers completed the prenatal assessment; 92, the postnatal assessment; 59 infants were assessed at 6.5 months and 43, at 11 months of age (Table 1).

The initial participation rate is comparable to the 80% we had projected, and only three mothers refused to continue in the study after completing the prenatal interview. One source of subject loss we had not anticipated was due to mothers already having enrolled in the study with a previous child (7%). Attrition due to perinatal mortality (4%) or congenital malformations (0%) has been markedly lower than the 16.1% projected, as have refusal rates at 6.5 and 11 months. However, postnatal attrition has been somewhat higher than projected due to difficulties associated with reaching mothers without telephones and mothers moving to other villages who, given the high cost of travel, could not be assessed. A final sample size of 218 infants is projected given the anticipated number of births projected for the three Hudson Bay communities over the 50-month period (Table 2).

Table 1. Participation and Attrition Rates

First 180 declared pregnancies		
Interviewed prenatally	146	81.1%
Refused	21	11.7%
Unable to contact	1	0.01%
Exclusion (already in study)	12	6.7%
Eligible for postnatal interview (N=111)		
Interviewed postnatally	92	82.9%
Refused	3	2.7%
Unable to contact	0	0%
Moved to another village	5	4.5%
No biological sample	7	6.3%
Perinatal mortality	4	3.6%
Eligible for 6.5 month assessment (N=70)		
Tested at 6.5 months	59	87.1%
Refused	2	2.9%
Unable to contact	3	9.7%
Moved to another village	4	3.2%
Exclusion (medical condition)	1	1.4%
Died	1	1.4%
Eligible for 11 month assessment (N=43)		
Tested at 11 months	43	100%
Refused	0	0%

Table 2. Projected Participation and Attrition in the three Hudson Bay Communities

Pregnancies projected over 50 months	426
Exclusions for 2nd child in study (-7%)	396
Participation in prenatal interview (80%)	317
Perinatal mortality and congenital malformations (-5%)	301
Postnatal attrition (-15%)	256
Attrition through 12-month assessment (-15%)	218

Sample Characteristics

As shown in Table 3, the mean age of mothers is 24.1 years (N = 145, SD = 5.7), ranging from 14 to 41 years. At their first prenatal visit, the height of the participants was measured and the mean height was 1.51 meters (N = 135, SD = 0.09), ranging from 1.17 to 1.68. The mothers' self-reported weight before pregnancy averaged 60 kilograms (N = 101, SD = 10.9) and ranged from 41 to 95. Parity ranged from 0 to 9 (N = 145) with an average of 1.9 (SD = 1.8). As far as smoking, 93.7% of women interviewed to date have smoked during pregnancy, the average number of cigarettes smoked per day was 9.5 (N = 143, SD = 5.8) and ranged from 0 to 25. Average numbers of traditional food meals eaten per week during pregnancy were 3.2 (N = 98, SD = 3.3, range 0-21) for fish meals and 1.6 (N = 98, SD = 1.9, range 0-8.3) for marine mammal meals. Traditional native foods are considered in these communities to be beneficial for fetal development.

Prenatal Exposure

Mean cord PCB, lead and selenium concentrations are virtually identical to those observed in the Cord Blood Study (Dewailly *et al.* 1995); mercury concentrations are somewhat higher (Table 4), probably because more fish and marine mammals are consumed in the communities selected for this study. In this study as well as in the Cord Blood Study, the associations between PCB concentrations and those of mercury, lead or selenium in cord blood are in the low or low-moderate range (Table 4).

Based on the results of the Inuit Health Survey (Dewailly *et al.* 1994), the correlation between plasma PCB and blood mercury concentrations in maternal blood was expected to be statistically significant and in the 0.60 to 0.70 range. We reanalysed those data by selecting cases according to their gender (women only), their community of residency (the villages included in the present study) and their age (less than or equal to 40). The PCB (Aroclor 1260)-mercury correlation in this subgroup was 0.55 (N = 63, p = .000). Surprisingly, this association is much weaker in pregnant women participating in the present study and similar to that reported for cord blood (r = 0.12, N = 91). Changes in blood composition which occur during pregnancy could be responsible for the weaker PCB-mercury associations noted in women approaching the time of delivery.

Based on the visual recognition memory effect, the most sensitive endpoint studied in infants of the Michigan study, Tilson, Jacobson and Rogan (1990) suggested a threshold for PCB of 1 mg/kg lipid wt. in maternal milk. Given the method used to quantify PCB levels in our laboratory, this concentration corresponds roughly to 2 mg/kg of PCBs in the current data set. The frequency distribution of maternal milk Aroclor 1260 concentrations revealed that 25.4% of infants enrolled in the present study were exposed to PCB concentrations above this 2 mg/kg threshold, the highest Aroclor 1260 concentration obtained being 5.9 mg/kg.

Table 3. Sample Characteristics

	N	Mean	Median	Std Dev	Min	Max
Age	145	24.1	23.7	5.7	14.1	40.7
Height (m)	1.35	1.51	1.53	0.09	1.17	1.68
Weight before pregnancy (kg)	101	60.0	57.7	10.9	40.7	94.5
Parity	145	1.9	2.0	1.8	0	9.0
Number cigarettes smoked per day during pregnancy	143	9.5	9.3	5.8	0	25.0
Fish meals per week during pregnancy	98	3.2	2.1	3.3	0	21.0
Mammal meals per week during pregnancy	98	1.6	0.9	1.9	0	8.4

Table 4. Cord Blood Concentrations of Contaminants in Nunavik

	94-95 Cord Blood Study		Current Study		Correlations with Aroclor1260[1]
	N	**Mean**	**N**	**Mean**	***r***
PCBs (Aroclor 1260) (μg/kg)	216	994.6	62	1050.4	—
Mercury (nmol/L)	238	93.51	55	122.4	.21
Selenium (μmol/L)	228	4.02	55	3.7	.25[2]
Lead (μmol/L)	238	0.24	55	0.2	.10

1 N=55

2 p≤.06

Table 5. Associations Between PCB (Aroclor1260)[1] Concentrations Measured in Different Biological Samples.

	Mean (N)	**Cord Blood**		**Maternal Blood**	
		r	**n**	**r**	**n**
Cord Blood	1050.4 (62)				
Maternal Blood	1208.6 (59)	.98[2]	57		
Maternal Milk	1484.5 (84)	.93[2]	45	.95[2]	60

1 fat basis, μg/kg

2 p ≤ .000

Table 6. Associations between Mercury Concentrations in Different Biological Samples.

	Mean (N)	Cord Blood		Maternal Blood	
		r	n	r	n
Cord Blood (nmol/l)	122.4 (55)				
Maternal Blood (nmol/l)	64.4 (93)	.91[1]	53		
Maternal Hair 3rd trimester of Pregnancy(μg/g)	5.1 (75)	.76[1]	41	.77[1]	64

1 p ≤ .000

Based on extrapolations from data collected following a mercury poisoning episode that occurred in Iraq, the World Health Organization suggested that there was a 5% risk of neurological problems arising from a prenatal exposure corresponding to a mercury concentration of 10 to 20 μg/g in maternal hair (WHO, 1990). An examination of the frequency distribution of maternal hair mercury concentration revealed that only 4% of infants in the present study were exposed to mercury concentrations above 10 μg/g and no infants were exposed to 20 μg/g. The highest maternal hair concentration obtained to date is 12.8 μg/g.

As shown in Table 5, mean Aroclor 1260 concentrations in cord blood, maternal blood and maternal milk were 1050.4 μg/kg, 1208.6 μg/kg and 1484.4 μg/kg, respectively. As expected given the improvement in precision of the laboratory methods used to determined organochlorine concentrations since the 1980, the Aroclor 1260 concentrations measured in these biological samples are highly correlated and ranged from 0.93 to 0.98. This correlation is much higher than that of 0.41 obtained in the Michigan study (Jacobson *et al.* 1984)

Average total mercury concentrations were 122.4 nmol/l in cord blood, 64.4 nmol/l in maternal blood, and 5.1 μg/g in maternal hair (Table 6). The association noted between hair mercury and blood mercury concentrations (r = 0.77, N = 64) is not as high as we had expected since hair concentration should reflect mercury blood concentration. However, the hair segment analysed for mercury reflects the average exposure during the last 3 months of pregnancy, whereas the maternal blood concentration qualifies the mercury exposure over the last 60 days. Moreover, some inter-individual factors such as the rate of hair growth and the hair composition may also weaken the association between hair and blood mercury concentrations. If these factors decrease the precision of mercury hair concentration and thus, influence the rank of the subject's exposure in the distribution, we might expect the maternal blood or the cord blood mercury concentrations to be better indicators of fetal mercury exposure. Nevertheless, only mercury hair concentrations can be used to document retrospectively the exposure occurring during the first and second trimester of pregnancy. The half-life of mercury in blood is too short to allow the use of blood levels for assessing mercury exposure during the entire pregnancy.

Maternal Characteristics, Consumption of Traditional Food and Prenatal Exposure

Certain maternal characteristics are moderately associated with cord blood PCB concentrations (Table 7). Maternal age, height and parity are positively correlated to Aroclor 1260 concentrations whereas maternal weight before pregnancy, socio-economic status, acculturation to the broader Canadian Society, and the number of cigarettes smoked per day during pregnancy were not.

Since a primary route of exposure to environmental contaminants in the Inuit population is the consumption of traditional food, especially fish and sea mammals, for descriptive purposes, we documented the frequency of fish and sea mammal consumption during pregnancy (Table 8). Arctic char, salmon, seal and beluga were the most frequently consumed species whereas the consumption of whale, narwhal and walrus was much less common in the selected communities. Among the fish species, arctic char is eaten much more often than salmon and lake trout. Seal meals included the consumption of meat, liver as well as fat (misarak) while the beluga meals comprised the consumption of meat, liver, blubber (misarak) and skin (muktuk). Average numbers of fish and sea mammal meals per week during pregnancy were 3.3 (N = 98, Median = 2.1, Min = 0, Max = 21) and 1.6 (N = 98, Median = 0.9, Min = 0, Max = 8.4) , respectively.

Table 7. Associations between Cord Blood Concentrations of PCBs (Aroclor 1260)[1] and Maternal Characteristics.

	Aroclor 1260	
	r	n
Age	.47[5]	62
Height	.47[5]	62
Weight before pregnancy	.05	61
Parity	.26[4]	62
SES[2]	-.02	62
PPVT[3]	.22	57
Number cigarettes smoked/day pregnancy	.06	61

1 Fat Basis
2 Socio-economic status obtained from an adapted version of the Hollingshead Index.
3 Peabody Pictures Vocabulary Test, used as an acculturation index.
4 $p \leq .05$
5 $p \leq .000$

Table 8. Traditional Food Consumption during Pregnancy.

	0.1 to 0.99 meals/wk[1]	1.0 to 1.9 meals/wk	2.0 to 2.9 meals/wk	3.0 and + meals/wk	Max meals/wk
Arctic Char (n=99)	44.4	20.2	10.1	25.3	9.3
Salmon (n=133)	92.5	2.2	3.0	2.3	7.7
Seal (n=105)	71.4	15.3	8.5	4.8	6.3
Beluga (n=109)	82.6	11.9	2.7	2.8	6.2
Whale (n=144)	98.6	1.4	0	0	1.3
Narwhal (n=145)	99.3	0.7	0	0	1.3
Walrus (n=137)	100.0	0	0	0	0.8

1 in percentage

Table 9. Associations between Traditional Food Consumption during Pregnancy and Maternal Characteristics.

	Fish Meals/week		Seal Meals/week		Beluga Meals/week	
	r	n	r	n	r	n
Age	–.13	98	–.11	105	.08	109
Weight before preg	–.11	68	–.09	73	-.08	75
Parity	.01	98	–.10	105	.05	109
SES[1]	–.05	98	–.20[3]	105	.00	109
PPVT[2]	–.20	87	–.21[3]	88	-.15	87
Raven	–.11	80	–.20	88	-.05	91
Cigarettes smoked /day during preg	.30[4]	98	.11	104	.21[3]	109

1 Socio-economic status obtained from an adapted version of the Hollingshead Index.
2 Peabody Pictures Vocabulary Test, used as an acculturation index.
3 $p \leq .05$
4 $p \leq .00$

Table 10. Associations between Concentrations of PCBs (Aroclor 1260) and Mercury and Traditional Food Consumption during Pregnancy.

	Fish Meals/week		Seal Meals/week		Beluga Meals/week	
	r	n	r	n	r	n
Aroclor 1260 Cord Blood	.01	56	.06	57	.07	56
Aroclor 1260 Maternal Blood	-.10	82	.06	84	.34**	83
Mercury Cord Blood	-.12	49	.04	50	-.02	49
Mercury Maternal Blood	-.16	81	.03	83	.00	82
Mercury Maternal Hair 3rd Trim Preg	.24*	71	.17	72	.17	71

1 $p \leq .05$
2 $p \leq .00$

As shown in Table 9, maternal weight before pregnancy and parity were not correlated to the frequency of traditional food consumption. However, the consumption of fish and beluga was associated with a higher number of cigarettes smoked per day during pregnancy, while the consumption of seal was related to a lower socio-economic status in the community as well as to a lower degree of acculturation, as evaluated by the English or French vocabulary proficiency (PPVT).

Traditional food consumption was not assessed as an indicator of exposure to environmental contaminants because neither meal size nor the food consumption before pregnancy were documented. However, despite these weaknesses, the frequency of fish meals during pregnancy was associated with maternal hair mercury concentration and the frequency of beluga meals was related to the concentration of PCBs (Aroclor 1260) in maternal blood (Table 10). The consumption of arctic char appears to be solely responsible for the significant correlation between the frequency of fish meals and the concentration of mercury in hair.

CONCLUSIONS

So far, the participation rate in the present study has been high (80%) and very few women withdrew their collaboration in the course of the study. The high retention rate probably indicates that the mothers are comfortable with the research procedures and interested in observing their infants' performance in the evaluation at 6.5 and 11 months of age.

The association between PCB and mercury concentrations in maternal blood was weaker than expected, possibly due to changes in metabolism during pregnancy. Because the associations between PCB and mercury, lead or selenium concentrations in cord blood are relatively low, it should be feasible to control for their respective effects by means of multivariate analysis. Moreover, in this sub-sample, there is a very low percentage of infants exposed to maternal hair mercury concentrations above 10 µg/g, which is currently believed to be the threshold for a 5% risk of neurological problems (WHO 1990).

By contrast, the high proportion of subjects exposed above the 2-mg/kg threshold for PCBs in maternal milk will increase the power of the study to detect subtle effects in the study group if indeed they are occurring. The very high correlation (r = .98) between maternal and cord blood PCB concentrations reflects the improvement of the laboratory methods since the Michigan and the North Carolina cohort studies were performed. The reduction of error on the measurement of prenatal exposure to PCBs will further increase the statistical power in confirmatory analyses.

Some maternal characteristics such as age, height and parity are moderately associated with cord blood PCB concentrations and therefore these variables might be considered in further multivariate analysis aimed to document the association between PCB exposure and the outcome variables.

The Hollingshead Index and the Peabody Pictures Vocabulary Tests are used to document two potential confounding factors: the socio-economic status in the community and the degree of acculturation. The significant correlations obtained between these factors and the consumption of traditional foods indicates that the selected instruments will allow us to control for these potential confounding factors.

Expected project completion date: Recruitment of mothers and administration of prenatal interviews began on November 1995. Newborn assessments started in May 1995 and postnatal interviews in June 1995. The 6.5-month assessment started in January 1997 and the 12-month assessment in June 1997. Data collection will end in August 2001. Data analysis and write-up of results for publication are planned for August 2001 to December 2001 so the expected project completion date is December, 2001.

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ASSESSMENT OF RADIATION DOSES TO NORTHERN RESIDENTS FROM CONSUMPTION OF CARIBOU MEAT

Project Leaders: B.L. Tracy and A.S. Baweja, Radiation Protection Bureau 6302D1, Health Canada

Project Team: Dr. P.T. Thomas, U. of Saskatchewan, Northern Health Services, Saskatchewan Health Department, Environment Canada (Prairie Region)

OBJECTIVES

Short-term:

1. to measure the uptake and retention of polonium-210 by the human body and to develop simple screening procedures that can be applied on a community-wide basis to measure polonium intakes. This will allow a more accurate assessment of radiation doses to northern communities.

Long-term:

1. to address concerns of northern residents about the safety of traditional foods and to establish reliable guidelines and recommendations.

BACKGROUND

Recent work carried out under contract to Health Canada (Beak 1995 Beak 1996) showed that some northern populations may be receiving substantial radiation doses –5 to 15 mSv per year compared to a normal background of 2 to 3 mSv per year. About 70 % of the enhanced dose resulted from one radionuclide, polonium-210, and one pathway, the lichen → caribou → human food chain.

A major uncertainty in this assessment lay in the amount of ingested polonium actually absorbed by the human GI tract. There is also uncertainty about how long polonium-210 is retained by the various body organs. The current study was undertaken to resolve these uncertainties. An accurate knowledge of these parameters is essential in assessing the impact of human activities, such as uranium mining, on northern lifestyles.

PROGRESS DURING 1997/98

During 1997/98 funding was arranged for the project as follows:

- Northern Contaminants Program (DIAND) $20K
- Saskatchewan Department of Health $20K
- Health Canada $10K
- **TOTAL FUNDING** **$50K**
- Environment Canada: Contribution in kind; provision of caribou meat samples.

This was adequate to carry out a pilot study on six volunteers from the Saskatoon area. The study was coordinated by Dr. Patricia Thomas of the Toxicology Centre, University of Saskatchewan. In January 1998 each volunteer consumed about 2 kg of freshly-killed caribou meat. Urine and fecal samples were collected over a period of two months. Analyses for polonium-210 in meat, urine, and feces were carried out by the Saskatchewan Research Council in Saskatoon. The Environmental Measurements Laboratory in New York performed Quality Assurance on the analyses. The University Hospital in Saskatoon assisted with sample collections and creatinine measurements in urine as a verification of completeness of the 24-hour urine collections.

The results of the pilot study are summarized in Table 1.

This preliminary study tends to confirm the ICRP recommended human GI uptake factor of 50% for polonium in caribou meat. The results are also consistent with a polonium biological half time of 50 days (effective half time = 37 days). If these parameters are established to be correct, then the earlier dose assessments carried out by Health Canada and CINE remain valid. That is, the radiation doses from polonium really are elevated for northern populations dependent on traditional foods.

WORK PLANS FOR 1998/99

Table 1. Summary of results of pilot study

Volunteer Number	#1	#2	#3	#4	#5	#6
Sex	M	M	M	M	F	F
Age	23	34	33	53	24	35
Total Po-210 intake (Bq)	23	23	23	23	20	20
Po-210 fecal excretion (Bq) (background substracted)	6.00	13.52	11.85	7.13	12.64	10.19
GI uptake = 1 - excretion/intake	0.739	0.412	0.485	0.690	0.368	0.491
Mean of the above	0.531					

The above measurements are being extended to a further eight volunteers from the Saskatoon area in order to obtain adequate statistics for the uptake factors and retention times in humans. The same contractor and analytical laboratories as in the 97/98 study are being used. This work is being funded as follows:

- Northern Contaminants Program (DIAND) $20K
- Health Canada $20K
- Saskatchewan Health Department $20K
- **TOTAL** **$60K**

An independent Review Committee has been formed to oversee the emerging results. The Committee includes two international experts to audit the quality of the results and the conclusions being drawn from them. This Committee also includes representatives from the Council of Yukon First Nations and the Dene Nation and technical experts from the relevant government departments. The Review Committee gives advice on the communication of results to communities and feedback from communities which might modify subsequent stages of the project.

IV EDUCATION AND COMMUNICATIONS

INTEGRATED CONTAMINANT EDUCATION PROGRAM FOR NORTHERNERS

Project Leader: W. Carpenter, Environmental Director, Métis Nation – NWT.

Project Team: J. Farrow, Education Coordinator, Contaminant Program, S. True, Research Assistant, Contaminant Program (Métis Nation – NWT); S. Daniel, Science Coordinator, Curriculum Division, GNWT Education, Culture and Employment (ECE)

OBJECTIVES

Short-term:

1. to give Northerners a better understanding of all issues relating to the Northern Contaminants Program (NCP).

Long-term:

1. to give Northerners some of the necessary information and tools to make informed decisions regarding health risks from anthropogenic industrial contaminants that are present in the Northern food chain.

DESCRIPTION

This project brings information that will assist informed decision making by individuals and communities in their food use, to the grass roots level, through schools and community learning centres. The Métis Nation Contaminant Education Program develops and integrates contaminant related program materials with existing NWT school curricula. The program materials are cross referenced to the relevant curricula and wherever possible to Dene Kede and Inuuqatigiit, documents that explore the school curricula from the Dene and Inuit perspectives, making sure wherever possible to reflect or validate the traditional point of view. These educational materials will educate those young adults who in the near future must make their own decisions on the subject of contaminants and country food. Children who are educated about contaminants at school often go home and tell their parents what they have learned. We can teach the adults through the children. Designing materials that fit into the required school curriculum means that the issue will be addressed on an ongoing basis. As students move through the school system the issues will be dealt with at a more sophisticated level.

The main source of information for the development of this education program has been the actual research projects funded by the AES: Northern Contaminants Program and the new NCP. During the planning stages, the NCP categories of Sources, Pathways and Fate; Ecosystem Uptake; Human Health and Education/ Communications were cross-referenced to the existing curricula. This exercise ensured proper representation of the scope of the NCP through the lesson plans.

ACTIVITIES IN 1997/98

Distribution of High School Materials

The following materials:

- a six poster set of Northern Ecozones
- class reading set of Contaminants in Northern Canada Booklet
- Manual for Science Teachers, NWT Science 15-25
- CD-ROM version of Teachers Manual

were distributed to all NWT High Schools offering grades 10 and 11. The packages were addressed to the attention of the Science Teacher for Science 15 and 25. Order forms allowed teachers to request further copies, if required. Materials were mailed out for the beginning of the 1997/98 school year. Program materials (minus the poster set) were sent to the District Education Council Offices and Yellowknife School Boards.

There are 37 NWT High Schools, 8 Divisional Education Councils and 2 School Boards. Reference copies were also be made available to NCP Partner Agencies and other Education Authorities that express an interest in this program. Copies were requested by and provided to AMAP, as a basis for discussion of their education program.

CD-ROM Format

The existing files for the school books, teacher manuals and overview booklet were converted to PDF and HTML formats. This allows them to be copied to CD-ROM or posted to an internet site. This task has been accomplished using Adobe Acrobat, Microsoft Word and Microsoft Front Page software. All these software

Table 1. Distribution List for High School Program

Council/Board	Number of High Schools
Baffin Divisional Council	12
Beaufort-Delta Divisional Council	4
Deh Cho Divisional Council	3
Dogrib Divisional Council	1
Keewatin Divisional Council	6
Kitikmeot Divisional Council	4
Sahtu Divisional Council	3
South Slave Divisional Council	2
Yellowknife Education District #1	1
Yellowknife Education District #2	1
Total	**37 + 10 for District Offices**

programs can be used with a Windows operating system and can be operated by anyone with a basic knowledge of word processing.

Grade 12 Program

Science 35 is a new grade 12 science program being developed by an NWT curriculum committee. Steven Daniel, the science co-ordinator for GNWT ECE, suggested development of contaminant materials to fit with this new course. The course outline was cross referenced to NCP research and the CACAR and Highlights reports that were published in the summer of 1997. These materials will be distributed to selected teachers for comments and pilot testing in the 1998/99 school year.

RESULTS

To date the project has produced:

- a database of NCP contaminant research, school reference materials, community profiles and Health Risk Assessments.
- junior high books have been distributed to Schools, School Board Regional Resource Centres in the Northwest Territories, Aurora Research Institute and Nunavut Research Institute.
- Program materials for Grades 10 and 11, NWT Science 15 and 25, distributed to all NWT schools offering those grades.
- the overview booklet entitled 'Contaminants in Northern Canada', is available for educators, professionals working in the contaminant field as well as the general public.
- draft Grade 12 materials
- hard copy has been converted to PDF and HTML formats.

DISCUSSION/CONCLUSIONS

Generally, reaction to the program has been very positive. Requests for the schoolbooks have exceeded the quantities available, but we continue to supply photocopies or CD-ROM versions. The preference expressed by teachers is for hard copy materials. Some are still reluctant to use CD-ROM or Internet. In some

Table 2. Metis Nation – NWT Northern Contaminants Education Program Five Year Plan

Year	Work Plan	Expected completion
1997-98	Environmental Studies 35 develop draft lesson plans	Completed March 98
	Reformat Junior High Program	Completed March 98
1998-99	Pilot test Environmental Studies 35	
	Consultation and planning, Social Studies grade 7,8 and 9, Senior High Northern Studies	
	Consultation and planning Traditional Knowledge Units	
	Social Studies 7,8 and 9, Northern Studies develop draft lesson plans	
	Develop Traditional Knowledge Units	Expected completion March 99
1999-00	Publish Environmental Studies 35	
	Revise Science 15 and Science 25	
	Pilot test Social Studies, Northern Studies	
	Adult education as required	
2000-01	Publish Social Studies and Northern Studies	
	Review background materials	
	Develop multimedia on line presentations	
2001-02	Develop on line resources for teachers and community professionals	
	Final report	

cases it is because the school does not have the facilities or the budget to access materials in this way. In the last two years there has been a high turnover of teachers, particularly at the junior high level. The result is that teachers often take their manuals with them and the new teachers are not aware of our materials. Distribution via bulletin boards and Internet may prove useful. Many schools have disbanded their libraries because of budget cuts, so the copies are "lost". The experience of the past year demonstrates the importance of in-service training with classroom teachers and development of an ongoing distribution system. In 1998/99 there will be a greater emphasis on holding workshops with teachers, which we hope will alleviate this problem.

Expected Project Completion Date: High School Program will be distributed at the beginning of the 1998/99 academic school. The school materials will also be available on a Métis Nation - NWT web site. Draft lesson plans developed in 1997/98 will be pilot tested in 1998/99. The project five-year plan 1997-2001 is shown in Table 2.

APPENDIX 1

The materials produced by this project are available on request from the Métis Nation – NWT.

NCP Overview Booklet

This 15-page, illustrated booklet, written in plain language, contains a straightforward explanation of the sources and effects of contaminants in the North. It covers contaminants in general, their effects on wildlife and possible effects on human health. It includes a discussion of the various programs in place to study contaminants in the North. As well, the booklet provides a list of ways that people can learn more about the Northern Contaminants Program. The booklet has been made available to AES agencies, partners and the general public. It has been reprinted twice.

Junior High Science Lesson Plans

Lesson plans are designed to fit a particular unit within the curriculum. In the manuals, teachers are introduced to the Arctic Environmental Strategy, Northern Contaminants Program then guided to the appropriate curriculum unit. An overall view of lesson plans and sequence are provided to aid teachers in scheduling and preparation. A chart is used to guide teachers to the curriculum unit where the lesson plans can be used.

Science 15 and Science 25 High School Lesson Plans

Programs have been developed for the new NWT integrated science curriculum. NWT Science 15-25 (New) is an integrated science program that allows students to meet the credit requirements for a High School Diploma. The focus is on helping students understand the scientific principles behind the natural events they experience and the technology they use in their daily lives. It is designed to develop in students the knowledge, skills and attitudes to help them become capable of and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities. A key component of this new curriculum is the demonstration of connections between science, technology and society.

JUNIOR HIGH SCIENCE LESSON PLANS

Title	Contaminants in Northern Canada. Lesson Plans for Grade 7 Science 1. Environmental Concerns 2. Nuclear Energy.
Date	1995
Format	Spiral bound teachers manual.
Description	Background information on AES: NCP, lesson plans and student activities referenced to the required NWT Science Curriculum. Spiral bound to allow easy copying of student activity sheets. Set of overhead transparency masters are also included. Lists ways to access more information about NCP.
Length	144 pages
Community	Applicable to all NWT communities offering grade 7.

Title	Contaminants in Northern Canada. Lesson Plans for Grade 8 Science 1. Northern Food Chains and Webs 2. Pulp and Paper.
Date	1995
Format	Spiral bound teachers manual.
Description	Background information on AES: NCP, lesson plans and student activities referenced to the required NWT Science Curriculum. Spiral bound to allow easy copying of student activity sheets. Set of overhead transparency masters are also included. Lists ways to access more information about NCP.
Length	108 pages
Community	Applicable to all NWT communities offering grade 8.

Title	Contaminants in Northern Canada. Information for Science Teachers Grades 7, 8 and 9.
Date	1996
Format	Spiral bound teachers reference manual.
Description	Background information on AES: NCP, curriculum guide, guides teachers to where NCP information may be used with the required curriculum. Reference list of NCP projects, listed by species being studied and reference section on contaminants. Lists ways to access more information about NCP.
Length	58 pages
Community	Applicable to all NWT communities offering grade 7, 8 and 9

SCIENCE 15 AND SCIENCE 25 HIGH SCHOOL LESSON PLANS

Title	Contaminants in Northern Canada. Lesson Plans and Reference Materials for NWT Science 15 and NWT Science 25.
Date	March 1997.
Format	CD - ROM and quick print hard copy on 3 hole paper.
Description	Background information on AES: NCP, lesson plans, and student activities referenced to the required NWT Science 15 and 25 Curriculum. CD - ROM format provides the opportunity to access reference information by computer or provide hard copy print out capabilities. Reference materials and appropriate graphics are provided to assist teachers. Lists ways to access more information about NCP.
Length	650 MB
Community	Applicable to all NWT communities offering grade 10 and 11.

TRADITIONAL AND SCIENTIFIC WORKSHOPS

Project leader: N. Kassi, Contaminants Coordinator, Council of Yukon First Nations

Project Team: G. Frost-Tetlichi, Vuntut Gwichin First Nation; B. Morris, Daak Ka Tlingit Nation; D. Dickson, Kaska Tribal Council; K. Kane, Southern Tuchtone Tribal Council; L. Joe, Northern Tuchtone Tribal Council; Tr'ondek Hwech'in First Nation

OBJECTIVES

1. the future health workshops were to devolve program funds to the Yukon's six nations for the development and implementation of a series of locally relevant workshops on contaminants in the Northern food chain and other health risk issues.

2. the workshops were to generate discussion on human health issues pertaining to diet changes within a nation and to incorporate local traditional knowledge into the research analysis and workshop presentations and to hopefully come up with solutions in dealing with some of the health issues plaguing our communities.

DESCRIPTION

The workshops were designed and implemented by the tribal councils based on the six linguistic nations. Each tribal council submitted a proposal to the CYFN-NCP office whereupon they were given the funds to conduct their workshop. Half the funds were given to begin the workshops. The remaining funds were allocated once the workshop was completed and a report submitted.

RESULTS

The workshops held were on contaminants and health risk issues in the northern food chain, utilizing traditional knowledge. There were discussions on health issues pertaining to diet changes within a specific nation. Elders discussed traditional medicines and what they were used for. There was a strong feeling of teaching and incorporating traditional knowledge into the research process, in hope of coming up with solutions in dealing with some of the health issues plaguing our communities.

DISCUSSION/ CONCLUSIONS

The workshops were very informative to all of the communities. Some individual members have made significant changes in their lives as a result of their participation. The workshops received a tremendous amount of support and some communities have recommended having more dialogue and to participate more fully in NCP initiatives. One of the key recommendations was to have research guidelines for Yukon First Nations on traditional knowledge.

Expected Completion Date: March 1998.

TRADITIONAL KNOWLEDGE RESEARCH GUIDELINES

Project Leader: N. Kassi, Contaminants Coordinator, Council of Yukon First Nations

Project Team: Elders Council, Yukon Fish and Wildlife Management Board, Yukon Land Use Planning Council, Development Assessment Process, Yukon Enrollment Commission, Training Policy Committee, Yukon Heritage Resources Board, Yukon Territory Water Board, Yukon Salmon Sub-committee, Yukon Surface Rights Board, Yukon Contaminants Committee

OBJECTIVES

1. to help realize the NCP's mandate of enhancing linkages between scientists and the First Nation communities.
2. to ensure the interests of Aboriginal people are foremost in any approach when integrating traditional and scientific knowledge.

The overall objective is to ensure that traditional knowledge will be effectively used in the monitoring of the health of Yukon Aboriginal Peoples and their environment. This will ensure that equal respect is given to scientific and traditional knowledge.

DESCRIPTION

The proposed guidelines will set out methods for compiling, storing, and retrieving Yukon First Nations traditional knowledge. It will ensure methods of interpretation, ownership, how the information is used, and getting results back to the communities.

ACTIVITIES IN 1997/98

In 1997 we conducted regional workshops to generate discussions on human health issues pertaining to diet changes within a nation and to incorporate local traditional knowledge into the research analysis and workshop presentations. One of the key recommendations was to have research guidelines in relation to the integration of traditional and scientific knowledge.

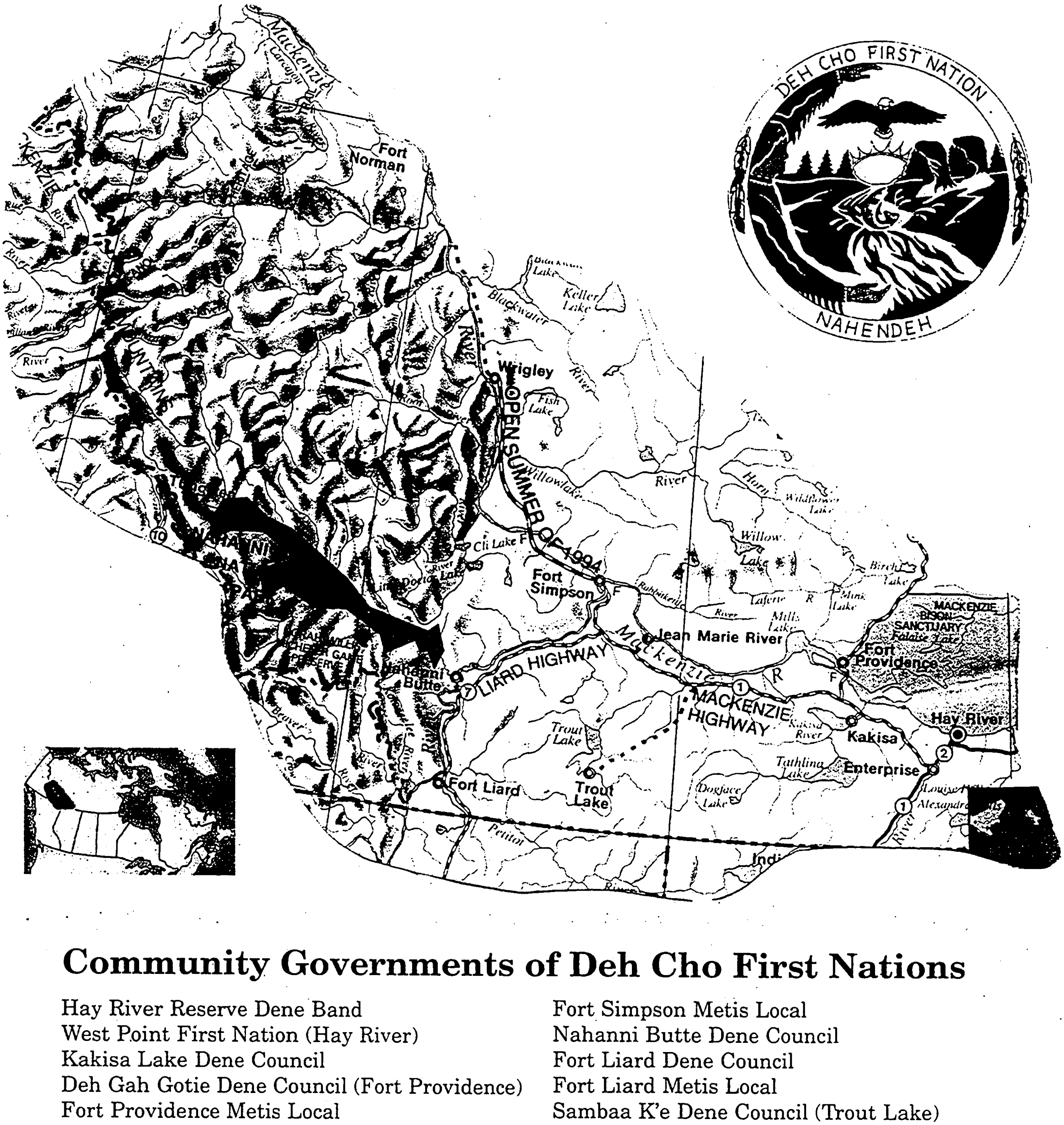
Our project will begin by taking inventory of research that was done in the Yukon and compiling the information, location, and who to contact to assess this information. After the inventory has been completed we will establish a steering committee to begin guideline development.

Expected Completion Date: The target date for draft guidelines is September 1998.

CONTAMINANTS IN THE DEH CHO
A SUMMARY OF FIVE YEARS OF RESEARCH
UNDER THE
NORTHERN CONTAMINANTS PROGRAM

Deh Cho

Traditional Territory of Deh Cho First Nations



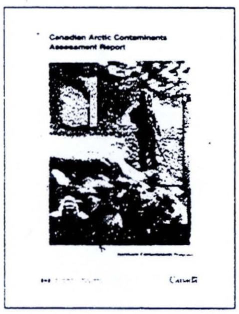
Community Governments of Deh Cho First Nations

Hay River Reserve Dene Band
West Point First Nation (Hay River)
Kakisa Lake Dene Council
Deh Gah Gotie Dene Council (Fort Providence)
Fort Providence Metis Local
Jean Marie River Dene Council
Liidlii Kue First Nation (Fort Simpson)
Fort Simpson Metis Local
Nahanni Butte Dene Council
Fort Liard Dene Council
Fort Liard Metis Local
Sambaa K'e Dene Council (Trout Lake)
Pehdzeh Ki Dene Council (Wrigley)
Begade Shuhtagot'ine Dene Band (Fort Norman)

CONTAMINANTS IN THE DEH CHO:

A Summary of Five Years of Research Under the Northern Contaminants Program

Introduction

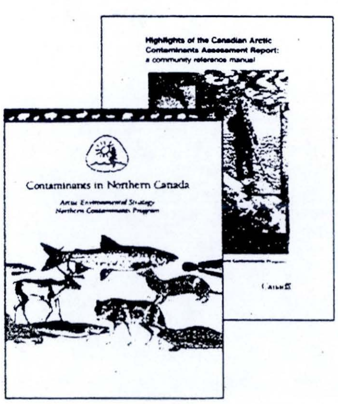


In 1991, the Northern Contaminants Program (NCP) was set up to undertake scientific research about contaminants in the northern environment. There was concern about contaminants in the air, water, land, and wildlife of the North. Since aboriginal peoples eat large amounts of traditional food, there was also concern about the effects of contaminants on human health. In 1997, the results of five years of scientific research across the North were published in a lengthy scientific book called the *Canadian Arctic Contaminants Assessment Report* (CACAR).

The purpose of this report is to:

- Summarize the results of scientific research carried out in the Deh Cho First Nations traditional territory over the past five years as reported in the CACAR; and

- Recommend the kind of contaminants research and monitoring projects that might be carried out in the future by Deh Cho First Nations to protect their traditional lands, waters, and wildlife.



For the reader unfamiliar with the basic definitions and concepts in northern contaminants research, the NWT Metis Nation has published a 16 page illustrated booklet called *Contaminants in Northern Canada*. In particular, this booklet provides excellent explanations of scientifc terms such as bioaccumulation and biomagnification.

For the reader with some scientific training who wants more information, the Department of Indian Affairs and Northern Development (DIAND) has published a 50 page book describing CACAR results across the North called *Highlights of the Canadian Arctic Contaminants Assessment Report: A Community Reference Manual*.

The Northern Contaminants Program (NCP)

Since the 1960's, scientists have known that contaminant levels in animals and people in polluted southern industrial areas are quite high. In the 1970's and 1980's, scientists wanted to compare this to the North. Since there is very little industrial development in the North, the scientists thought that there would be almost no contamination. The scientists were surprised to find that the levels of contaminants in the air, water, and animals of the North were higher than they expected. In 1991, the NCP was created to:

1. Identify where contaminants are coming from and how they get to the Canadian North;

2. Measure contaminant levels in the air, snow, water, soil, plants, wildlife, and people of the Canadian North;

3. Assess the effects of contaminants on the health of northern ecosystems, including human health;

4. Provide information on contaminants to people who live in the North and eat traditional foods; and

5. Promote agreement and co-operation with other countries and the circumpolar community to establish internation controls for contaminants.

The NCP is part of the Arctic Environmental Strategy (AES), which is managed by the DIAND in partnership with five northern aboriginal organizations:

ARCTIC ENVIRONMENTAL STRATEGY • STRATÉGIE POUR L'ENVIRONNEMENT ARCTIQUE •

- Dene Nation
- Metis Nation - NWT
- Council of Yukon First Nations
- Inuit Tapirisat Canada (ITC)
- Inuit Circumpolar Conference (ICC)

After March 1997, funding under the AES for the Community Resource Management Program (CRMP), the Environmental Action Program (EAP), and the Northern Water Network ended. However, DIAND has decided to continue funding the NCP as well as hazardous waste clean-up projects for another five years.

Under this new funding program, priority will be given to NCP research projects that are:

- Strongly Community-Oriented
- Scientifically Rigorous
- Integrated (Combining Traditional Knowledge and Science)
- Multi-Disciplinary (Using a Holistic Ecosystem Approach)

Aboriginal communities are now being encouraged to develop their own contaminants research proposals in partnership with scientists.

The Importance of a Traditional Diet

It has been known for a long time that a traditional diet is healthy. To put the contaminants issue in context, it is necessary to understand the importance of traditional diets. In 1994, researchers from the Center for Indigenous Peoples Nutrition and Environment (CINE) at McGill University surveyed 1,012 aboriginal people in 16 Dene/Metis communities. The survey participants told the researchers that traditional foods are important because they:

- keep people in tune with nature;
- promote sharing in the community;
- are essential to community culture;
- teach children skills in survival, food preparation;
- provide opportunities for learning, patience and other good personal qualities; and
- bring respect from others and build pride and confidence after a successful harvest .

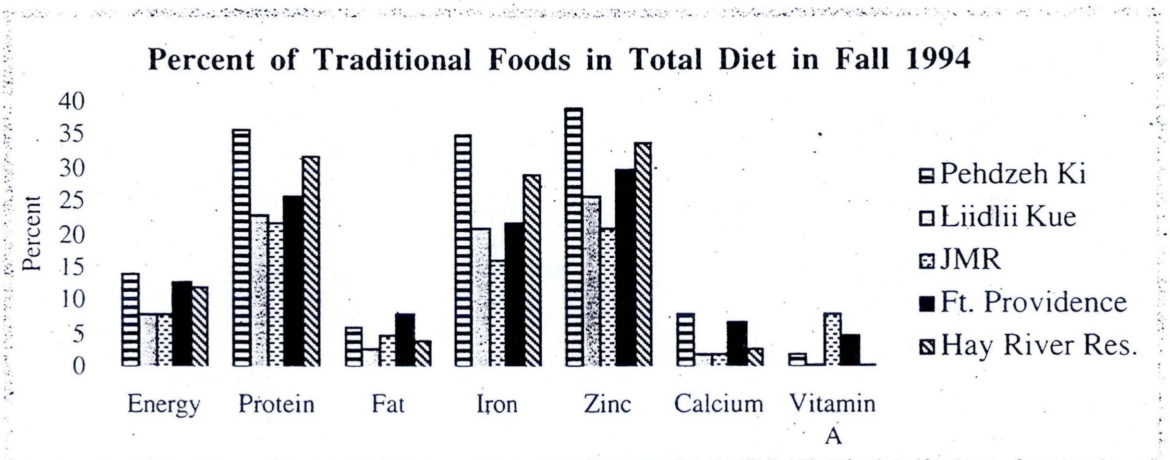
Traditional foods represent the Dene/Metis way of life and are an important part of spirituality. It has also been said that traditional foods are the only kind of food that make people feel strong, and that really keep them warm in winter.

In the Deh Cho, a total of 217 people were surveyed in Pehdzeh Ki (Wrigley), Liidlii Kue (Fort Simpson), Jean Marie River, Fort Providence, and the Hay River Dene Reserve. Dene and Metis in the Deh Cho eat 50 different species of traditional animal and plant foods. In order of priority, the most frequently eaten traditional foods in Deh Cho communities are:

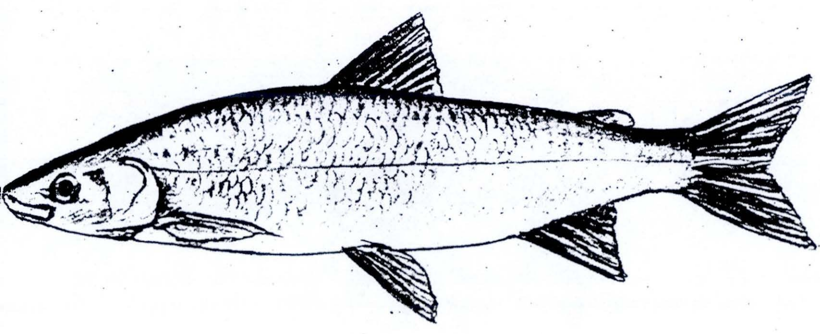
- Moose
- Woodland Caribou
- Whitefish

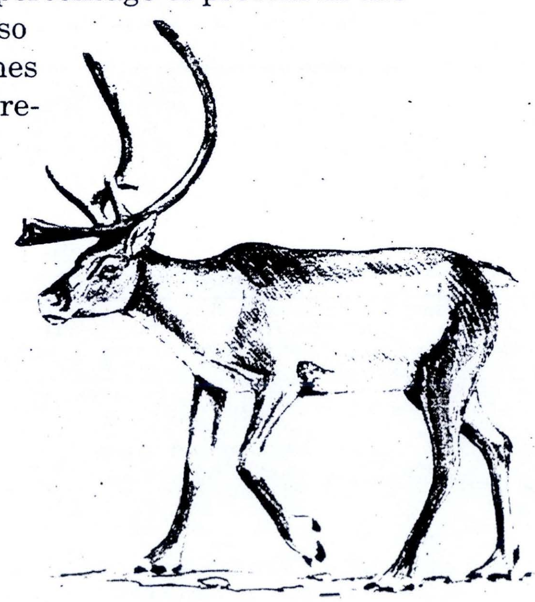
In the NWT, it has been estimated that the average replacement value of traditional foods for each aboriginal family is about $10,000 per year. Traditional foods make up a large part of the total diet of Dene and Metis in the Deh Cho. Figure 1 shows the percentage of traditional foods in the total diet. The total diet includes traditional foods as well as store-bought foods.

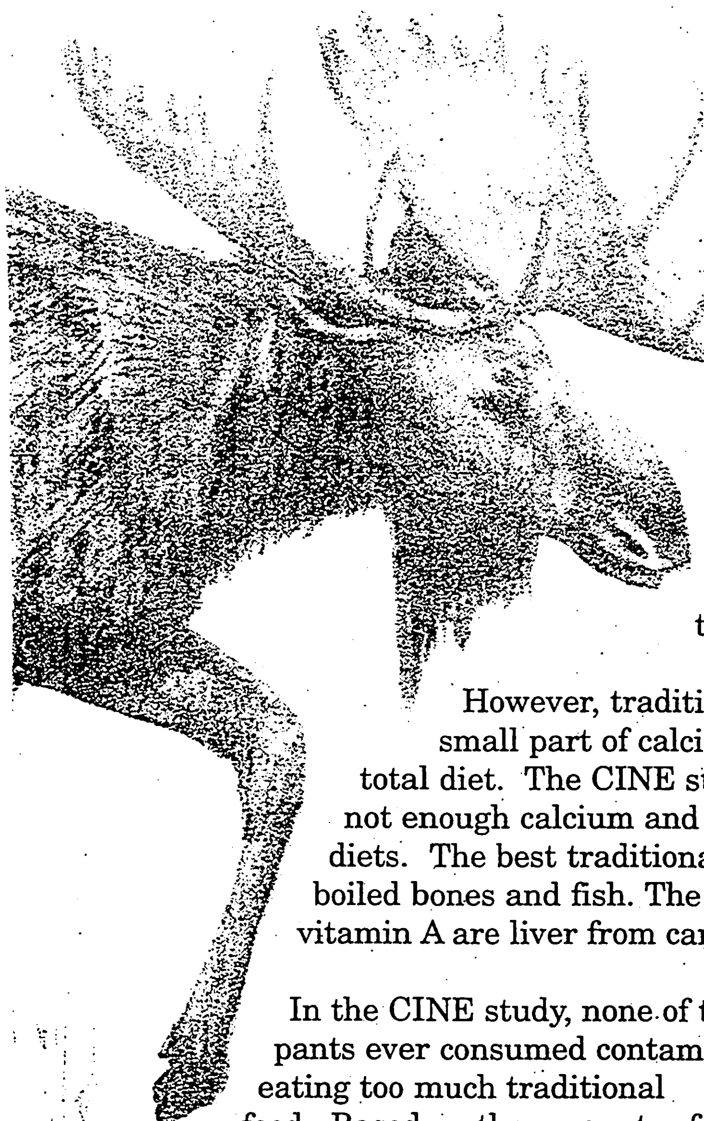
Figure 1



Most traditional foods consumed are meat and fish. This means that traditional foods make up a high percentage of protein in the total diet. Caribou and moose meat also have six times more iron and three times more zinc than a similar serving of store-bought lean pork. Thus, these meats contribute a high percentage of these essential nutrients in the total diet.



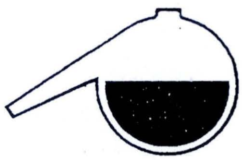




Traditional foods only make up a small part of fat in the total diet. For example, caribou meat has only 1% fat compared to 12-20% fat in beef, pork, and poultry from the store. The CINE study found that Dene and Metis were eating too much fat, most of which came from store-bought foods. Because they are low in fat, traditional foods are healthier than store-bought meat.

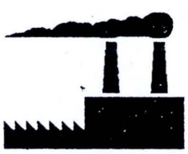
However, traditional foods contribute only a small part of calcium and vitamin A to the total diet. The CINE study found that there was not enough calcium and vitamin A in Dene and Metis diets. The best traditional sources of calcium are boiled bones and fish. The best traditional sources of vitamin A are liver from caribou, moose, loche, and pike.

In the CINE study, none of the Deh Cho survey participants ever consumed contaminants at unsafe levels by eating too much traditional food. Based on the amounts of traditional food people actually eat, the CINE study concluded that traditional foods are safe and good for you!



Organochlorines

Metals



olycyclic aromatic hydrocarbons

Types of Contaminants

A contaminant is a substance that is found in a place where it should not be. This does not necessarily mean that it is harmful, but depending on what it is and the amount that is present, it may be. The main groups of contaminants that were measured in the Deh Cho are:

- Organochlorines (OC's)
- Metals
- Polycyclic Aromatic Hydrocarbons (PAH's)

Organochlorines (OC's)

OC's are manufactured chemicals. They do not occur naturally. OC's found in the North include toxaphene DDT, and PCB's.

Toxaphene and DDT are pesticides that are sprayed on agricultural crops to kill insects. They have been banned in North America and Europe because they are very poisonous and long-lasting. However, they are still used in countries all over South America, Africa, and Asia. In these countries, farmers cannot afford the newer and safer pesticides.

Polychlorinated Byphenils (PCB's) were mainly used as insulators and coolants in electrical transformers. Since they are also very poisonous and long-lasting, PCB's have not been manufactured for over twenty years. There are still large quantities of PCB's left over in old electrical transformers all over the world. PCB's are leaking from many of the transformers that have been abandoned or dumped.

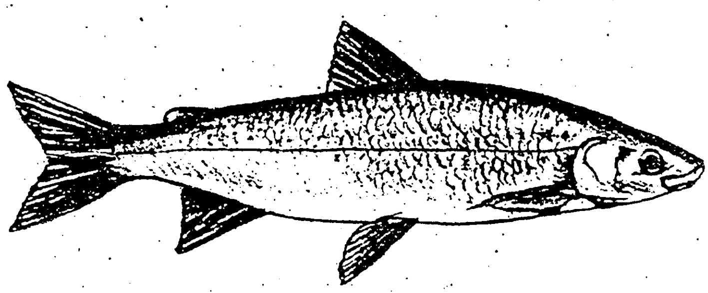
OC contamination is measured as parts per billion (ppb). This is a very small unit of measurement. For example, if an OC were measured at 1 ppb, there would be one-billionth (1/1,000,000,000) of a pound of the OC in each pound of fish.

Metals

Metals are found naturally in rocks and soils and are released into the environment through weathering. Human industrial activities also release metals into the environment. In small quantities, some metals such as iron and zinc are good for plants, animals, and people. "Heavy metals", such as cadmium and mercury, are poisonous to most living things, even in very small doses.

> Mercury is a silver coloured liquid, often used in thermometers. Until the 1970's, pulp mills released mercury pollution. Other human sources of mercury pollution are mine smelters, coal-burning power plants, and flooding from hydro-electric dams. Natural sources such as the weathering of rocks, erupting volcanoes, and forest fires also release mercury into the environment. There are relatively high natural levels of mercury in northern lakes, especially in the rocky landscape of the Canadian Shield.
>
> Cadmium is used in nickel-cadmium ("Ni-Cad") dry cell batteries. The main human sources are burning coal in electrical power-plants, burning garbage, mining smelters, and manufacturing cement. Volcanoes and wind-blown dust are the main natural sources.

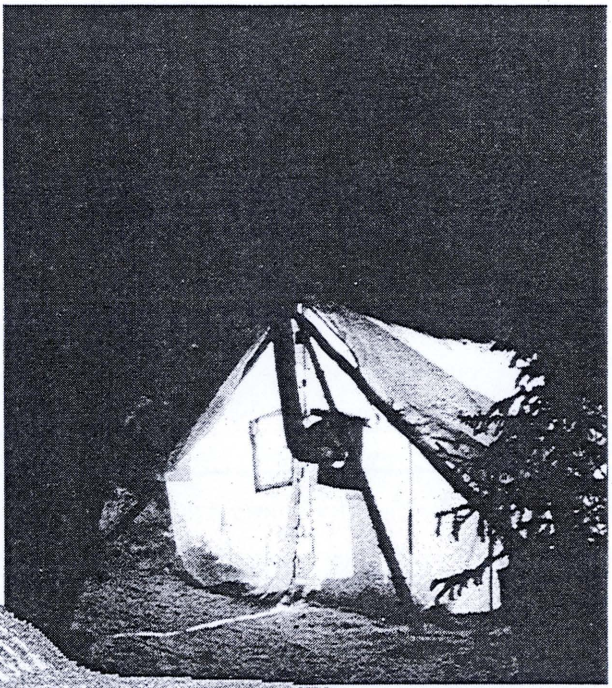
Metals contamination is measured as parts per million (ppm). This is a larger unit of measurement than for OC's. However, metals are less poisonous than most OC's. For example, if mercury were measured at 1 ppm, there would be one-millionth (1/1,000,000) of a pound of mercury in each pound of fish.

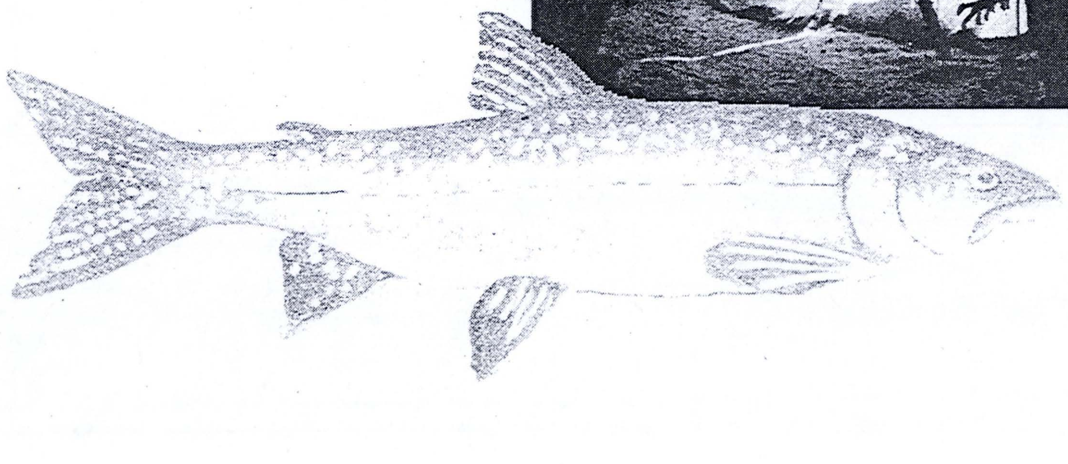


Polycyclic Aromatic Hydrocarbons (PAH's)

PAH's are the by-products of burning, which can be either natural or human-caused. PAH's are mainly produced when oils and tars are burned. However, burning wood also produces some PAH's. Rather than looking at specific PAH's, scientists usually put the 17 most toxic ones into a group called "total PAH."

PAH contamination is measured as parts per billion (ppb). This is a very small unit of measurement. For example, if a PAH were measured at 1 ppb, there would be one-billionth (1/1,000,000,000) of a pound of the PAH in each pound of fish.

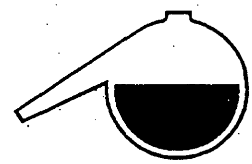




Contaminants in Fish

Most of the scientific research conducted in the Deh Cho looked at contaminants in fish.

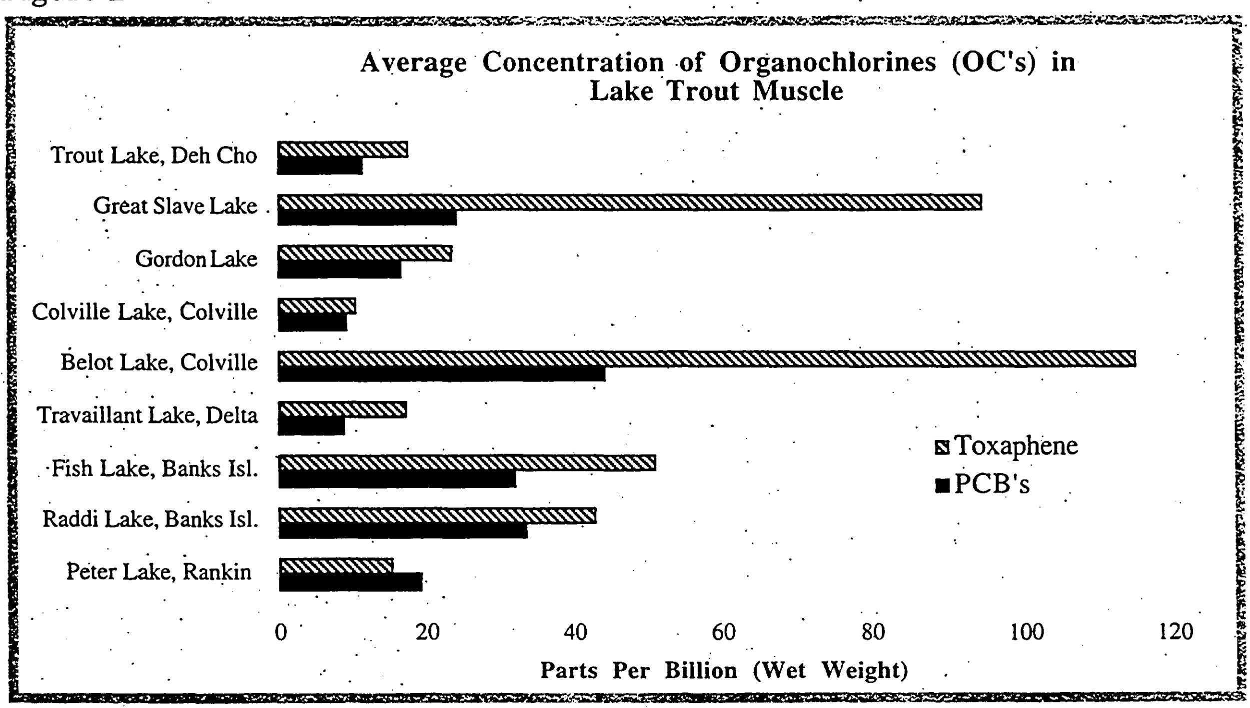
Organochlorines (OC's)

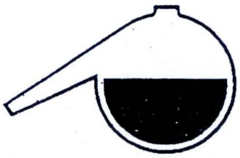


In 1994, lake trout from Trout Lake was tested for OC's. Figure 2 shows the average concentration of toxaphene and total PCB's in lake trout muscle from lakes across the western NWT. In Trout Lake, there was an average concentration of 17.2 ppb toxaphene and 11.2 ppb total PCB's in lake trout muscle. This level is among the lowest in the western NWT.

Scientists think that the reason why some lakes have much higher levels of OC contamination is that lake trout in these lakes eat only fish and no insects. By feeding higher in the food chain, more contaminantsare biomagnified into their diet.

Figure 2





In 1995, burbot liver from Trout Lake were tested for OC's. Figure 3 shows the average concentration of toxaphene and total PCB's in burbot liver. OC's tend to concentrate in fatty internal organs such as liver. In burbot liver, the typical levels of toxaphene and total PCB's are several times higher than typical levels in lake trout or whitefish muscle.

In Trout Lake burbot liver, there was an average concentration of 93.2 ppb of toxaphene and 51.9 ppb of total PCB's. These levels are among the lowest in the western NWT.

In 1992, a Health Advisory was issued for burbot liver only in the Slave River at Fort Smith. Because of the high toxaphene levels, it was recommended that people eat no more than 52 burbot liver per year from the Slave River. No Health Advisories for burbot liver have been issued anywhere else in the NWT.

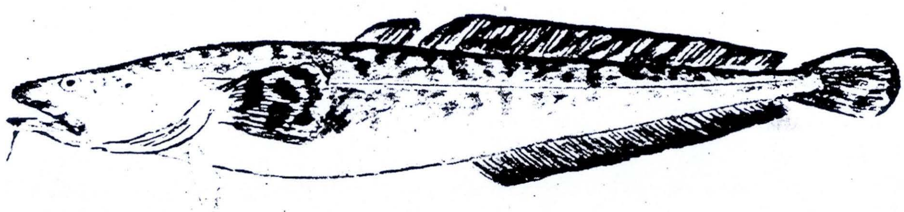
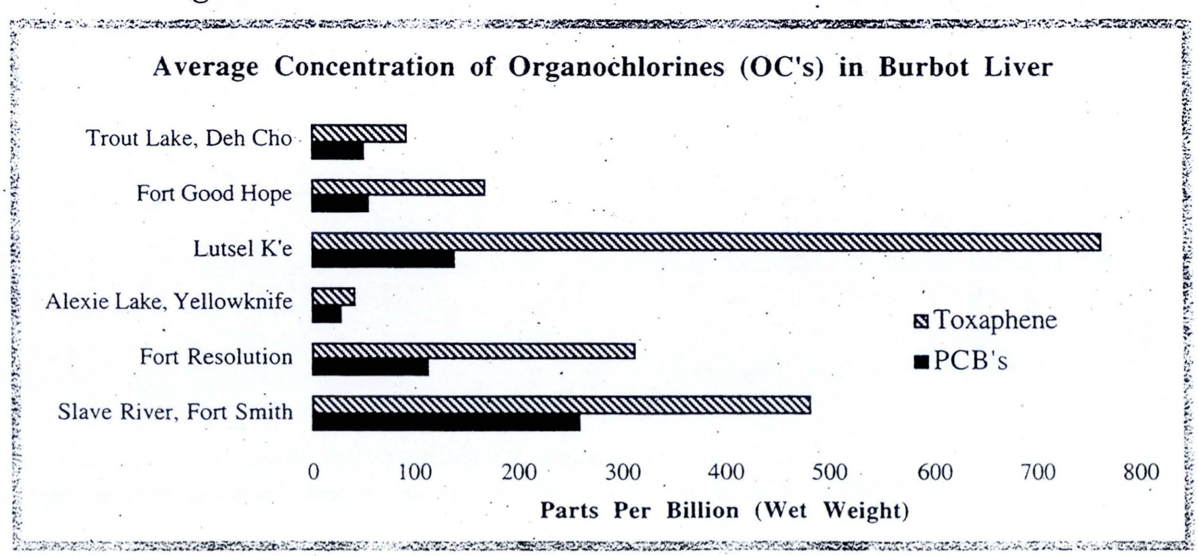
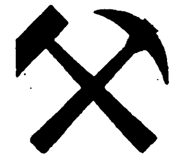


Figure 3

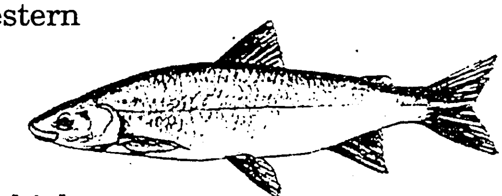


Mercury



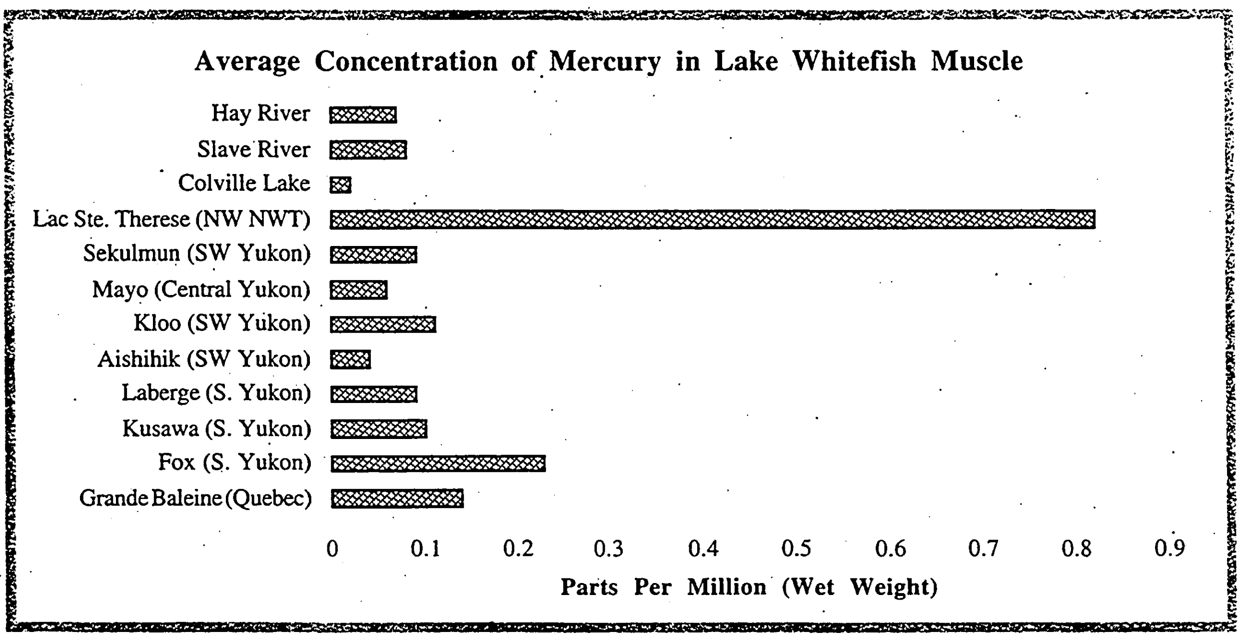
Health and Welfare Canada has set guidelines for safe levels of mercury in fish. The subsistence guideline is 0.2 ppm. This is for people who eat a lot of fish as a traditional food. The commercial guideline is 0.5 ppm. This is for selling fish through the Freshwater Fish Marketing Corporation.

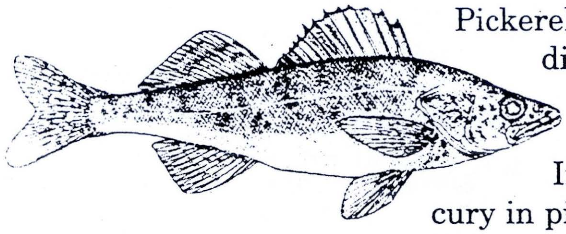
In the Deh Cho, fish were tested for mercury only in the Hay River. Figure 4 shows the average concentration of mercury in lake whitefish muscle. At 0.07 ppm of mercury, lake whitefish sampled in the Hay River have among the lowest mercury levels in the western NWT. The 0.07 ppm level at Hay River is well below the 0.2 ppm subsistence guideline.



Mercury levels in whitefish are generally low because whitefish eat mainly insects. Scientists think that the very high mercury levels in lake whitefish at Lac Ste. Therese, which is just south of Great Bear Lake, are mainly due to the natural weathering of rock.

Figure 4

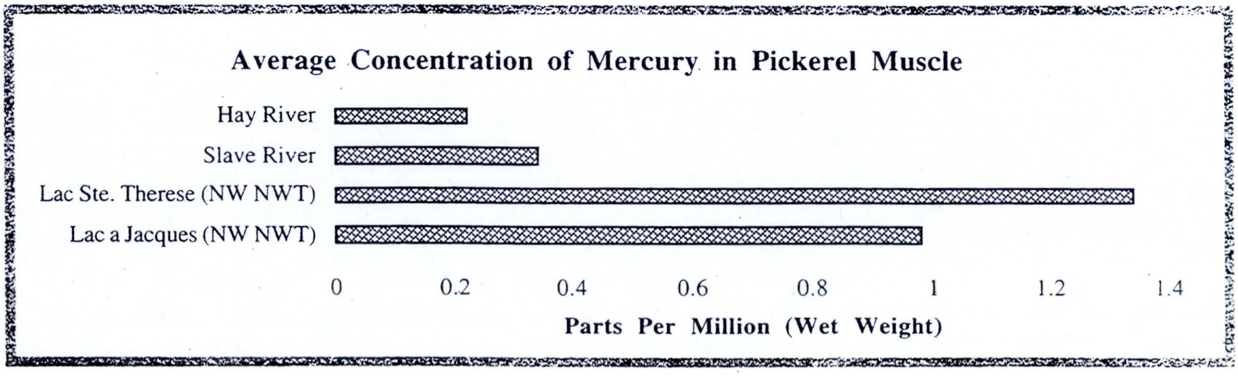




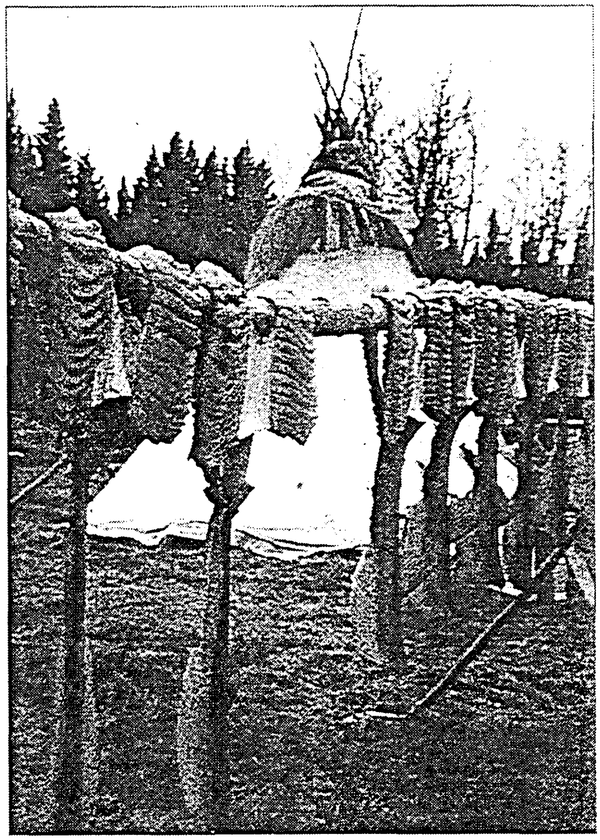
As shown in Figure 5, all concentrations of mercury in pickerel muscle are considerably higher than in lake whitefish muscle. Pickerel eat higher in the food chain than whitefish. The diet of pickerel consists of both insects and other fish. This causes mercury to biomagnify in pickerel.

In the Hay River, the average concentration of mercury in pickerel muscle was 0.22 ppm. This is slightly above the subsistence guideline of 0.2 ppm, but well below the commercial sale guideline of 0.5 ppm.

Figure 5

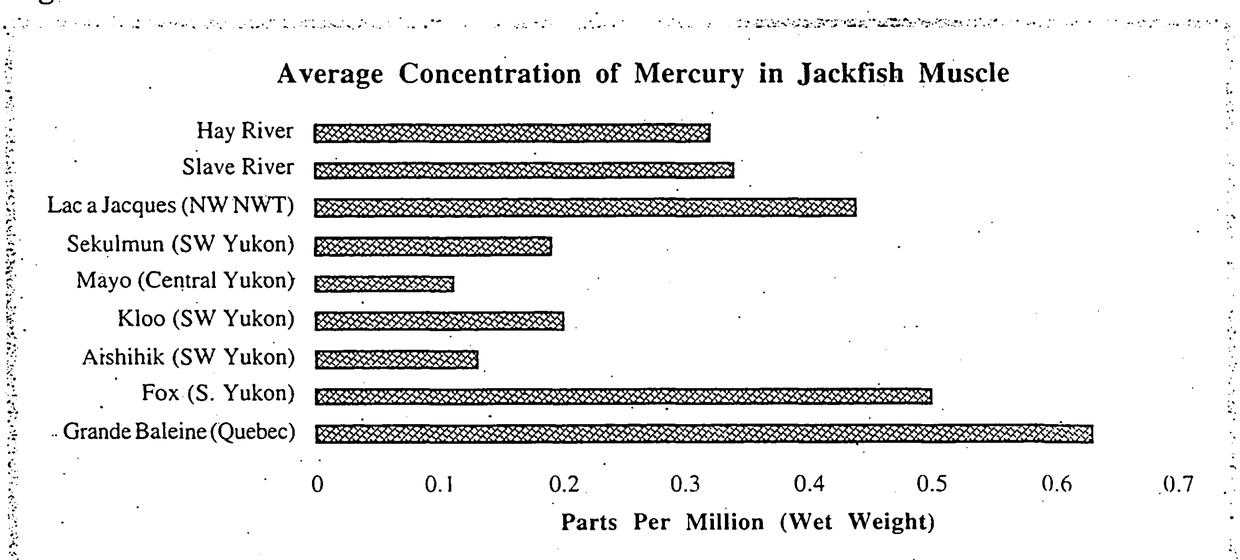


As shown in Figure 6, all the concentrations of mercury in jackfish muscle are a lot higher than in lake whitefish muscle. Jackfish eat at the very top of the freshwater food chain. The diet of jackfish consists mainly of other fish and even small birds and animals. This causes mercury to biomagnify in jackfish.



In the Hay River, the concentration of mercury in jackfish muscle was 0.32 ppm. This is above the subsistence guideline of 0.2 ppm, but still below the commercial sale guideline of 0.5 ppm.

Figure 6



Polycyclic Aromatic Hydrocarbons (PAH's)

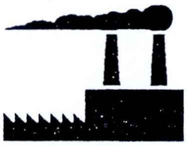


Figure 7 and 8 show the total PAH concentrations in various fish species in the western NWT. In these figures, PAH levels are compared between isolated lakes and the three major river systems (Liard River, Hay River, and Slave River) that drain oil-producing areas in northern Alberta and British Columbia.

There are no significant differences in PAH levels between fish from the isolated lakes and fish from the Liard, Hay, and Slave Rivers. Hence, scientists think that the main source of PAH contamination in the western NWT is the atmosphere, not water transport.

None of the PAH levels are of concern to human health.

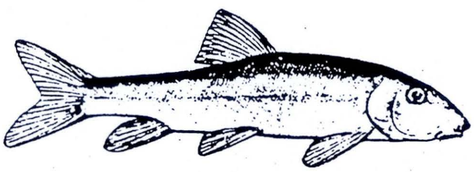


Figure 7

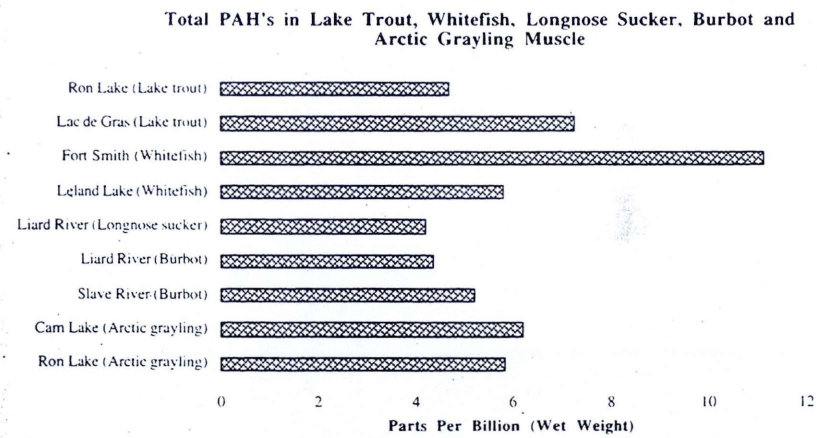
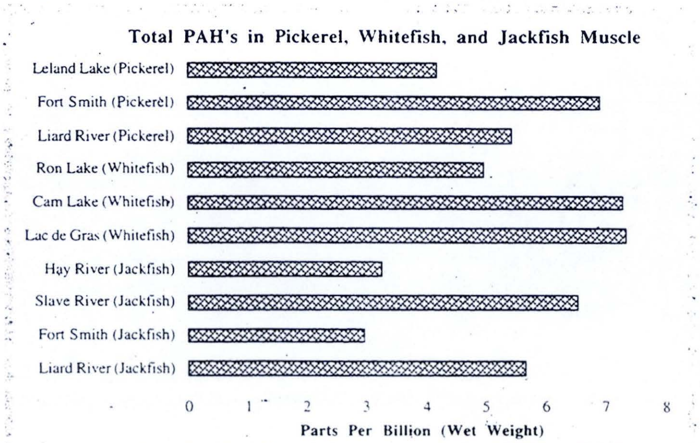
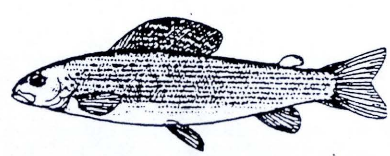


Figure 8





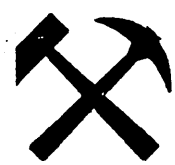
Contaminants in Mammals and Birds

Birds

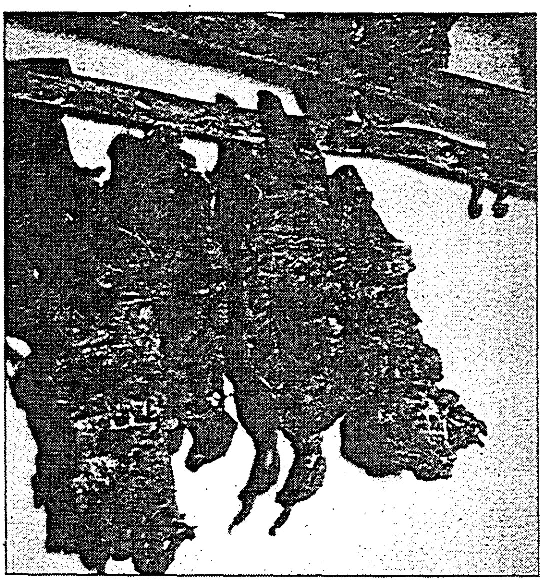
No birds were studied for contaminants in the Deh Cho. Elsewhere in the North, ducks and geese showed higher levels of contamination than ptarmigan and grouse. This is due to the fact that they migrate to the south in the winter. In the polluted areas of the south, ducks and geese are exposed to higher levels of contaminants. However, contaminant levels in birds are generally quite low.

Caribou and Moose

No caribou or moose were studied for contaminants in the Deh Cho. Only barren-ground caribou were studied in the NWT while two herds of woodland caribou were studied in the Yukon. Cadmium was found at relatively high levels in caribou. The highest levels of cadmium were found in the kidneys of woodland caribou in the Yukon.

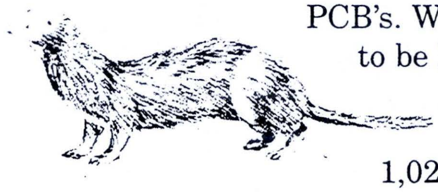


In the NWT, a Health Advisory has been issued for eating caribou and musk-ox kidney. This advisory states that people can safely eat up to 50 kidneys per year.

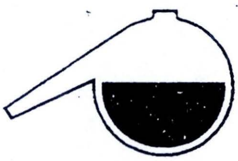


Mink

Mink are considered an "indicator species" for the overall health of the ecosystem. Mink feed high on the food chain and thus biomagnify contaminants. They are also very sensitive to contaminants such as PCB's. When mink are healthy, the whole ecosystem is likely to be healthy.

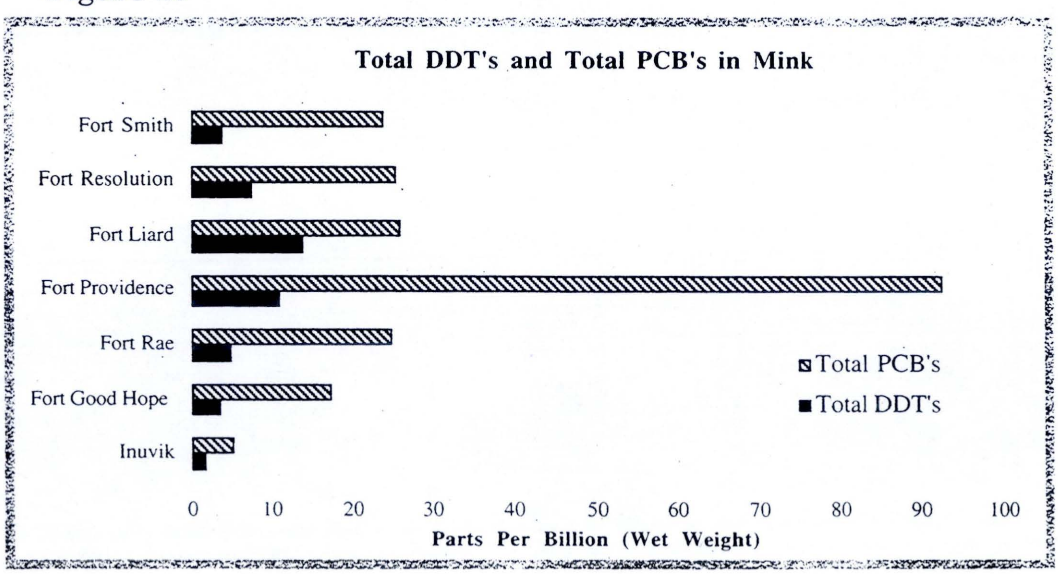


During winters between 1991 and 1995, a total of 1,025 mink were collected from trappers in seven different communities. It was found that OC contaminants level in mink from the NWT were 100 to 1,000 times lower from than in mink from polluted southern areas. In the south, mink have had trouble growing, surviving, and reproducing when contaminant levels from Aroclor (an OC similar to PCB's) reached 1,200 to 2,000 ppb. All mink studied in the NWT are well below that level. As a result of these findings, scientists think that mink in the NWT are healthy



However, Figure 10 shows that mink from around Fort Providence have two to three times higher levels of total PCB's than mink from elsewhere in the NWT. The scientists have not yet been able to explain this. Mink from around Fort Providence do not have a different diet. As well, levels of total DDT's and other OC's were not significantly different from mink in other parts of the NWT.

Figure 10

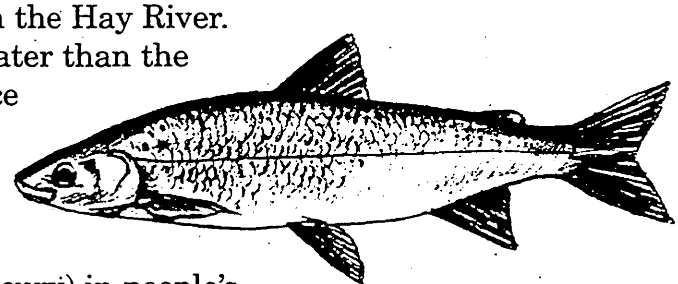


Research Recommendations

The following contaminants research should undertaken in the Deh Cho under the renewed Northern Contaminants Program. The research projects are presented in order of priority.

Mercury in Fish

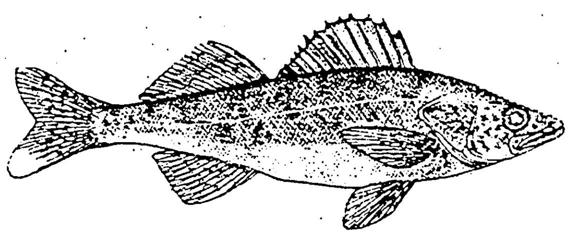
In the Deh Cho, fish were only tested for mercury in the Hay River. Mercury levels in both pickerel and jackfish are greater than the Health and Welfare Canada guideline for subsistence consumption. Only whitefish has levels below this guideline.

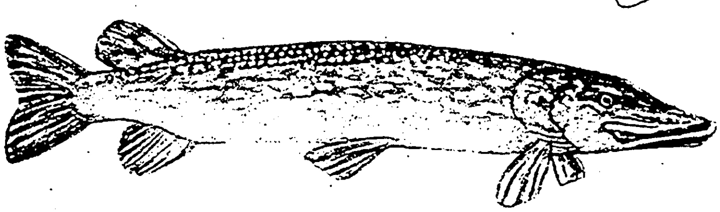


Health and Welfare Canada has set a safe level of 20 ppb for methylmercury (a more toxic form of mercury) in people's blood. If a person's level of methylmercury goes above 100 ppb, Health and Welfare Canada considers them "at risk."

Between the early 1970's and the early 1990's, about one-fifth of adult Dene had blood methylmercury levels over 20 ppb. However, only 2 out of 711 Dene surveyed (0.28%) had blood methylmercury levels above 100 ppb.

All species of fish eaten by Dene/Metis should be sampled for mercury in lakes and rivers that are traditionally fished in the Deh Cho. As discussed below, this work could be combined with sampling for OC's along the Deh Cho (Mackenzie) River.





Cadmium in Caribou and Moose

No woodland caribou or moose kidneys were sampled for cadmium and other heavy metals in the Deh Cho. The highest levels of cadmium have been measured in the kidneys of woodland caribou and moose from the Yukon.

The Deh Cho is next to the Yukon. As well, woodland caribou and moose are among the main parts of the Dene/Metis diet in the Deh Cho. Therefore, it is important to sample cadmium and other heavy metals in woodland caribou and moose kidneys from the Deh Cho. This will determine whether levels are similar to the Yukon or to other parts of the NWT.

Organochlorines (OC's) in Fish

All the fish sampled for OC's in the Deh Cho came from inland lakes. Among Elders and traditional land users, there is a long-standing concern about tumors and meat quality from fish in the Deh Cho (Mackenzie) River. Sampling for OC's in river fish could be combined with a Traditional Knowledge study. This study might show how the quality of river fish has changed over decades. The study might also indicate whether OC's have played a role in these changes.

PCB's in Mink from Fort Providence

Mink from around Fort Providence were found to have total PCB levels two to three times higher than in other parts of the NWT. Scientists were not able to explain this. Another sample of mink should be taken from around Fort Providence and analyzed. This will determine whether the sample was representative of the actual mink population in the area. If the second sample continues to show high levels, then more detailed ecosystem studies of the mink food chain should be conducted around Fort Providence. As well, all possible local sources of PCB's in the Fort Providence area should be examined.

This project was sponsored and coordinated by the Deh Cho First Nations.
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Special thanks to Dene Elders and Chiefs for thier dedication in this process. Carole Mills (formerly Lands and Environment Manager, Dene Nation) and Siu-Ling Han (Environmental Services and Research Division, DIAND) provided extensive assistance and technical support to this project, which is gratefully appreciated.

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The Deh Cho First Nations gratefully acknowledges the Metis Nation for providing illustrations and graphics for use in this document.

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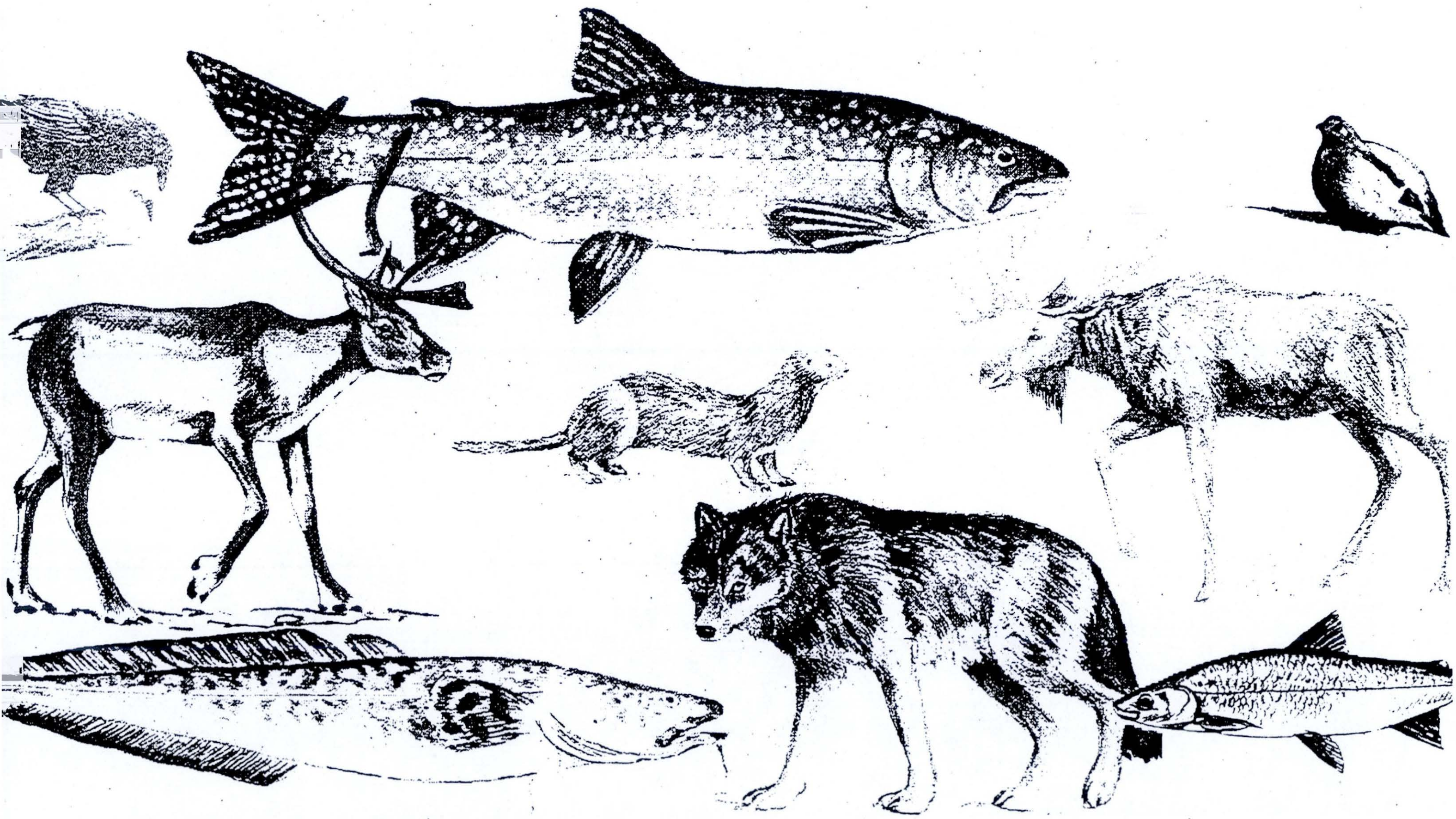
DEH CHO FIRST NATION

NAHENDEH



ELDERS COMMUNITY TOUR

Project Leader: S. Sibbeston, Lands & Environment Manager, Dene Nation

Project Team: Elders: C. Snowshoe,Fort MacPherson, Gwich'in Region; A.J. Kenny, Deline, Sahtu Region; A. Bonnetrouge, Fort Providence, Deh Cho Region; A. Beaulieu, Fort Resolution, Akaitcho Territory Region

OBJECTIVES

1. to disseminate the results of the Elders/Scientists Retreat II, September 9–12, 1997 to the five regions of Denendeh: Gwich'in, Sahtu, Dogrib Treaty #11, Deh Cho, and Akaitcho Territory

2. to provide an opportunity to receive feedback from community members

3. to enhance the awareness of the efforts of scientists to meet and live with the Dene on their land.

DESCRIPTION

In an effort to communicate the results of the first Elders/ Scientist Retreat, February 11–12, 1997, a video was produced as an educational tool for both the Dene and Western scientists. This video has been distributed to the five Denendeh Tribal Councils, and 30 band Elders. The video has been aired numerous times on TVNC, and has been shown at Dene Assemblies and NCP workshops.

The second retreat was held, September 9–12, 1997 at Trout Rock, outside of Yellowknife. Nine Elders, six scientists, and four youth met for four days as a continuation of the first retreat. The Elders felt there was a need to further disseminate the enormous amount of information generated from the retreat to the community members. Thus determining the need for this project.

ACTIVITIES IN 1997/98

A youth, Amos Scott, was hired to assist in preparation for the Elders Community tour. This entailed the preparation of information kits; copies of the Elders/ Scientists retreat reports and *Strengthening the Ties* in Denendeh video, and region specific posters for each of the Elders to use for their tour.

Four Elders who attended the retreats, were contracted out to tour within their respective regions and met with community members to discuss the two Elders/Scientist Retreats.

The Dene National office worked in conjunction with the Band offices to organize opportunities for the Elders to speak about the retreats. Two approaches were taken. Elders either visited communities or took advantage of regional gatherings to give presentations. Charlie Snowshoe, a Fort MacPherson Elder who spearheaded this project, visited four Gwich'in communities and disseminated information about the retreats. Andrew John Kenny spoke at the Sahtu regional contaminants workshop, where community members from Fort Good Hope, Tulita, and Deline were present. Albert Bonnetrouge visited and presented at the Hay River Dene Reserve and Fort Providence. And Angus Beaulieu spoke at the Intergrated Resource Management, Community Visioning Workshop with community people present from Fort Resolution.

The most effective communication vehicle was to speak at meetings that are already organized, with leaders and community members present. There were some difficulties in respect to the amount of traveling that was required by the Elders, therefore their attending regional meetings was less taxing and gave them more time and energy to speak with people present at the pre-planned meetings.

In general, the response from the communities has been very supportive of the initiative.

Expected Project Completion Date: Project is complete.

ELDERS/SCIENTIST RETREAT II : "STRENGTHENING THE TIES IN DENENDEH II"

HOSTED BY:
DENE NATION

SPONSORED BY:
NORTHERN CONTAMINANTS PROGRAM

Report prepared by:
Stephanie Sibbeston, Dene Nation

EXECUTIVE SUMMARY

Four Dene youth, nine Dene Elders and six scientists attended the retreat at Trout Rock, September 9–12, 1997. Trout Rock was an ideal place to hold the retreat due to historical significance as a traditional gathering place for the Dene. The close setting enabled scientists to appreciate the Dene and provided an opportunity to live with them. The personal setting gave an opportunity for the Elders and youth to learn more about the scientists in an environment in which they were comfortable.

This report summarizes the questions and concerns that the youth, Elders and Scientists had about each other, answering such questions as "What are respectful ways of confirming traditional knowledge?", "How to involve Elders and youth in scientific research?".

The following recommendations were made during the retreat were:

- elders should be compensated for the knowledge that they contribute
- elders want to be asked what questions they have themselves, especially about contaminants
- elders want to be kept up-to-date on the studies that are being done
- youth have an important role with communication between Elders and scientists because they have their feet in both worlds
- scientists must have patience, respect and courtesy for the people, the knowledge and the land
- youth need to be utilized in the research, to build the capabilities of the communities
- elders must be recognized as Dene scientists
- we must learn to be patient when the Elders speak; often they say things in a long format
- scientists should let people know that what they are trying to do is because they care about the land and want to protect it too
- scientists should let people now clearly what it is your study is trying to accomplish in the bigger picture, and how it will be useful to northerners

INTRODUCTION

The objective of the second retreat was to continue from the trust and respect we built at the first retreat, by providing a relaxed and informal atmosphere for an exchange to occur among Elders, youth and scientists. We have heard that many scientists would like to involve communities in their research and incorporate traditional knowledge. In addition we have heard the communities say they want to be involved and have a lot to contribute to science, which can save both time and money.

The question is "How do we do this?". The Dene National Office has been the primary link between the communities and the scientific community, particularly within the Northern Contaminants Program. Therefore it was a natural step for the Dene National Office to host retreats where Elders and Scientists could meet and exchange information and ideas. The first Elders/Scientists retreat was at the Sah Naji Kwe Camp, February 23–24, 1997. The purpose of this retreat was to build trust and respect between Dene Elders and scientists. A video and report from this first retreat has been produced and distributed to all Dene communities. Additional copies can be obtained by contacting the Dene Nation.

This report is based on the second Elders/Scientist and youth retreat that we hosted, September 9–12, 1997 at Enodah Wilderness Camp, Trout Rock, NT. At this second retreat we worked at maintaining this trust and worked on taking a second step of getting to know each other by asking questions related to research in the north. This is a summary account of the discussions that took place while there.

ACKNOWLEDGMENTS

The Dene Nation wishes to thank the Elders, youth and scientists for their participation at the retreat. In addition we would like to thank the following individuals for their hard work and active participation in this retreat.

Retreat Planning Committee and Facilitators:

Stephanie Sibbeston, Dene Nation
LeRoy Bloomstrand, Dene Nation
Judy Sabourin, Dene Nation
Jody Walker, GNWT Health

Special thanks to the following people for contributing to the planning and report writing:

Dene National Chief Bill Erasmus
Shelly Anderson, Dene Nation
Eric Davey, Dene Nation

Denendeh Environment Committee:

Pat Simon/ Maurice Boucher
Margaret Donovan
Chief Gordon Yakelaya
Siu-Ling Han, DIAND

Sincere thanks and appreciation to the following organizations who, with their support made this retreat possible:

DIAND, Northern Contaminants Program
Enodah Wilderness Camp
Indivisual Productions
Discovery Inn
Interpreters: Joe Tambour and Laura Tutcho

SYNTHESIS OF DISCUSSIONS

"Even though we have our differences we need to think of ourselves as one people, we're here for a purpose and that is to work together."

Alexis Arrowmaker, Snare Lakes
1st Elders/Scientists Retreat

Partnership - the difference between giving and sharing

The very basis of these Elders/Scientists retreats has been to go beyond the recognition that both the Dene and the scientists want to work together. We are now at the point of asking the question of "How can we work together?" To find ways to work together we must first remove the blindfolds that each of us wear. We can do this by learning more about each other, learning to trust each other, and by asking and answering each other's questions.

At this retreat we asked the youth, the Elders, and the scientists what questions they had of each other. From there we attempted to answer some of those questions:

"What can we (the scientists) give back to you for all of the stories and knowledge you (the Elders) have given us?"

- give respect to the people who provide you with the knowledge
- give respect to the land from which you take samples
- give equal value to Dene knowledge that is given to scientific knowledge
- get to know the people in the communities
- respect that the Elders believe the stories they are telling you and let them know that. (The stories may seem far fetched and hard to believe, but they are not much different from the stories of turning water into wine, and resurrection of people after three days.)
- elders should be compensated for the knowledge that they contribute

"How do Elders want to be involved in scientific research?"

- elders want to see how contaminants are found in the fish and wildlife that are sampled
- elders want to be asked what questions they have themselves, especially about contaminants
- elders want to be kept up-to-date on the studies that are being done
- some of the scientific research that is conducted need not be done, if instead they consult with the Elders, for example radio collaring the caribou reiterated the same information that Elders have been providing.

"How do Elders want the youth to be involved in scientific research?"

- youth have an important role with communication between Elders and scientists because they have their feet in both worlds
- youth need to be at the meetings to hear, learn, and observe, once they are informed they will become interested and want to be involved
- youth are our future leaders, who will influence the types of science done in the future

"What are the expectations that the youth and Elders have for their involvement in scientific research?"

- scientists must have patience, respect and courtesy for the people, the knowledge and the land
- scientists need to re-educate and relearn in the Dene way
- youth need to be utilized in the research, to build the capabilities of the communities

- scientists need to make an effort to get to know northerners, i.e. stay in a community longer than the time of your meeting
- elders must be recognized as Dene scientists
- elders must be compensated for their knowledge and to treat the knowledge equally
- youth and Elders must be given the opportunity to be invited to meetings, and to be involved and consulted in studies from the very beginning
- We must learn to be patient when the Elders speak, often they say things in a long format
- elders should be provided with information such as the outcome of the information gathered, and what it will be used for
- scientists should let people know that what they are trying to do is because they care about the land and want to protect it too
- change from just taking information to working together with both traditional knowledge and scientific knowledge
- scientists should let people know clearly what it is your study is trying to accomplish in the bigger picture, and how it will be useful to Northerners

Removing the blindfolds

What is the make up of the blindfolds we wear? In order to remove them, we need to answer this question, we need to know how they got there for both the Dene and the scientists.

The Dene have had a long experience of scientists studying in the north. The history and nature of the relationship is still remembered, and affects the relations today. Many people mistrust scientists, over and over again at meetings we hear about researchers who have come up north, asked a lot of questions, took samples, didn't tell people what they were doing, and were never heard from again. Rarely were reports sent to the communities.

By looking at the problems and concerns from the people we can see the ways to improve and build trust.

> *"A lot of research has been done with our people. Our people have been giving and giving information, and we were never given anything back. This is what has been happening. Bob Phillips and Jody Walker have been to this place where we are from, this is what is important about this workshop. If you want to help the people, you need to get to know them first."*
>
> Elder Mary Teya, Fort MacPherson

The fabric of the blindfolds scientists wear is the lack of knowledge they have about the Dene, their culture, their values and their beliefs. Those who believe traditional knowledge is not useful are those who know very little about the culture and the knowledge that Elders hold. By coming to this type of retreat, scientists learn about who we are as a people and how valuable and useful the knowledge is. At the same time, Dene need to learn and understand how scientists work, and why they do research.

Communication

The basic requirement for communication is knowing how to make the initial contact with people. Although some communities have built up their capacity to conduct community based studies, it remains primarily the scientists who are initiating the research in the north. A majority of these scientists lack the understanding of the basic structure of the regions of Denendeh, the communities and the people. Videos produced from these retreats will help scientists understand the Dene better.

At the retreat, a list of organizations was synthesized, identifying who should be contacted/consulted if scientists are planning on conducting research within their region:

Tribal Councils
Band Offices
Renewable Resource Councils
Hunters and Trappers Associations
Elders Councils
Community Health Representatives

The Dene Nation over the last several years has developed a Denendeh communication strategy. One component of the strategy deals with the mode of communication, the following are listed in order of the most effective to the least:

- personal/one-on-one
- workshops/meetings
- "interpreted" briefing notes
- videos
- fact sheets/resource materials
- technical documents
- electronic access

One option is to contact the Tribal Council/ Band office to find out when the next assembly or special gathering will be held and ask if you could speak at it. This approach will more effectively reach the key people you would need to communicate with, and would be more successful than trying to hold your own community meeting. Although there may be hesitance towards inviting yourself to a meeting, it would have better results.

Respect

"Respect: One showed respect for oneself and for others, for leaders and Elders and those with special skills, and for the land and all living things."

Lesley Malloch,
Dene Government Past and Future, 1984

The Elders believe that everything is alive, the trees, the birds, the animals, the water, and even the air. We must pay respect to all these living things. People are not supposed to take anything from the land without giving something back. Respect is shown by returning something of yours to the land from which you have taken.

Elders at the retreat said that the reason animals are disappearing is because we are always abusing/touching the wildlife, and taking from the land. About 50 years ago, there was a man, in the Sahtu region, who hit a caribou with a stick, and only now the caribou are starting to come back to that area.

The Elders do not like the collaring and tagging of animals, because you are not supposed to touch them unless you are going to harvest them. Handling animals is unnecessary, unless you plan on eating them, and it is believed that if the animals are not respected they will not return.

Scientists, who attended the retreat, are beginning to learn that the knowledge Elders hold can be very useful. For example, the results from collaring Bathurst caribou cows are very similar to what Elders have been saying all along. It is these types of things that show Elders should be trusted and respected for their knowledge.

Traditional Knowledge

"It is there [Traditional Knowledge], its just that we have to get it out, its like we are books."

Joe Tambour, Hay River Dene Reserve

Our Elders have a wealth of knowledge that has been passed down from generation to generation, and the knowledge they have gained over time. Each Elder holds a book of knowledge, but unless you have help you won't know where to find the information you need. It is only by getting to know the people, will they begin to trust you enough to let you know the knowledge you are seeking.

At the retreat, the Elders spoke a lot about the changes on the land and water that they have seen during their lifetime. A Sahtu Elder has been a captain on a boat for most of his life, he talked about the changes in the water levels over the last 50 years. Another Elder from Akaitcho Territory was telling us about the changes on the land from the pulp mills in Alberta, and from the debris of the Cosmos 954 satellite that re-entered the earth's atmosphere over the south eastern portion of the NWT. Another Elder spoke about the change in climate, winters used to get down to –60% C, now the temperature only drops down to –40% C. This change in temperature has affected the quality of the fur bearing animals. Changes in fish populations have also been observed. In Yellowknife Back Bay, trout are starting to come back, but the Coney have yet to return. The Elders believe that the water and food in the area was contaminated and this has caused the fish to move somewhere better. The trout that gave the name to Enodah, too, have also left.

Knowledge can also be provided about possible contaminated sites, or the negative effects of pollution on wildlife. An Elder, from Akaitcho Territory also spoke about the water six to seven miles from Trout Lake which is turning an orange-red colour. He told us, that this water comes from a mine, and a sign has been constructed warning people not to drink the water.

Many people when designing research projects make the choice to not incorporate traditional knowledge into their work, with the notion that traditional knowledge will not be useful or applicable. Those people who make those decisions, are those who have not tried to use traditional knowledge, and who don't know the value of traditional knowledge.

Environmental Issues

On the second day of the retreat, the participants broke out into three groups; concentrating on wildlife, health and environment. The following are short summaries of some of the discussions that occurred.

Wildlife

The main concern voiced by the Elders about the wildlife was towards activities carried out by the scientists studying wildlife. The collaring, tagging, tattooing, the handling of wildlife, these are the things the Elders feel are causing harm to the wildlife. The Elders say that the collars drive the rest of the herd away and the alienated animal will suffer after it has been abandoned. The collar wears away the fur on the neck and becomes raw, then infection sets in ... eventually killing it.

Contaminants

"Contaminant: A substance that is found in a place where it should not be. This does not necessarily mean that it is harmful, but depending on what it is and the amount present, it may be."

(Han and Adare, 1997)

Within the environment break out group, Siu-Ling Han and myself spoke shortly about the general background about contaminants; what are contaminants, where they come from etc. The majority of concerns about contaminants are those that are local and visibly apparent. Concerns were raised about:

- Saw Mill Bay – there are thousands of empty oil/gas drums lying around
- Con Mine – orange-red water is being emitted into Great Slave Lake
- present-day radiation exposure from Port Radium
- present-day radiation exposure from Stark Lake Mine
- present-day radiation exposure from Cosmos 954 Satellite Crash
- The Peel River Water Shed

Health

The main health concern due to environmental issues were health effects from working at Port Radium mine. People were not provided with the proper protection and were not warned about the health effects from uranium exposure. Elders spoke about how the workers used to sit on bags of uranium ore and have their lunch.

The Elders and youth spoke about the sense of hopelessness they feel when they think about pollution and contaminants in the north. "If the air is polluted than what is the point of maintaining a healthy lifestyle of eating right, staying sober, etc." There is a sense of despair, frustration and confusion. These feelings can be turned around, and are being turned into empowerment as more and more regions and communities are developing their own contaminant studies, and becoming involved and changing the course.

Youth

"The land and the environment are our future, we have to be involved."

At the first Elders/Scientists retreat, we did not have any youth involved and it was duly noticed. The Elders felt it was important for youth to be there, to learn both from the Elders and the scientists, and to make contributions too.

Four youth attended the workshop. At first their participation was limited and they were unsure of their involvement at the retreat. One purpose of the youth was to act as a link between the Elders and the scientists. But in order to do this the youth said that they need to learn more about their traditional ways. The Youth representatives also told us that they need to feel needed and they should be encouraged by us and by the communities they live in.

RECOMMENDATIONS

Communities:

- community leaders, such as Chiefs and Tribal councils, Committees, or Boards need to effectively pass information to community members
- inter-agency committees would be useful in communicating information exchange in communities

Youth:

- it is important that youth when they are very young learn to have a sense of appreciation and respect for their heritage.
- elders could reach out to youth, to teach readings in first official Dene language, through the bible, Dene stories written in their language, legends, history ...etc. ...
- the land and the environment are our future, we have to be involved
- when youth are asked for their opinion, youth feel good about being involved and discussing what they think are important issues that will affect their future
- information should be distributed to youth.
- it is important that youth know traditional ways in order to become strong.
- youth need encouragement from their Elders, leaders, parents, friends, to speak out and participate in actions and decision making about community issues, including environmental concerns.
- patience, respect, courtesy should be acknowledged by the scientists and youth in regards to working with the Elders. This information can not be given away freely, it's a lesson that needs to be learned, with patience, respect and courtesy

Dene Nation:

- act as an information base for abnormalities of animals in conjunction with the Hunters and Trappers Association and local Renewable Resources officer.
- seek communication links
- youth are learning both the Dene and English language and Western science terminology
- schools for Elders to help/learn in communicating with scientist and other people in government agencies, churches, etc....with different aspects to traditional knowledge.
- strengthen communication pathways in the communities
- Elders/Western Science/Youth Centres
- enhance Elders knowledge in the field of Western Science, invite Elders/youth into science field
- look into setting up some kind of inter-agency committee to represent and report to various boards,

Health, Wildlife and Environmental committees, to make recommendations, so information may be obtained through this pathway

Scientists:

- scientists should work with Elders, and exchange knowledge from both sides with respect, to strengthen the ties.
- scientists should be more involved, always give results back, do not wait a couple of years. The Elders mentioned that it takes a least two years to receive a report. Should keep in contact throughout the duration of research/studies.
- keep the lines of communication open between sampling and results communications
- personal contact is important between community and Scientists/researchers
- the scientist's need to be re-educated to learn the Dene way, and what the Dene want
- be open-minded about information given and taken from the Dene, do not be afraid to ask questions, to obtain a better understanding.
- Gathering information from Dene medicine to combine with Western Science

Wildlife:

- the collaring of wildlife is not accepted by Dene, if scientists want to know where the animals go, they should ask the Dene people of that area.
- tattooing of wildlife is also unacceptable
- the wildlife should not be disrespected
  examples:
  - collars, testing, giving needles/tattoos, studying up close is not good for animals
  - in the past, a caribou was hit with a stick, then the caribou herd which was in that area moved (went elsewhere for awhile)
  - the Elders are concerned for the well being of animals, they feel that studies and probing of wildlife is not good for the animals

Health:

- learn traditional knowledge from Elders in relation to spirituality, inner strength, outer strength, development of understanding
- elders that are dying of cancers, diseases, is it from contaminants?
- youth should be more involved with traditional ways, this would increase their health in several ways, because they would feel strong when they know about their background and grandparent's language.

Communication:

- communication is an important tool in working together, especially in smaller groups
- it is important to have basic contaminants information available to all parts of the community.
- monthly newsletters should be started up

Workshop Structure:

- elders feel that it should be the same people to carry through this workshop from start to finish, including following retreats that are upcoming.
- there need to be longer workshop days to cover the many concerns raised
- youth and Elders workshop need more funding from other organizations
- elders would like to be paid equal wages such as the scientists for sharing their knowledge.
- the same Elders from the first retreat should be there for the whole duration of the Elders/scientist workshops.
- the retreat should be during the summer months when it is warm.
- the next retreat should be in a rural community location such as the Tl'oon dih healing camp
- elders think that retreat participants should keep working together to resolve and address common issues/concerns that need to be dealt with. (Elders/ youth/scientists)
- elders would like to see work done by the scientists, lab results from testing, i.e. testing of contaminants, measurement of contaminants

REFERENCES

Malloch, Lesley. 1984. *Dene Government Past and Future,* Friesen & Sons. p.16.

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APPENDIX A

AGENDA
ELDERS/SCIENTIST RETREAT II
SEPTEMBER 9-12, 1997

Tuesday, September 9th, 1997

9:00 a.m.- 1:00 p.m.	Departure to the Enodah Wilderness Camp
2:00 p.m.	Feeding The Fire Ceremony
2:30 p.m.	Introductions
3:00 p.m.	"Strengthening The Ties In Denendeh" Video
5:00 p.m.	Checking the Fish Nets
Evening	open: moose hunt, berry picking, free time

Wednesday, September 10th, 1997

8:30 – 9:30 a.m.	Breakfast
9:30 – 10:00 a.m.	Checking the nets
10:00 – 12:00 p.m.	Break out into three groups to discuss questions and expectations people have: 1) Youth 2) Elders 3) Scientists
12:00– 1:30 p.m.	Lunch
1:30 – 3:30 p.m.	Break out into three groups, mixed, to work on answering questions and meet expectations 1) Health 2) Wildlife 3) Environment
4:00 – 5:00 p.m.	Reconvene into one large group to give summaries of what was covered in the afternoon
Evening	Open: moose hunting, berry picking, free time

Thursday, September 11th , 1997

8:30 – 9:30 a.m.	Breakfast
9:30 – 10:00 a.m.	Checking the nets
10:00 –12:00 p.m.	Break out into the same three groups to work on three specific questions: 1) Health 2) Wildlife 3) Environment
12:00 –1:30 p.m.	Lunch
1:30 – 3:30 p.m.	Break out into two groups 1) Elders 2) Youth & Scientists
4:00 – 5:00 p.m.	Reconvene into one large group to give summaries of what was covered in the morning and afternoon
Evening	Open: moose hunt, berry picking, free time

Friday, September 12th , 1997

8:30 – 9:30 a.m.	Breakfast
10:00 – 11:00 a.m.	Review of main recommendations, thank yours and gift giving.
11:00 – 11:30 a.m.	Feeding the Fire Ceremony

Flights returning to Yellowknife

* *The retreat was meant to have an informal atmosphere, so no definite agenda had been set in advance. The above agenda was based on what occurred at the retreat.*

APPENDIX B

PARTICIPANTS LIST

Elders	
Charlie Snowshoe	Tetlit Gwich'in
Elizabeth Collins	Tetlit Gwich'in
Mary Teya	Tetlit Gwich'in
Andrew John Kenny	Deline First Nation
Isadore Yukon	Deline First Nation
Pete King	Deninu K-ue First Nations
Joe Martin	Yellowknives Dene First Nation
Jonas Fishbone	Yellowknives Dene First Nation
Stanley Bertrand	Acho Dene
Youth	
George Stewart	Tetlit Gwich'in
Matthew Betsidea	Deline First Nation
Priscilla Bonnetrouge	Deh Gah Got'ie Dene Council
Dennis Drygeese	Lutsel K'e Dene Council
Scientists	
Tim Johns	CINE, Montreal
Jody Walker	GNWT Health, Yellowknife
Bob Phillips	Environmental Health Officer, Yellowknife
Siu-Ling Han	DIAND, Ottawa
Suzanne Carrier	RWED, Yellowknife
Bob Bromley	RWED, Yellowknife
Interpreters	
Joe Tambour	Hay River Dene Reserve
Laura Tutcho	Yellowknife
Film	
Tookie Mercredi	Indivisual Productions Ltd.
Dene Nation Staff	
Stephanie Papik	Dene Nation
Leroy Bloomstrand	Dene Nation
Judy Sabourin	Dene Nation

APPENDIX C EVALUATIONS

What did you enjoy about the retreat?

- The discussions about saving our environment as a whole team, as scientists, Elders and youth
- Sharing the Dene spirituality, traditional knowledge, and wisdom through legends, stories, and tales
- How everyone spoke their minds
- Youth's encouragement from Elders and scientists
- I learned a lot about the environment and some things I didn't know before. I enjoyed every minute of the retreat
- Everything – especially going out on the land and hunting
- A perfect setting for thought provoking discussions on how traditional knowledge is being applied to environmental contaminant crisis. It gave me an opportunity to experience Dene culture first hand, and consequently has changed the way that I implement southern standard in the north.
- The people – good mix, Elders, scientists and youth
- The location – great, the historical comments were neat. The camp was well organized
- The activities – especially drum dances, prayer songs and of course the hand games!
- The food – caribou, fish, bannock ... yes
- Great facilitators
- It was a nice place to have the retreat out on the land. Also everyone did things to gather and helping each other
- Opportunities for one-on-one and small group conversations, sharing tents, having time to go walking and doing things outside. Small breakfast groups given fairly specific items to discuss with facilitator leading discussions. Being in a non-smoking sleeping tent. The Elders (who were also non-smokers) were glad of this too
- I enjoyed the location. I also enjoyed the company of different Elders and youth from various communities.

What did you dislike about the retreat?

- There were not enough people
- The retreat was not long enough, because they are not giving the youths enough time to learn everything
- Not enough Dene activities – drum dances, hand games, etc.
- I didn't dislike anything about it
- Nothing – because everything was well organized by the camp tenders
- Not much

- It seemed tough to get into nitty gritty discussions about the issues. It is tough to feel we can speak out when our opinions differ from that of the Elders
- We didn't get a moose
- Everything was okay for me, good meals and a nice warm place to sleep
- Some of the Elders seemed physically uncomfortable, difficult for them to get around
- Youth participation was good by the end of the meeting but it would have been nice if they had a little more clear role - knowing why they were at the meeting and also having a position in their community so they would feel more clear on what to do after the workshop
- It worked out well in the end but a lot of people at the beginning seemed unsure of why they were there
- There was no meeting place for a big group to do discussions. The food was already pre-cooked and have cooked bannock not pancakes. The food should have been cooked the day it was supposed to be eaten. There should have been a drum dance but there was none

Would like to see more workshops with Elders and Scientists?

- Yes, there should be equal members of youth, Elders, and scientists. More meetings will be good, so that we will be recognized by other people. Let people know ahead of time, to those who you think will show up. Always let people know of what is happening, where it is being held and the purpose of the retreat
- Yes, I would, all four seasons of the year we should have workshops
- Yes - A.S.A.P. and again there should be one elder and one youth from each place they represent
- Absolutely!
- Yes, and the youth, they were great. The speak straight from the shoulder
- Yes, it was so good to get to know the scientists and to be in groups with them
- Yes, but maybe encourage more scientists to come that work on subjects that Elders are likely to be familiar with or have interest in (e.g. caribou, wolf, bear biologists, scientists that are doing fieldwork in the Elders communities). Make sure it is clear to the scientists what they can offer to the Elders (what Elders might expect from scientists) and vice versa
- Yes, I definitely would, and more youth, as the youth are the future leaders. Maybe 5,6 youth from each region, not enough youth here at the time

If so, are there any other dimensions, topics, you would like to address at future workshops?

- More bush skills and fishing too
- Not really – except with issues and just go with the flow of individual concern
- More of the same – maybe additional time for local point sources
- Topic – problems in communication between Elders and scientists. How to address them so mutually satisfying
- Topic – how can scientists share their knowledge - as Joe Martin did with us - so that Elders find it rewarding
- This is my first meeting so I will go with anything
- Maybe come up with more specific research questions of interest to scientists and Elders and have discussions of ways of combining their specific knowledge to come up with projects to answer those specific questions - need to have the right scientists though – i.e. GNWT-RWED has a Traditional knowledge policy
- They should have these workshops in different regions and during the summer not the fall time or every four months, or three workshops per year

Comments in general:

- I had lots of fun their and look forward to the next one
- For the next workshop we will need more instruments for evening entertainment
- Congratulations on a successful workshop
- Many thanks for the opportunity to join in. Its needed
- Good workshop, felt like some real relationships are being built. Really encouraging to see active interest, some Elders and youth are taking in communicating information to others and carrying this further
- I enjoyed the retreat and would like to see more of this happen in the near future. It is great to be out on the land

NORTHERN CONTAMINANTS PROGRAM
YEAR-END REPORT
OCTOBER 1, 1997 - MARCH 31, 1998

Denendeh National Office

INTRODUCTION

The Denendeh National Office (DNO) Lands & Environment Department received core funding from the Northern Contaminants Program (NCP) to provide technical assistance and advice to the NCP. This is the first year we have received funding from the NCP; previously our core funding was provided by the now terminated Arctic Environmental Strategy program. This report continues on from the Mid-Year Progress Report which was submitted in November 1997.

To date, the environment has become more of an issue for Dene Communities as apparent by inclusion at most Dene meetings, workshops and assemblies. This is not reflective of the increased environmental degradation, but of increased community-capacity to address environmental issues. This increased capacity has been apparent by the various projects and workshops some of the communities and regions have conducted in the past year; from the Lutsel K'e Environment Committee developing their own Radiation study to listening to Elders at workshops talking, in North Slavey, about the long-term health effects of low doses of contaminants.

This report sumarizes the Lands & Environment Departments activities from October 1997 to March 31, 1998.

HIGHLIGHTS

The Denendeh Environment Committee

The Denendeh Environment Committee is an advisory committee to the Dene Nation. The representatives/ observers of this Committee represent each of the five regions of Denendeh, and have met on a regular basis either by conference calls or meetings. The representatives/observers include the following people:

Akaitcho Territory Tribal Council	Marilyn Sanderson
Dogrib Treaty # 11 Tribal Council	Violet Camsell-Blondin
Deh Cho First Nation	Danielle Sonfrere
Gwich'in Tribal Council	Margaret Donovan
Sahtu Dene Council	Chief Raymond Tutcho

Interim Resource Management Assistance:

Many of the regional environment departments were created through the previously existing Community Resource Management Program (CRMP) funding. As of March 31, 1997 as part of the Arctic Environmental Strategy, CRMP ended. On August 13, 1997 the Minister of Indian Affairs announced the creation of a new equivalent program, the Interim Resource Management Assistance Program (IRMA) designed to help Aboriginal communities in unsettled land claim areas in the NWT participate in resource management decisions affecting traditional lands.

March 12–14, our staff participated in the Interim Resource Management Assistance (IRMA) Program Workshop. This workshop was hosted by DIAND, RWED and the North Slave Métis Alliance for the community organizations of the Deh Cho, South Slave, and North Slave Regions. The workshops main objective was to inform communities about IRMA and how to acquire IRMA funding. It was also an opportunity for communities to discuss the particular resource pressures found in their areas. This particular discussion was initiated to determine similar resource pressures and potentially create partnerships where IRMA funds could be combined and maximized. Overall the workshop was very helpful to participating communities and helped prioritize concerns with the IRMA program, which should be addressed in the 1999/2000 fiscal year.

Dene Environmental Newsletter:

The Department has produced an environment newsletter, titled *"As Long As This Land Shall Last"* for the past three years. This publication addresses environmental issues, studies, meetings, conferences and events in Denendeh. Our newsletter has been an important communicator to our five regional Tribal Councils and 30 Communities, as well as schools, nurse stations and other interested parties. Our media brought all Denendeh Communities up to date on global and local issues pertaining to all aspects of our environment. On top of expanding our knowledge, the newsletter assisted all persons in the North to exceed their abilities. Such is the *Chief George Kodakin* Environment Scholarship.

This newsletter has continued despite the lack of funding to support it. Indirectly the Youth Environmental Corps funded the newsletter by sponsoring the employment of one of their Youth environmental trainees. This youth spent six weeks co-ordinating the December 1997, Vol 5 No. 2 edition. Volume 5, Number 3 will be forthcoming this April.

Arctic Council:

Over the last seven years the Dene Nation has been actively involved with Inuit Tapirisat of Canada (ITC), Métis Nation, Inuit Circumpolar Commission, Council of Yukon First Nations, and External Affairs to establish an Arctic Council. The Arctic Council is currently in the process of being established. This Council will address issues related to the environment and sustainable use of resources in the Arctic. It is made up of eight member countries: Russia, Finland, Sweden, Norway, Iceland, Denmark, United States, and Canada.

The Dene Nation, as part of the Canadian delegation, attended an Arctic Council Meeting of Senior Arctic Officials and Permanent Participants in Ottawa, October 3–17, 1997. The primary purpose of this meeting was to discuss the wording of the draft "Rules of Procedure for the Arctic Council". A Heads of Delegation meeting was held in Ottawa, February 1998, whereupon the Rules Of Procedure was agreed upon by the Heads of State. The Senior Arctic Official of the Arctic Council will be meeting May 10–11, 1998 in Whitehorse for their first official meeting.

Currently, the Dene Nation and Council of Yukon First Nation have asked to apply together for a Permanent Participant seat on the Arctic Council, separate from the Canadian Delegation.

Northern Aboriginal Coordinating Committee on POPs:

The Inuit Circumpolar Conference, Inuit Tapirisat of Canada, Métis Nation, the Council of Yukon First Nations and the Dene Nation have worked together to establish an Aboriginal Peoples Persistent Organic Pollutants Co-ordinating Committee. In addition to this committee, a technical specialist was hired to brief the aboriginal politicians on the file. Together the five organizations lobbied the Canadian government to maintain a strong position in the United Nation European Commission on Economics (UNECE) Persistent Organic Pollutants (POPs) Protocol.

Our lobbying has been quite successful; a final UN ECE POPs protocol has been agreed upon, which included a pre-amble highlighting the special interest of the Arctic and its residents and the particular concerns related to human health effects of POPs.

The Director of the United Nations Environment Programme (UNEP) has written that the involvement of the Northern Aboriginal Co-ordinating Committee on POPs would be most useful for the negotiating of a global protocol on POPs. We have been asked to have an Aboriginal representative as part of the Canadian negotiating team. This first UNEP – POPs meeting will take place in Montreal, June of 1998.

Other International Initiatives:

The DNO Lands & Environment Department was asked by leadership to participate in more international activities since many of the pollutants from other countries affect the North. Therefore, in the last seven years the DNO has participated in the following international-based initiatives:

- Persistent Organic Pollutants (POPs)
- Hazardous Air Pollutants (HAPs)
- Heavy Metals (HM)
- United Nations Economic Commission for Europe, Long-Range Transboundary Air Pollution (UN-ECE, LRTAP & UN-ECE)
- Arctic Council
- Arctic Environmental Protection Strategy (AEPS)
- Nordic Council
- International Committee on Arctic Research Planning (ICARP)

NWT Environmental Contaminants Committee:

The Contaminants Division of the Department of Indian and Northern Affairs has been working with members of the NWT Technical Contaminants Committee to put together a draft terms of reference for a NWT Environmental Contaminants Committee. The Dene Nation has been involved in the draft version and attended the Terms of Reference Workshop in Calgary, January 30, 1998. In addition we will be a member of the new committee.

NWT Environmental Contaminants Committee- Terms of Reference Workshop, January 30, 1998

Our Lands & Environment Manager, and Assistant Manager attended and aided in the facilitation of breakout groups for this meeting.

Elders/Scientists Retreats II, Summary Report, September 9–12, 1997:

The objective of the retreat was to continue from the beginnings of trust and respect we built at the first retreat, by providing a relaxed and informal atmosphere for an exchange to occur between elders, youth and scientists. We have heard that many scientists would like to involve communities in their research and incorporate traditional knowledge. In addition we have heard the communities say they want to be involved and have a lot to contribute to science, which can save both time and money. The question is how do we do this, the Dene Nation has been the primary link between the communities and the scientific community, particularly within the Northern Contaminants Program, so we decided to host a retreat. The first retreat was at the Sah Naji Kwe Camp, February 23–24, where the Dene Nation hosted the first Elders/ Scientists Retreat. The purpose of this retreat was to build trust and respect between Dene elders and scientists. A video and report from this first retreat has already been produced, and copies can be obtained by contacting the Dene Nation.

This report is based on the second Elders/Scientist and youth retreat that we hosted, September 9–12, 1997 at Enodah Wilderness Camp, Trout Rock, NT. At this second retreat we worked at maintaining this trust and worked on taking a second step of getting to know each other by asking questions in particular to research in the north. A copy of the report can be obtained from our department. A video based on the second retreat is currently in production, and will be available in the near future.

Several Elders who attended the retreats met with members of their respective communities to tell them about what has been happening at the retreats. People's general response has been that the retreats have been beneficial to the regions and to the communities because all the discussions relating to Elders' knowledge contributes to the future generations.

NWT Water Board Hearings for Royal Oak Mines Inc., January 29, 1998

A Lands & Environment staff member, along with the National Chief and the Yellowknives Dene, took part in the NWT Water Board hearings for the renewal of the Royal Oak Mines Inc. water licence. The hearings were held to allow all interest groups to present their interventions. The following recommendations were made to the NWT Water Board on January 29, 1998:

- existing licence be extended for six months beyond its expiration date of April 30, 1998 until October 31, 1998;
- development of an arsenic management plan within six months;
- involvement of Yellowknives Dene in the development of this arsenic management plan;
- public hearings should be held once the arsenic management plan is submitted;
- a water licence should only be issued if an acceptable arsenic management plan proposal has been submitted and reviewed in public hearings;
- increase of the current security bond to $10 million and should be payed upon renewal of the water use licence; and
- ammonia discharges should be decreased to less than 10mg/L.

Deline Radiation Workshop, February 3, 1998:

The community of Deline is very concerned with radiation exposure and resolutions to this regard have been passed at our 1997/1998 National Assembly and the Assembly of First Nations Confederacy Meeting, November 1997. This concern prompted a radiation workshop in Deline on February 3, 1998. The main purpose of this workshop was to educate community members about radiation and to discuss any other contaminants concerns that the local residents may have. The main role of the Dene Nation Lands & Environment representative was to take note of community concerns and help with the translation of technical terms into the local language. Overall, the workshop went well and helped the community understand radiation exposure and address other local contaminant concerns.

Lutsel K'e Radiation Workshop, October 28–30, 1997 & February 18, 1998

The Lutsel K'e Lands & Environment Committee obtained funding from the Northern Contaminants program to initiate a Radiation study in Lutsel K'e. The project was designed and implemented by the Lutsel K'e Lands & Environment Coordinator and Environment Committee. The study addressed community concerns in regards to possible radiation exposure from Cosmos 954 satellite, and the abandoned Stark Lake mine. As part of the Advisory Committee, one of our staff attended the October meeting to discuss a sampling strategy. Both the Lands & Environment Committee and community members identified the animals, berries, and location of water, and homes to be sampled.

A second meeting was held, February 18, 1998 to follow up with some of the preliminary results from the study. The results indicated that the levels exposure to radiation in the homes, water, and food are at safe levels.

Human Contaminants Monitoring Workshop, Inuvik, April 30–May 2, 1997

GNWT Health in conjunction with the Inuvik Regional Health Board, and the Aurora Research Institute coordinated a Human contaminants monitoring workshop. The purpose of the workshop was:

- to consult with community representatives about their interest in participating in the development and implementation of a human contaminants monitoring project in the Inuvik Health District; and

- to bring together representatives from Inuvialuit, Gwich'in, and Sahtu communities to exchange information, particularly about health and contaminants

The Dene Nation's primary role was to be a source of information for the Gwich'in and Sahtu.

Northern Contaminants Program Funded Workshops:

- Upper Mackenzie Basin Planning Workshop, August 18–20, 1997
- Northern And Arctic Contaminants Health Initiative, June 26–27, 1997
- Archipelago Workshop, Iqaluit, July 25–28, 1997
- Mercury Workshop, Ottawa, December 2–10, 1997

One of our staff attended and participated in the NCP funded Workshops. The purpose of the workshops were to develop an integrated action plan for the next five years.

Sahtu Regional Contaminants Workshop, Tulita, January 18-21, 1998:

The Sahtu regional contaminants coordinator organized and facilitated a regional contaminants workshop. The purpose and outcome of the workshop was to identify a five-year strategic plan for contaminant studies. We participated on the advisory committee, aided in the facilitation of the breakout groups and we gave a presentation on the Elders/Scientist Retreats.

Deh Cho Contaminants Workshop, February 11–13, 1998

One of our staff attended the Deh Cho Regional Contaminants Workshop. The prime purpose of the workshop was to bring the Deh Cho leadership up to speed on the CACAR report. Petr Cizek did an excellent job of explaining the results to the people.

Akaitcho Territory Regional Contaminants Workshop, March 31–April 1, 1998

The Lands & Environment Department hosted the Akaitcho Territory Regional Contaminants Workshop. The purpose of the workshop was to bring community members involved in contaminants studies or with interest to be updated to contaminant studies already conducted in the Territory, and to develop a five year strategy. Community representatives from Lutsel K'e, Fort Resolution, Fort Resolution, and Fort Smith were present. The Yellowknives Dene were unable to attend the meeting.

NCP Results Workshop, Calgary, January 26–30, 1998

Our Lands & Environment Manager, and Assistant Manager, attended the 1997/1998 NCP Results Workshop. A presentation was given on the first and second Elders/Scientists Retreats. In addition, we co-ordinated several out-of-session meetings with the aboriginal representatives and government employees.

OTHER DIAND/ENVIRONMENT CANADA INITIATIVES

The DNO Lands & Environment Department has also participated regularly in other DIAND and Environment Canada initiatives besides NCP including:

- Land and water licence reviews
- Interim Regional Environmental Review Committee (IRERC)

COMMUNITY COMMUNICATION

The DNO Lands & Environment Department forwards general information, including NCP information to the five Denendeh Tribal Councils and thirty communities.

The 28th Dene National Assembly will occur June 15–19, 1998 on the Yellowknife River. With every Assembly, the environment is one of the top important issues. Therefore, the DNO Lands & Environment Department has scheduled one-half day on the agenda to discuss various environmental issues in Denendeh including NCP.

TRAINING FRONT-LINE COMMUNITY PROFESSIONALS FOR THEIR ROLE AS CONTAMINANTS COMMUNICATOR AND RESEARCH LIAISON.

Project Leader: S.-L. Han and J. Simms - NCP, DIAND; J. Farrow and W. Carpenter, Métis Nation - NWT

Project Team: S. True, Research Assistant, Métis Nation - NWT; J. Shirley, Nunavut Research Institute, Iqaluit, NT; S. Moss, Baffin Regional Health Board, Iqaluit, NT; S. Peterloosie, Pond Inlet, NWT; V. Walker, Aurora Research Institute, Inuvik, NT; B. Archie, Contaminant Co-ordinator, Aklavik, NT

OBJECTIVES

1. to provide information that assists decision making by individuals and communities in their food use.
2. to develop materials to assist communication and interpretation of the technical aspects of the NCP to communities in Northern Canada.
3. to provide information and training that will assist front-line community professionals with skills that will enhance their ability to perform functions which 'default' to then as part of their regular jobs, relating to contaminant information and scientific research, including evaluation of proposals, in their communities.

Short-term:

1. to develop and deliver a three-day course on contaminants and research issues. Target participants will be front-line community professionals who may act as liaisons with researchers and their communities through their positions, e.g. Community Health Workers, Renewable Resource Officers, Community Wellness Coordinators, Hunters and Trappers Associations and local aboriginal organizations.

Long-term:

1. to create capacity in all northern communities to deal with contaminant information and participate fully in the research process.

DESCRIPTION

The Northern Contaminants Program (NCP) has prepared a three-day course that will offer "frontline training" for northern community professionals. In the summer of 1997, the NCP published a major report entitled Canadian Arctic Contaminants Assessment Report (CACAR). This report provides an evaluation of the current state of contamination in the Canadian Arctic environment and documents the results of six years of research conducted under the NCP. A companion document, Highlights of the Canadian Arctic Contaminants Assessment Report: A Community Reference Manual (Highlights Report) is written in non-technical language and was prepared in consultation with the NCP Aboriginal Partners and with input from community level participants. As this information becomes available it is expected that it will raise questions in the minds of residents of northern communities. For more information, guidance and/or interpretation of this information, residents are likely to turn to someone they know and trust living in their community. It is likely that professionals, who have strong ties to and reside in the community, may be asked to deal with contaminant information and/or research on contaminants.

This course is intended to help those who are already in Health or Wildlife oriented jobs, and who need to understand more about contaminants in order to perform their duties.

Participants receive resource materials referenced to the Highlights Report and CACAR and other sources of information regarding contaminants, particularly in Northern Canada. The course provides an opportunity for networking, to get to know other people that are dealing with the same issues. Participants should leave with a greater understanding of the work that is being done, in the North, on contaminants. They will be better prepared to evaluate and negotiate incoming research proposals to their community or area and ultimately prepare their own community driven proposals. The course will address three main categories: 1) Contaminant Information, 2) Scientific Research and 3) the Proposal Process.

ACTIVITIES IN 1997/98

In the fall of 1997, consultation was undertaken in the Baffin Region to seek the cooperation and support of the following agencies:

- Baffin Regional Health Board
- Qikiqtaaluk Wildlife Board
- GNWT RWED
- Nunavut Research Institute
- Nunavut Arctic College

Consultations regarding the Aklavik delivery were undertaken early in 1998 with the following agencies:

- GNWT RWED
- GNWT HSS
- Inuvialuit Game Council
- Aurora Research Institute
- Aklavik Métis Local
- NCP Regional Contaminant Coordinator

The course was developed and delivered by Judy Farrow, Education Coordinator at the Métis Nation – NWT, in consultation with NCP headquarters in Ottawa and other partner agencies. The logistics and planning for the pilot tests were handled on a contractual basis by Siobhan Moss, in Iqaluit and Billy Archie, in Aklavik. An assistant instructor was recruited from both of the regions where the pilot test took place. The assistant instructors were Sipporah Peterloosie of Pond Inlet and Billy Archie of Aklavik. A two-day training session for the Baffin assistant instructor was held in Iqaluit and a similar session took place in Yellowknife prior to the Aklavik delivery. The course was pilot tested in Iqaluit, February 4 – 6, 1998 with participants from Baffin Region and in Aklavik, March 10 – 12, 1998 with participants from the Inuvialuit communities and Fort McPherson.

RESULTS

Thirty-two people participated in the Iqaluit course and seven attended in Aklavik. Occasional observers dropped in during the course presentation.

DISCUSSION/CONCLUSION

This is a community 'capacity building' exercise, which judging from participant reaction, needs to continue. During the course there was lively interaction between the different professional groups. Most participants commented that this was a beginning, but there was a need for continued updating. On the whole particpants expressed a willingness to act as resource people in their communities. Some expressed concern, due to heavy work loads and did not want to be involved further, but were grateful for the information. The course needs to be revised and updated on a regional basis and may eventually be transferred to Nunavut and Aurora Colleges for delivery. The course materials are currently being revised for delivery in the Kitikmeot late in 1998.

Expected Project Completion Date: Pilot testing was completed in March 1998. The revised course will be delivered to participants from the Kitikmeot Region in late November or December, 1998. A report will be available for March 1999.

APPENDIX A

Iqaluit Frontline Course "Communicating About Contaminants" Feb 4, 5, 6 1998

Participant	Affiliation	Phone #	Fax #	Box #	Community	
Qavavauq Issuqangituq	Hunter & Trapper Organization	439-9949	1-867-439-8341	103	Arctic Bay	X0A 0A0
Johanne Coutu	Resources, Wildlife & Econ Dvlpt.	439-9945	439-8480	92	Arctic Bay	X0A 0A0
Morty Iqqaqsaq	Health Centre	439-8816	1-867-439-8315	83	Arctic Bay	X0A 0A0
Peter Kooneeliusie	c/o Resources, Wildlife & Econ Dvlpt.	927-8836	927-8525	Gen. Del.	Broughton	X0A 0B0
Andrew Keim	Resources, Wildlife & Econ Dvlpt.	897-8932	1-867-897-8495	29	Cape Dorset	X0A 0C0
Bob Wortman	c/o Resources, Wildlife & Econ Dvlpt	897-8932	1-867-897-8495	179	Cape Dorset	X0A 0C0
Reesie Churchill	Hunter & Trapper Organization	924-6202	1-867-924-6197	138	Clyde River	X0A 0E0
Shane Sather	Resources, Wildlife & Econ Dvlpt	924-6235	924-6356	90	Clyde River	X0A 0E0
Meeka Kiguktak	Health Centre	980-8827	1-867-980-9067	36	Grise Fiord	X0A 0J0
Judah Innualuk	Hunter & Trapper Organization	928-8994	1-867-928-8765	14	Hall Beach	X0A 0K0
Julia Issigaitok	Health Centre	928-8827	1-867-928-8847	8	Hall Beach	X0A 0K0
Mika Qattalik	Hunter & Trapper Organization	934-8807	1-867-934-8067	89	Igloolik	X0A 0L0
Brad Parker	Resources, Wildlife & Econ Dvlpt.	934-8999	1-867-934-8995	209	Igloolik	X0A 0L0
Simon Iyyiraq	Health Centre	934-8833	1-867-934-8901	81	Igloolik	X0A 0L0
Joanasie Akumalik	Qikiqtaaaluk Wildlife Board	979-1560	1-867-979-1491	478	Iqaluit	X0A 0H0
Noolie Iou	Qikiqtaaaluk Wildlife Board	979-1560	1-867-979-1491	478	Iqaluit	X0A 0H0
Johnny Nowdluk	Qikiqtaaaluk Wildlife Board	979-1560	1-867-979-1491	478	Iqaluit	X0A 0H0
Adamie Ipeelie	Hunter & Trapper Organization	979-6848	1-867-979-3390	1002	Iqaluit	X0A 0H0
Pitseolak Alainga	Hunter & Trapper Organization	979-6848	1-867-979-3390	595	Iqaluit	X0A 0H0
Kevin Robertson	Resources, Wildlife & Econ Dvlpt.	979-7800	1-867-979-8809	1870	Iqaluit	X0A 0H0
Jimmy Noble Jr	Resources, Wildlife & Econ Dvlpt.	979-7800	1-867-979-6026	147	Iqaluit	X0A 0H0
Josiah Kadlutsiak	Resources, Wildlife & Econ Dvlpt.	979-7800	1-867-979-6026	1870	Iqaluit	X0A 0H0
Micah Arreak	Health Centre	979-7658	979-4612	Bag 200	Iqaluit	X0A 0H0
Siobhan Moss	Independent	979-4231	979-1870	457	Iqaluit	X0A 0H0
Martha Padluq	Hunter & Trapper Organization	939-2355	1-867-939-2112	Gen. Del.	Kimmirut	X0A 0N0
Jacopie Maniapik	Hunter & Trapper Organization	473-8751	1-867-473-8741	Gen. Del.	Pangnirtung	X0A 0R0
Sakiasie Sowdloapik	Resources, Wildlife & Econ Dvlpt.	473-8937	473-8326	87	Pangnirtung	X0A 0R0
Pitsiulak Kilabuk	Health Centre	473-8826	1-867-473-8674	364	Pangnirtung	X0A 0R0
George Koonoo	Resources, Wildlife & Econ Dvlpt.	899-8819	899-8248	194	Pond Inlet	X0A 0S0
Rachel Ootoova	Health Centre Wildlife & Econ Dvlpt.	899-8820	1-867-899-8997	125	Pond Inlet	X0A 0S0
Tony Romito	Resources,	252-3879	252-3752	217	Resolute	X0A 0V0
Annie Amitook	Health Centre	266-8965	1-867-266-8802	General Delivery	Sanikiluaq	X0A 0W0

ICC AND TRANSBOUNDARY CONTAMINANTS
– ACTIVITY REPORT –
SEPTEMBER 1997 TO MARCH 1998

This period has seen extensive work on the transboundary contaminants file using funding pursuant to the agreement between ICC (Canada) and the Inuit Tapirisat of Canada (ITC). Activities have focussed on:

The Aboriginal Peoples Coalition on POPs
This coalition has been further developed through conference calls and face-to-face meetings, usual in conjunction with meetings of science managers. The coalition has generated significant political correspondence with federal ministers, particularly the Minister of Foreign Affairs and International Trade. In addition, we have encouraged and partially directed Stephanie Meakin, who coordinates the coalition, and drafted needed reports to obtain funding for the coalition from the Department of the Environment.

Expanding the Coalition
The Sami Council and the Russian Association of Aboriginal Peoples of the North have expressed an interest in joining the Aboriginal Peoples Coalition on POPs. We will be meeting with these groups in Whitehorse in May to explore this opportunity.

POPs negotiations
Terry Fenge of ICC (Canada) and Stephanie Meakin attended negotiations in Geneva on the POPs protocol to the Convention on Long-Range Transboundary Air Pollution. We tabled a well-received position paper, drafted by Nigel Bankes of the Faculty of Law at the University of Calgary, dealing with preambular and scope clauses to the protocol. Some of these clauses have been included in the draft protocol to be signed in Europe this summer. This is the coalition's major achievement to date. In addition, we have spent considerable time briefing the members of the coalition on events in Europe.

AEPS/Arctic Council
We have actively participated in the Arctic Monitoring and Assessment Programme working group of the Arctic council, with a view to promoting Phase Two of AMAP's work on the public health implications of contaminants. As well, we have participated in meetings of senior arctic officials pursuant to the Arctic Council urging greater attention to the transboundary contaminants file.

Participating in CINE
ICC has participated earnestly as well as actively as a member of the board of CINE, seeking to put this institution on a firmer financial footing and to promote a strategic plan for CINE's next five years. This has involved meetings with ministers, foundations and the President of McGill University.

ITC in the Northern Contaminants Program.
ICC has participated with ITC in the Northern Contaminants Program. This has involved evaluating proposed research and writing summaries and articles for use by Inuit organizations.

Funding
ICC has visited foundations in New York to advise them of pressing transboundary contaminant issues and to persuade them to consider granting in the Arctic. Currently, we are preparing a major submission to these foundations.

Regional Contaminants Report – Nunavut:
Over the course of the past fiscal year (1997/98), Nunavut has become increasingly involved in the Northern Contaminants Program (NCP). The three regional Inuit organizations – the Kivalliq Inuit Association and the Qikiqtani Inuit Association have all participated in the ITC Environmental Network, giving in put to ITC positions on contaminants issues, and attending various meetings and workshops (see below). In addition, Nunavut Tunngavik Incorporated (NTI) has been more active than ever in the NCP.

Contaminants Communications Activities:
NTI and Regional Inuit Associations (RIA) staff have been actively involved in a number of key contaminants communications exercises over the past fiscal year:

- NTI and RIA staff gave input into the content and distribution plan for ITC's English and Inuktitut contaminants glossary – a glossary of key contaminants terms that has since been distributed to key interpreter-translators across Nunavut
- NTI and RIA staff assisted in the planning and execution of three planning workshops (on in each region) for the Centre for Indigenous People's Nutrition and the Environment's (CINE) dietary study, one of the most comprehensive assessments of risks and benefits in the Inuit diet ever undertaken in the North

- NTI and RIA staff gave input and advice regarding ongoing communication for the CINE study, which is now entering its second year
- NTI and Kivalliq Inuit Association staff (with the assistance of ITC and DIAND staff) gave advice and input into the creation of a contaminants committee for community of Baker Lake.

Key Workshops/Meetings:

NTI and RIA staff and/or representatives assisted in the planning of/attended the following NCP/ITC meetings or workshops regarding contaminants:

- Health Canada's Northern Health Initiative workshop, held in Ottawa in June
- a pre-planning workshop on the CINE dietary study, held in June in Ottawa
- the NCP Archipelago Project workshop, held in Iqaluit in July
- the NCP Mercury workshop held in Ottawa in December
- the Kitikmeot Region CINE dietary study planning workshop, held in Yellowknife in November
- the Kivalliq Region CINE dietary study planning workshop, held in Baker Lake in January
- an NCP workshop on radiation, held in Baker Lake in December
- the Qikiqtani Region CINE dietary study workshop, held in Iqaluit in January
- the NCP Results Reporting Workshop, held in Calgary in January
- a special meeting with the World Wildlife Fun on endocrine disrupting contaminants, held in Calgary in January
- a meeting of the ITC Environment and Contaminants Contacts, held in Calgary in January
- a planning meeting for the NWT Contaminants Committee, held in Calgary in January
- ITC's Annual Environment Workshop, held in Inuvik in March
- a special briefing session on the NCP's Archipelago Project, held in Iqaluit in March.

General contaminants activities:

- NTI and RIA staff maintained a watching brief on the contaminants file throughout the fiscal year through, for example, the following activities:
- giving in put into NCP proposals, directly or through ITC, such as the FY 98–99 proposals on Cancer Workshops and an NCP Results Workshop for the Eastern Arctic
- participating in the planning of (and membership in) the new NWT Contaminants Committee
- planning for a Nunavut contaminants tour, to appear at meetings of key organizations who may be involved in contaminants issues in the future
- planning for the creation of a dedicated Contaminants Coordinator for Nunavut
- input into the work of the NWT Technical Committee on Contaminants
- input into ICC's international Contaminants activities, including the recently completed UN ECE LRTAP Process, the upcoming UN global POPs Protocol, ICC's contaminants-related activities on the Convention for Biological Diversity and the Arctic Council.

In addition, NTI and RIA staff keep in regular contact with ITC staff, and staff in other Inuit regions across the Canadian Arctic regarding contaminants issues on an ongoing basis. Such networking and cross-fertilization is essential for Nunavut, especially at this critical time when new institutions of public governance and accountability are in the process of being set up.

NORTHERN CONTAMINANTS PROGRAM FINAL ACTIVITIES REPORT

INUIT TAPIRISAT OF CANADA

INTRODUCTION

Throughout the six years of the Arctic Environmental Strategy, and into this, the initial, bridging year of the successor Northern Contaminants Program (NCP), ITC has taken pride in being a managing partner. This partnership continues to be fruitful and effective both for Canadian Inuit and to the Program itself. As the national political voice for Inuit, ITC continues to play a dual function within the NCP. First, ITC provides advice and direction to DIAND and the other NCP partners – bringing a national perspective representing Inuit interests to the NCP management and technical committees, of which ITC is a member. Consequently, the NCP can better respond to the needs and wishes of Inuit with respect to the design and delivery of programs and projects. Secondly, ITC is dedicated to facilitating appropriate, timely communications about contaminants and the NCP itself. By continuing to improve and systematize communications at the regional level, we are better able to represent Inuit needs within the NCP. Equally important, Inuit organizations and communities are making better use than ever before of NCP information and funding.

ITC has enjoyed a productive relationship with the NCP, and look forward to continuing this relationship in the future. We are pleased to present the following final, narrative report of our activities for the fiscal year 1997/98.

NCP MANAGEMENT

ITC has continued to participate fully in all management committees, program reviews and workshops (see outline, below). ITC has worked closely with regional Inuit organizations, community representatives, and many governmental partners involved in Arctic research and provide advice to these bodies on issues such as appropriate communications strategies, raising community concerns at the federal level, and bringing together community representatives with the appropriate partners regarding specific research initiatives.

NCP COMMUNICATIONS

ITC has continued to encourage and assist the regional Inuit organizations to make applications to the NCP to initiate and undertake research or conduct projects. The number of proposals authored by regional or community organizations has continued to increase. ITC has provided advice and technical support to these organizations and facilitate the initiation of numerous regional and community-driven projects. ITC has also continued to identify alternative funding sources for those projects that do not fall within the mandate of the NCP. We applaud the recent increased access the NCP has given to the Labrador and Nunavik regions, initially through the joint Labrador-Nunavik workshop held in May (see below) and the subsequent collaborative efforts that resulted.

ITC has been and will continue to work closely with NCP personnel to develop and distribute meaningful, appropriate information to Inuit communities about the NCP, its programs and research results.

ITC worked closely with NCP partners and ITC regions with regard to communications for the release of the Canadian Arctic Contaminants Assessment Report (June, 1997). This included working closely with DIAND in the development of a newsletter-style broadsheet for northern newspapers regarding the CACAR.

ITC took part in, assisted with the planning of, and engaged in follow-up to no fewer than eight NCP-related workshops this year (see below).

ITC has continued to participate in NCP-related activities such as regular Science Managers meetings, Technical Committee meetings, subcommittee meetings and special projects meetings (see below).

NCP INTERNATIONAL INITIATIVES

A very important function of the NCP is to provide Canada with the research and analysis it needs to play a strong leadership role in advocating preventative measures to address the problem of long-range transboundary pollution in the international arena. ICC and ITC have been providing a useful focus to this research by giving the program an active link to the people who are directly affected by the problem. A number of important initiatives have taken place over the course of this fiscal year:

ICC and ITC have joined together with the other NCP aboriginal partner organization (Dene Nation, Métis Nation-NWT and the Yukon Council of First NATIONS) in a loose coalition called the "Canadian Northern Aboriginal Peoples Coordinating Committee on POPs" to monitor and advocate on behalf of northern interests in the United Nations Economic Council for Europe's recently completed negotiations for a Convention regarding the Long Range Transport of Atmospheric Pollutants (LRTAP). Coalition representatives attended preparatory meetings in Canada and negotiating sessions in Geneva for the Convention, and succeeded in convincing governments to insert a reference to the situation regarding contaminants in the Arctic in the preambular language of the Convention.

The LRTAP negotiations, which have recently concluded and will result in the signing of the convention scheduled for this June, have set the stage for a global treaty on Persistent Organic Pollutants (POPs), negotiations for which are scheduled to commence in Montreal in June of this year.

ICC and ITC have both been very active in building alliances with other aboriginal peoples around the world regarding this issue, and have attended two regional briefing sessions on POPs, sponsored by the United Nations Environment Programme, in Bamako, Mali, in December, and in Lusaka, Zambia, in March. ITC staff gave numerous presentations regarding POPs and the Arctic, and organizing communities around the POPs issue.

The coalition partners have also developed a protocol for working together on the POPs issue. The protocol addresses how information is to be used and released among coalition partners, and to government and the public.

The committee is currently considering expanding its representation to include other northern peoples, including the Saami and Russian Indigenous Peoples.

ICC maintains a watching brief on the UN ECE initiative on Heavy Metals.

ICC has been participating very actively in the Arctic Environmental Protection Strategy, Arctic Monitoring and Assessment Programme and Arctic Council meetings in Norway, the Netherlands and Canada. This work has concentrated on translating data reported in CACAR and the AMAP report into policy statements.

ICC has worked closely with DIAND staff on the organizing committee for a major international meeting on sustainable development, scheduled for May, 1998 in Whitehorse. The problem of contaminants will be addressed at this meeting.

ICC participated in the UN Commission for Sustainable Development meetings in New York with a view to promoting international agreements on POPs.

DEVELOPMENT OF NEW NWT COMMITTEE ON CONTAMINANTS

ITC staff have been intimately involved in the development of the new NWT Contaminants Committee. ITC participated in numerous conference calls and the planning of an initial workshop, held in conjunction with the NCP Results Reporting meeting in Calgary in February. ITC expects to fully participate, along with the relevant regions, in the committee once its work commences.

DEVELOPING PARTNERSHIPS WITH NORTHERNERS

ITC has been and will continue to be a liaison between communities/regions and NCP government partners and researchers and to advocate and advise on securing and strengthening these relationships. Beyond ITC's "traditional" role in this regard (throughout the history of the AES-NCP), direct relationships between NCP scientists and the Inuit regions have been greatly strengthened over the past year. This is due to increasing capacity at the regional level (thanks in no small part to NCP funding) and the various workshops that have taken place on specific, contaminants-related issues or with region-specific foci. These workshops included:

- a joint Labrador-Nunavik workshop, held in Kuujjuak in May, aimed at initiating coordinated work on contaminants in these two regions, which have not previously been a priority for work under the old AES program (especially with regard to Labrador). ITC participated fully in the planning of this workshop, and is currently assisting these two regions with regard to developing
- further tools that would allow for a more coordinated approach to research in the area.
- a workshop for scientists and community re-

presentatives aimed at developing a coordinated workplan for the Arctic Archipelago, held in Iqaluit in July. Both ITC and ICC played key roles in the planning and follow-up to this workshop, including a briefing session with regional and Archipelago community representatives held in Inuvik in March/98 (see below).

- the upper Mackenzie River Basin workshop, held in Yellowknife in August. ITC staff attended as resource people, and to inform their own planning for the Inuvik meeting.
- Health Canada's Northern Health Initiative workshop, held in Ottawa in June. ITC and regional representatives participated in this in-depth discussion of possible priority projects regarding human health in the Arctic.
- ITC and regional representatives attended an issue-specific NCP workshop, regarding Mercury and the Arctic, in Ottawa in December.
- ITC staff played a key role in the planning and carrying-out of five planning workshops for the CINE Inuit communities dietary study, held in November in Inuvik (Inuvialuit) and Yellowknife
- (Kitikmeot), January in Baker Lake (Kivalliq) and Iqaluit (Qikiqtani), and February in Nain (Labrador). ITC staff have been intimately involved in the planning for this project, and attended
- and helped to organize a special meeting of ITC regions on this matter in June in Ottawa.

CENTRE FOR INDIGENOUS PEOPLES' NUTRITION AND THE ENVIRONMENT (CINE)

Both ITC and ICC remain on the Governing Board of CINE. This has been a particularly active year in terms of Inuit participation in CINE, and the future promises to be even more active.

It has long been a goal of our organizations to ensure that CINE gets as far down the road to self-sufficiency as is practicable. The hiring of a fund-raiser last year resulted in significant foundation funding for an education project. In addition, ITC and ICC staff and politicians played a key role in raising CINE's profile through meetings with federal politicians and others. CINE staff and Board members met with the Minister of Indian and Northern Affairs and Minister of Environment staff in December, as well as with the Principal of McGill University, McGill's Dean of Agriculture and DIAND staff on CINE's behalf. The latter meetings have been to help clarify the relationship (both financial and structural) between CINE and McGill University, its host institution.

ITC and ICC have also been extremely active in assisting with the development of a new strategic plan for CINE, which we hope will be completed in the first half of the next fiscal year. ITC and ICC staff attended meetings in Calgary in February, and conference calls in March regarding the planning process.

ITC and ICC have regularly attended CINE Board meetings and conference calls throughout the fiscal year, at our own expense through core NCP funding.

CINE DIETARY STUDY PROJECT

ITC staff are fully participating in the first stages of what likely is the most ambitious study on risks and benefits of the Inuit diet yet attempted in the Canadian Arctic. A significant amount of staff time has been devoted to planning for the study, including participation in five planning workshops in Inuit regions, attended by two representative from each Inuit community in that region. A total of seventeen communities in five Inuit regions will be studied in detail regarding consumption of country and market foods, the health benefits of those foods and the exposure to contaminants they pose. ITC staff will continue to play a key role in the ensuing two years of the study.

GUIDELINES FOR RESPONSIBLE RESEARCH

Within the NCP, a great deal of effort has been put into developing strategies to update, improve and implement ethical research guidelines governing the relationship between scientists and communities. This issue has been of great concern to Inuit for many years. In view of the requirements of the final agreements in the NWT and Northern Quebec (including land ownership provisions), the emphasis is not only on consultation and advisory procedures but on negotiated relationships that provide for ample community participation in scientific research. ITC has always played a key role in these discussions as partners in the AES-NCP.

ITC's discussion paper on research relationships has now been distilled into a plain-language version for Inuit communities, which is in the process of being distributed in cooperation with the Nunavut Research Institute.

COMMUNICATIONS RESEARCH

The NCP has shown a strong commitment to establishing a meaningful dialogue with Northerners. Undertaking to communicate across languages and cultures about contaminants and environmental health requires thoughtful, creative work, and ITC continues to be encouraged by efforts made within the NCP in this regard.

ITC recently completed pilot projects on contaminants communications in all six Inuit regions. This fiscal year also saw the distribution of an educational curriculum on contaminants in the Inuvialuit region, information sheets designed for the Labrador and Kivalliq regions, a glossary in Inuktitut and plain English of key contaminants terms (which has been distributed to interpreter-translators in the north), and a script for radio/ TV regarding contaminants issues in Nunavik.

In addition, ITC is in the process of distributing a guide for researchers presenting in Inuit communities. It is being distribute to key people in the NCP, community members and others who would benefit from its advice.

SPECIAL PROJECTS

ITC Regional Contaminants Coordination

ITC received project funding form the NCP in this fiscal year to further build capacity on contaminants issues at the regional and community levels. In three Inuit regions, regional contaminants coordinators were hired to work closely with communities regarding contaminants issues. The main goal of this work is for communities to have access to timely, understandable, and reliable information on contaminants, and to have the ability to use this and traditional knowledge to prioritize contaminants issues in communities. The reflection of such priorities at all level - including the NCP - would be a desired outcome.

As part of this capacity development, ITC and ICC have closely advised regional contaminants coordinators regarding no fewer that 10 project proposals for the NCP for the next fiscal year.

Regional activities have included:

- attendance by regional coordinators/representatives from all Inuit regions at key NCP meetings, including the Results Reporting Workshop, the Mercury workshop, five CINE dietary study workshops, the two Archipelago consultations, the Annual ITC Environment Workshop, the Health Canada NHI workshop, and the Labrador-Nunavik workshop.
- community contaminants information meetings in the Inuvialuit region, coordinated by the contaminants coordinator for that region.
- participation of the Inuvialuit Contaminants Co-ordinator in a cord blood study being undertaken in that region.
- participation by all regional coordinators in the CINE dietary study workshops and detailed planning for the study.
- participation by regional coordinators in the NCP Annual Results Reporting workshop, and a special Inuit regions meeting in conjunction with that workshop.
- participation by regional coordinators in NCP workshops for front-line contaminants communicators.
- participation in the planning of, and in presentations and follow-up for the Annual ITC Environment Workshop.
- fine-tuning the scope of contaminants activities in Labrador through the ongoing development of a regional contaminants communications strategy.
- development of communications aids to deliver messages on contaminants (including a video and open house in Labrador);
- participation in the Nunavik Health and Nutrition Committee.
- ad-hoc participation by some regional contaminants coordinators through the giving of advice to other regions – e.g., in the activities of the Kitikmeot Contaminants Committee.

Activities planned for the near-term:

- continued efforts at developing a Nunavut-wide program regarding contaminants, in cooperation with Nunavut Tunngavik Incorporated and the three regional Inuit organizations (including a potential tour of Nunavut for the ITC President to raise awareness on contaminants issues).
- participation in the development of a long-term ITC contaminants work plan.

Archipelago Community Briefing

ITC received mid-year funding from the NCP to conduct a briefing for community representatives and regional reps regarding planning for the Archipelago Project. NCP scientists(Robie Macdonald and Doug Bright) presented extensively to community and regional reps from the Qikiqtani, Kivalliq, Nunavik, Labrador and Inuvialuit regions, and from the communities of Resolute, Grise Fiord and Arctic Bay. Over a two-day period in March, in conjunction with ITC's Annual Environmental Workshop in Inuvik, the scientists developed community awareness, received feedback, and further refined plans for the physical and chemical contaminants studies planned under the Archipelago Project. On the Inuit side, the information will be taken back to the relevant communities to build general awareness and support.

A project report and summary is being produced for the NCP.

Other, contaminants-related activities:

- ITC and ICC participated in a consultation for a number of federal departments regarding their Sustainable Development Strategies, particularly one chaired by DIAND on July 9th. The Inuvialuit Regional Corporation also participated in a regional workshop on this subject.
- ITC, the Inuvialuit Game Council and Nunavut Tunngavik Inc. continue to participate in the NWT Technical Committee on Contaminants, which held meetings on April 23rd, June 12th, September 4th and January 7th.
- ITC staff presented to a special meeting of circumpolar Parliamentarians on contaminants issues and CINE, in Ottawa on November 28, 1997.
- ITC convened a special meeting between a representative of the Kativik Regional Government and NCP staff on site-specific contaminants cleanup in Nunavik.
- ITC convened a meeting with Environment Canada officials regarding alternate funding sources for the ITC/LIA Nain Waste Cleanup project.
- a July, 1997 meeting between ITC staff and Charles Caccia, Chair of the House of Commons Committee on Environment and Sustainable Development regarding CACAR and international issues.
- a meeting between ITC and ICC staff and representatives from the Government of Greenland regarding an international living conditions survey (July, 1997).
- a special resolution from the ITC and ICC-Canada Board of Directors in Inuvik regarding contaminants issues (Sept 22–24).
- participation in numerous calls and meetings of the Toxics Caucus of the Canadian Environmental Network regarding reforming the *Canadian Environmental Protection Act* and other federal initiatives.
- a presentation by ITC and ICC staff at a briefing session on endocrine disruptors for media in Toronto in February;
- a special meeting of Canadian and American environmental NGOs on the POPs process, in Toronto in January.

CONTAMINANT MONITORING AND COOPERATIVE RISK MANAGEMENT IN THE NORTHWEST TERRITORIES

Project Leaders: J.E.B. Walker, and J.A. MacKinnon, GNWT Health and Social Services; B. Elkin, GNWT Renewable Resources.

Project Team: M. Clusiau, Contaminants Project Officer; Kitikmeot Contaminants Consultation Working Group: J. Ogina (Holman); R. Mannilaq (Taloyoak); E. Kayaksak (Pelly Bay); W. Avalak (Cambridge Bay); J. Bourne (Kitikmeot Health and Social Services Board); M. Akoluk (Bathurst Inlet); R. Kagak (Kugluktuk), M. Kamingoak (Bathurst Inlet); G. Panegyuk (Bay Chimo); NWT Environmental Contaminants Committee (Dene Nation, Métis Nation–NWT, Inuit Tapirisat of Canada, Inuvialuit Game Council, DIAND, DFO, CWS, NWT Science Institute, Health Canada).

OBJECTIVES

1. to develop a strategic action plan by the Kitikmeot Contaminants Consultation Working Group for addressing contaminants issues in the Kitikmeot Region, including how best to invest time, funding and efforts in the future.

In the long term, the main objective of this ongoing project is to facilitate ongoing communications and management of information with NWT residents about contaminants so that confidence in traditional foods will not be unduly eroded.

DESCRIPTION

The Kitikmeot Contaminants Consultation Working Group was established following a workshop held in Taloyoak in 1993. This Working Group included Community Health Representatives from several communities, the Contaminants Project Officer, the Regional Nutritionist, the Health Promotion Officer, the Environmental Health Officer, and the Dept. of Health and Social Services Contaminants Consultant.

The Group was created to assist with, and guide, the development, implementation and results communication of the maternal and umbilical cord blood monitoring program that was being initiated in the Kitikmeot and Mackenzie health regions. Another key role of this group was to provide a means for community involvement in the design and implementation of this project, and to update the community regularly about progress. Details of the contributions of this Working Group are described in the *Maternal and Cord Blood Monitoring for Environmental Contaminants – Revised Final Report of the Kitikmeot and Mackenzie Program.*

ACTIVITIES IN 1997/98

The Kitikmeot Contaminants Consultation Working Group continued to meet on their own initiative (by conference call) after the Maternal and Cord Blood Monitoring Program had been completed. This was to provide members of the Group with a forum to exchange information about various contaminants issues, follow-up on requests for information or resources from their community, and share their experience, perspective, and knowledge with others. It was during this time that the Group decided that they wanted to get together to develop a strategic plan.

The Kitikmeot Contaminants Consultation Working Group's strategic planning workshop took place in Yellowknife from March 25–27, 1998.

The Group wanted to draw on the expertise of others to assist with the development of their plan. To help with this, presentations were solicited from the Dept. of Resources, Wildlife and Economic Development (B. Elkin), the Métis Nation-NWT (J. Farrow), the Department of Health and Social Services (S. Ashton, J. Walker), and the Inuvik Contaminants Monitoring Coordinator (J. Houseman). O Receveur from the Centre for Indigenous Peoples the Nutrition and Environments was also invited to discuss the upcoming dietary assessment in the Kitikmeot Region.

Additionally, the Working Group was interested in how other jurisdictions were managing contaminants issues from a community-based perspective, and so invited a representative from the Nutrition and Health Committee in Nunavik to the workshop. Robbie Watt from Kuujjuaq attended, and his presentation and participation in the discussions were an important contribution to the entire workshop.

The NWT Technical Committee on Arctic Contaminants actively continued to provide a forum for the exchange of information and collaboration between its members and their associates. Meetings and the ongoing distribution of resources and information facilitated cooperative risk management in the NWT. Near the end of this reporting period, the Contaminants Division of DIAND in Yellowknife was preparing to constitute the Terms of Reference for their NWT Environmental Contaminants Committee.

RESULTS AND DISCUSSION

This workshop was the first face to face meeting where *all* communities in the Kitikmeot region were represented – previously Bay Chimo and Bathurst Inlet had not participated, mainly due to logistic difficulties (no phones, expensive to charter out).

An environmental scan was done for each community in the Kitikmeot region, asking the following questions:

1. What are you doing about contaminants now?
2. What's in the planning/future?
3. What's needed even if you lack time/resources?
4. What people/resources/support do you have?
5. Who else should be involved (partners)?

The results of this scan are summarized in the report, and provide a common point for communities to know where others are that can help with specific issues in the Kitikmeot region.

After considerable discussion, five areas were identified by the Group as being the main elements of their action plan:

- training, including: the Frontline workers training workshop, scheduled to take place in 1998; conferences about Arctic contaminants issues;
- development of resource materials, including: pamphlets about the KCCWG , regional newsletters, public service announcements, and orientation kits for new Working Group members;
- community initiatives, including: community meetings, encouraging environmentally friendly activities such as recycling; developing an inventory of existing resource materials/information in each community; and training a partner in each community to assist with ongoing information exchanges;
- regional initiatives, including: forming an umbrella group in the region similar to the Nutrition and Environment Committee in Nunavik; meeting with Working Groups in other regions of Nunavut, strengthening linkage with the Inuit Tapirisat of Canada to contribute to ITC's Environment Committee – perhaps as its regional group in the Kitikmeot; and contacting the Nunavut Implementation Committee about the future of the Working Group following division in April 1999.
- research, including: forming an umbrella group to monitor research projects in the Arctic or the Kitikmeot Region; exchanging/comparing data with other regions; and forming partnerships with the Nunavut and Aurora Research Institutes regarding research issues.

CONCLUSION

The Kitikmeot Contaminants Consultation Working Group has continued to evolve in response to the interest and commitment of its members in contributing to the understanding, focus and direction of contaminants activities in the North, particularly in the Kitikmeot Region. They continue to play an invaluable role in exchanging information within and between their communities, as well as contributing to regional, territorial and national initiatives.

The Contaminants Committee structure in the NWT has evolved with the establishment of the DIAND Contaminants Division based in Yellowknife.

Expected Project Completion Date: Ongoing.

REFERENCES

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