Synopsis of Research

Conducted under the 2004-2005 Northern Contaminants Program

Indian and Northern Affairs Canada

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

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3. Education and Communication

Foreword

This report provides a summary of the progress to date of research and monitioring studies on contaminants in northern Canada, and related education, communications and policy activities that were conducted in 2004-2005 under the auspices of the Northern Contaminants Program (NCP). The projects cover all aspects of northern contaminants issues, as outlined in the NCP blueprints, including human health, monitoring the health of Arctic peoples and ecosystems and the effectiveness of international controls (abiotic monitoring and modeling, and biotic monitoring), education and communications, international policy and program management.

These projects were evaluated as proposals, by external peer reviewers, technical review teams, a social/cultural review team, territorial/regional contaminants committees and the NCP Management Committee to ensure that they support the overall Northern Contaminants Program objectives.

Further information about the Northern Contaminants Program is available on the NCP website at www.ainc-inac.gc.ca/ncp.

Préface

Ce rapport résume l'avancement de recherches et d'études de survelillance portant sur les contaminants dans le Nord canadien, ainsi que d'activités connexes au sujet de l'éducation , de la communication et de la politique qui ont eu lieu en l'année 2004-2005. Ces etudes et activités ont été menées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). Ces projets, tells que décrit dans les plans directeurs lies au programme, représentent tous les aspects portent sur les contaminants, incluant la santéhumaine, la surveillance de la santé des habitants et des ecosystems de l'Arctique et de l'efficancité des measures de contrôle internationales (surveillance et modélisation milieux abiotiques, et surveillance-milieux biotiques), l'éducation et la communication , la politique internationale et al gestion des programmes.

Ces projects on été examines par des pairs, des comités d'examen technique, un comité d' examen social et culturel, les comités territoriaux/régionaux sur les contaminants environmentaux, et le comité de gestion de la PLCN afin de s'assurer qu'ils respondent à l'ensemble des objectifs du programme de lutte contre les contaminants dans le Nord.

Pour de plus amples renseignements au sujet du programme de lutte contre les contaminants dans le Nord, visitez le site Web du PLCN au www.ainc-inac.gc.ca/ncp.

Introduction

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem. The Program's key objective is *to reduce and, where possible, eliminate contaminants in northern traditionally harvested (country) foods while providing information that assists informed decision making by individuals and communities in their food use.*

Under the first phase of the NCP (NCP-I), research was focussed on gathering the data required to determine the levels, geographic extent, and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, and confirmed our suspicions that the major sources of contaminants were other countries. The data, which included information on the benefits from continued consumption of traditional/country foods, was also used to carry out assessments of human health risks resulting from contaminants in those foods. Results generated through NCP-I are synthesized in the *Canadian Arctic Contaminants Assessment Report.*

Extensive consultations were conducted in 1997-1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, priorities for current and future research are based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

In 1998-1999, the NCP began its second phase (NCP-II), which continued until 2002-2003. Results of this phase are synthesized in the *Canadian Arctic Contaminants Assessment Report II (CACAR II).* NCP-II supports research designed to answer questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species. To ensure a balanced assessment of the risks, an emphasis is placed on characterizing and quantifying the benefits associated with traditional diets. Communications activities are also emphasized and supported under NCP-II. Under the leadership of the northern Aboriginal organizations, the dialogue between northerners and the scientific community, which was initiated in NCP-I, continues to build awareness and an understanding of contaminants issues, and helps to support the ability to deal with specific contaminant issues at the local level.

In addition, the NCP effort to achieve international controls of contaminants remains strong in NCP-II. The legally binding POPs protocol, under the United Nations Economic Commission for Europe (UN ECE) Convention on Long-range Transboundary Air Pollution, has been successfully negotiated and was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in A?rhus, Denmark in June 1998. Canada ratified this agreement in December 1998. Negotiations for a legally binding global instrument on POPs under the United Nations Environment Programme have now also been completed with the signing of the POPs Convention in Stockholm, Sweden, May 23, 2001. The Convention has been signed by more than 100 countries; Canada has signed and ratified the Convention. Cooperative actions under the Arctic Council, including the circumpolar Arctic Monitoring and Assessment Programme (AMAP) and the Arctic Council Action Plan (formally launched in October 2000), are continuing. NCP-II continues to generate the data that allows Canada to play a leading role in these initiatives.

The NCP is directed by a management committee that is chaired by the Department of Indian Affairs and Northern Development, and which includes representatives from four northern Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapiriit Kanatami, and Inuit Circumpolar Conference), the Yukon, Northwest Territories and Nunavut Territorial Governments, Nunavik, and four federal departments (Environment, Fisheries and Oceans, Health, and Indian Affairs and Northern Development). The management committee is responsible for establishing NCP policy and research priorities and for final decisions on the allocation of funds. Three territorial contaminants committees in the Yukon, Northwest Territories and Nunavut (established in May 2000), and a regional contaminants committee in Nunavik support this national committee. Funding for the NCP-II's $4.4 million annual research budget comes from INAC and participating federal departments.

The NCP Operational Management Guide, developed in 2000-2001, and available on the NCP website (www.ainc-inac.gc.ca/ncp), provides a summary of the management structures and review processes used to effectively implement the NCP. The Guide explains the overall management structures currently used, the proposal review process and outlines a protocol to be used to publicly disseminate health and harvest information generated by the NCP. Background information on all NCP committees and review teams is also provided.

In 1998, the NCP Management Committee redesigned the NCP-Phase II for application under the 1999-2000 funding year. The two main initiatives undertaken were: 1) the development of blueprints that represent the long-term vision and strategic direction for NCP-II; and 2) the implementation of a more open and transparent proposal review process. This new management structure is designed to ensure that the NCP remains scientifically defensible and socio-culturally aware, while at the same time, achieving real progress in terms of the Program's broad policy objectives.

Blueprints were developed for each of the four main NCP subprograms: i) Human Health, ii) Monitoring the Health of Arctic People and Ecosystems and the Effectiveness of International Controls, iii) International Policy, and iv) Education and Communications. The blueprints are used to provide the necessary guidance to project proponents for the development of proposals as well as to peer reviewers, review teams and the NCP Management Committee for evaluating proposals. They are evolving documents that are reviewed at least annually.

Under a revamped proposal review process, the NCP Technical Committee was replaced with an external peer review process facilitated by review teams. The review of proposals is a two-pronged approach involving a scientific review by external peer reviewers, facilitated by technical review teams, and a socio-cultural review facilitated by the regional and Territorial

Contaminants Committees (TCCs). Both sets of recommendations are considered by the Management Committee in making final funding decisions. Proposals submitted under the Education and Communications subprogram are evaluated by the TCCs. All peer reviewers, review teams and TCCs use evaluation criteria and the blueprints to review and rate proposals. Written consent from the appropriate northern community authority or national-level Aboriginal organization is required for all projects involving field work in the North and/or analyses of samples as a condition of approval for funding.

This report provides a summary of the progress to date of research and activities funded by the Northern Contaminants Program in 2004-2005. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2004-2005 fiscal years. The report is divided into chapters that reflect the broad scope of the NCP: Human Health; Monitoring the Health of Arctic People and Ecosystems and the Effectiveness of International Controls (including abiotic monitoring and biotic monitoring), Education and Communications, International Policy, and Program Coordination.

Human Health

Monitoring Temporal Trends of Human Environmental Contaminants in the NWT: Year 2 MOM'S (Monitoring our Mothers-Study): Environmental Health Trends-Inuvik Region - Expectant Mothers Blood Monitoring Program 2004-2007

Project leader(s)

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Project members

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Northern Contaminants Program (NCP) Human Health Technical Steering Committee: Jill Watkins, INAC; Constantine Tikhonov, Health Canada; Mark Feeley, Health Canada; Jay Van Oostdam, Health Canada; Jack MacKinnon, GNWT H&SS; Janet Brewster, GN H&SS; Eric Loring, ITK

Abstract

In May 2003 it was decided to conduct a feasibility study to establish trends for human environmental contaminants in the NWT and Nunavut as a follow up to the Human Environmental Contaminants Exposure Baseline study conducted between 1995 and 2001. The new study was approved and began in 2004 and will involve the collection of maternal blood samples and information on lifestyle and diet from pregnant women in the Inuvik Region of the NWT and Baffin region of Nunavut. Consultation was a key component that began with the feasibility study (Year 1), and consultation activities continue to include meetings with and presentations to: territorial health departments and regional health staff, regional health authorities, territorial environmental contaminants and health committees, regional hospital staff, regional and national Aboriginal organizations including the local Inuvialuit Regional Corporation and the Gwich'in Tribal Council, communities and representatives of the territorial and federal governments.

Year 2 of the program included starting participant recruitment; training the appointed project coordinator, local health staff and community representatives; collection of hair and blood samples and lifestyle information; ongoing communication with participants, stakeholders, and team members; and the formation of a local informal working group with key health staff and Aboriginal partner participation.

Key Messages

1. A coordinator was hired for the Mothers' Blood Monitoring Program in September 2004.
2. Training and recruitment began in November 2004 and sampling began in January 2005.
3. Interest and support for the study continued to be expressed by all stakeholders. A key focus has been on Aboriginal participation to prioritize and improve capacity building and communication.
4. A proposal for Year 3 of the program was submitted to the NCP. The recruitment and sampling process for this fiscal year is planned to continue with the aim of obtaining the target of 100 participants.

Objectives

Short Term Objectives:

1. Maximize, improve and build strong communication networks with territorial and regional health departments, communities and priority Aboriginal organizations.
2. Establish a temporal trend of maternal exposure to select organochlorine and metal contaminants in NWT and Nunavut.
3. Deliver recruitment and conduct sampling and lifestyle surveys that will be compatible/ comparable with the earlier baseline sampling program in the Baffin and Inuvik Regions.

Long-term objectives:

1. Increase Aboriginal participation and improve capacity building and communications relating to all aspects of this project.
2. Provide a variety of information to women of childbearing age that offers wise lifestyle choices and enables them to make informed decisions relating to human health and the environment, especially as these factors relate to traditional/country food choices.
3. Evaluate temporal trends of maternal exposure to selected organochlorines and metal contaminants in the NWT and Nunavut using blood and hair as biomarkers.
4. Comprehend, understand, describe and relay relationships between contaminant exposure and frequency of consumption of traditional/country foods.
5. Contribute to other, international blood monitoring programs and to Canada's commitment to the Global Monitoring Planunder the Stockholm Convention
6. Collaborate with other NCP researchers on both study design and sample collection.

Introduction

In May 2003 the Human Health Steering Committee under the Northern Contaminants Program (NCP) met in Calgary to discuss the need to conduct a feasibility study to establish temporal trend monitoring programs of human environmental contaminants in the NWT and Nunavut. The new study will follow up on the Human Environmental Contaminants Exposure Baseline study that was conducted during 1995-2001. The main purpose of conducting the new study will be to establish a time trend of human exposure to specific environment contaminants through the collection and analysis of human blood and hair samples. The Environmental Health Trends-Inuvik Region - Expectant Mothers Blood Monitoring Program 2004-2006 will locally be called: MOM's (Monitoring our Mothers-Study); and will collect information on dietary habits and describe relationships between contaminant exposure and frequency of consumption of traditional/ country foods and select lifestyle factors.

This follow-up monitoring study was also undertaken in response to results from the Public Health Research Unit at the CHUL/CHUQ Research Centre that showed beneficial effects of traditional/country food consumption on infant development as well as some subtle negative effects related to contaminant exposure. Further, the monitoring program will be valuable in Canada's effort to fulfill its international obligations to the Persistent Organic Pollutants (POP) and Heavy Metals Protocols of the United Nations Economic Commission for Europe (UN/ ECE) Long-range Transboundary Air Pollution (LRTAP) agreement. The program is also expected to contribute data to the Global Monitoring Plan, created under the Stockholm Convention, that includes human blood as a biomarker.

The Baffin and Inuvik Regions were selected as target regions for sample collection to provide data from contrasting regions characterized by high and moderate contaminant exposures. The Baffin Region was a priority as it generally had the highest maternal and cord blood contaminant levels in the original NWT and Nunavut environmental contaminants baseline study. In contrast, the Inuvik Region had the lowest levels of most contaminants in Inuit maternal samples, and overall was in the middle to low range of dietary exposure levels. The Inuvik Region also had the highest recruitment rates and the most detailed dietary study of all regions. Data collected from the Inuvik Region will also allow comparisons between ethnic groups, as it is home to Dene, Métis, Inuvialuit and Caucasian women.

A workplan outlining activities for Year 2 of the study was prepared and approved by the NCP Human Health Technical Steering Committee. Barbara Armstrong was hired as the project coordinator in September 2004, working under the Inuvik Health and Social Services Authority. Training sessions began and recruitment started in November and sampling began in January 2005. Expectant mothers are now being interviewed around the time of their delivery to assess diet and lifestyle during pregnancy, and are being asked to sign a consent form agreeing to provide blood and hair samples for the study.

Activities

In 2004-2005

Year 2 of the study focused on training, recruitment and beginning the sampling process with ongoing meetings with a variety of stakeholders to discuss project planning, protocols and communications.

Monthly activities for 2004/2005 are summarized in the list below:

September- December

- Project Coordinator was hired by the Inuvik Health and Social Services Authority.
- Training began with Erica Myles and Karen Tofflemire in Calgary, AB.
  - Meeting with the second coordinator of the baseline Inuvik study-Karen Tofflemire.
  - Introduction and review of both the old and new studies with Erica Myles.
- Barbara Armstrong attended and presented at the NCP Results Workshop in White Rock, BC, with Erica Myles.
  - First in-person meeting with the Human Health Technical Steering Committee.
- Informal working group set up and reviewed workplan, recruitment, and protocols.
- Meeting with Inuvialuit Regional Corporation: Roger Connelly, Nellie Cournoyea and Frank Pokiak. Alice Thrasher (IRC Regional Wellness Coordinator), appointed by Aboriginal partner.
- For Health Workers of the Inuvik Regional Health & Social Services Authority.
- Contacted the Gwich'in Tribal Council (GTC) - Norman Snowshoe (GTC Regional Wellness Coordinator), appointed by Aboriginal partner - Denise Kurszewski.
  - Meetings with Denise and Norm and Alice - reviewed baseline study and draft introduction booklet.
  - Several recommendations were offered and then incorporated into the next draft of the recruitment packages, posters design, sample protocols and lifestyle survey.
- Local informal working group set up with Aboriginal representatives from IRC - Alice Thrasher, and GTC - Denise Kurszewski; the Environmental Health Officer at the Inuvik Regional Hospital, Christopher Beverage; Elaine Bright, the Community Prenatal Nutrition Program (CPNP) Regional Coordinator / Nutritionist; and Lorraine Walton Manager, Regional Health Promotions.
  - Several recommendations were offered and then incorporated into the next draft of the recruitment packages, posters design, sample protocols and lifestyle survey.
- Produced the first draft of the introduction booklet; ABC'S of the MOM'S Study - for Health Workers of the Inuvik Regional Health & Social Services Authority.
- Reviewed and reprinted the previous study, MOM'S recruitment packages, and survey prompts.
- Ordered hair and blood sampling kits; reviewed protocols and refined analyses.
- Contacted Mary O'keenan to request a new project logo designed.
- Doctors and health workers' medical rounds and first of three workshop presentations.
  - One-day workshop with Community Health Workers (CHR). Informal working group attended and participated as well as Inuvik Hospital nurses and lab technicians.
  - Offered a half-day introduction to the NCP, long-range contaminants background presentation: Country Foods, Still Healthy Safe and Strong!
  - Karen Tofflemire presented on the results and study design of the baseline study.
  - Introduction to the MOM'S trend study and a lengthy review and training on the lifestyle survey and recruitment; suggested changes incorporated in working documents.

- Collaborated on content and design to produce the yearly CPNP newsletter.
- NCP mid-term reporting.
- A proposal for Year 3 of the study was prepared and submitted to the NCP.
- Physician and health workers rounds and two community frontline workers presentations.
  - One-day workshop with Community Nurses.
  - One-day workshop with the regional and local CPNP workers. Informal working group attended and participated as well as the Inuvik Hospital nurses and lab technicians .
  - Offered a half-day introduction to the NCP, long-range contaminants background presentation: Country Foods, Still Healthy Safe and Strong! Presented on the results and study design of the baseline study.
  - Introduction to the MOM'S trend study and a lengthy review and training on the lifestyle survey and recruitment; suggested changes incorporated in working documents.
- Collaborated on content and design to produce the monthly newsletters with presentation summaries for community nurses and healthcare workers.
- Participated in the organization and displays and presentations at the local Career Fair.
- NCP final year reporting, IRHSSA budgeting, expense reports and billing reconciliation.
- Database set up and training with Karen Tofflemire in Calgary, Alberta.
- Inuvik Healthy Babies presentations and participation in various activities.
- Several meetings with local informal working group set up with Aboriginal representatives from IRC - Alice Thrasher, and GTC - Denise Kurszewski; the Environmental Health Officer at the Inuvik Regional Hospital, Christopher Beverage; Elaine Bright, CPNP Regional Coordinator /Nutritionist; and Lorraine Walton Manager, Regional Health Promotions.
  - Several recommendations were offered and then incorporated into the next draft of the recruitment packages, posters design, sample protocols and lifestyle survey.
- New graphic - sent from Holman, digitized and ordered revised printed materials and recruitment packages from Gwich'in Graphics.
- Thank you gift bags ordered, organized and recruitment packages sent to communities.
- Ten lifestyle surveys and blood and hair samples have been completed and sent for analysis.

Teleconference calls and communications ongoing with: Human Health Technical Steering Committee; hair and blood sampling laboratories; Jack MacKinnon, Olivier Receveur and Jay Van Oostdam; previous baseline study lab; health workers and coordinators; local informal working group; Erica Myles and Karen Tofflemire; and the NWT Environmental Contaminates Committee.

Results

All Inuvik region and NWT stakeholders that participated in meetings, discussions and conference calls continued to be supportive of the study. In general, stakeholders were aware of the baseline program and understood the importance of conducting the trend monitoring study. There were several significant comments and concerns related to study design. These included: the possibility of including other Dene communities in the program; administration of project coordinator; communication of results and building community capacity in the region and concerns about increased workloads for the community frontline workers. To date, all these concerns have been incorporated into the overall study design.

Other key issues identified during consultations that have been incorporated and will remain priorities:

- Communication materials should be developed collaboratively and contain clear messages related to public health and healthy pregnancies.
- The need for a well-developed communication plan for results that included follow up with any women who had blood levels above guidelines.
- Visual and oral communication materials for participants and communities are preferred.
- Community visits with the Aboriginal partners will need to be planned.
- Lifestyle and dietary information collected during the prenatal interview is of significant interest from a public health perspective.

Discussion and Conclusions

The study will continue to involve the recruitment of pregnant women from the Inuvik region of the NWT. Consultations on project planning resulted in the establishment of a recruitment goal of 100 women. The Program Coordinator manages the project under the local health authority and undertakes all the aspects and responsibilities for the project, including recruitment and sampling. Expectant mothers are interviewed prior to delivery to assess diet and lifestyle during pregnancy, and are asked to sign a consent form agreeing to provide blood and hair samples for the study. Ongoing communications are offered to participants, community frontline workers and health professionals regarding a variety of information related to understanding long-range contaminant health and environment issues, the connections and importance of country/traditional food, and healthy lifestyle choices.

Expected Project Completion Date

March 2007

The Nunavik Health Study: Determination of Dioxin-like Compounds in Plasma Samples from Inuit Adults using the DR-CALUX Bioassay

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Abstract

Compounds that possess a chemical structure similar to that of dioxin are among the most toxic substances and can elicit a variety of effects in laboratory animals including hormonal disturbances, immune system dysfunction and cancer. There is little data on exposure of the Canadian Inuit population to these compounds and no information on possible adverse health effects possibly resulting from this exposure. In the course of the Inuit Health in Transition Study, a cohort study that started in Nunavik in 2004, we will be analysing plasma samples from 1000 Inuit adults for dioxin-like compounds using a cell-based assay: the Dioxin-Receptor Chemically-Activated Luciferase Expression (DR-CALUX) bioassay. During September 2004, we recruited over 1000 Inuit adults in the course of the Nunavik Health Study and plasma samples were obtained for persistent organic pollutant analyses. A semi-automated comprehensive extraction multiple fraction (SACEMF) method was refined to prepare, from a single plasma sample (~5 mL), different plasma sample fractions for GC-MS analyses (project H-11) and the DR-CALUX assay. We improved the sensitivity of the DR-CALUX assay and are proceeding to the formal validation of the assay, in the spirit of ISO17025 certification. Analyses of the samples are scheduled to start in July 2005.

Key Messages

1. A new automated method of solid phase extraction was developed for the extraction of the plasma samples and purification of the fractions to be analysed by GC-MS and the DR-CALUX.
2. Reproducibility and sensitivity of the DR-CALUX assay were improved.
3. Analyses of the 1000 plasma samples will start in July 2005.

Objectives

1. To determine the plasma concentrations of dioxin-like compounds in 1000 Inuit adults recruited in the course of the Nunavik Health Study;
2. To investigate the relations between concentrations of these compounds and those of other persistent organic pollutants measured in the course of this cohort study;
3. To relate DLC plasma levels to dietary habits in the North.
4. To relate concentrations of dioxin-like compounds to the incidence of chronic diseases documented during the follow up of participants (cohort study).

Introduction

Substances structurally related to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) such as non- and mono-ortho chloro-substituted polychlorinated biphenyls (PCBs) as well as 2,3,7,8-chloro-substituted polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), bind the aryl hydrocarbon receptor (AHR) with varying affinities. The ligand-receptor complex triggers the expression of genes that are involved in cell proliferation and differentiation. These compounds, referred to as dioxin-like compounds (DLCs), are ubiquitous pollutants that are associated especially with the aquatic food chain. DLCs elicit a number of species-specific toxic responses in laboratory and wildlife species, including hepatoxicity, body weight loss, thymic atrophy, and impairment of other immune responses, dermal lesions, reproductive toxicity, alterations in vitamin A and thyroid hormone metabolism, teratogenicity, and carcinogenesis (Safe, 1990, 1994).

In humans, a meta-analysis examining cancer risk from dioxin exposure in three occupational cohorts revealed excess risks for all cancers, without any specific cancer predominating (Crump et al., 2003). In specific cohorts, excess risks were observed for reproductive cancers (breast female, endometrium, breast male, testis) but, overall, the pattern is inconsistent (Kogevinas, 2001) and the carcinogenicity of dioxins remains controversial (Cole et al., 2003). Other possible effects linked to DLC exposure in humans include modification of the sex ratio at birth, alterations in thyroid function, and increased risk for diabetes (Kogevinas et al., 2001).

Inuit residing in the Arctic receive an unusually high dose of organochlorines through their traditional diet which includes large quantities of sea mammal fat. We previously reported results of DLC analysis in 20 pooled plasma samples made of individual samples collected from Inuit adults residing in Nunavik (Arctic Québec) who participated in a large health survey during the 1990s. The mean total concentration of DLCs (expressed in 2,3,7,8-TCDD toxic equivalents) for the 20 pooled samples was 184.2 ng/kg lipids, compared to 26.1 ng/kg lipids for three control pooled plasma samples from southern Québec. This DLC body burden in Inuit adults was close to the one which induced adverse health effects in laboratory animals, but this risk remains hypothetical. Only a large-scale cohort study conducted throughout the Arctic can generate the results needed to better characterize the risk associated with exposure to DLCs in this population. Such a study has been launched in Nunavik and will involve the participation of 1000 Inuit adults from Nunavik. In subsequent years, it is expected that the cohort study will be expanded to other regions of the Canadian Arctic, bringing the total number of participants in Canada to close to 4000. Details regarding this study can be found in the synopsis of project H-11 ("Inuit Health in Transition Study: the Nunavik Health Study"; Éric Dewailly, PI). Up to now, only pooled plasma samples or a few milk samples from this population had been analysed for DLCs. Because information on the diet of participants will be collected in the Nunavik Health Study, it will be possible to link plasma DLC levels to dietary habits of participants. Our study will also allow testing the hypothesis that DLCs are related to chronic diseases such as diabetes and cancer in the North.

The conventional method to quantify DLCs in a biological sample involves the determination of the various compounds individually by high-resolution gas-chromatography/high resolution mass-spectrometry (HRGC/HRMS) and knowledge of the relative toxic potencies of individual compounds compared to TCDD, which are expressed as toxic equivalency factors (TEFs). The concentrations of the individual congeners multiplied by their respective TEFs are added up to yield the total TCDD toxic equivalents (TEQ) of the mixture. However, the often small concentrations of individual congeners, the presence of unknown or not routinely-measured AHR agonists, the lack of TEF values for several DLCs, and the possible supra-additive or antagonistic interactions between compounds in a mixture are drawbacks to the TEQ approach. Furthermore, conventional analytical chemistry methods using HRGC/HRMS are expensive and require a large volume of plasma (>10 ml) and extensive sample clean-up. Therefore, in order to study the possible role of DLCs in disease through a large epidemiological study such as the Inuit Health in Transition Study, an alternative to the HRGC/HRMS-based methods is needed.

One such alternative is the DR-CALUX bioassay. In our laboratory, this test is performed using H4IIE.Luc cells (kindly donated by Dr. Abraham Brouwer, Vrije Universiteit, The Netherlands). To produce these cells, a vector containing the luciferase gene under transcriptional control of dioxin-responsive elements was stably transfected into a rat (H4IIE) hepatoma cell line that expresses the AHR. Plasma extracts are placed in the cell culture medium and DLCs that are present in the extract diffuse across the cell membrane, bind the AHR and the complex is translocated in the nucleus where it binds dioxin response elements and triggers the expression of luciferase. The response is determined by measuring the intensity of light emitted during the oxidation of luciferin added to the cell lysate, the rate of this reaction being proportional to the amount of luciferase produced by the cells.

In recent years, several researchers have used this bioassay to measure DLCs in plasma samples in the course of population studies (Covaci et al., 2002; Koppen et al., 2001; Laier et al., 2003; Pauwels et al., 2000, 2001; Van Den Heuvel et al., 2002). In general, moderate to high correlations were observed between results of the DR-CALUX assays and those obtained by HRGC/HRMS. In general, results obtained with the bioassay are somewhat inferior to those obtained by analytical chemistry (HRGC/HRMS), which may indicate antagonistic interactions between compounds in plasma extracts.

Activities

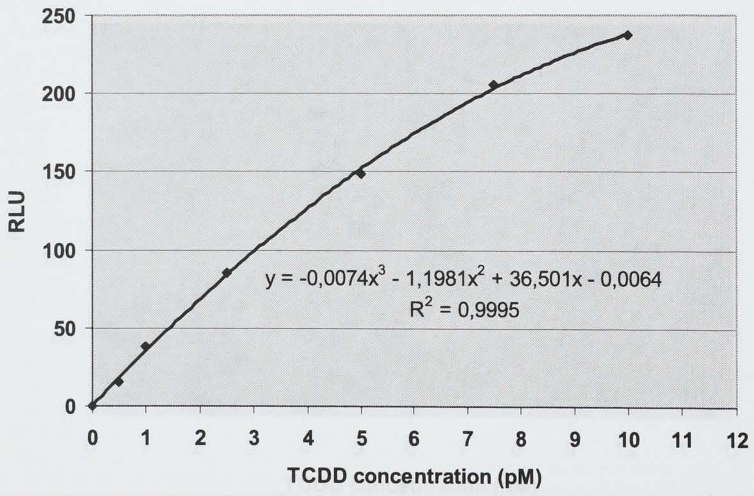
In 2004-2005

During September 2004, we recruited over 1000 Inuit adults in the course of the Inuit Health Study. Blood samples were collected in vacutainers containing EDTA as the anticoagulant, centrifuged and the plasma was transferred in a glass tube pre-washed with hexane and stored at 80°C. Because of the large number of samples, the extensive list of compounds to be analysed in the course of the Nunavik Health Study and the limited amount of plasma available, a semi-automated comprehensive extraction multiple fraction (SACEMF) method was set up. Zymark Rapidtrace automated solid phase extraction modules are used to prepare from a single plasma sample (~5 mL) the different fractions for GC-MS analyses (project H-11) and the fraction needed for the DR-CALUX assay. The benefits of using the Rapidtrace modules are increased reproducibility and less samples handling. Various clean-up procedures were tested for the fraction to be analysed by the DR-CALUX assay. We also worked on the sensitivity of the method and are proceeding to the formal validation of the assay, in the spirit of the ISO17025 certification.

Results

A great deal of work was conducted on improving the precision and the sensitivity of the DR-CALUX. Each step of the assay was reviewed for possible improvement over the original method used in our laboratory (Ayotte et al., 2005). Most notably, we improved the precision of the assay by using 24-well plates instead of the 96-well plates used previously. The coefficient of variation for triplicates in the

Figure 1. Dose-response curve with the DR-CALUX



same plate is now usually below 5%. A typical dose-response curve obtained with the current version of the bioassay is shown in Figure 1. We added more points in the lower part of the curve and are obtaining an excellent fit using a cubic polynomial model. The limit of detection is 0.5 pM, corresponding approximately to 15 pg TEQ/g lipid, assuming a 6 g/L total lipid content in plasma.

After extracting the compounds from plasma samples on an Oasis HLB (540 mg; Waters Corp.) solid phase extraction column and eluting the compounds with 10% MeOH/dichloromethane, half of the eluate is used for the DR-CALUX assay. Solvents are evaporated and the fraction is purified on an acid-silica column on the Rapidtrace modules. We also tested Florisil to purify the extract but we found that PCDD/Fs could not be eluted from the column. Hence acid silica was selected for cleaning-up of the fraction.

Discussion and Conclusions

Because of the large number of samples and analytes included in the Nunavik Health Study, a semi-automated solid phase extraction procedure had to be set up and validated. The development of this method delayed DLC analyses with the DR-CALUX. In the meantime, we worked on improving the precision and the sensitivity of the method. We are now proceeding to the formal validation of the method and samples will be analysed starting in July 2005. Data analysis will follow. Since the DR-CALUX bioassay can be conducted with as little as one ml of plasma, at a fraction of the cost of conventional analytical chemistry methods, it can be applied in the course of large-scale epidemiological studies such as the Inuit Cohort Study. This will allow examining possible associations between exposure to dioxin-like compounds and the incidence chronic diseases in the Inuit population.

Expected Completion Date

March 31, 2006

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Monitoring Temporal Trends of Human Environmental Contaminants in the NWT and Nunavut: Nunavut Study

Project leader(s)

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Abstract

A feasibility study for the temporal trends monitoring program began in September 2003. Work completed in 2003 mainly focused on project planning and consultation. Issues and concerns raised during consultation were incorporated into the study design details for 2004. Year two (2004/2005) of the temporal trends monitoring program was initially planned to include hire of a coordinator to manage the project, recruitment women and the collection of blood and hair samples for the program. Some significant delays were encountered in the hire of a Project Coordinator in 2004 which in turn delayed the initiation of program recruitment and sample collection. A Coordinator was hired in March 2005, and began her position on March 21st, 2005. Training of the Coordinator took place in April 2005. No sampling occurred in Year 2 of the program. All sampling and analysis is now proposed for Year 3 of the program. Recruitment will occur over an 8-10 month period with a target for the collection of 100 maternal blood and hair samples. The ICP full suite of metals, fatty acids and PBDEs (recently added) are included on the parameters list for blood analysis.

Key Messages

1. Work completed in 2004 focused on hire of a regional coordinator, ethics approvals, finalization of the maternal interview questionnaire and dietary survey, and approval of the consent form.

2. The project received ethical approval from the Nunavut Health and Social Research Ethics Committee and the Laval University Ethics Committee

3. A Coordinator was hired in March 2005.

4. Development of communication materials and protocols is ongoing in preparation for recruitment and sampling to begin in fall 2005.

Objectives

Short Term Objectives:

1. Recruitment and the collection of samples for 100 participants

2. Conducting maternal interviews with all participants
3. Establishment of communication networks with interested parties (hospital staff, community health center staff, Aboriginal organizations) and development of materials for ongoing communications of program activities
4. Establishment of an overarching communications advisory group between the NWT and Nunavut regions of the project
5. Linking the project to the Nasivvik Centre program.
6. Management of data collection and preparation for data analysis

Long-term objectives:

1. evaluate temporal trends of maternal exposure to selected organochlorines and metal contaminants in the NWT and Nunavut using blood and hair as biomarkers
2. describe relationships between contaminant exposure and frequency of consumption of traditional/country foods and select lifestyle factors
3. contribute to other international blood monitoring programs and to meet Canada's commitment to the Global Monitoring Plan under the Stockholm Convention
4. collaborate with other NCP researchers on both study design and sample collection

Introduction

A territorial baseline of selected organic and metal contaminants in maternal and cord blood was established for the NWT and Nunavut between 1994 and 1999. This program aims to establish temporal trends of selected environmental contaminants in human blood and hair in the Northwest Territories (NWT) and Nunavut. This program was initially proposed as a three-year program, but delays in getting coordinators in place in the two regions and getting the program up and running in 2004 have extended the program to run over four years.

For the Nunavut component of the program, year one (2003 – 2004) focused on feasibility and planning; and year two (2004-2005) focused on research licensing, advertisement and hire of a coordinator. Year three (2005–2006) will include preparation of materials for recruitment, maternal interviews and preparation for data management, as well as recruitment, sampling and some data analysis. Year 4 (2006-2007) of the study will be dedicated to further data analysis and communication of results.

This Nunavut part of the study will involve the recruitment of pregnant women from the Baffin region of Nunavut. Participants will be interviewed prior to delivery to assess diet and lifestyle during pregnancy, and they will be asked to sign a consent form agreeing to provide blood and hair samples for the study. The study will provide data to assess temporal trends of maternal blood and hair contaminant levels in the region, as well as contribute to international contaminant monitoring initiatives such as the Global Monitoring Plan under the Stockholm Convention. Communication activities will be ongoing throughout the program.

Activities

In 2004-2005

The following activities were conducted in 2004;

- The maternal interview questionnaire and dietary survey were finalized.
- The participant consent forms for the Baffin region were finalized and reviewed by the Nunavut Health and Social Research Ethics Committee.
- A research application was submitted to the Nunavut Research Institute.
- Project details and materials were submitted to the Nunavut Health and Social Research Ethics Committee and approval for the study was granted in September 2004.
- Project details and materials were also submitted to the Laval University Ethics Committee and approved in June 2004.
- A job description for the Coordinator was developed in June 2004.
- A poster was prepared and presented at the 2004 NCP Results Workshop in September.
- The Coordinator position was advertised and candidates selected in November 2004.
- Candidates for the Coordinator position were screened in December 2004, and interviewing was completed in January 2005.
- A Coordinator was hired in March 2005.
- An orientation session was held with the Coordinator in April 2005.
- Coordination with the NCP Human Health Technical Steering Committee and research team was ongoing.

Results

Due to project delays, sampling has not yet started. Preliminary analysis results for samples collected in Year 3 are expected in 2006.

Discussion and Conclusions

As the questionnaires have been finalized and a Coordinator has been hired and trained, recruitment and sampling are expected to proceed according to schedule to begin Fall 2005. Testing of the lifestyle and traditional food frequency questionnaire will occur in July 2005, to prepare for recruitment. The Coordinator will travel to Health Centres in Baffin communities to meet with health centre staff and inform them of the program. A Territorial Working Group has been established for the project and will meet on a regular basis to support the program. Communications with Baffin Regional Hospital staff, Aboriginal organizations and other interested groups have been initiated, and communications materials and protocols are being developed and will be ready for Fall recruitment. Recruitment, sampling and preliminary analysis are expected to be completed in 2006.

Expected Project Completion Date

May 2007

Developmental Immunotoxicity of a Commercial Polybromodiphenylether (PBDE) Mixture

Project leader(s)

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Abstract

The animal phase of the developmental PBDE study was delayed by the appearance of rat parvovirus in the Banting animal facility. Since pregnant rats and pups are vulnerable to this virus the decision was made by the Principle Investigator (Dr. G. Bondy) to wait until infection control processes were firmly in place before commencing the study. This has been done and the study will begin in May 2005. In the interim all of the required materials, chemicals, equipment and reagents have been purchased. The study protocol has been approved by the Health Canada Animal Care Committee and the study plan and calendar have been prepared. Validation of all developmental immunotoxicology endpoints has been completed. Protocols for milk collection and analyses have been finalized and tested. As a result of the extra planning time, the resulting study will be larger and more comprehensive than the original study. The parental generation (females and males) will be assessed for changes in immune function. Group sizes will be larger for the F1 generation immune challenges (10 instead of 8 juveniles/group). More importantly, the test dates for F1 juveniles (postnatal day [PND] 22-24 and PND 42-44) have been scheduled to reflect recent discussions in the scientific community regarding appropriate testing times for developmental immunotoxicology studies. At the conclusion of this study, NCP will have the most comprehensive data available on the developmental immunotoxicity of PBDEs.

Key Messages

The start of the PBDE developmental immunotoxicity study was delayed to ensure that vulnerable dams and pups would not be exposed to rat parvovirus, which would compromise immune endpoints. In the interim the study was planned and materials were purchased to complete the animal phase in the 2005 calendar year. The extended planning period was used to enhance the study design, which will ultimately provide NCP with stronger and more comprehensive data on the immunotoxicity of PBDEs.

Objectives

Short-term:

1. To assess immune function in rats exposed to PBDEs *in utero*, during lactation and post weaning, encompassing the entire juvenile development period

2. To measure residues in milk from dams exposed to PBDEs during pregnancy and lactation.

Long-term:
To determine whether levels of PBDEs in human blood, tissues and breast milk may be similar to PBDE levels in rodent blood, tissues and milk which are associated with adverse health effects in rodent toxicology studies. Data from this project will support regulatory decisions in Canada and the U.S. regarding safe levels of PBDEs in foods.

Introduction

PBDEs are regarded as "emerging contaminants" in the Arctic and in more southerly latitudes. Analyses of PBDEs in North American breast milk samples indicate that these contaminants have increased exponentially over the last 10 years (reviewed by Rahman *et al.*, 2001). Although the presence of PBDEs in breast milk is an indicator of both maternal and infant exposure, it is by no means clear what this signifies in terms of human health effects. In particular there are no data on the potential for immunomodulatory effects of PBDEs on infants exposed *in utero*, via breast milk and during critical stages of postnatal development. Fetal and early postnatal life are important periods in immune system development (Holladay and Smialowicz, 2000). There are profound changes in immune activity during infancy as a result of breast milk ingestion, which both protects against infection and plays a key role in the development of oral tolerance to food and bacterial antigens in the neonate (Cummins and Thompson, 1997). Since perinatal exposure to contaminants must be regarded as a continuum extending throughout fetal life and into the postnatal period, it is important that contaminant exposure scenarios include all of the critical windows in juvenile rodent development (Holsapple, 2003). Therefore, this study will assess the potential for PBDEs to modulate juvenile immune responses by examining the effects of PBDE exposure throughout rodent development and by measuring PBDE levels in milk to estimate exposure during lactation. Since there are no published data on the effects of PBDEs on the juvenile immune system this study will address a significant data gap.

Activities

In 2004-2005

- A study protocol was prepared and submitted to the Health Canada Animal Care Committee. The protocol was approved and the animal phase will commence in May 2005.
- The working study plan and calendar was completed. This is essential for coordinating dosing, breeding and all other activities related to the treatment and manipulation of rodents over the 7 month study period, as well as for scheduling staff overtime and weekend work during the animal phase of the study.
- All materials and equipment required for the study (with the exception of perishables that could not be purchased in advance) were acquired in anticipation of study commencement in May 2005.

Results

None to date.

Discussion and Conclusions

None to date.

Expected Project Completion Date

The animal phase of the study will be completed in November 2005. Tissue analyses and data summaries will be conducted as soon as possible following the completion of the animal phase. Completion of this project is a priority, not only because of the delayed starting date but also because this will be the first comprehensive study of the developmental immune effects of PBDEs. Both NCP and Health Canada will benefit if the work is published as soon as possible. All available immunology data will be summarized for presentation in March 2006. Some endpoints, mainly residue analyses and pathology, will take longer to complete (approximately 1 year after completion of the animal phase).

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Neurotoxicological, Thyroid and Systemic Effects of *In Utero* and Lactational Exposure to Polybrominated Diphenyl Ethers (PBDEs) in Sprague-Dawley Rats

Project leader(s)

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Abstract

In the last 20 years, exposure to polybrominated diphenyl ethers (PBDEs) has been increasing in North American populations. While there is little data on human exposures in Canadian Arctic populations, PBDEs have been found in the Arctic environment and wildlife. Because Aboriginal Arctic populations rely on wildlife as part of their diet, it is likely that they are also exposed and there is concern that levels of PBDEs may be increasing faster in the Arctic than elsewhere. Because PBDEs have structural similarities to PCBs, it is thought that neurobehavioural function, thyroid function and cancer are the most likely consequences of PBDE exposure and that fetuses and infants are the most susceptible populations. This study evaluates the toxicity of DE-71, a commercial mixture of PBDEs, in offspring of rodents exposed during gestation and lactation. While this study is ongoing, results to date indicate that 30 mg/kg/day PBDEs produces decreases in maternal and offspring weight gain but these decreases are transient. In addition, PBDEs alter thyroid hormone levels and CYP-450 enzyme activities in both mothers and offspring; however, offspring are about ten times more sensitive than mothers with 3 mg/kg producing significant alterations. A number of behaviours such as motor activity and startle are also altered in offspring. Though some behavioural effects appear to be transient, other effects seem to persist into adulthood. Further evaluation of the effects of PBDEs on learning and memory is in progress. Analysis of tissue levels of PBDEs in mothers and offspring is in progress and until these data are available the relationship between toxicity in this study and exposure levels in humans is yet to be determined.

Key Messages

1. This study evaluated the neurotoxic and systemic effects of gestational and lactational exposure to DE-71 (a commercial mixture of polybrominated diphenyl ethers (PBDEs)) in rodents because PBDE levels have been increasing in the Arctic environment.
2. Exposure to PBDEs at 30 mg/kg produce small but transient alterations in maternal and offspring growth but do not affect mortality rates.
3. PBDEs decrease thyroid hormone levels in mothers and offspring but offspring are about 10 times more sensitive than mothers.
4. PBDEs alter cytochrome P-450 drug metabolising enzyme levels in mothers and offspring but offspring are about 10 times more sensitive than mothers. Similarly, PBDEs alter clinical chemistry in PND 21 offspring but have no effect on mothers.
5. PBDEs alter behavioural development (grip strength, motor activity and startle responding) in young pups.

Some effects on behaviour disappear as animals matured (e.g., motor activity), while other behavioural effects persist into adulthood.

Introduction

Polybrominated diphenyl ethers (PBDEs) are a group of chemicals that have a chemical structure similar to polychlorinated biphenyls (PCBs) and, like PCBs, also appear to be persistent in the environment (Schecter, Pavuk et al., 2003). PBDEs are found in humans tissues and there is evidence that levels have been increasing in the last 20 years (Schecter, Pavuk, Papke, Ryan, Birnbaum, and Rosen, 2003; McDonald, 2002; Birnbaum and Staskal, 2004; Hooper and McDonald, 2000; LoPachin, 2004) especially in the Arctic environment, where levels may be increasing at a faster rate than elsewhere (Northern Contaminants Program, 2003). Consistent with this, PBDEs have been found in wildlife (Wilson, Ikonen et al., 2004; Utgikar, Chaudhary et al., 2004) that can form a substantial part of traditional/country diets. The limited toxicological information available on PBDEs indicates that the most likely adverse health effects of exposure are: a) neurobehavioural effects; b) thyroid effects (possibly a contributor to neurobehavioural effects); and c) cancer (McDonald, 2002). There is no NOEL established for PBDEs (McDonald, 2002).

A small number of studies have shown that PBDEs affect neurobehavioural function following perinatal exposure or single exposures to relatively high doses (e.g., 8-10 mg/kg) (Eriksson, Viberg et al., 2002b; Viberg, Fredriksson et al., 2003). The limited data available have been somewhat inconsistent but suggest that, similar to PCBs, PBDE congeners (e.g., PBDE 99) may exhibit congener specific toxicity that may not be reflected by PBDE mixtures (e.g., DE-71). Since the prominent congeners in DE-71 (47, 99, 153) are the ones most frequently found in human tissues (Birnbaum and Staskal, 2004) and in approximately the same proportions, experimental DE-71 exposure may provide a more realistic assessment of the potential neurotoxic and thyroid effects in exposed humans. Moreover, like PCBs, most researchers believe that the most sensitive populations to PBDE exposure are likely to be fetuses and infants (McDonald, 2002).

This study examines the impact of perinatal exposure of rodents to the DE-71 mixture on growth, neurobehavioural development, neuropathology, cholinergic receptor function (assessed both behaviourally and biochemically) and thyroid function. In addition, because there is limited information on systemic toxicity of PBDEs after perinatal exposure, we will assess systemic toxicity in these animals. We also measure blood levels of the major PBDE congeners in the exposed mothers and tissue levels (blood and brain) in the exposed offspring. The study design permits us to provide toxicological information on a range of health endpoints and to correlate toxicological effects with tissue exposure levels and to permit comparison with threshold effects levels expected in human populations. The results of this study will be relevant to Arctic populations by developing toxicological knowledge of exposure to PBDEs. Once exposure levels can be characterized in this population, this knowledge can then be employed to determine if adverse health effects are likely and if remediation strategies are required.

Activities

In 2004-2005

The animal phase for the main study is currently in progress and is scheduled for completion by November 2006. Pregnant rats were dosed with PBDEs from gestation day 1 to weaning at postnatal day 21 (PND 21). All reproductive, growth and early developmental measures have been collected. Offspring were sacrificed for tissue collection at PND 4, 11, 14, 21, 50 and 100, while the dams were sacrificed for tissue collection at weaning. The remaining offspring are still undergoing behavioural testing. Blood and liver from the dams and blood, liver and brains from the pups up to PND 21 were collected for residue analysis and this work is currently in progress. Neuropathology analysis for offspring at PND 11 and 21 is currently in progress. Blood and liver from the dams and from the offspring at PND 21, 50 and 100 were collected for systemic toxicology (clinical chemistry, haematology, liver enzymes). The laboratory analyses for the following have been completed: haematology (all); clinical chemistry (dams and pups at PND 21); and liver enzymes (dams and pups at PND 21); the remainder of the work is in progress. Thyroid hormone measurement from blood has been completed for the pups at PND 21 and 50 while analysis of thyroid morphology from the offspring at PND 21 is in progress. Cholinergic neurochemistry has been completed for pups at PND 21 and is in progress for pups at PND 50 and 100. Brain tissue for morphometric measures have been collected from pups at PND 11, 21 and 50. Morphometric analysis has been completed for subsets of PND 21 pups (see results below) and remaining tissue is currently under analysis. Neurobehavioural measures of activity, startle and emotionality have been collected. Additional measures of motor function (beam motor co-ordination) have been collected at PND 33 and 60. Measures of learning and memory (Morris Water Maze and delayed spatial alternation) are scheduled for completion in early September 2005.

Results

Reproduction and Growth: The lowest dose of PBDEs (0.3 mg/kg) produced a small decrease in litter size and implantation sites but no other dose affected either measure. These small effects are unlikely to be of substantial significance. No dose of PBDEs significantly affected litter mortality rates (mortality before culling at PND 4) or offspring mortality rates. Weight gain was affected by the highest dose of PBDEs (30 mg/kg). Maternal weight was reduced by about 10% during gestation and most of lactation but maternal weight had returned to normal values by the end of lactation at PND 21 (see figures below). Offspring weight gain was also decreased by 30 mg/kg of PBDEs up to weaning at PND 21. There was no indication that the effect of PBDEs on offspring weight persisted into adulthood as offspring weight returned to normal by PND 100. There was no indication of gender differences in the effect of PBDEs on offspring gain.

Residue Analysis:
Residue analysis is currently in progress but no results are yet available.

Systemic Toxicity:
Haematology: Haematology measures in dams were not affected by any PBDE dose. While PND 21 pups showed reduced red-cell counts (RBC), haemoglobin (Hb), and haematocrit (Hct) relative to mothers, this is not unusual as the pups have not fully developed their bone marrow erythroid maturation. PBDEs did not affect haematology measures in offspring at PND 21 or 50.

Clinical Chemistry:
PBDEs did not affect any measures of clinical chemistry in dams. In offspring at PND 21, there were reduced levels of alanine aminotransferase (ALT), alkaline phosphatase (ALP), glucose and uric acid in the 30 mg/kg PBDEs dose group. There were also significant elevations in cholesterol, total protein and albumin levels at this same dose level. The elevation in cholesterol is most likely linked to induction of liver cytochrome P-450 enzymes. At PND 50, clinical chemistry was not affected by PBDEs.

Cytochrome P-450 Dependent Drug Metabolism:
The highest PBDE dose (30 mg/kg) produced a significant induction of EROD, BROD, and PROD in mothers. When expressed as a percentage of control animals the magnitude of induction was 2944%, 1586% and 1043% for EROD, BROD and PROD, respectively. This is consistent with the increased relative liver weight also seen in the dams exposed to 30 mg/kg of PBDEs. In

Figure 1. Pregnancy weights for dosed & Preg dams

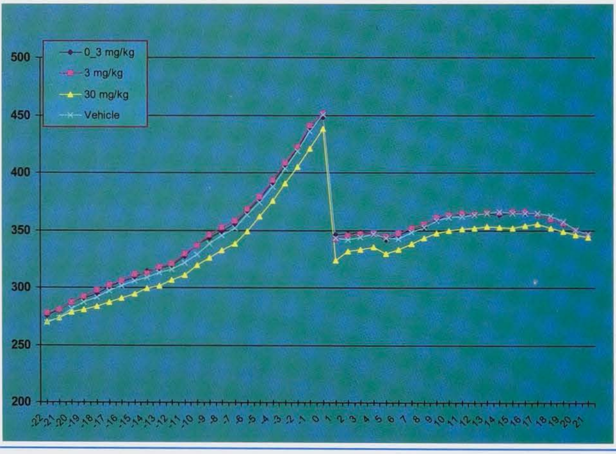
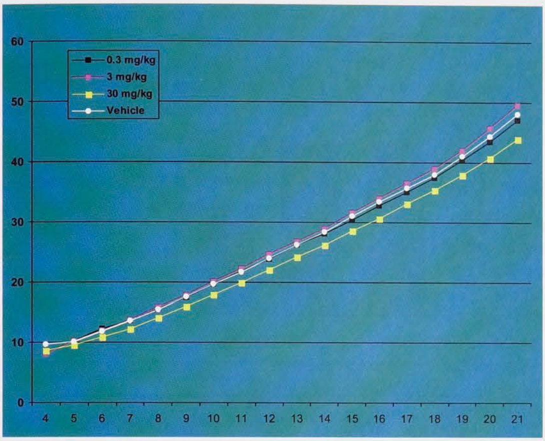


Figure 2. 2004: 023 PupGrowth



offspring at PND 21 the two highest doses of PBDEs (3.0 and 30 mg/kg) produced significant increases in EROD, BROD and PROD levels, about 2 times the increases over control values than observed in the dams.

Further, while 3.0 mg/kg PBDEs did not significantly increase EROD, BROD or PROD in dams, it did produce significant increases in 21 day pups. The highest dose of the PBDEs also increased liver weight in PND 21 offspring.

Thyroid toxicity:
Serum T3 and T4 was significantly decreased in dams at PND 21 by 30 mg/kg PBDEs (see figures below). Similar to cytochrome P-450 enzymes, T3 and T4 levels in offspring exhibit a ten-fold greater sensitivity to PBDEs than in mothers. In the 21 day old offspring serum T3 and T4 were significantly reduced by 3 and 30 mg/kg PBDEs. Measures of T3 and T4 from offspring at PND 50 indicate that thyroid hormone levels had returned to normal. In addition, serum thyroid stimulating hormone (TSH) levels were significantly elevated in PND 21 offspring exposed to 30 mg/kg PBDEs. Whole thyroid glands have been collected from PND 21 offspring, tissues have been processed for histomorphological analyses, and analyses

Figure 3. 2004: 023 PND21 Pups (STP) - Serum Triiodothyronine (T3) Levels

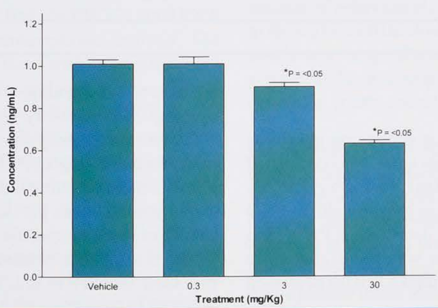


Figure 4. 2004-023 PND21 Pups (STP) - Serum Thyroxine (T4) Levels

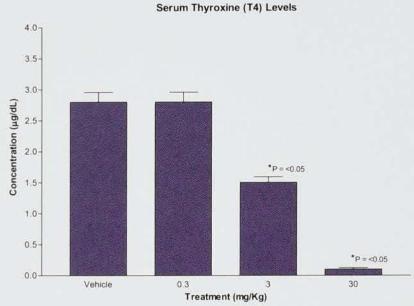
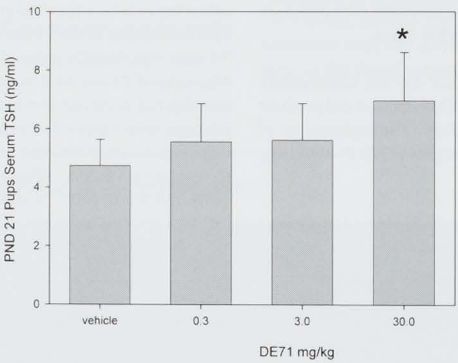


Figure 5. Levels of Serum Thyroid Stimulating Hormone in PND21 pups after exposure to PBDEs



are currently in progress.

Behaviour: Behavioural testing is continuing in subsets of offspring but results from behavioural tests conducted on young animals indicates that 30 mg/kg PBDEs produces a significant decrease in grip strength at PND 12. While grip strength was still decreased at PND 15 in this dose group, this decrease was not statistically significant. In addition, while 30 mg/kg PBDEs decreased the days to eye opening, it had no effect on onset of ear opening. Motor activity was tested at PND 16, 55 and 100. Preliminary analyses of PND 16 activity test results indicates that 30 mg/kg PBDEs produces hypoactivity in pups but there was little indication of altered habituation learning as has been previously reported for mice perinatally exposed to specific PBDE congeners (Eriksson, Viberg et al., 2002a; Ankarberg, Fredriksson et al., 2001; Eriksson, Archer et al., 1990; Viberg, Fredriksson, Jakobsson, Orn, and Eriksson, 2003). By PND 55, motor activity did not appear to be altered by PBDEs suggesting any activity effects detected in young animals are not persistent. More detailed statistical analyses of habituation learning are in progress. Preliminary assessment of acoustic startle responding at PND 21 suggests that the highest PBDE dose decreases startle responding. Acoustic startle responding in mature animals (PND 90) was increased by 30 mg/kg PBDEs suggesting that PBDEs may produce relatively permanent alterations in reactivity. Evaluation of the effects of PBDEs on pre-pulse inhibition of startle responding, a measure of sensory-motor integration, are scheduled for year 2 of the study. In addition, we have collected data on measures of anxiety (emergence latency) in young (PND 35) and mature (PND 82) animals. These results have not yet been analysed but will provide further information to help clarify the role of altered reactivity in mediating effects of PBDEs in startle and motor activity tests. Measure of learning and memory (Morris Water Maze, Discrimination learning) are scheduled for year 2 of the study. Tests of pharmacologically-induced motor activity using nicotine and amphetamine will provide information on the impact of PBDEs on functional responsiveness of cholinergic and dopaminergic brain neurochemical systems in adults. These tests are scheduled for year 2 of the study.

Neuropathology: Tissues have been collected, sections fixed and stained and slides are currently under evaluation. Morphometric measures in PND 21 female offspring have been completed in the highest PBDE dose group but no significant changes were detected. Morphometric evaluations of PND 21 brains have been completed in the females in the highest PBDE dose group and in the males in the low dose PBDE group. (These were conducted initially because these groups showed altered muscarinic and nicotinic expression.. Analysis of morphometric measures on remaining tissues is currently in progress.

Cholinergic neurochemistry: The brains have been collected for PND 21, 50 and 100. For PND 21, total RNA was isolated and used for transcriptional analysis. The preliminary results show that there are gender differences in the expression of the genes analysed to date. There are gender differences in the effects of PBDEs on cholinergic system in PND 21 offspring. We analysed the transcriptional changes in the muscarinic (M) receptor subtypes M1-M5. In females, the expression of M2, M3 and M5 subtypes is increased only in the highest PBDE dose (30 mg/kg) while in the males the M1 and M4 muscarinic subtype was increased but only in the lowest PBDE dose group (0.03 mg/kg). The highest PBDE dose also showed an upregulation in the expression of nicotonic (N) receptor subtypes N3, N5 and N7 but only in females. There were no changes in the expression of nicotinic receptor at any dose in males. Transcriptional changes were also monitored for acetylcholinesterase (AchE); this enzyme is responsible for degrading acetylcholine and thus terminating cholinergic neuron stimulation. In PND 21 the highest PBDE dose showed a 4-fold increase in AchE expression while no transcriptional changes were observed in males at any dose.

Discussion and Conclusions

Results collected to date indicate that gestational and lactational exposure to the commercial PBDE mixture, DE-71, produces effects on maternal and offspring growth; however, this occurs only at the highest dose (30 mg/kg/day) and both mothers and offspring appear to recover from the effects of PBDEs on growth. Results from systemic toxicity evaluation indicate that liver metabolizing enzymes are activated in both dams and PND 21 offspring. While no dose of PBDEs affected clinical chemistry in dams, clinical chemistry was altered in offspring exposed to the highest PBDE dose. Similarly, while only the 30 mg/kg/day dose decreased serum T3 and T4 levels in dams, both the 3.0 and 30 mg/kg/days doses decreased T3 and T4 levels in offspring. It appears that the effects of PBDEs on thyroid hormones are transient as serum thyroid hormones are unaffected by PBDEs at PND 50.

Available results from brain biomarker measures in PND 21 offspring indicate that the response to perinatal PBDE exposure is gender dependent and that males and females appear to exhibit both a different pattern of expression as well as differential sensitivity to PBDEs. These results will be important in the evaluation of gender differences in behavioural effects of PBDEs. Morphometric measures available indicate that no clear morphological changes are evident at any PBDE dose suggesting that gross morphological changes in brain structure is not a likely consequence of PBDE exposure. There do appear to be a number of behavioural changes that occur after exposure to the highest PBDE dose, particularly motor activity and startle reactivity. While PBDEs seem to affect motor activity only in young animals, effects on startle are evident in young and adult animals.

Future results from further activity testing in adults and tests of learning and memory will help determine both the permanence and extent of the effects of PBDEs. Taken together the results indicate that toxicity is evident in offspring at doses as low as 3 mg/kg. The translation of this into relevant human exposure will be determined by tissue residue levels that will be completed in year two of this project.

Expected Completion Date

March 2006

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Effects of Selenium, Vitamin E and Phytate on Methyl-Mercury Toxicity in Male Sprague-Dawley Rats

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Abstract

The Northern Contaminants Program (NCP) Phase II, with the release of the Canadian Arctic Contaminants Assessment Report II (CACAR II), concluded that there is a need to characterize the risk of mercury (Hg) exposure among Inuit communities because some Inuit populations are exposed to higher levels of methylmercury (MeHg). A recent report published by the United States National Research Council (US NRC) on the toxicological effects of (MeHg) concluded that dietary nutrients and supplements might protect against MeHg toxicity (US NRC, 2000). Moreover, intra-individual differences can be explained, in part, by nutritional factors that might exacerbate or attenuate the effects of mercury toxicity in the host (*ibid.*). The main sources of Hg in the northern diet, such as fish and marine mammals, are also rich sources of fish protein, polyunsaturated fatty acids, selenium, vitamin E and fibre. It is important, therefore, to characterize the risk by studying whether components of the Inuit diet may offer protective effects against MeHg toxicity.

This project was a follow-up study on the effects of nutrients on toxicity of MeHg using the rat as an animal model. Our previous study funded by NCP has shown that nutrients such as vitamin E and selenium may have protective effects against the toxicity of MeHg on newborn rats. This follow-up study was to investigate whether vitamin E and/or selenium, or phytate, a dietary fibre, will affect the accumulation of orally ingested MeHg in different organs and/or change the toxic effects of MeHg. This is a collaborative project between researchers from the Centre for Indigenous Peoples' Nutrition and Environment (CINE) at McGill University and the Toxicology Research Division, Bureau of Chemical Safety of Health Canada. This study was a laboratory-based toxicology experiment. Results of the study will help to characterize the risk of Hg exposure as well as beneficial effects from the consumption of the traditional Inuit diet.

Objective

Overall Objectives:
To study the effects of dietary factors on MeHg toxicity.

Specific Objectives (2003-2004):

(1) To study the effects of selenium on MeHg kinetics and toxicity in adult rats.

(2) To study the effects of vitamin E on MeHg kinetics and toxicity in adult rats.

(3) To study the effects of phytate on MeHg kinetics and toxicity in adult rats.

(4) To use state-of-the-art endpoint measurements to characterize the toxicity of MeHg.

These objectives are relevant to the project "Contaminant and Micro-nutrient Interactions Present in Traditional/ Country Foods of Arctic Residents"

Activities

In 2004-2005

The Contribution Agreement for NCP funding for this project which was to be completed in the fiscal year April, 2003 to March 31, 2004 was signed effective November 21, 2003. However, the funding was not received at McGill University until mid-January 2004. In addition, the format of the agreement did not allow a portion of funding to be transferred to the Toxicology Research Division, Food Directorate of Health Canada (HC) for the work that was to be done at HC. Thus, a lot of energy was spent in addressing the administrative and financial issues before the diets and other materials could be purchased and planned studies could begin. Despite these setbacks, the following activities were undertaken.

(1) Completion of experimental design, preparation of diets and dosing solutions and completion of animal dietary treatment (Jan-Apr 2004)

   i) Eleven different diets with or without high or low levels of vitamin E, selenium, or both, or phytate were prepared (**Appendix I, Table 1**). The treatment and sample collection and analysis protocols are summarized in **Appendix I, Figure 1**.

   ii) Male Sprague-Dawley rats (288) were purchased and acclimatized on a starch-based, semi-purified basal diet.

   iii) Rats were fed their respective diets for 28 days. Food consumption was recorded twice a week.

   iv) MeHg dosing solutions were prepared in 0.5 M Na_2CO_3.

(2) Completion of MeHg treatments, necropsies, and sample collections (May-Aug 2004)

   i) Rats were gavaged with 0.5 ml MeHg dosing solutions to give a dose of 3mg/kg BW everyday for 14 days. Twenty-four-hour urine and feces samples were collected in metabolic cages on the day before dosing and the 7^{th} and the 14^{th} day of dosing.

   ii) Rats were sacrificed on the 14^{th} day of dosing, and necropsied. Blood samples and selected tissues were collected, weighed, and fixed in 10% buffered formalin or stored at -80 ^{0}C for later analysis.

(3) Commencement of sample processing and analyses for MeHg kinetics and toxicological parameters (Aug 2004-Present.)

   i) Fresh 24-h urine samples were tested on urinalysis reagent strips for presence of ketones, glucose, protein, leukocytes, and hemoglobin.

   ii) Urine samples were aliquoted and preserved in buffer or frozen. They have been analyzed for levels of α-GST and μ-GST which are markers of kidney tubular damage.

   iii) EDTA-blood samples were shipped to Vitatech in Toronto, and have been analyzed for hematological end points.

   iv) Non-EDTA-blood samples were centrifuged. Serum samples were aliquoted and frozen, and will be analyzed for clinical biochemistry, immunoglobulin G and M, DNA damage and repair, and antioxidants.

   v) Brain, liver, kidney, and serum samples have been analyzed for vitamin E contents.

   vi) Total RNA was extracted from the brain cerebellum for each individual group, and used for the transcriptional analysis. Total of 14 neuro-specific biomarkers such as muscarinic acetycholine receptors (M1-M5), superoxidase dismutase, mitochondrial cytochrome oxidase 3, and Bcl 2- and Bax were examined.

   vii) Formalin-fixed tissues, including brain, liver, kidney, spleen, heart, thymus, testes, prostate, adrenal, and epididymis were sectioned. Kidney and testis slides have been H&E-stained for histopathological examination.

   viii) Slides of liver, kidney, brain, spleen and adrenal will be processed and immunohistochemically stained for markers of cell proliferation, apoptosis, renal damage, and oxidative DNA damage/repair.

ix) Liver, kidney, brain, and blood samples have been shipped to Dr. Laurie Chan at University of McGill for mercury analysis. Liver and blood have been extracted and analyzed for MeHg contents.

Results

As of December 31, 2004, the following data have been collated and analysed statistically, using a two-way ANOVA test.

Body and Organ Weights

Body Weight:

§ MeHg (3 mg/kg BW) significantly decreased body weight in all dietary groups, with the least change seen in the high selenium group followed by the low vitamin E +low selenium group.

Relative Brain Weight:

- MeHg significantly increased relative brain weight in low selenium, low vitamin E, high vitamin E, low vitamin E + low selenium, and low vitamin E + high selenium groups.

- The least effect of MeHg was seen in the high vitamin E+ high selenium group.

Relative Liver Weight:

- MeHg significantly increased relative liver weight in all dietary groups except the high selenium, the high vitamin E + high selenium, and the high vitamin E + low selenium groups.

- The least changes were seen in the high vitamin E + high selenium group.

Relative Kidney Weight:

- MeHg increased relative kidney weight in all dietary groups and to a similar degree.

- The MeHg-treated high phytate group had the highest relative kidney weight.

Relative Spleen Weight:

- MeHg significantly increased relative spleen weight in all dietary groups except the low vitamin E + high selenium group. The effect of MeHg in the low vitamin E + low selenium group on spleen weight was also small.

Relative Adrenal Weight:

- MeHg significantly increased relative adrenal weight in all dietary groups, however, too a lesser degree in the low vitamin E + low selenium and the low vitamin E + high selenium groups than the other dietary groups.

Relative Heart Weight:

- MeHg significantly increased relative heart weight only in the low vitamin E + low selenium groups.

Relative Thymus Weight:

- MeHg significantly decreased relative thymus weight only in the high vitamin E + low selenium, and the low phytate groups.

Relative Testes Weight:

- MeHg significantly increased relative testes weight in the low selenium, the high vitamin E, the high vitamin E + low selenium, the low vitamin E + high selenium, and the two phytate groups.

Relative Prostate Weight:

- No significant changes in relative prostate weight were observed in MeHg treated groups regardless of the diets.

Relative Epididymis Weight:

- MeHg significantly increased relative epididymis weight in all dietary groups except the control, and the low vitamin E + low selenium groups.

MeHg Levels in Liver and Blood

- In liver, MeHg content was the highest in the high selenium group, followed by the low vitamin E + high selenium group.

- In blood, MeHg concentration was similar in all treated groups except in the low phytate group which had higher MeHg level than the control, the low selenium, the high selenium, the high vitamin E, and the high vitamin E + low selenium groups.

- In all treated groups, MeHg concentration was 2-3 fold higher in the blood than the liver.

Urinalysis

- MeHg seemed to have increased urinary hemoglobin, protein, and leukocyte levels in all dietary groups. However, these changes occurred to a lower degree in the low selenium, and the low vitamin E + low selenium groups as compared with most of the other groups except for the high phytate group which also expressed most severe kidney damage.

- MeHg significantly decreased 24-h urine volume only in the control and the low vitamin E groups.

Urinary a-GST

- Results from partial sample analysis indicate that MeHg increased 24-h urinary secretion of a-GST (ug/24h) in all treatment groups but only to a statistically significant degree in the high vitamin E + high selenium, and the low vitamin E + high selenium groups.

Hematological End Points

Hemoglobin:
- MeHg significantly decreased hemoglobin levels in all treatment groups, with the least effects seen in the high vitamin E + low selenium group.

Hematocrit (%):
- MeHg significantly decreased hematocrit levels to a similar degree in all treatment groups.

Mean Corpuscular Volume (MCV):
- MeHg did not affect MCV level in any treatment group.

Mean Cell Hemoglobin (MCH):
- MeHg significantly increased MCH only in the high vitamin E + high selenium, and the low vitamin E + low selenium groups, with no change in any other treatment group.

Mean Cell Hemoglobin Concentration (MCHC):
- MeHg did not affect MCHC level in any treatment group.

Red Blood Cell Counts (RBC):
- MeHg significantly decreased RBC counts in all treatment groups.

White Blood Cell Counts (WBC):
- MeHg significantly increased WBC counts only in the high selenium group.

Neutrophils:
- MeHg increased neutrophil counts in all treatment groups, but only to a statistically significant degree in the low vitamin E and low selenium group.

Lymphocytes:
- No statistically significant changes with MeHg treatment were detected in any group.

Monocytes:
- MeHg significantly increased monocyte counts in the control, the high vitamin E + high selenium group, the low vitamin E + low selenium group, and the high vitamin E + low selenium groups.

Eosinophil:
- No statistically significant changes with MeHg treatment were detected in any group.

Basophils:
- No major changes were observed with MeHg treatment in any groups.

Polychromasia:

- No major changes were observed with MeHg treatment in any groups.

Platelets:
- No major changes were observed with MeHg treatment in any groups.

Vitamin E (a-tocopherol) Levels in Brain/Liver/Kidney/Serum

Brain Cortex:
- MeHg significantly decreased a-tocopherol level in the brain cortex in all dietary groups except the low vitamin E, the low vitamin E + low selenium, and the high phytate groups.

Brain Cerebellum:
- All vitamin E groups had higher a-tocopherol levels than all the non-vitamin E groups.

- MeHg significantly decreased a-tocopherol concentrations in the brain cerebellum in all dietary groups except the control, the low vitamin E, and the high vitamin E groups.

- MeHg treatment resulted in similar a-tocopherol levels in the cortex and cerebellum from the high vitamin E and the low vitamin E groups.

Liver:
- MeHg significantly decreased liver a-tocopherol content in the low selenium, high vitamin E + high selenium, low vitamin E + high selenium, and the high phytate groups.

- In rats treated with MeHg, all the high vitamin E groups had higher vitamin E contents in the liver compared to all the low vitamin E groups.

- The hepatic content of a-tocopherol in MeHg treated low vitamin groups were higher than the non-vitamin E groups, with the high phytate group having the lowest hepatic vitamin E level among all the groups.

Kidney:
- MeHg significantly decreased kidney a-tocopherol levels in all the dietary groups except the low vitamin E, the high vitamin E + high selenium, and the phytate groups.

- In MeHg treated rats, all the vitamin E groups had higher kidney a-tocopherol contents than the non-vitamin E groups.

- Similar a-tocopherol levels were observed in the kidneys from the high vitamin E and the low vitamin E groups.

Serum:
- MeHg significantly decreased serum a-tocopherol levels in the low vitamin E, the high vitamin E, the high vitamin E + low selenium, the low Vitamin E + high selenium, and the low phytate groups.

- In rats treated with MeHg, all vitamin E groups had higher serum a-tocopherol levels than the non-vitamin E groups.

- The MeHg treated high vitamin E + high selenium groups had higher serum a-tocopherol level than the low vitamin E groups.

Molecular Markers in Brain Cerebellum

- Different diets caused different levels of up or down regulation of the various biomarkers studied.

- The oxidative pathways (SOD, GCS or COX-3) did not show any protection by vitamin E and selenium against MeHg in any diet.

- The genes involved in apoptosis (Bax-a and Bcl-1) did not offer protection.

- The muscarinic receptors-subtype 3 and 4, were up-regulated, suggesting protection against MeHg, but only in the low vitamin E and low selenium group.

Histopathology

- In kidney, pronounced nephrosis was observed in all MeHg-treated groups, regardless of the diet. The lesions were similar in severity and quality throughout. In the high phytate groups the incidence and severity of glomerulonephroathy and nephrocalcinosis were markedly increased.

- In testis, no treatment-related effect was observed. There was a low incidence of degenerative change in most diet groups with or without MeHg treatment.

Conclusion

Overall the data analysed to date indicate protection from MeHg toxicity by Vitamin E and Se in the diet. This observation, however, will be further verified by analysis of more sensitive toxicity parameters at the cellular and molecular levels as summarized below. It is anticipated that such analysis will allow determination of any subtle dietary effects on MeHg toxicity.

Analysis in Progress, and Due for Completion in the Near Future:

§ Markers of oxidative DNA damage/repair will be analyzed in urine, liver, spleen, and kidney using ELISA and immunohistochemical methods.

§ Markers of antioxidants (TAC, GSSG/GSH) in serum, liver, spleen, and kidney will be measured using colorimetric and enzymatic methods.

§ Markers of cell proliferation, apoptosis and renal damage will be meaured in liver and kidney using immunohistochemical methods.

§ Markers of neurotoxicity including neurotransmiters, antioxidants, receptors, and key enzymes will be analysed using molecular techniques.

Proposed Future Study Submitted for the 2005-2006 NCP Call for Proposals

To fully understand the health risks of methylmercury exposure in Inuit populations, it is important to study the interactions between MeHg and the Northern diet. Our previous studies funded by NCP have shown that vitamin E and selenium may have protective effects against acute toxicity of MeHg in newborn (Chan et al. 2004) as well as in juvenile rats (preliminary data from this study) depending on the doses used. However, the long-term health benefits of dietary vitamin E and selenium are still unclear. In the NCP Call for Proposals for 2005-2006, we have proposed a follow-up study to investigate further if Vitamin E and Selenium also provide protection against chronic toxicity of MeHg at exposure levels similar to those found in the Inuit population. Findings from the proposed study will facilitate characterization of the health risks for Inuit population chronically exposed to a low level of MeHg, taking into consideration the nutritional benefits of the traditional diet as well.

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Managing the Issue of Mercury Exposure in Nunavut: A Pilot Study

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Abstract

Previous study has shown that Inuit in Nunavut may be exposed to elevated levels of mercury through traditional food consumption. This pilot study seeks to characterize the risk to human health by examining the relationships between diet and body burden of mercury in 2 communities in Nunavut. Food frequency data and hair samples were collected in adult volunteers in Igloolik (N=40) and in Repulse Bay (N=52) from May to July of 2004. Hair samples were collected for Hg analyses. A total of 65 most commonly consumed food samples were also collected for Hg analysis. The most consumed species on a g/person/day basis were caribou, ringed seal, walrus and char in Igloolik. In Repulse Bay the most consumed species were caribou, ringed seal, walrus, and narwhal. In Igloolik the estimated average Hg exposure is 11.3 ± 12.1 µg of Hg per day, with individual estimates ranging from 0.2 to 48.5 µg of Hg per day. In Repulse bay the estimated average Hg exposure is 30.8 ± 35.9 µg of Hg per day, with individual estimates ranging from 0.3 to 181.2 µg per day. Thirteen (13) people (33% of participants) from Igloolik had exposure estimates above the minimal risk level, and 31 people (60% of participants) from Repulse Bay had estimated exposure levels above the minimal risk level. The top three food items contributing to Hg exposure were walrus meat, caribou meat, and ringed seal meat in Igloolik. In Repulse Bay the top three contributors to Hg exposure were narwhal muktuk (with blubber), caribou meat, and beluga muktuk (with blubber). The average hair Hg level in Igloolik was 3.3 ± 3.3 µg/g, with individual values ranging from 0.1 to 13.1 µg/g. For women of childbearing age the average level was 2.1 ± 1.7 µg/g, with individual ranges from 0.2 to 7.0 µg/g. In Repulse Bay the average level of Hg in hair was 2.3 ± 1.5 µg/g with individual ranges from 0.2 to 6.3 µg/g. Of the women of childbearing age the average value was 2.1 ± 1.4 µg/g with individual values ranging from 0.5 to 6.0 µg/g. In Igloolik seven people had levels above the minimal risk level of 6 µg/g established by Health Canada, and Repulse Bay had two individuals. In each community only one woman of childbearing age had levels above the low risk level. There is a significant correlation between Hg in hair and both traditional food intake and estimated Hg intake in the two communities. A great majority of the participants agreed that traditional foods contribute to good health, eating traditional foods is a part of one's culture, eating traditional foods is completely safe, and that eating traditional foods has more benefits than risks. Results will be discussed with the communities and the Niqiit Avatittinni Committee for risk management purposes.

Objectives

The overall goal of the project is to develop a research and management paradigm to maximize benefits of traditional food-eating practices and minimize the risks of mercury exposure in Inuit communities in Nunavut by integrating traditional and scientific knowledge.

Long Term Objectives:

1. To characterize the risk of mercury exposure in Nunavut communities
2. To identify potential protective factors such as fatty acids and vitamins in the traditional diet
3. To develop indicators of well being of the communities
4. To develop management options to minimize the risk mercury exposure and maximize the benefits of traditional food consumption

Short Term Objectives (2003-2004):

1. To develop with the communities culturally acceptable protocols for the collection of hair for biomonitoring of mercury
2. To estimate dietary intake levels of the participants
3. To correlate Hg burden with dietary intake
4. To report test results to each participant and discuss the potential health implications
5. To discuss with the community representatives on the follow-up study

Introduction

There have been extensive studies of population groups, including the general population, indigenous peoples, and fishermen, on exposure and effects of mercury (Hg), ranging from the initial work in Minamata and Niigata, Japan in the 1950s (Tsubaki and Irukayama 1977) to work among remote population groups in the Amazon in the 1990s (Kehrigh *et al.* 1997; Lebel *et al.* 1996, 1997). Long-term exposure to either inorganic or organic Hg can permanently damage the brain, kidneys, and developing foetus (ATSDR 1999). Methylmercury (MeHg) that is ingested through the consumption of contaminated fish may cause greater harm to the brain and developing foetus because MeHg readily crosses the placenta and the blood-brain barrier and is neurotoxic. The developing foetal nervous system is especially sensitive to Hg effects. Prenatal poisoning with high dose MeHg causes mental retardation and cerebral palsy. The acceptable limits for steady-state exposure to MeHg is considered to be between 0.1 to 0.5 μg/kg-body weight/day (ATSDR, 1999).

Results of the dietary study conducted by CINE in 18 Inuit communities show that the average intake of Hg is 0.6 μg/kg-body weight/day (n=1875) and the 95th percentile has an intake level of 3.0 μg/kg-body weight/day (Kuhnlein *et al.* 2000). It is clear that some sectors of the populations are exposed to higher than desirable levels of Hg in their diet. The major contributors to Hg intake are ringed seal meat and organs, caribou meat and organs, lake trout, beluga and narwhal muktuk, Arctic char (Kuhnlein *et al.* 2000). It is, therefore, important to characterize the risk of Hg exposure in the Inuit communities by measuring body burden directly and to correlate the data with estimate dietary exposure followed by neurobehavioural testing of the subjects (if warranted). Dewailly *et al* (1999) reported mean Hg concentrations in hair samples collected in 1999 in the Salluit region to be 5.7 mg/kg. No similar data were collected by NCP in Nunavut.

Activities

In 2003-2004

Extensive consultations were conducted with the Niqiit Avatittinni Committee on the need for the research, methodology and the choice of communities. The project was endorsed by the Niqiit Avatittinni Committee on June 10, 2003. Historical data on Hg in hair collected from Nunavut between 1975-1985 were obtained from the First Nation and Inuit Health Branch of Health Canada (FNIHB). Based on the range of the historical data and the recommendation by the Niqiit Avatittinni Committee, the communities of Igloolik and Repulse Bay were selected as the participating communities. Both communities agreed to participate and research agreements were signed. The protocol and procedures were approved by the McGill Human Research Ethics Committee. Human hair samples and food use pattern data were collected from about 160 participants in the two communities. An M.Sc. student, Patricia Solomon, was recruited as the project coordinator. Two research assistants were hired in each of the two communities. Data were collected in Igloolik (May-June 2004) and in Repulse Bay (June-July 2004). Samples were sent to CINE for Hg analysis. Dietary Hg exposure was estimated using a food frequency questionnaire and body burden of Hg was assessed by measuring hair samples.. We plan to discuss the results and health implications with the communities in February of 2005.

Results

Traditional Food Samples

Traditional food samples were obtained from the Igloolik Hunters and Trappers Organization, and local hunters in both communities. In Igloolik 25 samples were obtained, including 10 char meat, 10 caribou meat, 1 walrus meat, 1

Table 1. Mercury Concentrations of Traditional Food Samples Collected in Current Study (mg/kg)

	n	mean	min	max
Caribou (flesh, raw)				
Igloolik	10	0.06	0.04	0.10
Repulse Bay	16	0.05	0.02	0.21
Char (flesh, raw)				
Igloolik	10	0.07	0.03	0.21
Repulse Bay	11	0.05	0.02	0.10
Narwale (muktuk-blubber)				
Repulse Bay	5	0.06	0.04	0.09
Narwale (muktuk-skin)				
Repulse Bay	5	0.39	0.05	0.66
Ringed Seal (flesh, raw)				
Repulse Bay	9	0.09	0.06	0.11
Ringed Seal (kidney, raw)				
Igloolik	1	0.44	n/a	n/a
Ringed Seal (liver, raw)				
Igloolik	3	0.72	0.27	1.23
Walrus (flesh, raw)				
Igloolik	1	0.08	n/a	n/a

seal kidney, 3 seal liver. In Repulse Bay samples were also obtained, including 16 caribou meat, 11 char meat, 5 narwhal muktuk, and 9 seal meat samples. All samples were analyzed for Hg content. A summary of the Hg concentrations from the raw samples are shown in Table 1.

Participation

For the community of Igloolik a random sample list of the adult population of the community was prepared proportional to gender category. The list of 120 adults consisted of 62 males and 58 females. The final participation rate from the random sample was 13%. Forty-nine percent (49%) of those sampled refused to participate, 17% had moved or were away from the community for the duration of the study, and 21% were unaccounted for. Including the volunteer participants the final group of participants included 40 adults from the community, the majority being women of childbearing age, as can be seen in Table 2a.

The random sample list for Repulse Bay was stratified by age, since the date of birth for each individual was available. The random sample list of 120 people included 83 members aged 18-40 years, 28 members aged 41-60 years, and 9 members aged 61 or above. The participation rate was 18% from the random sample list. Thirty-six percent (36%) of those sampled refused to participate, 18% had moved or were away from the community at the time of the study, and 28% were unaccounted for. The final study population for Repulse Bay including

Table 2a. Profile of Participants - Igloolik

	Male	Female	Total
Age 18-40	4	27	31
Age 41-60	2	3	5
Age 61 and above	1	3	4
Total	7	33	40

Table 2b.Profile of Participants– Repulse Bay

	Male	Female	Total
Age 18-40	13	32	45
Age 41-60	1	2	3
Age 61 and above	1	3	4
Total	15	37	52

volunteers was 52 adults with the majority also being women of childbearing age, which can be seen in Table 2b.

While it was not recorded for every person that declined participation, two main reasons were observed for not participating. Of the older adults who declined, most gave the reason that they would not change their current consumption patterns of traditional foods and were therefore uninterested in participating in a study about the contamination of traditional foods. For the younger adults who declined, the main reason for non-participation included the fact that they did not consume a great amount of traditional food and therefore the results of a study looking at contaminants in traditional food would not be applicable to them.

Traditional Food Intake

Table 3 presents the number of people who reported consuming specified traditional food items in the past year as per the food frequency questionnaire. Based on reported frequency of intake, estimates of daily intake were prepared using the appropriate portion size from studies conducted by Kuhnlein *et al*. 2000. These data are summarized on a per species basis presented in Table 4a and 4b along with the maximum estimated individual intake.

The most commonly consumed species/animal part, beginning with the greatest number of people who reported consuming it, for Igloolik were caribou meat, caribou broth/soup, char meat, walrus meat, ringed seal meat, ringed seal soup/broth, bird meat, ringed seal intestines, beluga muktuk with blubber, and char soup/broth. For Repulse Bay the list was caribou meat, caribou broth/soup, caribou tongue, char meat, narwhal muktuk with blubber, ringed seal intestines, walrus meat, ringed seal meat, caribou blood, and caribou fat.

Based on the total species quantity estimates, the most consumed species on a g/person/day basis were caribou, ringed seal, walrus and char in Igloolik. In Repulse Bay the most consumed species were caribou, ringed seal, walrus, and narwhal.

Mercury Exposure Estimates

Hg exposure was estimated by multiplying the reported frequency of consumption by the average portion size for each age group. Once a g/day value was determined the values were multiplied by the appropriate Hg content in food. Hg content of food was estimated using data from the Hg levels in food collected in this study and previous data collected by CINE. Hg concentrations used for each food item are shown in Table 5.

In Igloolik the estimated average Hg exposure is 11.3 ± 12.1 μg of Hg per day, with individual estimates ranging from 0.2 to 48.5 μg of Hg per day. Specifically for the group of women of child bearing age the average exposure was 6.0 ± 5.8 μg of Hg per day, with individual estimates ranging from 0.2 to 23.9 μg Hg per day. In Repulse Bay the estimated average Hg exposure is 30.8 ± 35.9 μg of Hg

Table 3. Frequency of Traditional Food Intake

	IGLOOLIK				REPULSE BAY			
Species - Part	n	% of population consuming	Average daily intake (g) mean ± stdev*	Max daily intake (g)	n	% of population consuming	Average daily intake (g) mean ± stdev*	Max daily intak e (g)
Beluga - Meat	3	7.7%	7.2 ± 8.2	18.4	6	11.5%	38.6 ± 30.1	64.4
Beluga - Muktuk with Blubber	27	69.2%	8.4 ± 11.6	57.2	37	71.2%	33.0 ± 48.6	178.0
Beluga - Muktuk without blubber	15	38.5%	5.1 ± 9.8	32.9	31	59.6%	15.2 ± 24.1	100.0
Beluga - Blubber	0	0.0%	0.0 ± 0.0	0.0	7	13.5%	12.1 ± 13.8	38.2
Beluga - Flippers	21	53.8%	6.6 ± 15.9	74.0	31	59.6%	37.1 ± 65.4	225.0
Beluga - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Narwhale - Meat	1	2.6%	1.8 ± 0.6	1.8	8	15.4%	114.1 ± 75.7	225.0
Narwhale - Eyes	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Narwhale - Flippers	9	23.1%	4.7 ± 5.5	18.5	33	63.5%	38.1 ± 70.1	225.0
Narwhale - Muktuk with blubber	21	53.8%	8.9 ± 15.6	71.3	35	67.3%	57.1 ± 66.3	250.0
Narwhale - Muktuk without blubber	7	17.9%	2.4 ± 2.1	4.1	32	61.5%	27.5 ± 35.2	150.0
Narwhale - Blubber	0	0.0%	0.0 ± 0.0	0.0	5	9.6%	35.3 ± 21.4	57.0
Narwhale - Heart	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Narwhale - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Walrus - Liver	15	38.5%	5.6 ± 10.2	34.5	13	25.0%	16.5 ± 30.2	84.0
Walrus - Heart	12	30.8%	10.5 ± 15.1	46.4	8	15.4%	35.3 ± 48.5	113.0
Walrus - Intestines	18	46.2%	5.8 ± 10.0	34.5	23	44.2%	29.2 ± 72.0	338.0
Walrus - Stomach and contents	7	17.9%	8.7 ± 12.6	37.2	9	17.3%	30.3 ± 40.5	113.0
Walrus - Flippers	11	28.2%	15.2 ± 21.0	74.0	11	21.2%	37.9 ± 72.2	225.0
Walrus - Blubber	15	38.5%	8.9 ± 12.1	41.1	19	36.5%	35.7 ± 48.3	150.0
Walrus - Oil	3	7.7%	7.0 ± 9.7	20.4	16	30.8%	18.9 ± 31.9	82.8
Walrus - Soup/Broth	11	28.2%	6.1 ± 14.9	49.3	16	30.8%	28.6 ± 48.7	136.8
Walrus - Meat	32	82.1%	29.3 ± 38.8	138.5	32	61.5%	50.0 ± 91.1	337.0
Walrus - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Polar Bear - Fat/Oil	26	66.7%	1.2 ± 5.2	8.2	4	7.7%	27.9 ± 48.3	100.0
Polar Bear - Feet	0	0.0%	0.0 ± 0.0	0.0	25	48.1%	23.4 ± 67.0	338.0
Polar Bear - Soup/Broth	1	2.6%	1.3 ± 0.2	1.3	9	17.3%	4.8 ± 10.3	32.2

Polar Bear - Meat	29	74.4%	2.4 ± 5.6	10.5	35	67.3%	13.1 ± 22.9	113.0
Polar Bear - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Ringed Seal - Liver	23	59.0%	4.4 ± 6.6	18.1	30	57.7%	18.8 ± 41.6	169.0
Ringed Seal - Kidney	15	38.5%	2.1 ± 5.0	15.3	20	38.5%	8.0 ± 16.6	56.0
Ringed Seal - Heart	8	20.5%	3.4 ± 4.6	14.4	9	17.3%	36.6 ± 66.6	187.0
Ringed Seal - Lungs	3	7.7%	2.1 ± 1.2	3.6	3	5.8%	40.8 ± 61.1	111.0
Ringed Seal - Brain	14	35.9%	0.1 ± 3.6	0.2	16	30.8%	0.7 ± 1.7	7.0
Ringed Seal - Eyes	5	12.8%	0.3 ± 1.9	0.7	9	17.3%	7.1 ± 9.7	20.0
Ringed Seal - Intestines	17	43.6%	13.9 ± 34.1	138.9	27	51.9%	55.9 ± 116.9	450.0
Ringed Seal - Flippers	5	12.8%	8.1 ± 5.7	18.5	13	25.0%	44.3 ± 87.4	253.0
Ringed Seal - Blood	3	7.7%	9.9 ± 6.7	15.8	15	28.8%	59.7 ± 122.8	360.0
Ringed SealFat/Oil	21	53.8%	6.8 ± 9.6	34.0	32	61.5%	7.8 ± 20.0	82.8
Ringed Seal - Soup/Broth	18	46.2%	14.8 ± 26.0	100.7	31	59.6%	26.3 ± 75.8	362.0
Ringed Seal - Meat	35	89.7%	25.5 ± 45.2	185.2	49	94.2%	27.6 ± 72.8	338.0
Ringed Seal - Cartilage	7	17.9%	1.7 ± 2.2	3.7	11	21.2%	13.2 ± 33.4	113.0
Ringed Seal - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Bearded Seal - Liver	0	0.0%	0.0 ± 0.0	0.0	4	7.7%	4.2 ± 4.8	11.1
Bearded Seal - Heart	1	2.6%	2.6 ± 1.1	2.6	2	3.8%	7.3 ± 5.2	10.9
Bearded Seal - Intestines	28	71.8%	4.9 ± 9.8	42.3	23	44.2%	13.2 ± 30.8	128.2
Bearded Seal - Fat/Oil	18	46.2%	2.9 ± 5.4	13.7	12	23.1%	11.1 ± 28.3	100.0
Bearded Seal - Soup/broth	1	2.6%	2.7 ± 1.2	2.7	8	15.4%	35.8 ± 69.8	206.3
Bearded Seal - Meat	22	56.4%	7.4 ± 8.1	30.8	22	42.3%	17.3 ± 34.8	128.2
Bearded Seal - Cartilage	1	2.6%	1.2 ± 0.2	1.2	2	3.8%	7.4 ± 5.3	11.1
Bearded Seal - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Bird - Meat	22	56.4%	11.9 ± 22.4	92.5	18	34.6%	19.2 ± 33.9	128.2
Bird - Gizzard/Stomach	8	20.5%	1.0 ± 2.4	1.5	5	9.6%	8.9 ± 12.6	31.1
Bird - Soup/Broth	3	7.7%	2.9 ± 2.7	6.7	9	17.3%	27.0 ± 43.7	139.6
Bird - Eggs	21	53.8%	2.5 ± 4.3	5.5	13	25.0%	4.7 ± 7.5	28.5
Bird - Other	0	0.0%	0.0 ± 0.0	0.0	0	0.0%	0.0 ± 0.0	0.0
Caribou - Liver	5	12.8%	4.5 ± 4.8	13.6	16	30.8%	30.6 ± 51.8	169.0
Caribou - Kidneys	5	12.8%	0.6 ± 1.9	1.5	18	34.6%	17.7 ± 23.2	56.0
Caribou - Heart	19	48.7%	2.8 ± 5.2	15.5	22	42.3%	15.4 ± 26.5	113.0

Caribou - Lungs	11	28.2%	2.4	±	3.1	7.4	6	11.5%	24.0	±	44.4	113.0
Caribou - Stomach and contents	10	25.6%	2.7	±	3.7	11.1	12	23.1%	58.4	±	73.0	169.0
Caribou - Intestines	9	23.1%	2.2	±	3.0	7.4	8	15.4%	24.6	±	41.8	113.0
Caribou - Nose	6	15.4%	2.0	±	2.8	6.8	2	3.8%	27.5	±	31.9	50.0
Caribou - Tongue	31	79.5%	5.2	±	8.6	27.4	47	90.4%	62.6	±	70.1	200.0
Caribou - Eyes	15	38.5%	0.4	±	3.7	2.1	22	42.3%	6.5	±	6.8	25.0
Caribou - Brain	19	48.7%	2.1	±	4.8	12.3	30	57.7%	19.2	±	27.2	89.5
Caribou - Bone Marrow	29	74.4%	5.6	±	9.1	30.8	40	76.9%	29.2	±	36.0	128.0
Caribou - Fat	35	89.7%	3.4	±	6.5	13.7	47	90.4%	28.0	±	31.6	106.0
Caribou - Blood	0	0.0%	0.0	±	0.0	0.0	6	11.5%	224.4	±	162.2	360.0
Caribou - Cartilage	10	25.6%	2.4	±	3.4	7.4	12	23.1%	40.9	±	41.5	113.0
Caribou - Broth/Soup	38	97.4%	33.3	±	38.4	134.2	48	92.3%	114.7	±	95.6	245.0
Caribou - Meat	39	100.0%	49.5	±	50.9	184.9	52	100.0%	165.6	±	139.9	450.0
Caribou - Other	0	0.0%	0.0	±	0.0	0.0	5	9.6%	70.6	±	58.1	113.0
Trout - Meat	13	33.3%	3.1	±	3.4	6.2	26	50.0%	39.2	±	73.0	225.0
Trout - Soup/Broth	1	2.6%	0.7	±	0.2	0.7	10	19.2%	57.8	±	99.0	245.0
Trout - Eggs/Roe	2	5.1%	0.6	±	0.8	0.8	7	13.5%	45.1	±	65.7	141.0
Trout - Other	0	0.0%	0.0	±	0.0	0.0	0	0.0%	0.0	±	0.0	0.0
Char - Meat	34	87.2%	31.2	±	35.6	123.3	48	92.3%	51.7	±	72.0	225.0
Char - Soup/Broth	8	20.5%	28.0	±	35.3	100.7	22	42.3%	60.0	±	88.0	245.0
Char - Eggs/Roe	10	25.6%	2.2	±	2.9	5.8	21	40.4%	32.2	±	48.9	141.0
Char - Other	0	0.0%	0.0	±	0.0	0.0	0	0.0%	0.0	±	0.0	0.0

* based on average portion size of those consuming

Table 4. Reported daily intake of traditional food species (g/day)

a. Igloolik

	Beluga	Narwhale	Walrus	Polar Bear	Ringed Seal	Bearded Seal	Bird	Caribou	Trout	Char
mean	11.9	6.4	43.1	2.5	45.9	9.2	8.5	98.7	1.1	33.1
stdev	24.5	13.5	74.2	3.9	87.6	16.5	18.9	96.2	2.0	47.0
min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
max	149.6	71.3	300.2	17.5	462.1	76.2	96.7	327.1	6.9	193.2

b. Repulse Bay

	Beluga	Narwhale	Walrus	Polar Bear	Ringed Seal	Bearded Seal	Bird	Caribou	Trout	Char
mean	61.6	99.9	104.5	22.2	134.3	21.1	13.0	462.6	35.4	83.4
stdev	129.5	196.6	300.5	76.4	440.5	77.6	46.9	465.7	119.6	149.7
min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
max	733.8	1067.2	1638.0	551.0	2383.8	503.3	327.4	2134.0	611.0	611.0

per day, with individual estimates ranging from 0.3 to 181.2 µg per day. The group of women from Repulse Bay had an average exposure of 21.3 ± 22.2 µg Hg per day with individual estimates ranging from 0.3 to 79.0 µg Hg per day.

The distribution of individual estimates is shown in Figures 1a and 1b. Using the World Health Organization Hg intake guideline of 0.24µg/kg body wt/day and assuming the average weight of females aged 20-40 is 64 kg as determined by Kuhnlein *et al.* 2000, the minimal risk level of exposure is 15 µg Hg per day. This minimal risk level is used for comparison as shown in Figures 1a and 1b. Thirteen (13) people (33% of participants) from Igloolik had exposure estimates above the minimal risk level, and 31 people (60% of participants) from Repulse Bay had estimated exposure levels above the minimal risk level.

Based on the estimated levels, the top three food items contributing to Hg exposure were walrus meat, caribou meat, and ringed seal meat in Igloolik. In Repulse Bay the top three contributors to Hg exposure were narwhal mutuk (with blubber), caribou meat, and beluga muktuk (with blubber).

Mercury in Hair

Mercury levels as measured in individual hair samples are all expressed as the average of the first 12 cms of hair. The average hair Hg level in Igloolik was 3.3 ± 3.3 µg/g, with individual values ranging from 0.1 to 13.1 µg/g. For women of child bearing age the average level was 2.1 ± 1.7 µg/g, with individuals ranging from 0.2 to 7.0 µg/g. In Repulse Bay the average Hg in hair was 2.3 ± 1.5 with individuals ranging from 0.2 to 6.3 µg/g. Of the women of childbearing age the average value was 2.1 ± 1.4 µg/g with individual values ranging from 0.5 to 6.0 µg/g.

Population distributions are shown in Figure 2a and 2b. As can be seen in these figures, in Igloolik seven people had levels above the minimal risk level of 6 µg/g established by Health Canada, and Repulse Bay had two individuals. In each community only one woman of childbearing age had levels above the low risk level. Profiles of all individuals above the low risk level are presented in Table 6. They are usually elderly people

Table 5. Mercury Concentrations in Traditional Foods used for Estimation of Dietary Exposure

	Igloolik	Repulse Bay
Beluga (muktuk)	0.135	0.205
Caribou (flesh, raw)	0.06	0.05
Char (flesh, raw)	0.07	0.05
Narwhal (muktuk)	0.205	0.225
Seal – Ringed (flesh, raw)	0.09	0.09
Walrus (flesh, raw)	0.15	0.14

Figure 1a Frequency Distribution of Estimated Hg Exposure in Igloolik

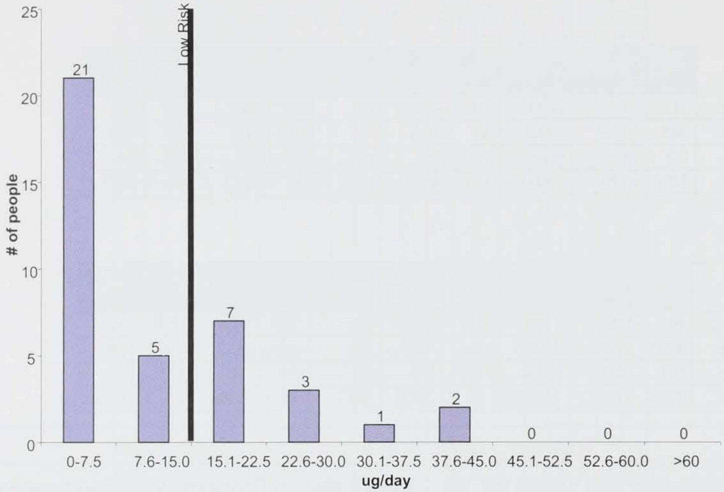


Figure 1b Frequency Distribution of Estimated Hg Exposure in Repulse Bay

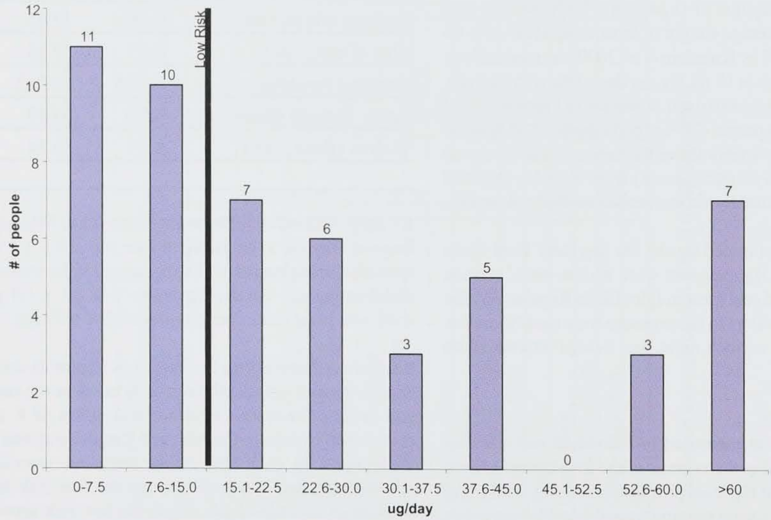


Figure 2a. Frequency Distribution of Hair Hg Concentrations - Participants in Igloolik

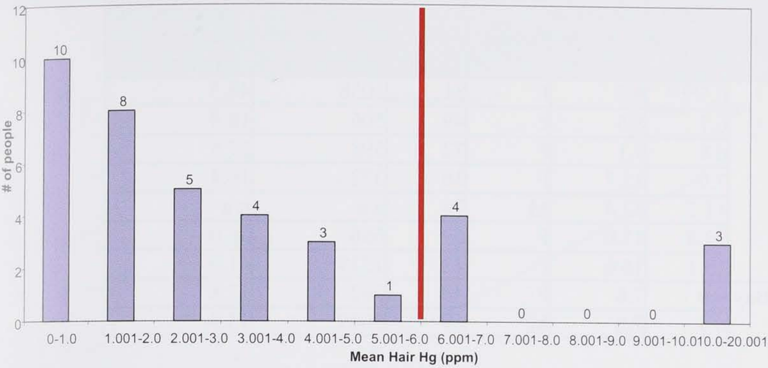
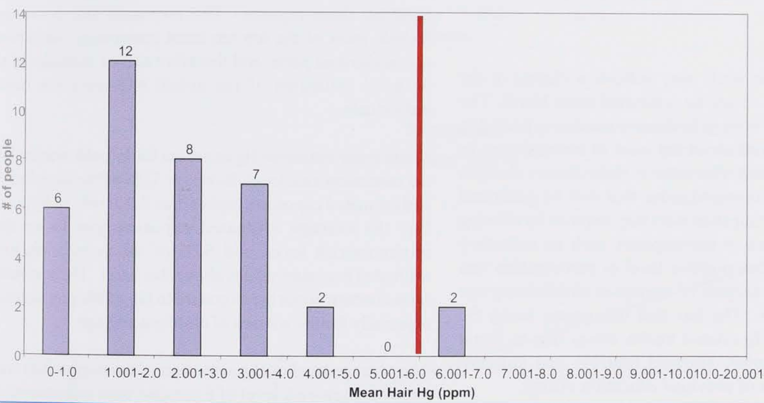


Figure 2b. Frequency Distribution of Hair Hg Concentrations – Participants in Repulse Bay



with high consumption of traditional food and a high intake of Hg.

There is a strong correlation between hair Hg concentrations and traditional food intake in both communities (Figure 3). Similarly, there is also a strong correlation between Hg concentrations and estimated Hg intake in both communities (Figure 4).

Sociocultural Data

The socio-cultural questionnaire revealed that more than half of the participants had someone in their household that hunted or fished, indicating a majority of the population still in touch with traditional practices. When asked if they had noticed a change in the availability of traditional foods the majority of respondents said no - 63% from Igloolik and 94% from Repulse Bay. Also a great

Table 6. Individual Profiles for Those with Hair Hg Concentrations above the Minimum-risk Level

Community	Mean Hair Hg (ppm)	Maximum Hair Hg (ppm)	Gender	Age	Total Traditional Food (g/day)	Estimated Hg exposure (μg Hg/day)
Igloolik	6.5	9.3	F	81	1058	48.5
	6.7	8.5	F	49	506	18.0
	6.8	9.1	F	72	598	27.5
	7.0	12.7	F	36	372	16.4
	11.7	12.4	M	78	n/a	n/a
	12.4	15.0	F	69	656	36.0
	13.1	16.6	F	42	1239	41.9
Repulse Bay	6.0	7.8	F	40	762	13.8
	6.3	7.8	M	69	2049	15.5

majority of the participants agreed with the followed statements: eating traditional foods contributes to good health, eating traditional foods is a part of one's culture, eating traditional foods is completely safe, and that eating traditional foods has more benefits than risks.

Discussion

The results of this study may indicate a change in the way that research should be conducted in the North. The low participation rates in both communities appeared to be due to disinterest about the issue of contaminants in traditional foods and reluctance to make dietary changes based on any recommendations that will be generated from the data. Participation rates may improve by offering further incentives to participants such as monetary compensation. One positive level of participation was seen by the large number of women of childbearing age who participated. The fact that this group, being the most at risk of Hg-related health issues due to foetal exposure outcomes, showed interest and concern indicated success of previous education efforts.

While Repulse Bay had slightly higher estimated intakes of the traditional food items surveyed. Results from both communities indicate that traditional foods are frequently consumed by most members. General perceptions by the community indicate that most people think that traditional foods are an important way to maintain a sense of culture, are healthy and safe to consume.

A large number of people had estimated exposure levels above the minimum-risk level established as previously described. It should be noted that these estimates of exposure are likely lower than the actual exposure as not all food items were included in the estimate; this is due to a lack of Hg concentration data for many species/animal parts for these regions. The estimates did, however, include most of the top ten most commonly consumed species/animal parts, and therefore can be considered to be good estimates of the actual exposure for most individuals.

The average estimated Hg exposure for Igloolik was below the minimum-risk level; however 33% of the population had estimated exposures higher than this level. In Repulse Bay the average estimated exposure was twice the minimum-risk level, and 60% of the population had estimated exposure values above this level. These results raise concern about the exposure to Hg of the population, especially for the women of childbearing age.

The average level of Hg in the hair of the population was below the low-risk level of 6 ppm for both communities. As shown in Table 6, nine people from both communities combined had levels above acceptable. All individual values of Hg in hair were below the "at risk" level of 30 ppm, indicating that individual intervention may be unnecessary at this point. Another positive result is that of the nine participants having hair concentrations considered to be high, only one was a woman of childbearing age from each community. The Canadian Arctic Contaminants Assessment Report II released by the Northern Contaminants Program states that a

Figure 3. Correlation between average hair Hg concentrations (mg/kg) and estimated total traditional food intake (g/day).

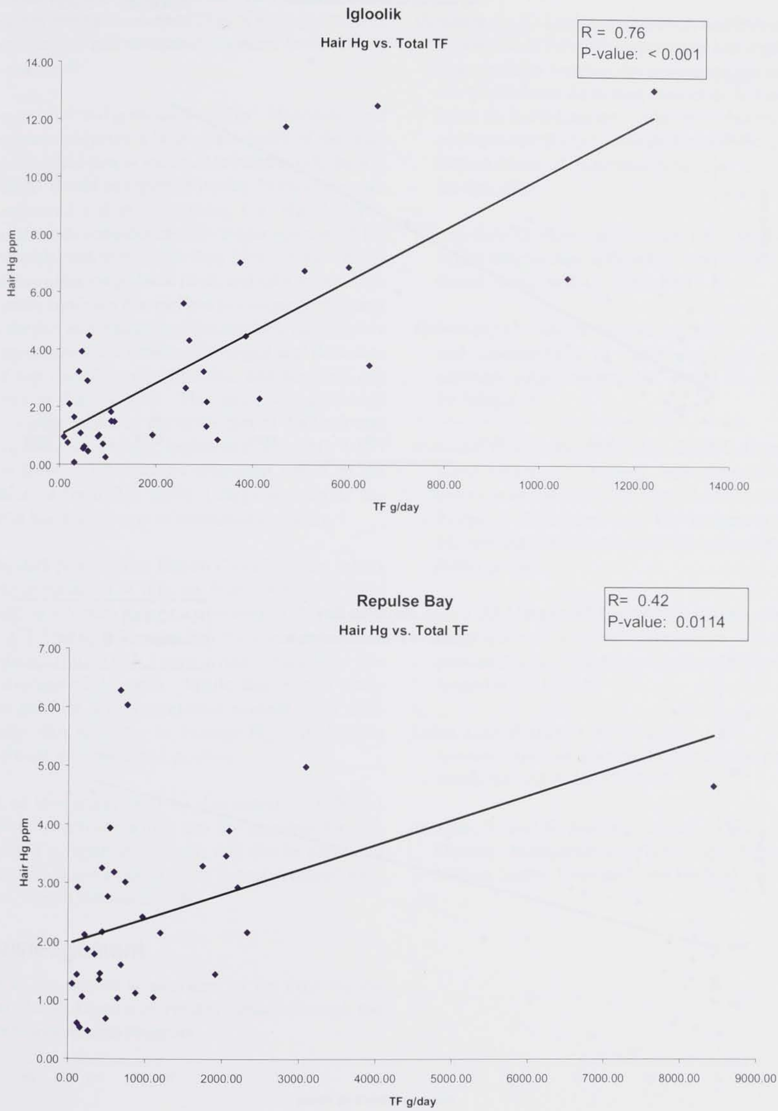
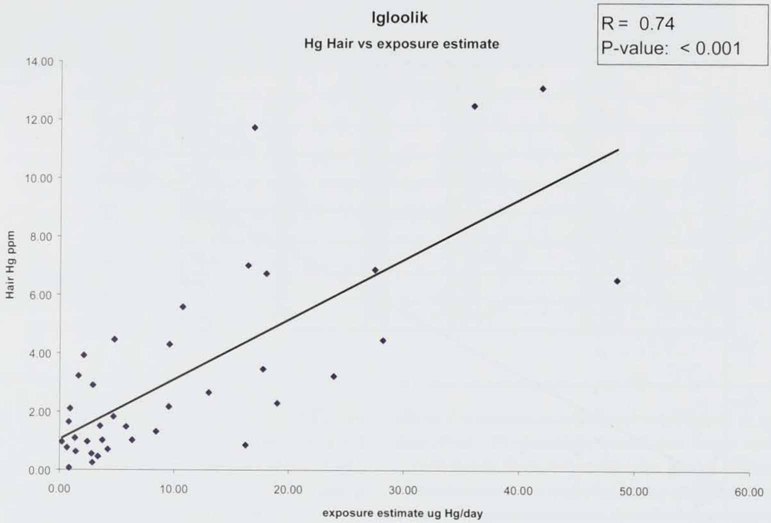
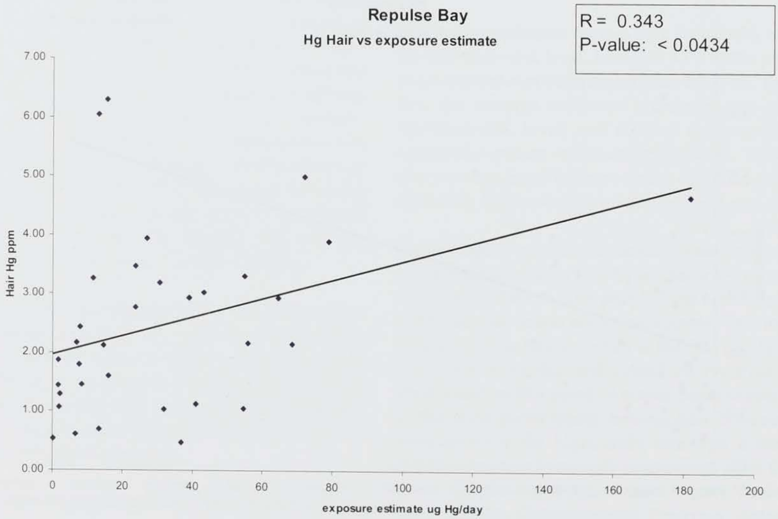


Figure 4. Correlation between average hair Hg concentrations (mg/kg) and estimated total Hg intake from traditional food (μg/day).





significant number of people have reported exposure levels of Hg and other heavy metals that are higher than the tolerable daily intake levels. Specifically in the Kivalliq and Baffin Regions, 25% of the populations of most communities are taking in levels of Hg that are higher than the tolerable daily intake levels. This current study reaffirms this point as more than 25% of the population of both communities had estimated exposure levels above the low-risk level.

The Centre for Indigenous Peoples' Nutrition and Environment conducted a large-scale study of the risks and benefits of the diet of the Inuit in Nunavut (Kuhnlein *et al.* 2000). Based on reported intake, "55% of person-days consumed a diet containing Cd, Hg, and Pb. Traditional foods considered to be major sources of Hg (found to each contribute more than 10% of total intake) were caribou meat, ringed seal flesh, and lake trout). This current study confirms that caribou is a major contributor to Hg in the diet as it was among the top three contributors in both communities. Furthermore ringed seal flesh was the third top contributor in Igloolik, and the sixth top contributor in Repulse Bay. This study also estimated that the average intake of Hg in the diet of the Inuit was 0.6 μg/kg body weight/day, higher than the FAO/WHO guideline level. As previously discussed, based on the data collected from this study a large portion of the population had high levels of estimated exposure.

Based on data provided by Health Canada, mean values measured in residents of Igloolik from 1976-1985 were equivalent to 9.5 ppm in hair, compared to this study's average of 3.3 ppm. In Repulse Bay the average values in 1977 were equivalent to 5.5 ppm in hair compared to this studies average of 2.3 ppm. While this current study does not provide a representative sample from each community, this decrease in average Hg body burden values should be considered positive.

Results of this study will be discussed with Niqiit Avatittinni Committee which has the mandate for risk management in Nunavut. Results will also be presented to the communities in a user friendly format in consultation with Inuit Tapiriit Kanatami (ITK).

Acknowledgement

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Developmental Neurotoxicity in Rats of a Persistent Organic Pollutant (POP) Mixture Mimicking the Exposure of Canadian Northern Populations: Correlation of Effects on Molecular Endpoints with Neurodevelopmental Outcomes and Markers of Thyroid Hormone Status

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Abstract

Neurodevelopmental toxicity was observed in rats following perinatal exposure to a mixture of environmental contaminants mimicking the exposure profile of Canadian Arctic populations. Subsequent studies were initiated to determine the influence of the mixture components on neurodevelopment and to identify molecular targets influenced by neurotoxicants in the developing brain. In the current study, we compared the effects of the whole contaminant mixture used in our previous studies to the effects of comparable levels of its three major component groups: methylmercury (MeHg), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCs). In addition, we examined the neurodevelopmental impact of perinatal exposure to a) polybrominated diphenyl ethers (PBDEs), which share structural similarities with PCBs and b) an antithyroid agent 6-propyl-2-thiouracil (PTU). The effects of MeHg, administered alone, on pups' growth and mortality were more severe than those of MeHg given as part of the contaminant mixture, suggesting that antagonistic effects exist among individual components. The effects of the contaminant mixture on thyroid hormone status were attributed to PCBs. While PCBs and PTU elicited similar changes on serum T4 levels, there were noticeable differences in other endpoints suggesting that the neurodevelopmental effects of PCBs are not all attributable to the impact of PCBs on thyroid hormone levels during development. Further evidence in support of this argument is that exposure to PCBs and OCs induced similar effects on hippocampus proteome, despite the fact that OCs failed to affect thyroid hormone status. Proteomic data also supported antagonisms between individual pollutants: effects on brain protein patterns resulting from exposure to MeHg, PCBs, or OCs alone were generally more severe than those resulting from the contaminant mixture. These results clearly indicate distinct patterns of developmental toxicity for each of the mixture components. However, accurate prediction of the toxicity of contaminant mixtures based on the list of their components will require a better understanding of the interactions between pollutants.

Key Messages

1. The effects of the contaminant mixture on pup growth and mortality could be attributed to MeHg.
2. The effects of the contaminant mixture on serum T4 and TSH levels in pups could be attributed to PCBs.
3. Despite similar serum T4 levels, PCB- and PTU-treated groups showed different toxicological effects, raising questions on the relative importance of

hypothyroxinemia in PCB toxicity and suggesting that other mechanisms of toxicity are involved.

4. Antagonistic effects occurred within the contaminant mixture: the effects of MeHg on pup growth and mortality were partially ameliorated when co-exposed with PCBs and OCs. The complete contaminant mixture affected the brain protein profile to a lesser extent than MeHg, PCBs or OCs administered individually.

Objectives

1. Compare the effects of rat perinatal exposure to the complete contaminant mixture with the effects of its major components (MeHg, PCBs and OCs).

2. Compare the effects of perinatal exposure to the contaminant mixture and PCBs with those caused by PTU-induced perinatal hypothyroxinemia.

3. Compare the effects of perinatal exposure to PCBs to those of the structurally related PBDEs.

4. Correlate brain genomic and proteomic data to systemic toxicity and neurobehavioural outcomes.

5. Develop and validate new molecular biomarkers of exposure/effects of environmental contaminants.

Introduction

The Northern Contaminants Program (NCP) has previously funded a proposal from our section to examine the impact on rat growth and neurodevelopment of a complex mixture of contaminants, mimicking the profile of persistent contaminants found in the serum of Canadian Arctic populations. The lowest dose of the contaminant mixture (0.05 mg/kg/day) produced blood methylmercury, organochlorine pesticide and polychlorinated biphenyl levels in offspring that approximated the concentrations found in the blood of Canadian Arctic mothers (Bowers, personal communication). More importantly, neurobehavioural deficits (attention and motor functions) were observed following perinatal exposure to the lowest dose of the contaminant mixture (Bowers 2004; Chu *et al.* 2004). Preliminary mRNA quantification work also uncovered significant changes in expression of genes related to key neurodevelopmental processes in rat pups (Gill, personal communication).

In order to determine the contribution of the major components of the contaminant mixture on various endpoints, we have conducted two follow-up studies in parallel, each using identical exposure regimens but evaluating different suites of responses in pups at different ages. The first study examined the impacts on functional neurodevelopment, neurobehaviour, neurochemistry and tissue distribution of the contaminants (Chu *et al.* 2004). The present study was designed to further investigate the neurotoxicity of the contaminant mixture and the toxicological contributions of its major chemical classes (MeHg, PCBs and OCs) at a molecular level. Effects of perinatal exposure to these mixtures on pup growth, survival, thyroid hormone status and on brain genomic (microarray hybridisation) and proteomic (2D SDS-PAGE) endpoints were evaluated. Genomic and proteomic studies typically produce a large amount of data that can lead to equivocal interpretation, as changes in gene expression and protein profile do not necessarily result in observable changes at the whole organism level. However, sharing of the mixtures and dosing scheme with neurobehavioural studies (Chu et al. 2004) allows the correlation of our molecular data with a wide array of relevant neurobehavioural, neurochemical and systemic endpoints.

Activities

In 2004-2005

The animal phase of the study was completed and many of the analyses are ongoing or have been completed. Data collection is close to completion for the vehicle, PTU and high dose contaminant mixture, MeHg, PCB and OC treatment groups. Measurements of serum T4 and TSH were completed. Proteomic analyses of cerebellum and hippocampus (2D SDS-PAGE and protein profile comparison) are close to completion. Messenger RNAs were purified from cerebellum and hippocampus of the vehicle, PTU and high dose groups. The microarray hybridisation method has been optimized and hybridization of cerebellum and hippocampus total RNA is almost completed. These data will be submitted to a rigorous program of normalization, LOWESS transformation and analysis to identify significant changes in steady state mRNA levels with results expected by late summer 2005. We anticipate that analysis of thyroid gland histomorphology will be completed by fall 2005.

Results

Dams were dosed with the contaminant mixture (5 and 0.05 mg/kg), or equivalent amounts of the components that constituted the mixture: methylmercury (2 and 0.02 mg/kg), polychlorinated biphenyls (1.1 and 0.011 mg/kg) and organochlorine pesticides (1.9 and 0.019 mg/kg). Dams were also dosed with polybrominated diphenyl ethers supplied as commercial DE-71 (0.3, 3 and 30 mg/kg body weight). A positive control group for hypothyroxinemia was dosed with propyl thiouracil (0.001% PTU in drinking water from GD 16 to PND 21). Subsets of pups were sacrificed on PND 14 or PND 21, corresponding to periods of intense synaptogenesis in the hippocampus and cerebellum (PND 14) and in higher brain areas (PND 21). Measurements were made on growth, mortality, thyroid hormone status and on brain proteomic (two-dimensional gel electrophoresis) and genomic (microarray hybridization) profiles.

Growth and mortality

Pups from dams administered MeHg alone had a reduced growth rate (Figure 1B) and showed a mortality rate

Figure 1: Body weight gain for A) dams and B) averaged male and female pups of the high dose groups. Errors bars for the contaminant mixture (Mix.) and methylmercury (MeHg) treated groups represent the standard deviation.

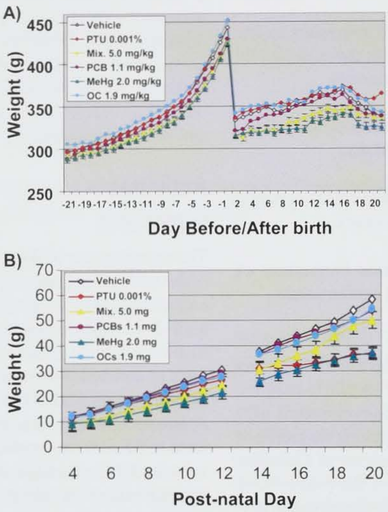
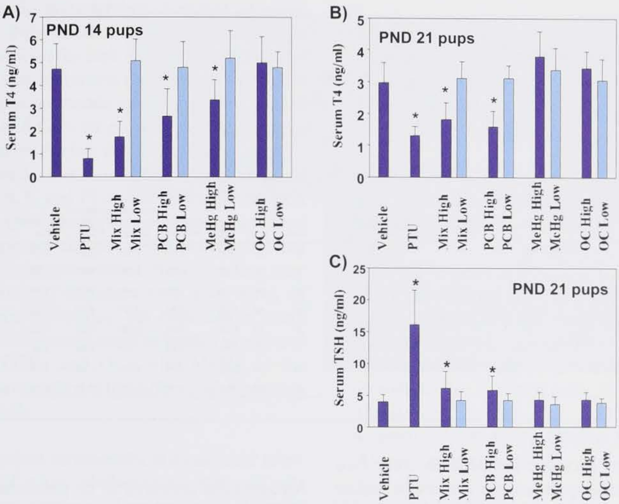


Table 1: Effect of perinatal exposure to the contaminant mixture, PTU, MeHg, PCBs and OCs on pup mortality. The number of litters and live births (pups) for each treatment group are listed. PND 1-4 column reports pup deaths occurring before culling and PND 5-21 reports the deaths occurring between culling and PND 21 necropsy.

			% Mortality	
Treatment	**Litters**	**Pups**	**PND1-4**	**PND 5-21**
Vehicle	13	192	**3.1**	**0**
PTU (0.001%)	11	176	**8.7**	**2.3**
OCs 0.019 mg	8	105	6.7	0
PCBs 0.011 mg	11	146	2.1	1.1
MeHg 0.02 mg	6	86	2.3	0
Mixture 0.05 mg	11	149	2.0	0
OCs 1.9 mg	10	138	2.2	0
PCBs 1.1 mg	10	127	5.5	1.3
MeHg 2.0 mg	8	121	**33.9**	**8.9**
Mixture 5.0 mg	10	156	**17.3**	**7.6**

Figure 2: Effects of perinatal exposure to the contaminant mixture on thyroid system functions. A) Serum T4 concentration in PND 14 pups. B) Serum T4 and C) TSH concentration in PND 21 pups. Error bars represent the standard deviation and * indicates statistically significant differences from the control group ($p < 0.05$).



significantly greater than any other group (Table 1), including pups who received an equal dose of MeHg as part of the total contaminant mixture, suggesting that antagonistic effects exist among individual components. MeHg also appeared to be responsible for the effects of the contaminant mixture on dam body weight after birth (Figure 1A). PCBs and OCs exposures failed to affect dam or pup body weights. All low dose groups also failed to affect weight gain (data no shown).

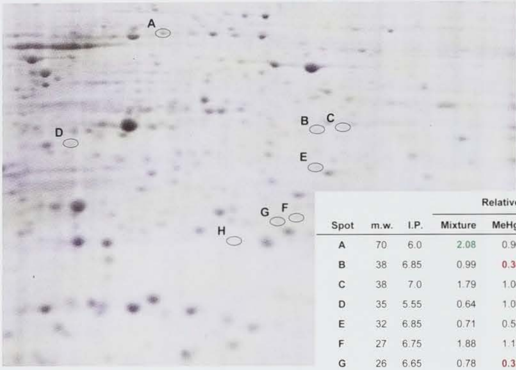
Thyroid hormone status

Exposure to the contaminant mixture and PCBs resulted in decreased serum T4 concentration that approximated PTU-induced hypothyroxinemia at PND 14 and PND 21 (Figure 2A and 2B). As previously reported (Goldey et al. 1995; Roth-Harer et al. 2001), PCB-induced hypothyroxinemia failed to increase the serum TSH concentration to the same extent as PTU exposure (Figure 2C). Surprisingly, MeHg exposure was also found to affect the serum T4 concentration at PND 14. In rats, this time period corresponds to a peak in thyroid hormone activity and brain growth (Seegal, 2001). It is therefore possible that by slowing the pups' weight gain, MeHg exposure also delays the appearance of the peak concentration of thyroid hormone. Unfortunately, blood was sampled only at PND 14 and 21, and TSH was not measured at PND 14 due to the small blood volume collected. This prevented us from further investigating this finding. Thyroid glands were stained and mounted on microscope slides. Thyroid histological measurement will begin shortly.

Proteomic analysis

Two-dimensional electrophoresis analysis of hippocampus extracts from the high dose groups was completed and analysis of cerebellum is underway. Due to the inherent variability of 2D gels, at least 10 samples per treatment group were analysed. Spots present in most gels that were consistently showing variation of intensity greater than two-fold using three background subtraction and two normalization methods were considered as significantly affected. Exposure to PCBs and OCs resulted in relatively similar protein patterns in the male pup hippocampus, with the two groups sharing four differentially expressed protein spots (Figure 3). Exposure

Figure 3: Hippocampus protein extract two-dimensional electrophoresis gel profile. Differentially expressed protein spots in the contaminant mixture-, MeHg-, PCB- or OC-treated groups are circled. The inset table presents the fold change in protein expression for each treated group. Significant protein up-regulation is indicated in green and down-regulation in red.



Spot	m.w.	I.P.	Relative Expression: Mixture	MeHg	PCBs	OCs
A	70	6.0	2.08	0.96	2.82	5.24
B	38	6.85	0.99	0.36	2.82	2.90
C	38	7.0	1.79	1.04	2.37	3.66
D	35	5.55	0.64	1.07	0.80	0.42
E	32	6.85	0.71	0.55	2.57	1.98
F	27	6.75	1.88	1.18	4.60	4.65
G	26	6.65	0.78	0.32	1.30	1.24
H	24	6.4	0	0.79	0.33	0.70

to the contaminant mixture resulted in only two differentially expressed spots (shared with PCBs and/or OCs). Exposure to MeHg also resulted in two differentially expressed spots. Preliminary analysis of cerebellum protein pattern also revealed that exposure to the contaminant mixture resulted in two differentially expressed proteins including spot B (data not shown). This observation differs from that of hippocampus where spot B was down-regulated by MeHg but not by the contaminant mixture, supporting the general view that the cerebellum is a primary target of MeHg toxicity (Castoldi *et al.* 2003). Identification of the differentially expressed protein by MALDI-ToF protease fingerprinting and confirmation of the data by immunochemistry and by Real Time RT-PCR will follow.

Discussion and Conclusion

The results of this study clearly dissociated the effects of the contaminant mixture. The results attribute pup growth and mortality to the presence of MeHg, and perturbation of thyroid functions to the presence of PCBs in the contaminant mixture. Data also uncovered interactions between contaminants and shed new light on the relative importance of thyroid hormone perturbation on the overall toxicity of the contaminant mixture.

Antagonisms appeared to be particularly important for MeHg as co-exposure with PCBs and OCs decreased MeHg-induced mortality from 33.9% to 17.3% at PND1-4 (Table 1). Antagonistic effects were apparent on growth curves where contaminant mixture-exposed dams and pups were less affected than those exposed to MeHg alone (Figure 1). Proteomic analysis also yielded examples of contaminant interactions: Spot B was up-regulated by PCBs and OCs, but down regulated by MeHg resulting in an expression in the contaminant mixture group that closely matched the control group (Figure 3). In fact, none of the differentially expressed protein spots in the MeHg treated group were found to change significantly in the contaminant mixture treated group. In other cases (spots C, D, E and F), despite an apparent lack of significant effects in the group administered MeHg alone, the presence of this compound in the contaminant mixture was sufficient to negate the effects of PCBs or OCs administered alone.

While many similarities between hypothyroidism and effects of PCBs have been reported (for review, see Porterfield 2004), PCB exposure and hypothyroxinemia have different effects on the timing of the eye opening developmental landmark (Goldey and Crofton 1998) and on neurotransmitter levels (Roth-Harer *et al.* 2001). This project uncovered further differences: despite similar T4 levels in PCB- and PTU-treated groups, only the latter affected the weight gain of pups (Figure 1). The growth curve induced by PTU was very similar to the control group until PND 10, and only after this time the weight gain of PTU-treated animals fell rapidly behind those of the PCB-treated and vehicle groups. A partial agonistic effect of PCBs or their metabolites on thyroid hormone receptors might explain the lack of effect on growth for similar serum T4 concentrations (McKinney and Waller 1994). Hippocampus proteomic analysis showed that the effects of PCBs and OCs on protein expression were closely related despite the fact that OCs failed to alter T4 serum level (Figure 3). The four differentially expressed protein spots (A, B, C and F) shared by PCBs and OCs are unlikely to be good biomarkers of neurobehavioural effects as OC exposure did not affect neurobehaviour (Bowers, personal communication). However, they may be good biomarkers of exposure to a wide array of chlorinated organic molecules, but their use in more complex contaminant mixtures might be limited as perinatal co-exposure to PCBs and OCs with MeHg in the contaminant mixture resulted in the differential expression of spots A and G only.

In summary, this project corroborates, at a molecular level, the conclusions of a neurobehavioural study of rats exposed to the same mixtures of contaminants (Bowers 2004): while some toxicological endpoints could be attributed to specific components of the contaminant mixture, others could not be accurately predicted from the list of individual pollutants, as significant interactions between contaminants occur. This observation has serious implications for the human risk assessment. In the coming year, we are planning to finalise the genomic analysis of the mixture-, PTU- and PBDE-treated groups. This will further clarify the interactions between the components present in the contaminant mixture and the relative importance of hypothyroxinemia in neurotoxicity. We will also identify new putative molecular biomarkers of exposure/effect, and correlate our molecular data with neurobehavioural outcomes of rats exposed to the same mixtures in parallel NCP-funded studies.

Expected Project Completion Date

October 2005

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Long-Term Effects Following Postnatal Exposure to Breast Milk Contaminants: Is it Real?

Project leader(s)

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Abstract

Our goal is to assess if the magnitude of the health risks associated with postnatal exposure to environmental contaminants is negligible relative to the health risks associated with *in utero* exposure. To achieve this a cross-fostering experiment will be conducted testing effects following pre and/or postnatal exposure to a mixture of northern contaminants. Classical indicators of effects will be measured, in addition to endpoints that could be indicators of long-term health effects, such as changes in estrogen metabolism and signalling, and DNA methylation. To optimize our techniques, and derive an idea of dosages to be tested in our cross-fostering experiment, we analyzed samples collected under projects NCP-H-05, and –H-17. In these experiments, pregnant rats were dosed each day from gestation day 1 to postnatal day (PND) 21, with either corn oil (control), or two dose levels of 12 organochlorine pesticides (OCs; 1.9 or 0.019 mg/kg/day), methylmercury (MeHg; 2, or 0.02 mg/kg/day), 14 polychlorinated biphenyls (PCBs; 1.1 or 0.011 mg/kg/day), or a mixture including all these chemicals (5, or 0.05 mg/kg/day). A preliminary analysis of the high dose groups revealed that the mixture induced synergistic increases in mRNA levels for cytochrome P450 (CYP[1]) 1A1, 1B1, and 2B1, relative to the effects induced by the separate chemical families. The PCBs increased hepatic mRNA levels of CYP1A1 and 1B1, and associated hepatic production of the toxic catecholestrogens, 2-hydroxy-, and 4-hydroxy-estradiol-17β (2OH-E2, 4OH-E2), and that of the beneficial 2-methoxy-E2 (2MeO-E2). In contrast, PCBs reduced mRNAs for all investigated DNA methyltransferases (Dnmt1, 3a and 3b), MeHg reduced only Dnmt1 and Dnmt3b mRNAs, whereas OCs and the whole mixture had no effects. These analyses of the high dose groups revealed major changes in the hepatic metabolism of estrogens, and the DNA methylation system, induced by specific chemical groups, but analysis of low dose and tissue specific effects, are required for an adequate interpretation of these findings.

Key Messages

1. Preliminary analysis revealed that in the rat, exposure of the fetus to high doses of contaminants during pregnancy, combined with exposure received by the pups through the mothers milk, dramatically changed the normal liver transformation of the hormone estrogen into toxic byproducts, and others that are beneficial to health. The cumulative impact on health is still unknown.

2. Three groups of contaminants (OCs, MeHg, PCBs) were found to increase the amount of cellular messages dictating the production of proteins required for the elimination of these chemicals. When tested altogether in a single mixture, the amount of cellular messages was much larger than when the amounts produced by

[1]Note: capital letters refer to proteins, or mRNAs, while small letters refer to the gene or cDNA.

the individual groups are added up together. In contrast, this "synergistic" effect was not observed when other endpoints, not involved in the elimination of the chemicals, were measured. Synergistic endpoints are sensitive indicators of exposure, but others are required to demonstrate toxicity.

3. Our genetic code is included in the DNA located in the chromosomes of our cells. The genetic code is constantly used by cells for normal functions and differentiation into various tissue types during development. A group of proteins called DNA methyltransferases (DNMTs), are involved in controlling access to the genetic code and in conferring the normal structure of our chromosomes. Exposure to PCBs, and MeHg (but not OCs), reduces the amount of cellular messages required for the production of these DNMTs, suggesting that cells may be at risk of not functioning and developing normally.

Objectives

1. Test if the magnitude of the health risks associated with postnatal exposure to environmental contaminants is negligible relative to the health risks associated with *in utero* exposure.

2. Assess if endocrine disruption involving estrogen metabolism and signaling, or early changes in DNA methylation, could be used as early indicators of long term adverse health effects, or adulthood diseases.

3. Derive an understanding of interactions among chemical families in the toxicity of contaminant mixtures.

Introduction

Investigations in wildlife revealed numerous examples of adverse health effects resulting from exposure to environmental contaminants. These concepts raise concerns that human health could also be threatened by exposure to environmental contaminants. Some environmental contaminants include persistent organic pollutants (POPs) that accumulate in fatty tissues of animals and humans. Given that breastmilk is rich in fat, it is during the postnatal period, while breastfeeding, that humans receive some of the highest exposure to POPs. The induction, by environmental contaminants, of abnormal developmental processes during the *in utero* and postnatal periods could have long-term health effects. It is possible that the level of exposure to environmental contaminants occurring in the general population has no health consequences. It is also known that the benefits of breastfeeding far outweigh putative risks in the general population. However, for reasons that are not fully understood, and which may include differences in detoxification enzyme activities or unusual exposure to environmental contaminants, some individuals have abnormally high levels of environmental contaminants in their body. Compared to southern populations, some northern communities may be at higher risk of adverse health effects because their populations have a higher body burden of some environmental contaminants. Government agencies must protect adults and infants from unacceptable exposure to environmental contaminants, but there is little information about the level of exposure during the postnatal period that could increase health risks. No interventions can prevent exposure of the foetus during pregnancy. However, if exposure during the postnatal period is responsible for increasing health risks above what is already attributed to *in utero* exposure, for mothers with unusually high environmental contaminant body burdens, it could be valid to reduce postnatal exposure by reducing breastfeeding intensity (the major source of exposure to POPs) during specific critical phases. Preventing unacceptable exposure levels to environmental contaminants in infants is complicated by the fact that tissue sensitivity, and the abundance of environmental contaminants, are not the same *in utero* and during the postnatal period. For example, the infant body burden of methylmercury declines postnatally whereas that of persistent organochlorines increases. Normal exposure occurs as a mixture of environmental contaminants and, given that the *in utero* and postnatal periods are distinct developmental phases, additional investigations are required to identify culprit chemicals and eventually improve risk management.

The current project, in addition to studying classical indicators of toxicity, focuses on endpoints that are major determinants of developmental processes. Estrogen metabolism and signalling are major regulators of brain development, and affect mood behaviours, numerous systems (ovaries, uterus, placenta, testicles, breasts, bones, vascular system, hypertension, lipid metabolism, immune system) and cancers (breast, endometrium, ovarian, prostate, liver, kidney, brain) in both the male and female. DNA methylation is one of the epigenetic modifications involved in chromosome stability, chromosome X inactivation, modifications in centromere structure, genomic imprinting, gene expression and tissue differentiation at the appropriate time during development. Studying these endpoints at different times following prenatal and postnatal exposure to environmental contaminants has great potential for identifying new bioindicators of health effects, and improving tools in risk assessment strategies.

Activities

In 2004-2005

Selection of endpoints and techniques

In rats, acute or short-term exposure to high doses of organochlorines and pesticides increases the expression of CYP 1A1, 1B1, 2B and 3A, and the production of the toxic catecholestrogens (CE) (estrogens hydroxylated in position 2 and 4). Methylation of the CE by the enzyme catechol-*o*-methyltransferase (COMT) is a major mechanism for deactivating CE and producing the beneficial 2MeO-E2 (Zacharia *et al.* 2004). Aroclor 1254 exposure in the adult rat generates metabolites of PCBs suspected of inhibiting the deactivation of CE by COMT (Garner *et al.* 2000). It has been shown that postnatal exposure to a mixture of aryl-hydrocarbon receptor agonists decreased mRNA expression of COMT (Desaulniers *et al.* 2005b). Collectively, these observations suggest that exposure to xenobiotics could lead to tissue-specific accumulation of toxic estrogen metabolites. Therefore, CYP 1A1, 1B1, 2B, 3A, and COMT mRNA expression are being monitored, as well as estrogen receptor α, and estrogen metabolites. The hepatic microsomal transformation of ^{14}C-E2 into 11 standard metabolites is being monitored by high performance-thin layer chromatography (HP-TLC) and phosphorimaging, which permits the visualization of treatment effects on the relative abundance of known and unknown radioactive metabolites. HP-TLC results are then confirmed by quantifying of E2 and its hydroxylated (2OH-E2, 4OH-E2), and methoxylated (2MeO-E2, 4MeO-E2) metabolites using gas chromatography mass spectrometry in negative chemical ionization mode (GC/MS-NCI) with selected ion monitoring. Analytes are derivatized with anhydride pentafluoropropionic acid prior to analysis by GC/MS.

Abnormal DNA methylation has been associated with a number of cancers, infertility, developmental, neurological, immunological, and age-related disorders, and may originate during early development or later during mitosis, when the methylation pattern of the original DNA strand is copied mostly by DNA methyltransferase-1 (DNMT1) onto the replicating DNA. DNA methylation reactions are catalyzed by families of DNA methyltransferases (DNMT1, 2, 3). The *de novo* methyltransferases, DNMT3a, 3b catalyze the transfer of a methyl group to previously unmethylated DNA, during gameto- and embryogenesis, but are also active at other times (Ko *et al.* 2005; Egger *et al.* 2004). The current project is monitoring by real time RT-PCR mRNA expression of DNMT1, 3a, and 3b. Consequences of possible changes in DNA methylation are being investigated in three ways. Methylation-specific PCR is being used to investigate the promoter regions of specific genes. Second, the methylation status of the retrotransposon Long Interspersed Nuclear Element-1 (LINE-1) has been analyzed by methylation specific PCR, sodium bisulfite treatment and methylation-sensitive restriction enzymes (*Hinf1*, *Mbo1*). This abundant DNA repeated sequence is normally methylated thereby preventing its expression and chromosome instability.

Origin of samples

First, the mRNA assay for DNA methyltransferase-1 was validated by comparing brain, uterus and liver mRNA expressions in female Sprague Dawley rats sacrificed at PND21, and exposed only postnatally to increasing doses of a mixture of AhR-agonists (3 non-*ortho* PCBs, 6 polychlorinated dibenzodioxins, and 7 polychlorinated dibenzofurans) present in breast milk. Second, to generate new information on the toxicity of "northern contaminants" within the first year of this project, brain, liver, and uterine samples from the projects NCP-H-05 (Bowers WJ, Nakai J, Chu I, *et al.*), and NCP-H-17 (Pelletier G, Wade M, Chu I, *et al.*), are currently being analyzed. This will permit us to determine the relevant OCs and MeHg dosages to be tested in our proposed cross-fostering experiment. In the NCP-H-05 and –H-17 experiments, pregnant rats were dosed each day from gestation day 1 to PND21, with either corn oil (control), or two dose levels of 12 OCs (1.9 or 0.019 mg/kg/day), MeHg (2, or 0.02 mg/kg/day), 14 PCBs (1.1 or 0.011 mg/kg/day), or a mixture including all these chemicals (5, or 0.05 mg/kg/day). Samples from male and female offspring were collected at PND 4, 14, 21, 29, and 98.

Discussion and Conclusions

Our results suggest synergistic and additive interactions among classes of chemicals. The synergistic increase in CYP1A1 mRNA levels is consistent with *in vitro* results (Korashy and El Kadi 2004). This *in vitro* study reports that mercury increases amounts of CYP1A1 mRNA, but has no effects on protein and activity levels. However, in the presence of AhR-agonists, mercury decreased CYP1A1 activity but increased its protein and mRNA levels (Korashy and El Kadi 2004). For DNMT mRNAs, changes appear to follow an additive model. While the PCB and MeHg treatments significantly decreased the abundance of DNMT mRNAs, there were no significant effects of the complete mixture. The effects of the OC treatment were always opposite to the effects of the PCB, and MeHg treatments. Therefore, using an additive model, it may be speculated that the combination of these three effects could explain the lack of response induced by the complete mixture. Also, interactions of the chemicals may have induced a large detoxification reaction increasing CYP proteins, metallothionein (Nishimura et al. 2001), and glutathione (Ballatori 2002), that are known to sequester environmental contaminants and metals. Perhaps this prevented the detection of effects on other endpoints not associated with the detoxification reaction in the high dose mixture group, such as a decrease in DNMTs (PCBs, MeHg) and an increase in ERα mRNA (OCs). Nevertheless, these interactions might be high dose-specific, and completing the analysis of the lower dose group should improve our understanding of chemical interactions.

The hepatic metabolism of estrogens was greatly modified by the PCB treatment (other groups and tissues still to be analyzed) in ways that favour the accumulation of toxic catecholestrogens, 4MeO-E2, and the beneficial 2MeO-E2 (Aikawa *et al.* 2005). The accumulation of catecholestrogens leads to the production of reactive oxygen species, lipid peroxidation, adduct formation, and carcinogenesis. The cyclical exposure to endogenous estrogens in female rats exposed to PCBs and AhR-agonists has been provided as an explanation for the higher rate of hepatic cancers in female than male counterparts (Painter *et al.* 2001). In contrast, the production of 2-methoxyestrogens could have beneficial effects, including reduction in cardiovascular diseases (Zacharia *et al.* 2004). An important enzyme involved with the detoxification of estrogen metabolites and deactivation of catecholneurotransmitters, COMT, appears to be affected in opposite directions by MeHg and AhR-agonists (Desaulniers *et al.* 2005b). While COMT mRNAs were reduced by AhR-agonists, MeHg induced a slight hepatic increase in COMT (membrane-bound form). This is in agreement with Boadi *et al* (1991) who found that mercury exerts an enhancing effect on the activity of COMT in human placenta. Should this enzyme be affected at low doses of exposure, this may have important consequences on estrogen- and catecholneurotransmitter-responsive tissues during fetal development.

The analysis of effects of environmental contaminants on DNA methylation is a new area of investigation in toxicology. The current NCP project demonstrates that mRNAs for DNMTs are targets for high dose exposure to PCBs and MeHg. As well, we showed that postnatal exposure to AhR-agonists also decreased mRNA levels for DNMT1 in the liver, and brain (particularly the hypothalamic area) (Desaulniers *et al.* 2005b). These observations raise the possibility of altered DNA methylation, as suggested by the detection of possible hypermethylation of the DNMT3b promoter in the PCB-treated group (this requires further confirmation). Given the persistent nature of some changes in DNA methylation, the hypothesis could be tested that the change in mRNA levels for DNMT3b might be persistent, while changes in mRNA expression for the other DNMTs could be adaptive. This could be one advantage of detecting changes in DNA methylation as an endpoint, as it might permit the distinction between effects that are transient (e.g. age-specific, circadian effects, stress-induced), adaptive, persistent, or those that might become detectable only later during development when activation of the gene is required. Changes in DNA methylation are associated with carcinogenesis. Given that AhR agonists and PCBs are known hepatocarcinogens, perhaps changes in DNA methyltransferase expressions are indicators of neoplastic transformation. In the brain, changes in DNA methylation have been associated with multi-factorial psychiatric disorders, short-term adaptation, neurological development and diseases (Abdolmaleky *et al.* 2004; Gosden *et al.* 2003).

We still cannot assess if the magnitude of the health risks associated with postnatal exposure to environmental contaminants is negligible relative to the health risks associated with *in utero* exposure. However, DNMT1 results obtained during the current year contributed to important conclusions related to the postnatal period. The lowest postnatal dose of AhR-agonists inducing effects was equivalent to 100 times (100X) the estimated average human exposure level during the first 24 days of life (Desaulniers *et al.* 2005b). Postnatal exposure to a mixture of PCBs, *p,p'*-DDT and *p,p'*-DDE, reconstituted based on breast milk levels, also induced effects at a 100X dose (Desaulniers *et al.* 2005a). Although AhR-agonists are approximately 1000 times less abundant in breast milk than PCBs, they significantly decreased thyroxine levels but the mixture of PCBs, *p,p'*-DDT and *p,p'*-DDE had no significant effects. Thus, perhaps AhR-agonists, at the levels found in humans, have a higher potential to exert toxicity than the PCBs, *p,p'*-DDT and *p,p'*-DDE, and to modulate the effects of "northern contaminants". Testing effects of "northern contaminants" in the presence of the ubiquitous AhR-agonists is required.

In conclusion, this work is novel in at least four ways; 1) in its HP-TLC technique, 2) in demonstrating a reduction in mRNA levels for DNMTs following early exposure to PCBs, MeHg, or AhR-agonists, 3) in demonstrating major effects of PCBs on estrogen metabolism, and 4) in showing chemical interactions on many endpoints in highly exposed weanling female rats. This preliminary work suggests that the highest dose is too high to be included in the proposed cross-fostering experiment. It supports the relevance of studying endpoints related to DNA methylation and estrogen metabolism and signalling, as possible mechanisms for inducing putative long-term effects.

Expected Project Completion Date

March 2007.

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Monitoring Spatial and Temporal Trends of Environmental Pollutants in Maternal Blood in Nunavik

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Abstract

The Inuit are exposed to a wide range of environmental contaminants through their traditional diet, which includes significant amounts of fish and sea mammal fat. During the past fifteen years, several studies monitored the exposure of Nunavik's Inuit to persistent organic pollutants and heavy metals. More recently, increased emphasis was put on health effects studies in relation to exposure to polychlorinated biphenyls, chlorinated pesticides, mercury and lead in the Hudson Bay area. This project proposes to focus on exposure assessments in Nunavik, to compare current exposure levels with those prevailing ten to fifteen years ago based on our last surveys and, additionally, to assess exposure to emerging environmental contaminants for which increasing concentrations in wildlife and human samples have been reported worldwide. Analyses have been conducted on maternal blood (only a few samples of umbilical cord blood were collected in the first year, and further analyses are being conducted on maternal blood only). This study aims at providing 1) an update of geographical patterns of exposure; 2) information about whether exposure levels to different classes of contaminants are increasing, decreasing or remaining the same in northern populations; 3) information about the efficiency of intervention programs implemented following earlier surveys. This project is still ongoing (although on hold for the coming year) and results presented in the current report are not final.

Key Messages

1) A data warehouse structure was defined and implemented for the integration of contaminants data in cord and maternal blood as well as in human milk obtained in the framework of past projects. Semantic integration of data from past projects is still ongoing. The aim is to obtain a harmonized database for further spatio-temporal trend assessments and other relevant applications, as well as to develop a standardized procedure for the continuous integration of new data in the data warehouse.

2) An inventory of archived samples was carried out in order to determine the availability of archived cord and maternal plasma that could be analysed for

emerging contaminants such as brominated diphenyl ethers (BDEs) and perfluorooctanesulfonate (PFOS). During this procedure, a bar code system has been developed for archived samples and this system is being integrated with our data warehousing system. Re-coding of the samples is ongoing.

3) Recruitment procedures to collect maternal blood in Tulattavik Health Centre as well as in other Nunavik health centres have proven to be difficult to implement during the past year due to an interruption of obstetrical services in Tulattavik. For this reason, recruitment was put on hold for the coming year to allow enough time to re-establish and stabilize obstetrical services in the different health centres of Nunavik before asking the medical personnel to get involved in research projects again.

4) In the meantime, a new analytical method has been developed in the Toxicology Laboratory of the Institut national de santé publique du Québec (INSPQ), which allows the measurement of a larger number of contaminants in a smaller volume of plasma. This method was compared on a small number of samples previously collected in the framework on this project and validated against methods formerly used to measure persistent organic pollutants (POPs) in plasma.

Objectives

The general objective of this project is to monitor prenatal exposure to food chain contaminants in Nunavik and to assess spatial and temporal trends of environmental contaminants found in maternal cord blood. Targeted contaminants include the traditional suite of contaminants measured in previous projects since the mid-80s (polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs), mercury (Hg) and lead (Pb)), as well as emerging contaminants such as halogenated phenolic compounds (HPCs), perfluorooctanesulfonate (PFOS) and related compounds, and brominated flame retardants (BFRs), including brominated diphenyl ethers (BDEs). The specific objectives are:

- **To improve sample management and implement data warehousing** : **1)** To build an archiving system by determining the availability of archived samples for further analyses and creating a sample identification system compatible with a data warehouse; **2)** To integrate data gathered in past studies regarding contaminant levels measured in umbilical cord plasma / blood and maternal plasma / blood and their related data into a single functional database;

- **To develop new analytical procedures**: **1)** To determine a new suite of environmental contaminants to measure in blood and plasma for temporal trends analyses; **2)** To optimise analytical methods by validating the use of the RapidTrace method for the measurement of several analytes in a small volume of plasma, including some emerging contaminants; **3)** To measure emerging contaminants (BDEs, PFOS, HPCs, as well as other relevant emerging environmental contaminants) in maternal blood to be collected in Nunavik until 2009, as well as in available archived samples.

- **To implement collection of new samples**: **1)** To generate new data on contaminant exposure in order to obtain an update on levels of exposure to the traditional suite of contaminants measured since the mid-1980s, as well as to emerging contaminants; **2)** To measure concentrations of environmental contaminants in maternal blood of 40 Inuit mothers recruited in Nunavik each year, for five years. Efforts will be made to recruit people in the Ungava and Hudson regions. This will provide data covering a larger geographical range, and will allow the assessment of the efficiency of the policy of banning lead ammunition use on lead exposure in the Ungava region.

- **To analyse spatial and temporal trends in contaminant exposure**: To derive spatial and temporal trends for all contaminants measured in umbilical (when available) and maternal blood (Hg, Pb, PCBs, OC pesticides, BDEs, PFOS, HPCs) using integrated data from previous studies, as well as from new analyses on archived and newly collected samples. This will provide an update of geographical patterns of exposure, as well as information about whether levels of exposure to different classes of contaminants are increasing, decreasing or remaining the same in northern populations.

Introduction

Early work conducted on Baffin Island and in Nunavik has demonstrated that because of their traditional dietary habits, Inuit people are exposed to unusually high quantities of environmental contaminants, mainly heavy metals and organochlorines (OCs) (Dewailly, *et al.* 1993, Kinloch, *et al.* 1992, Muckle, *et al.* 2001b). OCs form a class of persistent organic pollutants (POPs) including polychlorinated dibenzo *p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and various chlorinated pesticides or industrial products. Most epidemiological and experimental studies on health effects related to exposure to heavy metals (Pb, Hg) and OCs (mainly PCBs) suggest that prenatal life is the most susceptible period for the induction of adverse effects on physical and neurological development. Indeed, several studies have reported different developmental, immune and/or cognitive deficits in newborns exposed to OCs during prenatal and/or postnatal development, with some of these deficits persisting in later childhood (Dewailly, *et al.* 2000 Gladen *et al.* 2000, Guo, *et al.* 1994, Guo, *et al.* 1995, Jacobson and Jacobson 1997, Koopman-Esseboom, *et al.* 1994, Patandin, *et al.* 1998, Rogan, *et al.* 1986, Taylor, *et al.* 1989, Winneke, *et al.* 1998). As well, prenatal exposure to methylmercury (MeHg) has also been linked to developmental and cognitive deficits in infancy and childhood (Weihe, *et al.* 2002). However, studies focusing on temporal trends of these POPs in the Arctic have identified a decreasing trend during the last decades in several species (Muir, *et al.* 2001a, Muir, *et al.* 2001b). Decreases in body burden of these compounds in northern human populations have been reported, for instance in Sweden (Noren and Meironyte 2000) and in Canada, on the Lower North Shore of the St. Lawrence River (Dallaire, *et al.* 2002) and in Nunavik Inuit residing in the Hudson Bay area (Dallaire, *et al.* 2003). However, time trend data are not available for Inuit populations living in the eastern part of Nunavik, in the Ungava Bay area.

While these POPs might be of lesser concern in the Arctic if decreasing time trends are confirmed, several new compounds have emerged as potential threats to the Arctic. Organobromine compounds are among these emerging contaminants, including brominated flame retardants (BFRs) such as brominated diphenyl ethers (BDEs), commonly used in the composition of electronic equipments, plastics and textiles. BDEs share some physico-chemical and toxicological properties with OCs but, contrary to the latter for which production, sale and use generally tends to decrease, BDE use and environmental occurrence has dramatically increased since the 1980s (Ikonomou, *et al.* 2002, Meironyte, *et al.* 1999, Noren and Meironyte 2000). Few studies have addressed the toxic effects of BDEs, but their structural similarity to other polyhalogenated aromatic hydrocarbons and the evidence of toxicity gathered until now suggest that they may exert similar toxic effects through common mechanisms with PCBs, PCDDs and some other OCs (e.g. embryotoxicity, interference with thyroid hormone signalling, neurotoxic effects.) (Darnerud, *et al.* 2001, Zhou, *et al.* 2002).

Some halogenated phenolic compounds (HPCs) are also considered emerging contaminants, as their monitoring was not commonly carried out in the past along with the conventional suite of OCs and heavy metals. These include the hydroxylated metabolites of PCBs (OH-PCBs) and halogenated phenols such as pentachlorophenol (PCP), which have been measured earlier in the Inuit population of Nunavik, as well as in samples from the Lower North Shore of the St. Lawrence River and Québec City (Sandau, *et al.* 2000, Sandau, *et al.* 2002). Significant amounts of these compounds were found in plasma from Nunavik Inuit and some evidence of their potential to interact with thyroid hormones was also shown. However, no temporal trends for these compounds are yet available.

Perfluorooctanesulfonate (PFOS) and related compounds are other emerging contaminants that require monitoring in the Arctic. These chemicals have been produced commercially for over 40 years. PFOS is very stable, repels water and oil and was largely used as a stain repellent ("ScotchGuard"). Kannan, *et al.* (2002) have reported widespread occurrence of PFOS in fish, birds and marine mammals from the Mediterranean and Baltic Seas. PFOS has also been detected in marine mammals from the North American Arctic (Kannan, *et al.* 2001). Endocrine effects (decreased estradiol and T3 serum levels) have been observed in sub-chronic toxicity experiments in monkeys (Seacat, *et al.* 2002). However, data on human exposure to these compounds in northern regions are scarce and, therefore, dietary exposure to PFOS and related compounds in the Inuit population as well as potential toxic effects related to the latter remain to be addressed.

Given the potential health hazards related to these environmental contaminants, worldwide agreements have been taken to make appropriate efforts to decrease the input of several of these substances in the environment and decrease human and wildlife exposure to the latter (i.e. Stockholm Convention, POPs and Heavy Metals Protocols of the UN/ECE Long-range Transboundary Air Pollution Convention). Included in these conventions are measures aiming at assessing current exposure levels in human populations and deriving spatial and temporal trends for these environmental contaminants, in order to follow and understand their behaviour in the environment, evaluate the efficiency of intervention programs, and undertake appropriate actions to efficiently decrease potentially hazardous human exposures (e.g. recommendations about dietary habits).

However, taking action to modify lifestyle habits and diets in order to reduce environmental exposure to POPs and heavy metals must be done carefully, taking in consideration not only the risks associated with diets including fish, seafood and sea mammal meals (exposure to contaminants), but also the benefits of such diets. Indeed, high exposure to n-3 fatty acids during prenatal life increases birth weight and visual acuity of newborns. Inuit have very high levels of n-3 fatty acids in their blood due to their high consumption of fish and marine mammals. These substances are transmitted to the foetus during pregnancy and have a direct effect on the weight of the newborn and on prolonging the gestational time.

Selenium (Se) is another essential nutrient found in sea products. This element is an antioxidant as well as a micronutrient that regulates the action and/or enters in the composition of several essential enzymes. It interacts with mercury in an antagonistic way, hence exerting a protective effect with regards to mercury-induced toxicity. Therefore, this project not only aims at assessing exposure to environmental contaminants through maternal blood monitoring, but it also proposes to examine n-3 fatty acids and selenium content and profiles. This work will provide sufficient information to attempt to weigh the costs and benefits of the Inuit traditional diet, and hence make appropriate recommendations, adapted to the specific needs and concerns of northern Aboriginal people.

Newly obtained data will be compared to data obtained earlier in Nunavik (Ungava Bay and Hudson Bay regions); hence, the results of this comparison will provide information about whether exposure levels to different classes of contaminants are increasing, decreasing or remaining the same in northern populations. Since there is a strong correspondence between POP concentrations in human milk, maternal blood and cord blood (and most available past data is for maternal and cord blood), and since maternal blood is easier to sample than cord blood, we will focus on maternal blood for future exposure assessments and spatio-temporal comparisons. Additionally, this time and geographical trend analysis will provide information about the efficiency of intervention programs previously implemented in Nunavik (i.e. cessation of lead ammunition use; dietary shifts from sea mammals to Arctic char). Efforts will be made to link exposure with potential sources of exposure, by using dietary profiles based on n-3 fatty acids, a marker that is available in past surveys as well as in newly generated data, and other sources of information according to the availability and comparability of data. Hence, this project aims at providing information that will serve as a basis for decisions and actions to reduce exposure to pollutants, while considering the benefits associated with traditional diets.

Activities

In 2004-2005

In the course of the 2004-2005 NCP funding year, women from Hudson and Ungava were recruited and we collected maternal blood as well as a few corresponding cord blood samples to measure the conventional suite of POPs and heavy metals. These analyses have being carried out using previously described laboratory methods, which are comparable to methods used in the framework of our past studies (methods already extensively described in (Muckle, *et al.* 2001a, Muckle, *et al.* 2001b)). Additionally, the new RapidTrace method was used on some of these samples for comparison purposes. Hence, in addition to other conventional validation methods already applied on the RapidTrace method, results of the cord blood and maternal blood analyses obtained with both methods are being compared to further validate the use of the RapidTrace method in temporal trend studies (RapidTrace method described in next section). Laboratory analyses are conducted by the human toxicology laboratory of the INSPQ, which is accredited by the Canadian Association for Environmental Analytical Laboratories and accredited ISO 17025. However, recruitment procedures had to be modified along the course of 2004-2005 due to an interruption of obstetrical services in Tulattavik Health Centre. In the meantime, progress was made regarding the integration of data already available from previous projects and major improvements were brought to our sample archiving system. The following section describes the events and the current status of recruitment procedures, presents available analytical results and a comparison of both analytical methods used, and provides a short update on the status of our data and sample management system.

Results/Discussion

Recruitment and sample collection

Recruitment actively started in early March 2004 at the Ungava Tulattavik Health Centre but in June 2004 recruitment was stopped because of logistical problems at Ungava Tulattavik Health Centre (lack of medical personnel; no more obstetrical services). To that date, five participants had been recruited from which cord and maternal blood samples had been collected. Given the fact that women were no longer giving birth in Tulattavik, recruitment had to be put on hold during the summer period when medical personnel were especially scarce. In order to circumvent the lack of obstetrical services in Tulattavik, women were either re-routed to Montreal or to maternity facilities in the Hudson Bay area to give birth. This imposed a significant workload increase on all personnel involved with these host institutions. The heavy work load put on La Maison Nunavik in Montreal (Module du Nord) and in other Nunavik maternity centres, as well as logistics problems encountered when trying to track where women were re-routed from Tulattavik to give birth, prevented any sample collection from being started from Montreal or the Hudson Bay area maternity centres during the past funding year.

Nevertheless, to circumvent the above-mentioned hurdles faced during recruitment procedures, as well as to avoid recruiting the same subject twice, pregnant women participating in the Nunavik Health Survey in Fall 2004 were included in the current study. Blood samples for contaminant analyses were taken during the Fall Health Survey and measured for environmental contaminants (among other parameters pertaining to the health survey). These samples have been incorporated in the current analyses in order to increase the samples size for 2004-2005 and to circumvent the recruitment problems that we encountered. Thus Tables 2, 3 and 4 are based on the five maternal blood results merged with the 26 maternal blood results from the Nunavik survey (27 for metals).

Preliminary analysis of contaminants

Metals were analysed using conventional methods. Mercury is analysed by cold-vapour AAS, selenium by an HPLC-ICP-MS method, and other metals are assessed by an ICP-MS screen.

For organochlorine measurements, two different methods were compared: the conventional method used in the framework of our past studies (extensively described in Muckle, Ayotte *et al.* (2001); Muckle, Ayotte *et al.* (2001)) and the new RapidTrace method, which allows the measurement of several analytes of halogenated hydrocarbons in a smaller volume of biological sample (1 to 5 ml). This method was validated using conventional laboratory standards and validation methods, and it is currently being compared to earlier, conventional methods in cord and maternal plasma samples from Nunavik in order to ensure analytical method comparability in the framework of time trend analyses.

The RapidTrace method is based on a first fractionation of the plasma extract leading to two fractions (F1 and F2); followed by different extraction, fractionation and derivatization methods for F1 and F2; finally leading to the separation of three extracts, containing non-polar, non-planar compounds (F1a), non-polar, planar compounds (F1b) and polar compounds (F2). Using this sample preparation method, PCBs, OC pesticides, and brominated compounds such as BDEs, as well as other compounds can then be measured by mass spectrometry. The extraction method theoretically allows the separation of up to 145 analytes. However, the measurement and quantification of the latter require different mass spectrometry procedures. The INSPQ laboratory has currently validated the RapidTrace method followed by MS procedures to measure 15 PCB congeners and 11 OC pesticides (similar to the traditional suite of OCs, but more compounds are being validated), two toxaphene congeners (Parlar # 26 and 50) and five brominated compounds including PBB-153 and 4 BDE congeners (congeners # 47, 99, 100 and 153). Development and validation is ongoing for the detection of more analytes, including more toxaphene congeners, hydroxylated PCBs, hydroxylated PBDEs, brominated/chlorinated phenols, methyl-sulfonyl-PCBs/DDE and polychlorinated naphthalene congeners.

Table 1 shows some preliminary analytical results for 10 samples analyzed using conventional analytical methods (five cord blood samples and five maternal blood samples). Arithmetic means and standard errors are shown, with range shown in parentheses. These 10 samples were collected in the framework of the current study before sample collection had to be stopped. Other analytes were included in these preliminary analyses and comprise the following organochlorines: 14 PCB congeners, aldrin, â-HCH, mirex, á-chlordane, ã-chlordane, oxychlordane, *cis*-nonachlor, *trans*-nonachlor and *p,p'*-DDT. Other metals included selenium cadmium, arsenic, zinc and copper. Statistics for these compounds are shown in Table 2, using a larger sample size for maternal blood only. No further statistics were computed for cord blood given the small sample size available. However, the data from Table 1 and Figure 1 show that the concentrations in maternal and cord blood are strongly associated, as shown in many previous studies.

Preliminary comparison of the results obtained with the conventional and RapidTrace methods for PCB-153 and *p,p'*-DDE are shown in Figure 2. The two methods were used on the same five samples of cord blood and five samples of maternal blood for which results are show in Table 1. In Figure 2, distinction is made between cord blood and maternal blood. However, when cord blood and maternal blood are considered together and both

Table 1: Comparison of certain OCs and metals between cord blood and maternal blood

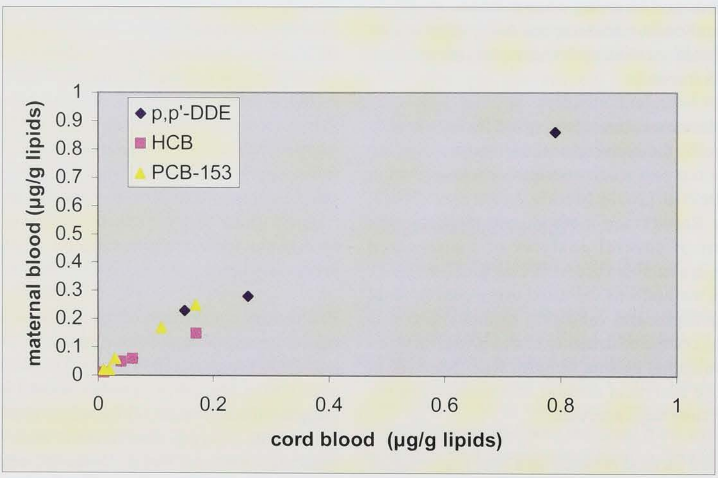
	Cord blood (n=5)	Maternal blood (n=5)
DDE (µg/g lipids)	0.26 ± 0.31 (0.04-0.79)	0.30 ± 0.33 (0.05-0.86)
HCB (µg/g lipids)	0.06 ± 0.06 (0.01-0.17)	0.06 ± 0.06 (0.01-0.15)
PCB-153 (µg/g lipids)	0.07 ± 0.07 (0.01-0.17)	0.10 ± 0.10 (0.02-0.25)
Lead (µmol/L)	0.11 ± 0.04	0.12 ± 0.04
MeHg (nmol/L)	48.4 ± 29.10	28.8 ± 12.69
Total Hg (nmol/L)	59.20 ± 33.60	36.60 ± 14.75

Table 2: Heavy metals in maternal blood from Nunavik (2004)

	n	% detection	AM	SE	CI 95% AM	GM	CI 95% MG	Minimum	Maximum
Cadmium	32	100.0	32.38	3.57	(25.12-39.64)	24.10	(17.33-33.51)	3.00	71.00
Mercury	32	100.0	50.61	5.92	(38.54-62.68)	38.87	(29.01-52.09)	6.00	150.00
Lead	32	100.0	0.106	0.014	(0.079-0.134)	0.088	(0.071-0.109)	0.028	0.410
Selenium	32	100.0	3.72	0.33	(3.04-4.40)	3.36	(2.87-3.94)	1.60	8.90

*Lead and selenium in µmol/L , cadmium and mercury in nmol/L

Figure 1: Organochlorine concentrations in cord and maternal blood



methods are compared by Spearman's correlation analyses, we find that for all three OCs compared, the two methods showed similar results and data were strongly associated. For DDE, the Spearman's correlation coefficient between both methods was 0.998 ($p<0.001$), for HCB, Spearman's r was 0.976 ($p<0.001$) and for PCB-153, Spearman's r was 0.988 ($p<0.001$). These preliminary analyses suggest that the RapidTrace method can be used and compared to the conventional method of organochlorine measurements without inducing a significant bias in time trend analyses. However, further comparisons are ongoing on larger datasets and on more analytes in order to validate this hypothesis.

Analyses of PFOS were carried out according to a method recently validated by the INSPQ human toxicology laboratory. This method is based on alkaline extraction of PFOS with methyl-tert butyl ether and tetrabutylammonium hydrogen-sulfate, followed by electrospray LC-MS-MS analysis. Results for PFOS analyses on 10 samples from Nunavik (five maternal blood and five cord blood samples) are presented in Figure 3

Figure 2: Comparison of results obtained with the conventional method and the RapidTrace method for A) *p,p'*-DDE, B) PCB-153 and C) HCB (μg/l)

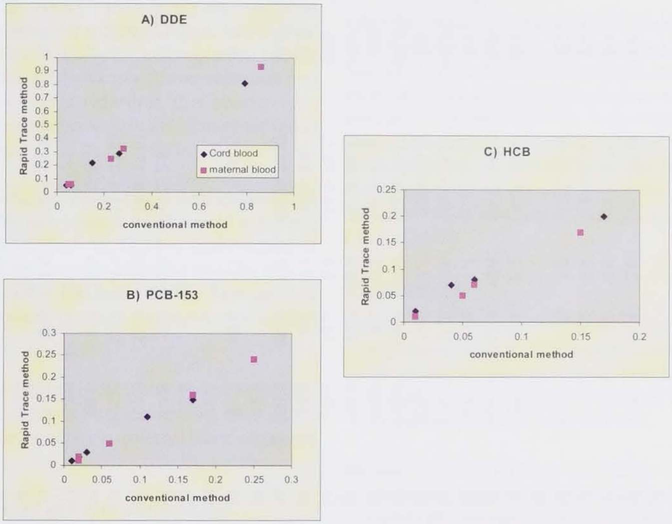


Figure 3: PFOS levels in Ungava vs. recent data from Japan

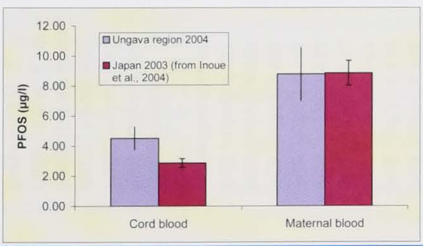


Table 3: POPs in maternal blood from Nunavik (2004)

	n	% detection	AM	SE	CI 95% AM	GM	CI 95% GM	Minimum	Maximum
PCB , Aroclor 1260	31	100.0	808.5	110.7	(582.84-1034.25)	594.3	(436.17-809.70)	117.2	2758.0
PCB , IUPAC # 28	31	25.8						DL	6.7
PCB , IUPAC # 52	31	0.0						DL	DL
PCB , IUPAC # 99	31	100.0	18.4	2.0	(14.3-22.5)	14.8	(11.4-19.2)	3.6	48.4
PCB , IUPAC # 101	31	87.1	3.0	0.4	(2.2-3.7)	2.4	(1.9-3.1)	DL	10.0
PCB , IUPAC # 105	31	83.9	3.3	0.4	(2.4-4.2)	2.6	(2.0-3.4)	DL	11.7
PCB , IUPAC # 118	31	100.0	15.5	1.9	(11.5-19.5)	12.3	(9.6-15.9)	3.7	53.3
PCB , IUPAC # 128	31	32.3						DL	3.0
PCB , IUPAC # 138	31	100.0	46.4	5.7	(34.7-58.1)	35.3	(26.4-47.3)	7.8	121.1
PCB , IUPAC # 153	31	100.0	108.4	15.6	(76.7-140.2)	78.5	(57.2-107.7)	14.8	413.7
PCB , IUPAC # 156	31	87.1	6.1	1.1	(3.8-8.4)	3.9	(2.7-5.6)	DL	29.3
PCB , IUPAC # 163	31	100.0	18.7	2.8	(13.0-24.5)	13.3	(9.6-18.3)	2.3	69.0
PCB , IUPAC # 170	31	100.0	14.9	2.7	(9.4-20.4)	9.8	(6.9-13.9)	1.2	77.6
PCB , IUPAC # 180	31	100.0	53.9	10.6	(32.3-75.6)	34.5	(24.2-49.4)	5.6	310.3
PCB , IUPAC # 183	31	96.8	6.5	0.9	(4.7-8.3)	4.8	(3.6-6.6)	DL	20.1
PCB , IUPAC # 187	31	100.0	24.2	3.5	(17.0-31.4)	17.4	(12.7-23.7)	3.7	74.1
Hexachlorobenzene	31	100.0	46.6	5.9	(34.6-58.7)	37.5	(29.3-48.1)	11.1	169.6
Mirex	31	93.5	6.4	1.1	(4.1-8.8)	4.3	(3.1-6.1)	DL	26.6
Oxychlordane	31	100.0	52.6	8.6	(35.0-70.2)	36.9	(26.9-50.8)	7.1	230.1
PBB , IUPAC # 153	31	12.9						DL	1.8
PBDE , IUPAC # 47	31	67.7	10.6	1.7	(7.1-14.1)	6.7	(4.6-9.9)	DL	39.0
PBDE , IUPAC # 99	31	16.1						DL	7.1
PBDE , IUPAC # 100	31	12.9						DL	7.9
PBDE , IUPAC # 153	31	54.8	2.0	0.3	(1.3-2.6)	1.4	(1.0-1.9)	DL	8.1
Parlar no. 26	31	100.0	12.9	2.2	(8.3-17.5)	9.6	(7.2-12.7)	2.5	70.2
Parlar no. 50	31	100.0	23.2	4.3	(14.5-31.9)	16.9	(12.6-22.5)	4.3	133.2
ß-HCH	31	96.8	6.4	0.9	(4.5-8.3)	4.8	(3.6-6.4)	DL	23.0
alpha-chlordane	31	0.0						DL	DL
***cis*-nonachlor**	31	100.0	12.0	2.0	(7.9-16.0)	9.0	(6.8-11.9)	2.3	61.8
gamma-chlordane	31	0.0						DL	DL
***p,p'*-DDE**	31	100.0	307.7	43.6	(218.8-396.6)	230.6	(172.3-308.7)	55.4	1086.0
***p,p'*-DDT**	31	58.1	9.0	1.5	(6.0-11.9)	6.9	(5.4-8.9)	DL	43.6
***trans*-nonachlor**	31	100.0	78.9	13.4	(51.6-106.2)	57.6	(42.8-77.4)	13.5	411.8

*POPs are lipid adjusted (μg/kg)

Table 4: Concentration of POPs in plasma of pregnant women from Nunavik (trend 1995-2004, mg/kg lipid adjusted)

	1995* n=30	2004 n=31	Variation %
Aroclor 1260	693	594	-14.3
HCB	36	37.5	+4.2
Mirex	7.8	4.3	-45
Oxychlordane	33	36.9	+11.8
β-HCH	5.1	4.8	-5.9
p,p'-DDE	244	230.6	-5.5
p,p'-DDT	15	6.9	-54

and compared with results obtained from a population in Japan (Inoue *et al.* 2004). PFOS levels are similar in Nunavik and in Japan for maternal blood, but slightly different for cord blood. However, our very small sample size for cord blood precludes any firm comparison and conclusion to be drawn regarding this observation. Results for PFOS on a larger sample size of maternal blood are shown in Table 2.

Analyses of 32 merged maternal blood samples show that lead concentrations now average 0.088 μmol/l with none over the 0.48 μmol/l threshold. This low concentration is a continuation of the decrease observed after the ban of lead shot use in 1998 (Dallaire, 2003). Mercury has certainly not decreased like lead compared to year 2000 (40 μmol/l).

For POPs we show here (Table 3 and 4) that except for *p,p'*-DDT which shows a strong decrease, most POPs have the same concentrations in maternal blood compared to 1995.

Sample management and data warehousing

The archived sample inventory and database integration were started in early fall and are currently ongoing. The archived sample inventory was completed, but a bar-code system remains to be implemented and related to the data warehouse system under development. Database integration is being achieved with the help of a statistician as well as a specialist in Geographic Information Systems (GIS) dedicated to the development of multidimensional databases and OLAP systems. The framework of this database has been designed and data from past studies have been collected into a unique flat file that will be integrated in this database. New data will be added in as soon as they are available and statistical analyses will then be carried out.

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Decision Support Tool for Risk and Benefit Balancing of Country Food Issues in the Canadian Arctic (Year 1)

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Partners: Nunavik Nutrition and Health Committee (NNHC)

Abstract

This project is developing a decision support tool for northern health professionals / experts, and other decision makers (e.g. Territorial Contaminant Committees including NNHC) incorporating the qualitative and quantitative benefits and risks associated with country food consumption, associated contaminant exposure, nutrient intake and social and cultural benefits. The tool takes the form of a computer based model and is being developed using the software Analytica™ (2002). In its first year a review of literature and selection of appropriate methodologies for the balancing of benefits and risks applicable to this issue and initial model development / adaptation has been conducted. Through working with the NNHC and using Nunavik-specific data for country and market food consumption, macro and micro nutrient intakes, contaminant exposure and public perspectives on the social and cultural benefits of country foods, the model will first be applicable to Nunavik. However, the overall framework being developed is generic enabling future consideration of other communities facing similar concerns regarding food consumption risks and benefits. The model will therefore support the decision-making activities of northern health professionals and others having to make decisions and provide advice on health, nutrition, and contaminant issues in Aboriginal communities in the North and elsewhere.

Key Messages

1. A decision support tool to help northern health professionals and others in balancing the benefits and risks of country foods and contaminants is being developed incorporating Nunavik data using the software Analytica ™;

2. The model is bringing together quantitative and qualitative data on country and market food consumption, macro and micro nutrient intakes, contaminant exposure and public perspectives on the social and cultural benefits of country foods enabling a comparative assessment of the benefits and risks associated with country food and market food consumption.

Objectives

This project is developing a tool to help decision makers face the challenges in understanding and making decisions regarding country food consumption. The tool will facilitate the explicit consideration of a number of key components in such a decision process including the level of contaminant exposure, nutrient intake, personal food preferences, and social and cultural norms. The project involves the review of existing methodologies for benefit / risk balancing developed elsewhere; consultation with northern health professionals and other decision makers; and expert technical review at various stages of the work. Because of this, this project is providing balancing methods applicable to the issue of contaminants, food and health to help decision makers and others explicitly consider and integrate various aspects of this issue in their decision making processes and development of policies / advice.

Specifically, this year the project:

- Adapted a preliminary version of an existing decision model developed for the general issue of food security in the North and has been oriented to facilitate decision making on contaminants / health / country foods in Nunavik;

- Worked with the Nunavik Nutrition and Health Committee to involve decision makers in the model development process;

- Produced a critical literature review for peer review exploring methodologies for balancing benefit / risk; this will support the conduct of an expert consultation workshop to be held in 2005-2006.

Introduction

The management and communication of the risks posed by environmental contaminants in the food chain of northerners comprises a very challenging issue for health and environmental managers and health professionals. Country foods are the anchor to cultural and personal well-being in the North. They are essential to the nutritional and social health of northern Aboriginal people (e.g. CACAR II a,b; Condon *et al.*, 1995). They continue to contribute significant amounts of protein to their total diet, and help individuals meet or exceed daily requirements for several vitamins and essential elements (AMAP, 2003; Blanchet *et al.*, 2000; Kuhnlein *et al.*, 2000). In addition to the substantial nutritional benefits, traditional foods provide multiple cultural, social and economic benefits to these communities and individuals. However, they are also the main source of several environmental contaminants to these populations. Data now exists to suggest associations between exposure to some contaminants found in country food species (e.g. PCBs and Hg) and subtle neurodevelopment effects in Inuit infants at 6 and 11 months of age (CACAR II a,b, 2003).

It is critical that northern health decision makers and community residents have the most recent and pertinent information available to make truly informed decisions regarding these issues, considering the range of risks and benefits posed by country foods and their alternatives. However, it is critical that this information be provided in way(s) that are accessible and easy to use. In the past, decisions and advice based more on the risks associated with contaminant exposure have resulted in fear and confusion, distrust and anxiety; in some instances, among community residents they have had significant direct and indirect social, economic, and health impacts (Furgal *et al.*, *in press*; Wheatley and Wheatley, 1981).

Formal literature on comparative risk and benefit methodology has been accumulating over the past few decades. Methodology development is continually being updated and expanded (e.g. Wong *et al.*, 2003). Much of the methodology developed to date has been directed toward risk-based regulatory reform in the United States, focusing on the mandate of the US Environmental Protection Agency. While there is a diverse literature on comparative risk assessment (or risk ranking) techniques and issues, there have been relatively few papers which address a common framework for considering diverse negative and positive health outcomes across an entire diet. A recent and very relevant attempt was carried out with regard to the risks and benefits of fish consumption (Anderson *et al.*, 2002). These developments provide a sufficient basis to proceed with the development of policy-relevant comparative risk and benefit decision-support tools.

To help northern health decision makers face these challenges, this project is developing a decision support tool, which incorporates the most relevant benefit-risk balancing methodologies to aid northern health professionals and other decision makers in considering these issues and providing advice.

Activities

In 2004-2005

Review and Orientation of Preliminary Model to Focus on Contaminants in the Nunavik Population

A prototype model developed by Furgal and Paoli to look at the basic components of northern food security was adapted to support a wide range of policy issues facing decision makers in the North related to contaminants and country food consumption.

Critical Literature Review

Various methodologies have been proposed to address comparative risk assessment. Some of these methods are very generic (e.g. general models and indices of health impact) and some have direct relevance to this work (e.g. balancing the risks and benefits of fish consumption, for example, TERA, 1999). These methodologies were critically reviewed for their relevance and appropriateness to the proposed approach and context. A small number of candidate methods are being selected for potential implementation in the model.

Consultation with northern health experts (NHE) to determine decision-making needs and priorities related to contaminants and food

Northern health experts and other decision makers / researchers were consulted to identify specific decision-making needs and priorities related to this target population, and preoccupations in the region with regards to specific country foods and contaminants. This group was made up of the members of the Nunavik Nutrition and Health Committee (including national Inuit through an Inuit Tapiriit Kanatami representative).

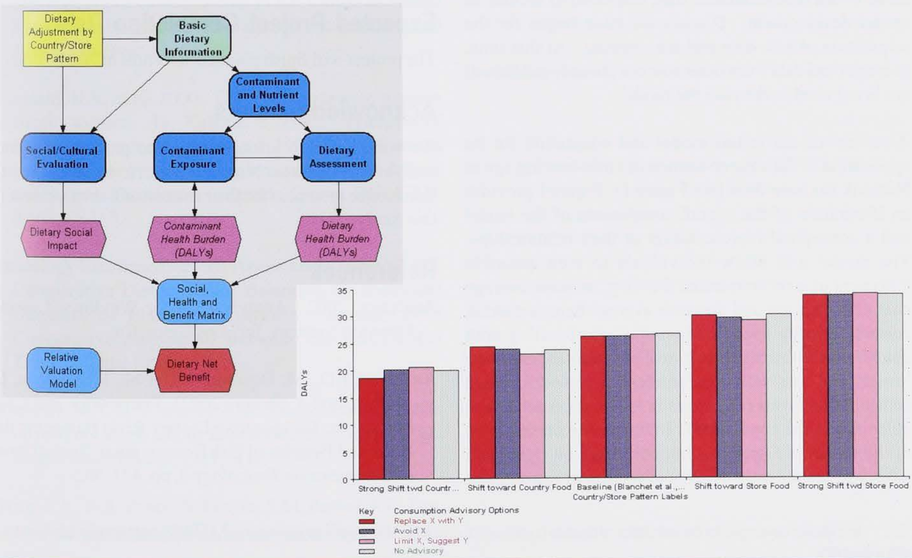
Identification, Selection, and Acquisition of Data

From the early stages of the project, data requirements have been documented and candidate data sets are being identified. Both raw data (individuals) and group averages are being requested from researchers working in Nunavik communities on these issues. This "real" data includes information on contaminant exposure, foods consumed, diet behaviour, food preferences/diet determinants, risk perceptions, and nutrient intakes.

Model Detailing and Development to Include Candidate Methods and Sample Data

A first version of the benefit decision-support tool was developed to incorporate: i) the methodologies selected, ii) the data collected on intake, burdens, and health impacts and iii) the model diets / preferred consumption scenarios that have been selected for exploration. The tool will allow decision makers to review transparently the full range of inputs into the decision (e.g. see Figure 1 – top left image) the implications of various

Figure 1. Updated overview of decision support model



assumptions, and the implications of model diets under these assumptions (see Figure 1 – bottom right figure).

Results and Discussion

A critical literature review of candidate methods for balancing benefits and risks has been done and the document will be sent for peer review as the basis for an expert consultation meeting including northern health professionals and technical experts in the areas of diet modelling and contaminant and nutrient risk assessment. The metric being used for comparison of calculated health risks associated with high contaminant intake or low nutrient intake (including cancer and other adverse health outcomes) is the Disability Adjusted Life Year (DALY)[1].

The initial concepts of the model and project were presented to the Nunavik Nutrition and Health Committee in Kuujjuaq and then further consultation took place between the team and members of the committee at a meeting held in Montreal this spring. Two to three members of the NNHC have shown specific interest in working with the research team in aspects of the development of the model. At the Montreal meeting, potential reviewers for the literature review paper and participants for the experts meeting to be held in 2005-2006 were suggested. Further, the NNHC has supported the team in requesting access to the most recent data from researchers working in Nunavik communities on these issues (contaminants, diet, nutrition) to include in model development. Discussions have begun for the acquisition of raw data and are ongoing. At this time, averages and data from other sources (already published) are being used to develop the model.

A review of the initial model and adaptation for its application to the case of women of child-bearing age in Nunavik has been done (see Figure 1). Figure 1 provides an illustration of the overall components of the model and a conceptual representation of their relationships. The model will allow individuals to view possible outcomes of a recommended diet (e.g. increase average char consumption and decrease average beluga muktuk consumption by specific amounts) incorporating both quantitative information (e.g. real contaminant exposure levels) and qualitative parameters (e.g. user-defined consumption levels or changes in levels of certain health outcomes in the population). In the draft representation of the model in Figure 1 – bottom image on right hand side - you can see one possible mechanism of representing community values in terms of a single health metric, in this instance the Disability Adjusted Life Year (DALY). The output measure of health burden can be directly compared across possible dietary options facilitating the identification of an advisory / policy associated with an acceptable level of health risk / benefit. The model is being focused to concentrate on the diet, nutrient needs, and contaminant impacts among Nunavimmiut. However, as the development is taking a generic approach to the analytical components of the model it will be transferable to other regions upon completion.

Conclusion

At the request of the NNHC the model is being developed using data that includes all segments of the population in Nunavik. However, focus on a specific segment of the population (e.g. women of child-bearing age) will be possible when running the model. Development of the basic components of the model are now complete and Nunavik-specific data is being entered. Further model development and refinement, consultation with members of the NNHC and data input will be conducted in the early stages of Year 2. In the fall – winter of Year 2 an experts meeting will be convened to review technical aspects of the model as well as its usefulness for northern health decision makers in Nunavik. The literature review paper produced this year and a description of the model will help form the background material for this meeting.

Expected Project Completion Date

The project will finish planned activities in 2005-2006.

Acknowledgements

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[1]DALY - an indicator developed for the calculation of disease burden which quantifies, in a single indicator, time lost due to premature death with time lived with a disability.

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Characterizing Risks Associated with Fetal Exposure to Methylmercury in an Animal Model to Aid Guideline Development for Exposure in Human Pregnancy

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Abstract

The report describes progress on a new technique being used to explore aspects of prenatal neurological damage that may occur from the ingestion of methylmercury (MeHg) during pregnancy. It uses a mouse model to examine the transfer of MeHg from the mother to the developing fetus, particularly the accumulation of MeHg in the fetal brain, as well as measuring levels in maternal brain and other tissues. The method incorporates a stable mercury isotope approach to create unique 'tracer' doses, and gas chromatography combined with high resolution mass spectrometry (GC-MS) for measuring tissue concentrations. Commercially available enriched isotopes of mercury (^{198}Hg, ^{200}Hg and ^{202}Hg) have been purchased and used in the laboratory to formulate unique doses of methylmercury chloride having a distinct signature or 'fingerprint' different from the isotopic mixture found in nature ('native' mercury). Although the total quantity administered over the duration of pregnancy remained the same, groups of animals received differing patterns of exposure (including 'bolus' doses). The enriched isotopes are non-radioactive. These have been administered on cookies to pregnant mice as part of a 'pilot phase' where the principle goal was to determine if the GC-MS method is sufficiently sensitive and precise to distinguish between the different isotopic mixtures of methylmercury which had accumulated in the maternal and fetal tissues. Also described are the results of the intricate dissection techniques to obtain intact fetal brain tissues.

The provisional data set which is presented for the concentrations of MeHg in mouse dams and fetuses confirm the feasibility of the proposed study design in the main phase to investigate the 'bolus dose' effect. The data also show that the 'total' levels of methylmercury in the brain tissue are consistent with previously published data (by one of the current investigators) in this mouse strain, where similar dosing regimes had been administered. This is important since – as well as the kinetic aspects of the methylmercury currently described here - a key goal is to demonstrate the existence of neurobehavioural impairments in pups born to similarly exposed 'parallel' groups of female mice.

Key Messages

1. A 'pilot' phase of the study has been successfully carried out this year to test the proposed analytical method and the design of the study protocol. Pregnant mice (strain C57BL/6) were administered different formulated isotopic mixtures of methylmercury and a technique was developed to harvest very small samples of brain tissue from the mouse fetuses.

2. Using test tissue samples, experiments were carried out to verify the extraction efficiency and recovery of the isotopic methylmercury compounds used in the analytical method; this was then applied to tissues collected in the pilot phase.

3. Using a developed extraction method and measurement using gas chromatography / high resolution mass spectrometry (GC-HRMS) it has been possible to separate and identify the quantities of the different MeHg doses (with unique isotopic 'fingerprints') which have accumulated in the tissues of the exposed dams. The same isotope mixes of methylmercury were also measured in the pooled fetal brain samples, and the concentrations were found to be elevated (1-2 times) compared to those measured in the maternal brain samples.

Objectives

1. To carry out a pilot phase (breeding study) in mice and take measurements of body weight changes over pregnancy; to dose different groups of mice with administered methylmercury chloride in ethanol, which have been formulated to contain different quantities of enriched stable isotopes of Hg (so that each dose has a unique "isotopic fingerprint").

2. To take note of the 'lessons learned' during all aspects of the pilot phase carried out this year so as to be able to incorporate these appropriately into improving the design of the main phase of the study to be done in 2005-6.

3. To refine the analytical methodology and data transformation process, so that the isotopic measurements are as precise as possible.

4. To provide further physiological information for the mouse strain utilized for development of the physiologically-based pharmacokinetic (PBPK) model of MeHg in pregnancy. (This is to be the basis for providing guidance on exposure in human pregnancy.)

Introduction

That the developing nervous system of the fetus has an increased sensitivity to MeHg compared to the adult, has been known for some time (Inskip and Piotrowski, 1986, W.H.O., 1991, Choi, 1989, and Lapham *et al.*, 1995) but there are many questions surrounding why this is so (Watanabe and Satoh, 1996., Zheng, Aschner, and Ghersi-Egea, 2003). The current project is to examine in a mouse model, whether the magnitude and duration of exposure alter the toxicological impact of MeHg on the fetal nervous system at different times in pregnancy. The question posed in the current work is whether a 'bolus' or 'pulse' exposure of the mother in pregnancy results in a different distribution of MeHg accumulation in the fetal brain. If such elevated MeHg levels occur, these may have an equivalent or greater effect on brain development as compared to the same intake of MeHg spread over the whole gestation period (Inskip *et al.*, 2003). This consideration has particular relevance in communities - or to individuals - where fish /marine mammals are an important part of the diet and where women may consume meals containing MeHg during pregnancy in a periodic fashion, especially if the size and species of fish consumed indicate that the mercury concentrations may be elevated.

Justification as to the selection of the animal model (C57BL/6 mice) has been previously discussed (Inskip, 2004). As well as exhibiting more physiological similarities to humans than the rat, the strain demonstrates subtle neurobehavioural effects in the offspring (Doré *et al.*, 2001, and Goulet, *et al.*, 2003), and at concentrations of MeHg in the intended concentration ranges (physiologically relevant to human exposure regimes).

The analytical tool that was selected (using enriched stable isotopes of mercury) has been used previously in an environmental setting (Hintelmann *et al.*, 1997) but not previously in controlled dosing experiments, (although it has been successfully used in the case of lead (Pb) (Inskip, *et al.*, 1996). It utilizes a unique stable isotope dosing regimen administered to the mice during pregnancy. By providing the 'bolus' dose in the form of MeHg formulated using a unique isotopic fingerprint (enriched in one specific isotope), its detection and measurement in the brain of the fetus links it *solely to the bolus dose* consumed by the dam. The *remaining* MeHg in the fetal brain tissue (also with a unique isotopic fingerprint of its own) will have been deposited there as a result of transplacental transfer during the normal dosing with MeHg in pregnancy.

Because of the newness of the approach, a pilot study was carried out in preparation for a main phase - to verify (i) the methodology from an analytical aspect (chemical formulation of the isotope mixture, detection and measurement of the isotopes using a GC-high resolution mass spectrometer, data transformation to determine relative contributions of the administered mercury isotope species to the total tissue burden, and comparability with a previously reported ICP-MS based techniques); and (ii) a number of study design considerations related to the use of the test animal (acceptance of formulated dose, capacity for matching doses for groups receiving bolus and native MeHg, adequacy of methods for harvesting sufficient fetal brain tissue for the analyst, and the pregnancy success rates in the strain of mice to ensure efficient use of the costly isotopes).

The report briefly describes the results from this year's pilot phase, and includes preliminary evaluation of recent data on isotopic measurements using the GC-HRMS method.

Activities

In 2004-2005

The year's research has focussed on verifying the proposed analytical technique for the isotopic enrichment of doses of MeHg to the mouse strain used (C57BL/6), the detection and measurement of these isotopes in mouse tissues and (following approval of the protocol by the Departmental Animal Care Committee) the carrying out of a protocol for breeding and test dosing of mice, as part of a 'pilot' phase of the study. The recently received results from this phase (GC-MS analysis of animal tissue) have been preliminarily assessed and demonstrate a successful outcome for this technique. Procedurally, opportunities for improvement have been identified for the upcoming 'main phase' of the study this year, particularly on the breeding aspects of the mice. Valuable data have been recorded for body weight gain in pregnancy and the number (and weight) of pups produced. As well, practical aspects of manipulating, harvesting and weighing very small fetal brain samples for analysis have been completed successfully, while also providing data for the further development of the PBPK model of methylmercury during pregnancy in the mouse. The results of breeding success are particularly important in relation to the calculation of the dose needed for the animals, due to the considerable expense of the stable mercury isotopes.

Methylmercury chloride (CH_3HgCl) synthesis

Approximately 50 mg each of $CH_3{}^{198}HgCl$, $CH_3{}^{200}HgCl$ and $CH_3{}^{202}HgCl$ was synthesized from purchased enriched isotopes - ^{198}Hg, ^{200}Hg and ^{202}Hg respectively - using a procedure adapted from Banton-Montigny *et al.* (2004). The purity of the $CH_3{}^{198}HgCl$, the $CH_3{}^{200}HgCl$ and the $CH_3{}^{202}HgCl$ stock solutions was examined by nuclear magnetic resonance (NMR), total mercury analysis, gas chromatography-atomic fluorescence spectrometry[1] and GC-MS.

MeHg extraction from maternal brain tissue

A liquid-liquid extraction procedure for CH_3Hg (Forsyth *et al.*, 2004) was followed; however, the more rapid micro-extraction technique (MET) will be investigated for the main study. The brain tissue and blood were homogenized and 50 mg samples of brain (in wet weight (w/w)) and 100 µl samples of blood were analyzed. Prior to sample preparation, a surrogate addition of a known amount of $CH_3{}^{198}Hg$ was administered to each sample. CH_3Hg was extracted with toluene from enzymatically hydrolysed samples after the addition of sulphuric acid and potassium bromide. An L-cysteine back-extraction was used to separate the CH_3Hg from most organic co-extractives and the analysis of CH_3Hg (as CH_3HgBr) was carried out by high resolution GC-MS.

Analytical determinations of CH_3Hg by GC-HRMS, and data transformation

Chemical identification was achieved by the retention time on a 15 m DB-1 GC column. Matrix interferences were separated by high resolution mass spectrometry. In order to simplify the calculations and minimize the cross-contributions from other organic constituents (such as ^{79}Br and ^{81}Br), the $[M\text{-}Br]^+$ fragment ion in the electron impact ion source (CH_3Hg^+) was monitored. Every mass in the CH_3Hg^+ ion cluster (i.e. m/z 210.9893, 211.9824, 212.9902, 213.9917, 214.9918, 215.9938, 216.9941, 217.9974 and 218.9969) was monitored in voltage-selected ion monitoring mode. Intensity fractions of each mass were then calculated and fit into the formula for quantitation. Although isotope dilution mass spectrometry techniques applied to binary systems (an enriched stable isotope and the native element) have been documented in the literature (Yang *et al.*, 2003), the development of complex mathematic equations is required to determine two unknowns in a tertiary system (a surrogate, the native

[1] Thanks to Dr D Lean of the University of Ottawa

CH_3Hg^+ and another enriched isotope) as in the case of mouse tissues from these feeding studies. These equations were first tested in a binary system and then extended to the tertiary system by preparing a series of spiked mixtures. We also spiked a rat blank brain tissue with different combinations of stable isotope enriched species and native CH_3HgCl to validate the method.

Pilot Dosing Study

The year's research focussed on verifying the proposed analytical technique for the isotopic enrichment of doses of CH_3Hg to the mouse strain used (C57BL/6), the detection and measurement of these isotopes in mouse tissues and the carrying out of a protocol for breeding and test dosing of mice (maintained on a mouse chow diet).

Feeding Study Methodology

For the dose formulation prior to administration to animals, both stock solutions and individual doses for the animals were prepared in 95% ethanol. Dosages were administered to the pregnant dams daily, for a total of 18 days. All doses were calculated assuming 30 gram animals, and delivered on portions of animal crackers. The goal was to have each animal receive similar amounts of mercury over the dosing period.

- *Group A – Chronic 'native' study:*

Native mercury was dosed at 2mg/kg BW/day for a total of 1080µg dose per animal.

- *Group B – Chronic 'enriched' study:*

Enrichment was 1:1 mixture of $CH_3{}^{202}HgCl$: native CH_3HgCl.

This formulation was dosed at 1.8mg/kg BW/day for a total of 972µg.

- *Group C – 'Bolus' treatment:*

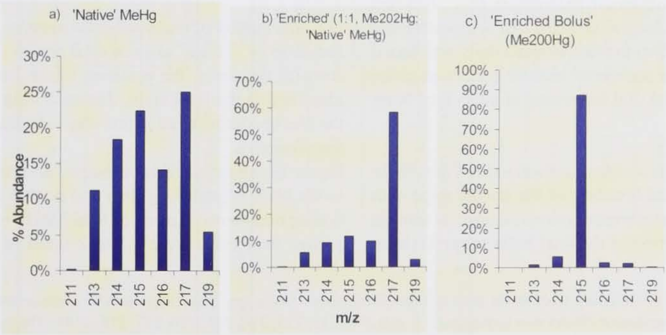
Native mercury was dosed at 1.1mg/kg BW/day for 16 days, plus 2 bolus mercury events (at gestation days (GD) 12 and 16) were dosed at 7.8mg/kg BW/event, for a total mercury load of 996µg per animal. Fetal and various maternal tissue samples were harvested prepartum on GD 18 and stored in Teflon® containers at -20°C until chemical analysis.

Results

a) *Methylmercury chloride (CH_3HgCl) synthesis for dosing of animals and analytical determinations by GC-HR-MS and data transformation*

The stock solutions of $CH_3{}^{198}HgCl$, $CH_3{}^{200}HgCl$ and $CH_3{}^{202}HgCl$ prepared were verified against a known native CH_3HgCl standard. Also, measurements of total Hg and methylmercury (as Hg) content indicated that no inorganic mercury was present (results not shown). Unlike organic isotope dilution (i.e. $^{12}C/^{13}C$) mass spectrometry, in which the cross-contribution between the stable-isotope labeled internal standard and the native analyte is generally minimal provided the mass difference between these two compounds is more than 3 mass units, inorganic isotope

Figure 1 Isotopic abundances for dosing solutions administered to treatment groups: a) 'native' group, b) 'enriched' $Me^{202}Hg$, and c) enriched $Me^{200}Hg$ administered at bolus events in 'enriched bolus' treatment group. (N.B. Note scale differences.)



dilution mass spectrometry has complications due to the existence of naturally occurring multi-stable isotopes of the element such as ^{79}Br and ^{81}Br isotopes. Therefore to simplify, the calculations were switched to the monitoring of the $[M-Br]^+$ fragments and the formula for quantitation derived accordingly. The choice of internal standard was also restricted to one of those enriched stable isotopes[2]. The accuracy of the results stems from the precision of the isotope ratios in the samples as well as in the standards. In general, deviations from the tested spiked values do not exceed ±10% using the derived IDMS calculations.

Figure 1 (a, b and c) shows the isotopic abundance of the native mercury dose and the two enriched doses used in the pilot phase, which were formulated from the purchased enriched mercury isotopes. Each constitutes a dose having a particular, unique isotopic 'signature' or 'fingerprint'.

b) *Harvesting and preparation of mouse tissue*
Figure 2 (a and b) shows the brain weights and equivalent fetal brain weights of selected female maternal-fetal pairs from the study. Dam brain weights (approximately 0.5 grams) and pooled fetal brain weights (approximately 0.8 grams) suggested this tissue mass would be sufficient for analysis, based on the projection of the expected MeHg concentrations, and given the dose ranges of MeHg administered. This was confirmed (discussed below). Exsanguination of anaesthetized dams prior to tissue harvesting revealed a (almost) complete absence of blood in the maternal brain, which is important since the isotopic content of the MeHg in the blood will likely differ somewhat from that in the brain. Fetal brain samples appeared to contain more residual blood in comparison, with most removable by delicate swabbing and rinsing with ultra-pure distilled water. Maternal organ weights, placenta weight and blood parameters (e.g., red cell volume) were recorded for use in the PBPK mouse model being developed. Two to three animals daily was found to be the maximum number able to be processed given the care needed for skilful harvesting of intact fetal brain tissue.

c) *Breeding success and fetal growth in the Pilot Phase*
Timed and staggered breeding of the female mice with males was carried out to ensure optimal numbers of animals for efficient harvesting of the fetal brain material (from approximately 8-9 pups on average but up to 15 pups in one case) and corresponding maternal tissues as described in (b) above. Maternal body weight increases were monitored daily prior to, and during pregnancy. Figure 3 shows data for 3 selected animals, with an approximate average body weight increase of x2 during pregnancy (about 20 grams for an 18 gram mouse). Selected non-dosed animals were also harvested for measurement of fetal body weight/brain weight prior to full term (data not shown).

Results also showed that the anticipated breeding success with males was lower than initially expected and will be reflected in adjustment of required animal numbers for breeding sufficient pups during the main study.

d) *Methylmercury in brain and blood*
The preliminary data represented in Table 1 are results for 10 animals: 3 animals administered 'native' MeHg, 3 animals administered 'enriched $Me^{202}Hg$', and 4 animals administered 'native' MeHg (as a background dose) as well as $Me^{200}Hg$ (at 2 bolus events). Total MeHg levels in maternal brain and blood tissues for all treatment groups range from 8.4 (±3.2) to 9.2 (±1.7) μg/g and from 4.2 (±0.3) to 7.6 (±3.2) μg/ml respectively. Figure 4 shows a plot of maternal brain and blood data and demonstrates that measurable levels of enriched mercury isotopes were achieved and distinguishable from the 'native' Hg doses. For all treatments, the levels of MeHg in blood were approximately half that present in the brain with some animal variability in the 'native' MeHg group. Although total MeHg levels differed between maternal brain and blood tissues, similar contributions of enriched $Me^{202}Hg$ were present in both tissues (41.9% and 39.9% of total MeHg, respectively). A greater contribution of $Me^{200}Hg$ was received in the blood than in the brain during the bolus treatment (47.2% versus 40.2% of total MeHg).

e) *Confirmation of maternal-fetal transfer of MeHg and detection of "bolus" dose in fetal tissues*
As with the dams, the presence of the bolus dose was identified in the fetal brain, demonstrating the ability of the MeHg administered in this way to be transplacentally transferred.
Figure 5 compares levels of 'native' and enriched MeHg in the brain of matching dam and pooled fetuses for all dosing treatments. Levels of total MeHg received in the pooled fetal brain were 1.5 to 2 times higher than the

[2] In order to calculate the intensity fraction for each isotope [Fr(i)] accurately, every mass (separated by one nominal mass unit) in the mercury containing isotope cluster was monitored (i.e. m/z 211, 212, 213, 214, 215, 216, 217, 218, 219). The summation of all intensities at different masses generates the total ion current (TIC) or S Fr(i). The individual intensity fraction at channel "i" [Fr(i)] is defined as the ratio of the intensity measured at channel "i" over the total ion current for compound "r".

Table 1. Levels of native and isotopic enriched MeHg in maternal and fetal brain tissues (μg/g wet weight) and in maternal blood (μg/ml) of mice.

Treatment	Animal ID	Tissue Type	Native MeHgCl		Me(200)Hg		Me(202)Hg		Total MeHg‡
			Concentration†	% of total MeHg	Concentration	% of total MeHg	Concentration	% of total MeHg	Concentration
Native	MF023	Maternal Brain	8.3						8.3
		Maternal Blood	N/A*						N/A
		Fetal Brain	16.3						16.3
	MF033	Maternal Brain	8.4						8.4
		Maternal Blood	9.9						9.9
		Fetal Brain	N/A						N/A
	MF035	Maternal Brain	N/A						N/A
		Maternal Blood	5.4						5.4
		Fetal Brain	19.6						19.6
Group Summary (Mean (± S.D))	**Maternal Brain**	n=2	8.4 (± 3.2)						
	Maternal Blood	n=2	7.6 (± 3.2)						
	Fetal Brain	n=2	17.9 (± 2.3)						
Enriched	MF037	Maternal Brain	5.9	56.9			4.5	43.1	10.4
		Maternal Blood	2.4	58.5			1.7	41.5	4.0
		Fetal Brain	10.3	60.0			6.9	40.0	17.1
	MF039	Maternal Brain	4.2	57.9			3.1	42.1	7.3
		Maternal Blood	N/A	N/A			N/A	N/A	N/A
		Fetal Brain	8.5	59.1			5.9	40.9	14.5
	MF040	Maternal Brain	5.9	59.5			4.0	40.5	10.0
		Maternal Blood	2.7	61.8			1.7	38.2	4.4
		Fetal Brain	N/A	N/A			N/A	N/A	N/A
Group Summary (Mean (± S.D))	**Maternal Brain**	n=3	5.4 (± 1.0)	58.1 (± 1.3)			3.9 (± 0.7)	41.9 (± 1.3)	9.2 (± 1.7)
	Maternal Blood	n=2	2.5 (±0.3)	60.1 (± 2.3)			1.7 (± 0.0)	39.9 (± 2.3)	4.2 (± 0.3)
	Fetal Brain	n=2	9.4 (±1.2)	59.5 (± 0.7)			6.4 (± 0.7)	40.5 (± 0.7)	15.8 (± 1.9)
Enriched Bolus	MF029	Maternal Brain	5.7	59.8	3.8	40.2			9.5
		Maternal Blood	N/A	N/A	N/A	N/A			N/A
		Fetal Brain	9.1	57.1	6.8	42.9			15.9
	MF041	Maternal Brain	5.2	61.8	3.2	38.2			8.4
		Maternal Blood	2.1	52.4	1.9	47.6			3.9
		Fetal Brain	N/A	N/A	N/A	N/A			N/A
	MF042	Maternal Brain	5.4	58.9	3.8	41.1			9.2
		Maternal Blood	2.9	53.7	2.5	46.3			5.4
		Fetal Brain	8.4	55.6	6.8	44.4			15.2
	MF043	Maternal Brain	4.2	58.9	2.9	41.1			7.1
		Maternal Blood	2.2	52.3	2.0	47.7			4.2
		Fetal Brain	6.6	51.9	6.1	48.1			12.8
Group Summary (Mean (± S.D))	**Maternal Brain**	n=4	5.1 (± 0.7)	59.8 (± 0.4)	3.4 (± 0.4)	40.2 (± 1.4)			8.6 (± 1.1)
	Maternal Blood	n=3	2.4 (± 0.4)	52.8 (± 0.8)	2.1 (± 0.3)	47.2 (± 0.8)			4.5 (± 0.8)
	Fetal Brain	n=3	8.1 (± 1.3)	54.9 (± 2.6)	6.6 (± 0.4)	45.2 (± 2.6)			14.6 (± 1.7)

† units in μg/g wet weight for brain tissues and μg/ml for blood.
‡ a summation for each measured isotopic MeHg (i.e 'native' + $Me^{200}Hg$ + $Me^{202}Hg$ = total MeHg)
* N/A, samples not available for analysis

maternal brain levels. However, the ranges of total MeHg across the three dose groups were comparable in each tissue, 8.4 (±3.2) to 9.2 (±1.7) μg/g in maternal brain and 14.6 (±1.7) to 17.9 (±2.3) μg/g in fetal tissue, which was not unexpected, since animals in each group received approximately the same overall amount of MeHg. Of the total MeHg levels found in the pooled fetal brains, a consistent contribution of 45.2% of $Me^{200}Hg$ originated from the bolus doses, whereas an average of only 40.5% was received in the maternal brain. Similar contributions of $Me^{202}Hg$ in the enriched dose treatment were found in both maternal and fetal brain tissues (41.9% and 40.5%, respectively).

f) *Split samples for analysis by ICP-MS methodology*
Following advice received at the previous NCP Results Workshop (Whiterock B.C., 2004) it was decided to explore the feasibility of carrying out some analyses for total and methylmercury by ICP-MS during the pilot phase of the study, and to this end, a contract was let with an acknowledged expert in the field, Dr Holger Hintelmann from Trent University. Although the full data sets for this exercise of comparison of two methodologies (ICP and GC-MS) have not yet been confirmed, initial assessment of the data shows good agreement between the methods.

Figure 2. Measurements of a) selected maternal brain weights from pregnant female mice, and of b) brain tissue from their fetuses at time of harvesting.

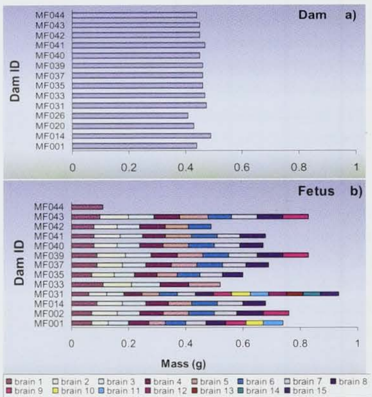


Figure 3. Measurement of increase in body weight during pregnancy in the C57BL/6 mouse.

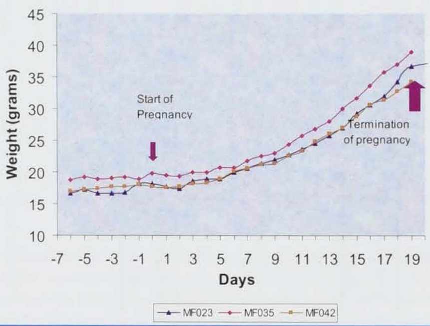


Figure 4. Levels of 'native' and enriched MeHg found in maternal brain tissue and corresponding blood samples.

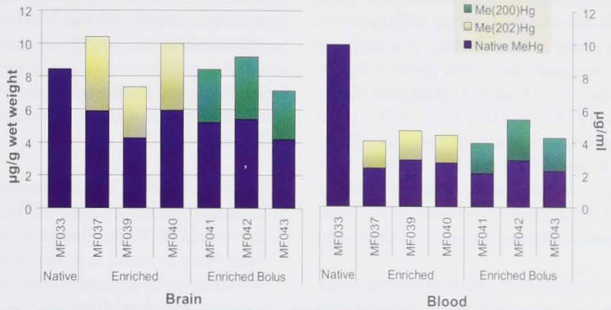
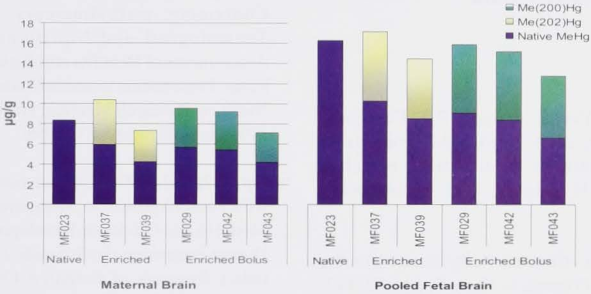


Figure 5. Levels of 'native' and enriched MeHg found in maternal brain and corresponding pooled fetal brain tissue.



g) *Progress on PBPK model development*

Good progress was made with development of the mouse model in pregnancy, following on from previous work that assembled and adapted data from the literature on a PBPK model of methylmercury in rats. Measured data for animals participating in the current phase have been useful in providing various physiological parameters for this particular mouse strain (C57BL/6) including bodyweight changes over pregnancy, pup brain weight and blood parameters.

Discussion and Conclusions

The data sets accruing from the pilot phase of the study - on isotopic and total mercury measurements, and on growth during pregnancy - have demonstrated encouraging results as to the feasibility of the stable isotope method for examining dosing patterns in this animal model to reflect possible non-steady state kinetics of methylmercury intake (pulse or bolus – as likely happens in 'real life' consumption patterns. The pilot phase of the study has been successfully completed this year with a number of lessons learned that can be readily incorporated into the upcoming main phase of the study.

The GC-MS method has performed as planned and the measured data successfully transformed in a manner that confirms the ability to detect the presence in the animal tissues of the enriched stable mercury isotopes administered in the dosing regimen. Thus, it allows the brain tissue levels of MeHg accrued in the fetus to be measured – further delineating whether it has originated from the chronic dosing regimen during pregnancy or from the bolus dose events superimposed on the chronic dosing regimen. Preliminary analysis of the results from analysis of duplicate samples by another technique (ICP-MS) confirms the comparability of the techniques. Data on fetal tissue levels are also comparable with previous work in this mouse strain – for example, in a study by Doré *et al.* (2001), pregnant mice were given 6 mg/kg MeHg on gestation days 12, 13, and 14. Resulting MeHg levels in fetal brain were 16.74 (GD15), 13.26 (GD17), and 12.09 (birth) µg/g respectively. In a study using rats, (Rossi *et al.*, 1997) dosed from GD7 to day 7 of lactation with 0.5mg/kg BW per day of MeHg, brain levels of 1.24ì g/g in the cerebrum and 1.27ì g/g in the cerebellum were found, using cold vapour atomic absorption spectrophotometry.

Thus, pending funding approval, the study is now on-target for completion of the main phase of the study this year, and it will be incorporating the knowledge gained from information accrued during the pilot phase of the study.

Expected Completion Date

March 31st, 2006

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Interactions between Northern Contaminants and Omega-3 Fatty Acids and Selenium in Central Nervous System Development

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Abstract

The traditional Inuit diet is rich in n-3 or omega-3 polyunsaturated fatty acids (ω-3) and selenium (Se) but is also contaminated by environmental pollutants such as methylmercury (MeHg) and organochlorines. Little is known on the interaction between these toxicants and dietary factors. The effects of four diets, low-Se/low-ω-3, high-Se/low-ω-3, low-Se/high-ω-3, high-Se/high-ω-3 on MeHg gestational toxicity was evaluated in newborn mice. Supplementation of a low-Se/low-ω3 diet with both Se and ω3, but not each dietary factor alone, completely suppressed MeHg-mediated offspring mortality. Of note, the diet enriched in ω3 only was developmentally toxic *per se* (~20% mortality at day-4, $p<0.01$), an effect suppressed by Se. These results support the hypothesis that elevated dietary intake of *both* Se and ω3 may reduce the developmental toxicity of MeHg, while Se-deficiency may enhance *in utero* MeHg toxicity, especially if combined with high intake of ω-3 fatty acids.

Key Messages

Our experimental results suggest:

- Supraoptimal intake of dietary selenium can antagonize gestational toxicity of methylmercury when the diet also includes high ω-3 fatty acid contents.
- Elevated intake of ω-3 fatty acids with low selenium was found to have detrimental effects on mouse perinatal development, effects that were exacerbated by methylmercury and suppressed by selenium.

Objectives

- To evaluate the effects of semi-purified diets enriched in fish-derived ω-3 fatty acids and supplemented or not with high selenium, on the *in utero* developmental toxicity of contaminants such as methylmercury and organochlorines.

Introduction

This experimental NCP study is directly relevant and complementary to the Canadian study "**Inuit Health in Transition Study: Nunavik Study**" and the circumpolar study "**The Inuit Health in Transition Cohort Study**", which examine the significance of the environment, diet and living conditions for Inuit health. Our studies are addressing NCP issues that cannot be addressed through exposure or epidemiological studies. Our 2004-2005 studies have provided novel information on the effects of dietary ω-3 fatty acids, selenium and MeHg, and their interactions during perinatal development.

MeHg and PCBs are currently listed among the most hazardous environmental pollutants, primarily due to their potential detrimental effects on perinatal brain development. A high prenatal exposure to both MeHg and PCBs was documented for the Inuit population of Northern Québec (Muckle *et al.* 2002; Sandau *et al.* 2002) with significant decreasing trends recently reported for PCBs (Dallaire *et al.* 2003). Today, the chief concern is with the effects arising from prenatal and early postnatal exposure, such as early sensorimotor dysfunction, delayed development and cognitive changes in children (reviewed in (Myers *et al.* 1998)). There is abundant evidence supporting the hypothesis that the major mechanism for Hg toxicity involves oxidative stress (Park *et al.* 1996; Yee and Choi 1996).

w-3 FA plays an essential role in the development of the central nervous system and neuronal function. In animal models, w-3 FA deficiency caused memory deficit (Gamoh *et al.* 1999), learning disability (Carrie *et al.* 1999) and loss of visual acuity (Neuringer 2000). In humans, various neurological disease states have been associated with a deficient DHA status (Hoffman and Birch 1998; Martinez 1992). In preterm infants with underdeveloped brains, the inclusion of DHA fatty acid in infant formula has been shown to improve visual attention (Birch *et al.* 1998). Because w-3 FA are quite sensitive to oxidation, the antioxidant status is most important to avoid detrimental effects of enhanced lipid peroxidation potentially associated with excess w-3 FA (Suarez *et al.* 1999).

The rationale of our study was based on the following points:

- Inuit are exposed to elevated levels of MeHg and OC mixtures including PCBs (Sandau *et al.* 2002). These toxins affect perinatal brain development in animals (Schantz and Widholm 2001) and are potential sources of oxidative stress (Mariussen *et al.* 2002; Yee and Choi 1996)
- Inuit have elevated blood levels of sea food-derived ω-3 fatty acids and selenium (Dewailly *et al.* 2001), which are essential factors for perinatal development of the central nervous system (Gamoh *et al.* 1999; Schweizer *et al.* 2004)
- Selenium is a critical element of several antioxidant enzymes including seleno-glutathione peroxidases (GPx). Inuit have elevated blood GPx activity, which was positively associated with w-3 FA content of red blood cell membranes (Bélanger *et al.*)
- GPx is essential for mitochondrial functions (Esposito *et al.* 2000; Legault *et al.* 2000) and is neuroprotective in neuronal function (Furling *et al.* 2000; Mirault *et al.* 1994)

Activities

In 2004-2005

Mouse experiments were carried out to evaluate the effect of a dietary ω-3 FA supplementation combined or not with elevated Se, on MeHg-mediated *in utero* developmental toxicity. Similar experiments were previously carried out with diets low in ω-3 FA combined or not with elevated Se (low-Se/low-ω-3, high-Se/low-ω-3). The NCP studies with diets enriched in ω-3 FA were carried out at the Centre Hospitalier de l'Université Laval (CHUL), Québec City, as previously. Two groups of mice were treated with one of the two diets, high-ω-3/low-Se, high-ω-3/high-Se. After mating, gestating mice were administered MeHg in the third quarter of gestation. The diet treatment started six weeks before mating and was maintained through gestation and lactation. The effects of the diets on *in utero* MeHg developmental toxicity were assessed in newborns. The following endpoints were assessed:

- Dam's fecundation success rate (investigator, Mirault)
- Offspring survival from birth to weaning (day-21) (investigator, Mirault)
- Offspring weight from birth to weaning (day-21) (investigator, Mirault)
- Brain mercury burden (CTQ), selenium status (CTQ) and fatty acid composition at birth (investigator, Julien)
- Brain GPx activity at birth (investigator, Mirault)

Results and Discussion

The fecundation success rate defined by the fraction of females that became pregnant over an 18-day mating period was significantly enhanced by the high-ω-3/high-Se diet (94 % vs 76 % for high-ω-3/low-Se, or vs 73% for low-ω-3/low-Se, $p<0.02$). **Conclusion**: this result suggests that a diet rich in both ω-3 fatty acids and selenium may increase the chance of a female to become pregnant post coit.

The offspring survival results are presented in Fig. 1. As compared to unexposed controls (no MeHg), *in utero* MeHg exposure produced a significant decrease of survival (day-4) in the low-ω-3/low-Se (-42.7%, $p<0.001$), low-ω-3/high-Se (-27%, $p=0.015$) and high-ω-3/low-Se (-50.9%, $p<0.01$) but not with the high–ω-3/high-Se diet group (-4%, p = 0.57). Survival was improved by Se when ω-3 intake was low (low-ω-3/high-Se vs low-ω-3/low-Se, p=0.015). The high-ω-3/low-Se diet produced a significant decrease of survival in the absence of MeHg exposure (-17.3% vs low-ω-3/low-Se diet, $p<0.01$). The high–ω-3/high-Se diet totally suppressed MeHg-mediated toxicity. Two major observations come out of the survival results: 1) Se had significant protective effects against MeHg-mediated fetal toxicity, which were most evident with the diet enriched in both Se and ω-3. **Conclusion**: these results suggest a strong benefit of high selenium and ω-3 fatty acids contents in the traditional Inuit diet, which might antagonize the risk of perinatal toxicity potentially associated with high gestational exposure to MeHg.

2) The low-Se diet enriched in ω-3 showed a significant intrinsic prenatal toxicity. Although the origin of this developmental toxicity is uncertain, we speculate that it could result at least in part from increased basal lipid peroxidation associated with elevated polyunsaturated ω-3 fatty acid contents, which might overwhelm insufficient antioxidant defenses. **Conclusion:** this observation suggests that optimal amounts of dietary antioxidants including selenium and vitamin E should be included in ω-3-rich diets in order to avoid any developmental toxicity potentially associated with excess ω-3 fatty acids.

Pups body weights were measured from birth to day-21 in order to assess the effects of Se, ω-3 and MeHg on birth weight and postnatal weight gain. The statistical analysis of birth weights shown in Fig. 2 indicates: 1) a reduction of average birth weight associated with prenatal MeHg exposure (-0.077 g, $p<0.0001$) observed with both low-ω-3 diets, enriched or not with Se (no effect of Se), and a larger MeHg-associated birth weight reduction (-0.157 g)

Figure 1. Diets enriched in both selenium and w-3 fatty acids suppress neonatal mortality of mice exposed *in utero* to methylmercury. Four diet treatments were administered to C57BL/6 female mice six weeks before mating and during gestation and lactation: 1) a semi-purified diet low in w-3 FA and low in Se (0.05 ppm); 2) a diet low in w-3 FA and enriched in Se (1 ppm); 3) a diet enriched in w-3 FA (13.2 g EPA $\cdot kg^{-1}$ and 8.1 g DHA $\cdot kg^{-1}$, high w-3) and low in Se; and 4) a diet enriched in both w-3 FA and Se. Gestating mice of each diet group were administered three consecutive doses of MeHg (4 mg $\cdot kg^{-1} \cdot day^{-1}$, p.o.), or vehicle (controls) at gestation days 12, 13 and 14. The data express offspring survival at postnatal day 4 (PND4) as percent of the mice born in the unexposed group. The number of litters per treatment group ranged from 15-19, with a total number of newborns ranging from 107-148. The results obtained with the low w-3 FA diets come from a previous study funded by FRSQ/Hydro-Québec and Health Canada. * Different from controls, $P<0.01$; † different from controls treated with the low-w-3/low-Se diet, $P<0.01$.

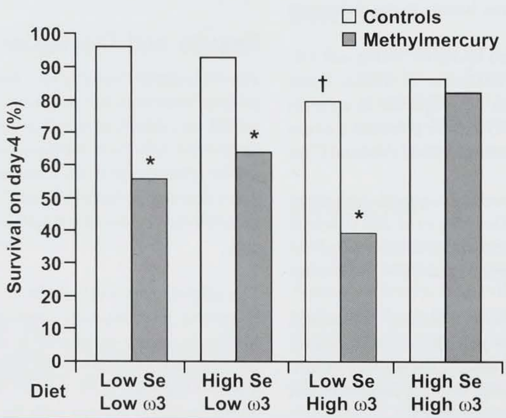


Figure 2. Diets enriched in both selenium and w-3 fatty acids suppress birth weight deficits of mice exposed *in utero* to methylmercury (see text in Results for interpretation and statistical significance *P* values).

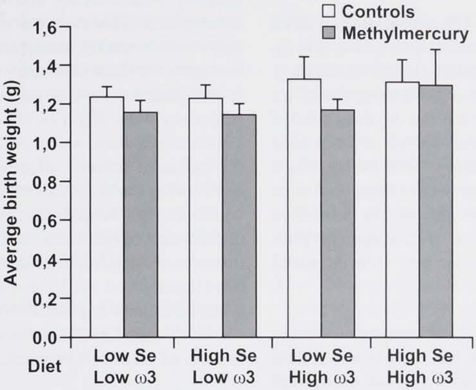
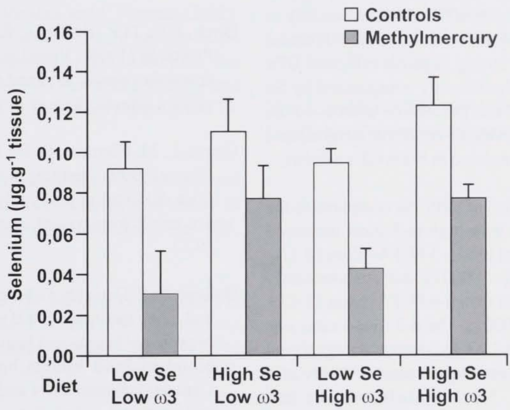


Figure 3. Effects of dietary selenium, w-3 fatty acids and prenatal exposure to methylmercury on brain selenium status at birth (see text in Results for interpretation and statistical significance *P* values).



observed with the high-ω-3/low-Se diet, which was totally suppressed by Se enrichment; 2) an increased birth weight associated with high ω-3 intake (0.090 g, $p<0.0001$). **Conclusion:** These results confirm the protective effects of Se in the presence of elevated ω-3, which were observed at the level of survival. Deficits in birth weights associated with MeHg exposure are thought to reflect delayed fetal development, while in contrast ω-3 associated birth weight excess may be related to increased developmental age.

Brain mercury burden at birth. Brain total Hg levels were strongly reduced by dietary Se in mice treated with the low-ω-3 diets (from 6.61 ± 0.56 to 3.43 ± 0.27 $\mu g{\cdot}g^{-1}$ tissue, $p<0.01$). Surprisingly, Se had no effect on Hg levels in mice treated high ω-3 diets. **Conclusion**: the protective effects of combined Se and ω-3 observed on survival and birth weights of MeHg-exposed offspring were not related to brain Hg levels (not affected by Se).

Brain selenium status at birth. The statistical analysis of the data presented in Fig. 3 shows: 1) an increase in brain Se associated with both diets enriched in Se (+0.024 $\mu g \cdot g^{-1}$, p<0.0001, no interaction with ω-3); 2) a negative effect of MeHg in mice treated with the low-Se diets (-0.056 $\mu g \cdot g^{-1}$, p<0.0001); and 3) a positive effect of Se in mice treated with the low-Se diets and exposed to MeHg, which was stronger than the effect observed in unexposed mice (+0.040 $\mu g \cdot g^{-1}$, p=0.032). **Conclusion:** The protective effects of Se observed at the level of development (birth weights) and survival were associated with increased levels of brain Se.

Brain GPx activity at birth. Prenatal exposure to MeHg decreased GPx activity in mice receiving low-ω-3 diets (mean: –76.2 $U \cdot mg^{-1}$ protein or –45% of unexposed controls, p<0001, no Se effect) and high-ω-3 diets (mean: -37.2%, p<0.0001). A positive effect of Se was observed in MeHg-exposed mice treated with the high-ω-3/high-Se diet as compared to the high-ω-3/low-Se, which was almost statistically significant (+11.5%, p=0.08). Unexpectedly, GPx activity was decreased by the high-ω-3 diet treatments (-37%, p<0.0001, no effect of Se) as compared to the low-ω-3 diets. **Conclusion:** Prenatal exposure to MeHg had a strong negative effect on GPx activity, which was not significantly antagonized by Se supplementation. Thus, the protective effects of Se observed at the level of development (birth weights) and survival are apparently unrelated to brain GPx activity.

Brain fatty acid composition at birth. As compared to the low-ω-3 diets, treatment with high-ω-3 diets increased the percentage by weight of total n-3 PUFAs from 10.71 ± 0.53 to 19.0 ± 0.64 % (p<0.0001) and concomitantly decreased the percentage of total n-6 PUFAs from 17.45 ± 0.65 to 8.02 ± 0.25 (p<0.0001). The n-3 to n-6 ratio was thus increased from 0.61 to 2.37. In contrast, no significant changes in total saturated and monoinsaturated fatty acid content were observed. Neither MeHg nor Se had significant impact on brain fatty acid composition. **Conclusions**: as expected, the high-ω-3 diets drastically increased the ratio of n-3 to n-6 PUFAs in phospholipids of newborn mice.

Conclusion

We found that diets containing elevated levels of selenium and ω-3 fatty acids had protective effects against prenatal toxicity of methylmercury in the mouse. These results suggest that the high levels of selenium and ω-3 fatty acids present in the traditional Inuit diet may antagonize, at least to some extent, the potential developmental toxicity mediated by methylmercury during fetal development. However, the traditional Inuit diet is not only contaminated by methylmercury but also by complex mixtures of organochlorine contaminants including PCBs. It will thus be very important to also assess in the laboratory what might be the beneficial or detrimental effects of selenium- and ω-3 fatty acid-enriched diets on the perinatal toxicity of mixtures of organochlorine contaminants, as proposed in the 2005 H-09 NCP proposal, which was not funded. Until we know what can be the interactions of selenium, ω-3 fatty acids and relevant mixtures of organochlorine contaminants during perinatal development, it will not be possible to draw any conclusion about potentially attenuating effects of selenium and/or ω-3 fatty acids on the developmental toxicity of these contaminants.

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Completing Regionally Relevant Health Risk Assessments for Mercury Levels in Fish in Northwest Territories Lakes and Rivers

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Abstract

In 2004/2005 the Northwest Territories Environmental Contaminants Committee (NWT ECC) undertook a Northern Contaminants Committee (NCP) funded project to complete regionally relevant health risk assessments for mercury levels in fish in Northwest Territories (NWT) lakes and rivers. The NWT ECC services the NCP as one of four territorial contaminants committees reporting to the NCP Management Committee. It is a multi-party committee that applies for NCP funding to, amongst other tasks, provide regional coordination for the NCP in the NWT, as well as current information and results on contaminants studies to the residents of the NWT.

The NCP's present focus is to understand the relationship between human health effects and exposure to long range contaminants. In this regard the NWT ECC undertook a project to ensure health risk assessments (HRAs) andcurrent health advisories for mercury levels in fish in NWT lakes and rivers are relevant to the residents of the NWT. The NWT ECC was fortunate to engage the expertise of Dr. Laurie Chan, Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University, to lead the health risk assessments. These results will provide the NWT ECC with valuable information to assist and advise GNWT Health and Social Services in reviewing their current fish consumption advice for specific lakes in the NWT.

The NWT ECC was provided with regional summaries of mean and maximum mercury levels in fish species, regional estimates of mercury exposure from fish consumption for a number of scenarios, and preliminary guideline levels for intake of specific fish species on a regional basis. Exposure estimates using the average fish consumption rates for regional gender-age groups, and either the mean and maximum mercury concentrations in fish, showed that no groups exceed the mercury intake guideline levels.

Exposure estimates for heavy fish consumers showed that the women (age 20-40) in Deh Cho regions and all women above the age 20 in the Sahtu regions exceed the guideline levels (using the average mercury concentrations). Using the maximum concentrations of mercury in fish, the exposure estimates for the Sahtu men (aged 41+) can also exceed the guideline levels. It is important to point out that the calculated fish intake rates indicate that many fish meals can be consumed numerous times per week without risk of exceeding guideline levels of mercury exposure. In particular, white fish and Arctic char can be consumed in large quantities without concern.

The next step is to ensure continued discussion between the NWT ECC and GNWT Health and Social Services to ensure health advisories currently in place are still relevant to the people consuming the fish from these lakes, given the information presented to the committee by CINE.

Key Project Messages

1. The calculated fish intake rates by CINE indicate that many meals of fish can be consumed numerous times per week without risk of exceeding guidelines levels of mercury exposure. In particular, whitefish and Arctic char can be consumed in large quantities without concern.

2. Exposure estimates using the average fish consumption rates for regional gender-age groups, and either the mean or maximum mercury concentrations in fish showed that no groups exceeded the mercury intake guideline levels.

3. The mercury health risk assessments undertaken by CINE for the NWT ECC will serve as a tool for the NWT ECC in working with GNWT Health and Social Services in revisiting and potentially updating advisories for fish consumption, as well as providing regional education programs for the general population. Local traditional knowledge needs to be incorporated into this discussion and decisions should be made only after taking into consideration current dietary patterns and traditional harvest patters. The outcome will be collaborative risk management decision making.

4. NWT ECC members gained an understanding of mercury toxicology and health risk assessment and management as a result of the one-day workshop presented by CINE. This will help build the capacity of the committee in more fully understanding this subject matter.

Objectives

1. Review and compile all existing data on mercury levels in fish in the NWT.
2. Compile all existing HRAs and health advisory information for the NWT.
3. Complete draft HRAs for all lakes and rivers in the NWT that have not had data assessed for mercury levels in fish.
4. Revisit existing health advisories for lakes which have had HRAs to ensure the most recent Health Canada guidelines are being applied.
5. Provide an estimate of average exposure of NWT residents to mercury on a regional basis.
6. Identify age/gender groups potentially at risk of exceeding guideline levels for mercury.
7. Provide training to NWT ECC members on risk management and risk assessment to build internal capacity to assist in the assessment of contaminants data and subsequently in making decisions regarding the issuance of health advisories in the NWT.

Introduction

Following fourteen years of research the NCP has provided northerners with a valuable balance of human health, environmental trends and education/ communication research pertaining to long-range contaminants in the North. It is timely in the NWT that health advice on fish consumption due to mercury contamination be revisited considering the current focus of the NCP on mercury. There are presently sixteen lakes for which health advisories on mercury have been released by GNWT Health and Social Services for different species of fish (Appendix 1). These are in the form of recommended maximum weekly intakes based on health risk assessments by Health Canada between 1997 and 2001. In general, non-predatory fish such as whitefish and Arctic char had low levels of mercury not warranting advisories. Conversely, advisories for predatory fish such as trout, walleye (pickerel) and northern pike (jackfish), are more common for the three categories (adults, women of childbearing age, and children) in several of the lakes. Some of these lakes are not regularly harvested for fish, and thus the necessity for advisories and the context for communicating advisories have been questioned by NWT ECC members.

The need for HRAs, and subsequently the potential issuance of health advisories related to contaminants such as mercury, are some of the primary challenges of the NWT ECC and northern health professionals. Traditional foods such as fish are essential to cultural, social and

Table 2. Average daily intake (grams/meal) of fish recorded by 24-hour recall (consumed in either late fall or winter)

	Women Age 20-40	Women Age 41-60	Women Age 61+	Men Age 20-40	Men Age 41-60	Men Age 61+
Inuvialuit						
Arctic Char flesh	253	382	680	225	416	284
Whitefish flesh	427	-	450	212	-	338
Cisco flesh	-	-	281	-	450	393
Lake trout flesh	-	187	-	-	225	-
Gwich'in Communities						
Whitefish flesh	300	223		270	508	
Loche (burbot) flesh	450	428		450	426	
Arctic char flesh	-	-		-	252	
Trout flesh	225	-		-	-	
Sahtu Communties						
Whitefish flesh	-	523		193	434	
Trout flesh	147	450		221	225	
Loche (burbot) flesh	-	223		-	225	
Dogrib Communities						
Whitefish flesh	113	267		226	242	
Loche (burbot) flesh		337		-	337	
Pike flesh	-	-		-	225	
Trout flesh	-	112		-	-	
Deh-Cho Communtities						
Whitefish flesh	375	225		262	337	
Trout flesh	-	225		112	113	
Loche (burbot) flesh	-	-		-	136	
Akaitcho						
Whitefish flesh	202	337		274	344	
Trout flesh	113	225		225	300	
Loche (burbot) flesh	-	-		-	450	

Table 3. Average mean regional mercury concentrations in fish species (µg/g)

Region	Lake Trout	Lake Whitefish	Northern Pike	Walleye	Arctic Char	Loche (Burbot)	Other
Inuvialuit	0.17	0.05	0.45	n/a	0.04	0.21	0.12
Gwich'in	0.17	0.05	0.45	n/a	n/a	0.21	0.08
Sahtu	0.48	0.12	0.32	0.54	n/a	0.26	0.16
Deh Cho	0.28	0.09	0.34	0.40	n/a	0.38	0.12
Dogrib	0.26	0.08	0.26	n/a	n/a	n/a	0.05
Akaitcho	0.21	0.08	0.38	0.24	0.02	0.14	0.11

Table 4. Average maximum regional mercury concentration in fish species (µg/g)

Region	Lake trout	Lake Whitefish	Northern Pike	Walleye	Arctic Char	Loche (Burbot)	Other
Inuvialuit	0.17	0.05	0.45	n/a	0.04	0.21	0.14
Gwich'in	0.17	0.05	0.45	n/a	n/a	0.21	0.10
Sahtu	0.84	0.25	0.50	0.61	n/a	0.38	0.26
Deh Cho	0.32	0.12	0.47	0.61	n/a	0.46	0.15
Dogrib	0.34	0.11	0.34	n/a	n/a	n/a	0.06
Akaitcho	0.35	0.15	0.71	0.38	0.02	0.15	0.11

per week (i.e. one serving of both fish per week, and that serving is the DAILY serving size) by the mercury concentrations in fish (mean and maximum). Women of child-bearing age in the Sahtu and Deh Cho regions can exceed the guideline levels of 0.2 µg/kg bodyweight/day (Table 7). Furthermore, the Sahtu women aged 41+ can also exceed the guideline level for adults of 0.47 µg/kg bodyweight/day (Table 7). When calculating the theoretical high intake using the maximum mercury concentrations in fish, the Sahtu men aged 41+ also potentially exceed the guideline levels of 0.47 µg/kg bodyweight/day (Table 8). The NWT ECC and regional representatives from the Aboriginal governments will need to consider these results relative to current fish intakes within different age and gender groups in their regions.

Guideline Levels:
Preliminary guideline levels of intake were prepared by CINE based on the available data. The detailed recommendations will be carefully considered by the NWT ECC and GNWT Health and Social Services. In particular, each region will need to consider the data generated in comparison to the average intake of various fish species by community members to determine its accuracy. Overall, women of child-bearing age are recommended to have lower fish consumption levels compared to rest of the population. Furthermore the recommended intake levels for whitefish and Arctic char are much higher than for the other fish species, since these fish have lower concentrations of mercury compared to the other species. These data are not presented in this report as they require NWT ECC and GNWT Health and Social Services review to ensure it is regionally relevant.

Conclusions

The calculated fish intake rates by CINE indicate that many meals of fish can be consumed numerous times per week without risk of exceeding guidelines levels of mercury exposure. In particular, whitefish and Arctic char can be consumed in large quantities without concern.

The average mercury concentrations in fish indicate that most of the fish in water bodies used by the residents of the NWT have low mercury concentrations and are below

Table 5. Exposure estimates (µg/person/day) based on average mean values in fish and estimated average intake

	Inuvialuit	Gwich'in	Sahtu	Deh Cho	Dogrib	Akaitcho
Women:						
20-40	0.016	0.054	0.040	0.015	0.011	0.032
41-60	0.040	0.132	0.262	0.103	0.107	0.053
61+	0.074					
Men:						
20-40	0.007	0.040	0.181	0.049	0.035	0.055
41-60	0.060	0.084	0.213	0.047	0.137	0.057
61+	0.063					

Table 6. Exposure estimates (µg/kg/day) based on average maximum values in fish and estimated average intake

	Inuvialuit	Gwich'in	Sahtu	Deh Cho	Dogrib	Akaitcho
Women:						
20-40	0.016	0.054	0.070	0.020	0.015	0.057
41-60	0.040	0.132	0.487	0.124	0.147	0.096
61+	0.074					
Men:						
20-40	0.007	0.040	0.322	0.064	0.049	0.101
41-60	0.060	0.084	0.399	0.056	0.187	0.093
61+	0.063					

Table 7. High intake exposure estimates (µg/person/day) based on average mean values in fish and one meal of trout and whitefish per week

	Inuvialuit	Gwich'in	Sahtu	Deh Cho	Dogrib	Akaitcho
Women:						
20-40	0.119	0.126	0.317	0.230	0.091	0.095
41-60	0.115	0.117	0.661	0.197	0.120	0.176
61+	0.122					
Men:						
20-40	0.091	0.102	0.259	0.108	0.093	0.136
41-60	0.095	0.126	0.315	0.122	0.096	0.178
61+	0.123					

Table 8. High intake exposure estimates (µg/person/day) based on average maximum values in fish and one meal of trout and whitefish per week

	Inuvialuit	Gwich'in	Sahtu	Deh Cho	Dogrib	Akaitcho
Women:						
20-40	0.119	0.126	0.605	0.278	0.120	0.166
41-60	0.115	0.117	1.206	0.234	0.160	0.306
61+	0.122					
Men:						
20-40	0.091	0.102	0.469	0.132	0.124	0.236
41-60	0.095	0.126	0.586	0.150	0.128	0.308
61+	0.123					

guideline levels. The average mean walleye (pickerel) mercury concentration in the Sahtu region, and several average maximum mercury concentrations in the Sahtu, Akaitcho and Deh Cho regions exceed the guidelines. Results of the exposure estimates for the general population of each region indicate that the risk of mercury exposure from fish consumption is low. Using the average mean and average maximum values in fish, it was found that there are no gender/age groups exceeding the Health Canada guideline levels. While several groups do exceed the guideline levels when assuming consumption of one meal of whitefish and one meal of trout per week, the majority of the population continues to remain below the guideline levels for mercury exposure in this scenario.

These data alone do not immediately imply the need for advisories for these areas. The causes behind high mercury levels in specific lakes warrant further research. Furthermore, it is important to study whether the specific fish species from the various water bodies in question are frequently consumed by the local residents. If the people do not fish or desire to fish these species in these lakes, then an advisory may not be necessary.

The exercise did not include children as there is no dietary data available for children (under 18 years old). However, the usual portion size is generally smaller among children and that should account for the relatively lower body weight associated with dietary intake estimate. Therefore, the general recommendations regarding the choice of fish species and young women of child-bearing age should apply to children as well.

The guidelines and data presented in this report and in CINE's report to the NWT ECC should act as a tool to be used by the NWT ECC in working with GNWT Health and Social Services in updating advisories and providing regional education programs for the population. By working collaboratively, such significant information can be carefully considered to determine the most appropriate means of relevant communication with the general public.

Acknowledgements

The NWT ECC wishes to acknowledge Dr. Laurie Chan and Patricia Solomon from CINE for their dedication to this project. The Committee would also like to thank Lyle Lockhart and Gary Stern, Fisheries and Oceans Canada, for the draft Science in the Total Environment paper providing a compilation of all the mercury data for fish in the NWT. The analysis would not have been possible without this data. We would also like to thank Marlene Evans, Environment Canada, for providing draft Science in the Total Environment papers with detailed mercury information for certain lakes in the Mackenzie Basin.

Expected Project Completion Date

This project has been completed. The final report will be sent to the NWT chief medical officer at GNWT Health and Social Services for consideration such that health advice pertaining to mercury levels in NWT fish can be revisited to ensure it is accurate and regionally relevant. We encourage discussions between GNWT Health and Social Services and the regional Aboriginal government representatives to further discuss regional relevance of the information presented.

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In Vitro Examination of Food-borne Polychlorinated Pesticide Residues for Effects on Cytochrome P450 Isozyme Induction/ Activity

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Abstract

Although never used in the Arctic, residues of components and metabolites of the polychlorinated pesticides toxaphene and chlordane have been identified in northern samples of human blood and milk, apparently carried to the North on prevailing winds. In this study, technical toxaphene and technical chlordane, as well as individual components *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor and the metabolite oxychlordane were examined for effects on various cytochrome P450 isozymes involved in drug and xenobiotic metabolism. When purified, cloned isozymes (Cyp 1A2, Cyp 2A6, Cyp 2C8, Cyp 2C9, Cyp 2D6, Cyp 2E1, and Cyp 3A4) were incubated with the test chemicals up to 75ug/ml, dose dependent inhibition was generally observed to varying degrees. With the exception of oxychlordane, Cyp 3A4 exhibited a biphasic response with most of the test chemicals where an initial inhibition with an IC_{50} of 300-700 ng/ml was followed by an increase in activity at higher chemical concentrations. Cyp 2C8 exhibited a similar biphasic response when incubated with technical toxaphene and *trans*-chlordane. When rat hepatoma H4IIE cells were incubated with the test chemicals up to 1 mg/ml to test for induction of cytochrome P450 isozyme activity,Cyp P450 activity was generally induced at higher concentrations of 250 ug/ml to 1 mg/ml. However, lower concentrations were found to inhibit endogenous activities of Cyp 3A4 and Cyp 3A7-like activities with IC_{50}s ranging from 35-250 ng/ml. These concentrations were approximately one-tenth of those found to affect the purified enzymes and may be due to an effect of the test chemicals on cytochrome P450 isozyme transcription or translation. This effect was found at chemical concentrations approximately 1000-fold higher than those described in adult plasma and at least an order of magnitude greater than encountered in maternal milk samples. Therefore, although the effect of polychlorinated pesticide residue levels on adult drug metabolism appears to be minimal to nil, the possible accumulation in Inuit infants and associated health effects deserve further study. Further characterization of polychlorinated compound effects on cytochrome P450 induction by known inducers is currently underway.

Key Messages

The polychlorinated pesticides toxaphene, chlordane, and related compounds which persist in wildlife and humans have been found to inhibit the activity of several purified enzymes involved in the deactivation and breakdown of drugs and poisons. However, the levels of chemicals needed to exert these effects are several-fold higher than those detected in blood and milk samples. Therefore there is little concern that polychlorinated pesticide contaminated has an effect on drug metabolism by the adult population.

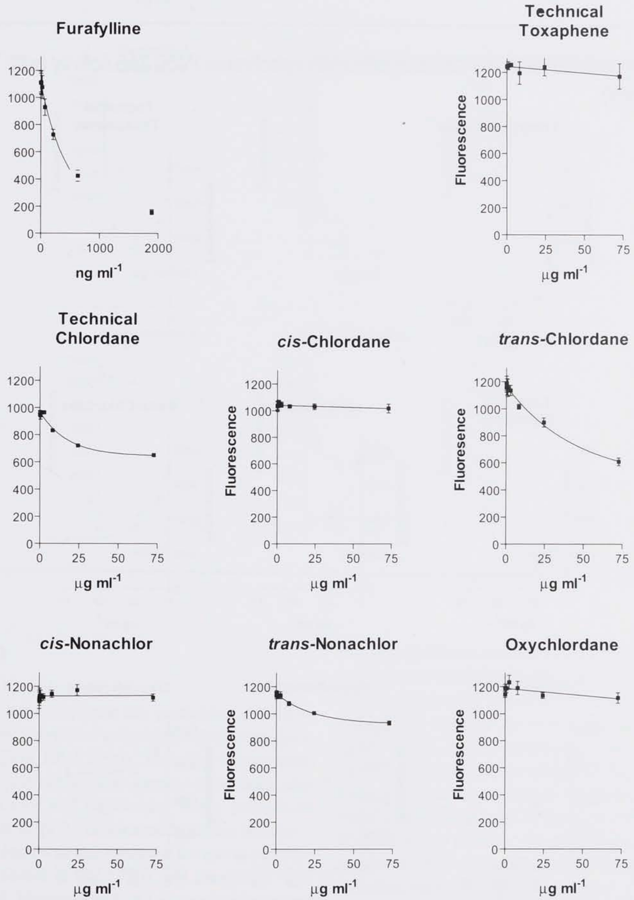
When the polychlorinated pesticides were examined for induction of various drug breakdown enzymes in a rat liver cell line, an activity corresponding to a fetal enzyme form was found instead to be inhibited at levels of contaminants approximately 10-fold higher than have been detected in human milk. With the available data, it is difficult to assess whether any significant health risk exists and this aspect is being examined more closely in additional experiments.

Objectives

Short-term:

1) To determine direct effects of the persistent organochlorines on specific human cytochrome P450 isozyme activities (using commercially available kits containing cloned cytochrome P450 isozymes); enzyme activity is assessed through metabolism of a fluorescent substrate.

Figure 1. Polychlorinated pesticide inhibition of human cytochrome P450 1A2 Activity (with Furafylline as positive control).



2) To determine the effects of major persistent chlordane- and toxaphene-related compounds on cytochrome P450 enzyme induction in rat hepatoma H4IIE cells.

Long-term objectives:
To characterize the effects of exposure to polychlorinated pesticide-related residues on cytochrome P450 isozyme expression/activity to better assess risks associated with drug interactions, endocrine disruption and carcinogenesis.

To assist in the evaluation of current tolerable daily intakes (TDIs).

Results may support further molecular-based studies to examine mechanisms by which polychlorinated pesticide residues exert effects their on cytochrome P450 isozyme induction and activities. These could include examinations of structure/activity relationships, gene expression changes using reverse-transcriptase/PCR/array analysis, transcription factor binding, RNA turnover analysis, etc.

Figure 2. Polychlorinated pesticide inhibition of human cytochrome P450 2A6 Activity (with Tranylcypromine as positive control).

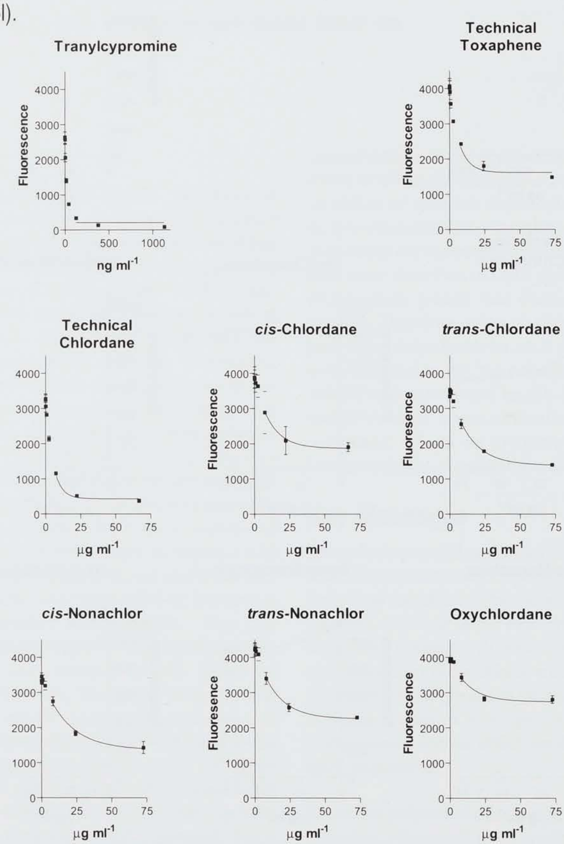
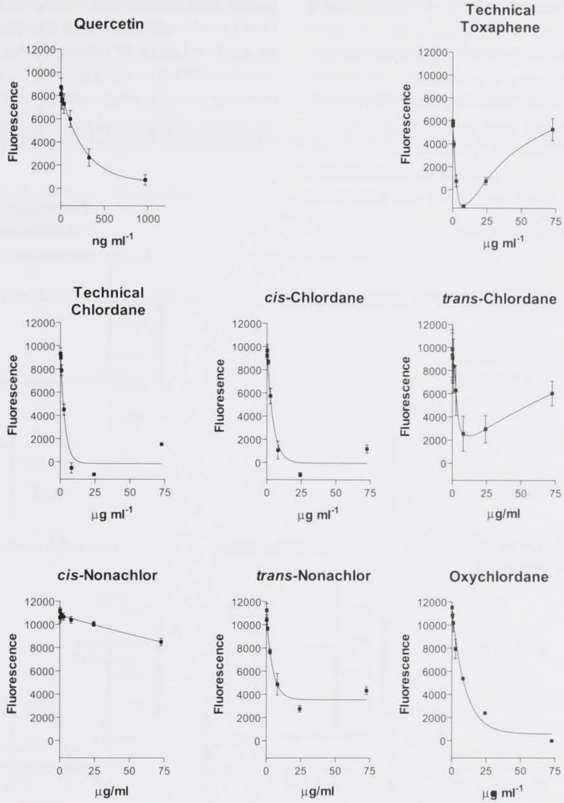


Figure 3. Polychlorinated pesticide inhibition of human cytochrome P450 2C8 Activity (with Quercetin as positive control).



Introduction

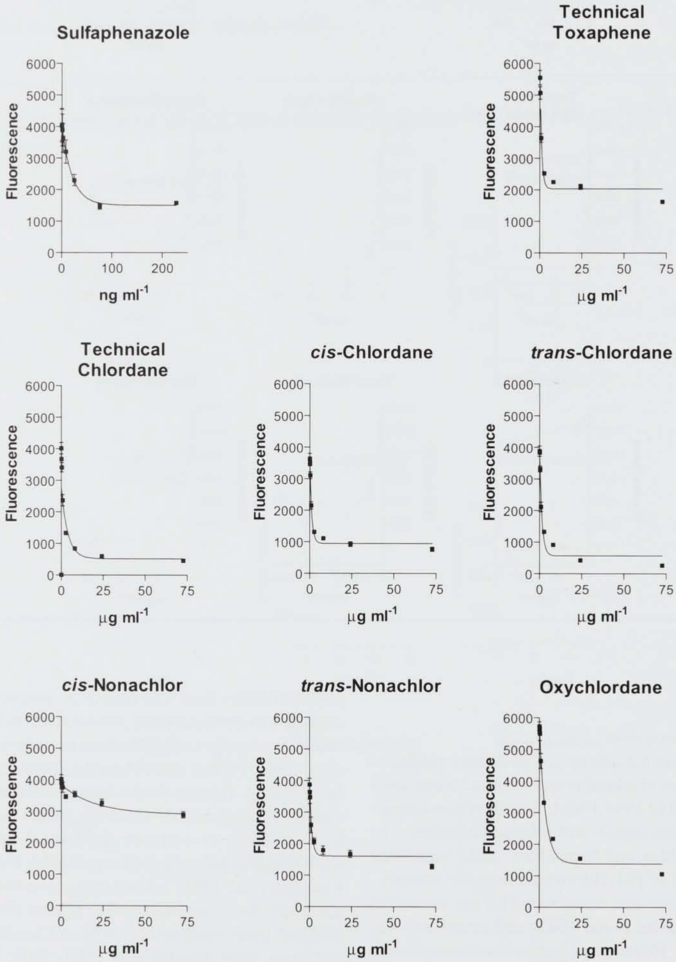
Chlordane and Toxaphene:

Both chlordane and toxaphene are pesticides produced as complex mixtures of related polychlorinated compounds (Saleh, 1991; ATSDR 1994,1996). The chief constituents of chlordane include *alpha*- and *gamma*-chlordane, *cis*- and *trans*- nonachlor and heptachlor while toxaphene contains hundreds of polychlorinated bornane isomers. In Canada, chlordane was deregistered for use in parallel with the United States in the 1980s and toxaphene was never widely used. However, polychlorinated components and metabolites from both pesticides have been identified as persistent environmental contaminants in the Canadian Arctic, apparently carried North on prevailing winds (Muir *et al.* 1990; Voldner and Schroeder, 1990; Bidleman and Leone 2004). Both pesticides have contaminated the food chain, raising questions about the health risks posed by these residues to northern residents dependent upon traditional fish and game (Muir *et al.* 1988; Kuhnlein, 1995; Kuhnlein *et al.* 1995;). Contaminants arising from both pesticides have been detected in human blood and milk sampled from residents of northern Canada (Newsome and Ryan, 1999; Muckle *et al.* 2001; 2003; Walker *et al.*

2001). The consequences of long term exposure to chlordane and toxaphene and the effects of specific chlorinated components on all stages of life from the developing fetus to adult remain a topic of active research.

Cytochrome P450- mediated xenobiotic metabolism: The majority of drugs and xenobiotics, as well as endogenous substrates such as steroid hormones, are metabolized into more water soluble and easily excreted compounds through the activity of the cytochrome P450 family of inducible microsomal monooxygenase hemoproteins (F.P. Guengerich, 1995; 1997; 2002).

Figure 4. Polychlorinated pesticide inhibition of human cytochrome P450 2C8 Activity (with Sulfaphenazole as positive control).



Cytochrome P450 isozymes differ from each other in catalytic activity, substrate specificity, and inducibility by xenobiotics. The expression of cytochrome P450 isozymes is regulated by many factors including tissue, age, gender, and exposure to drugs and other xenobiotics. These factors can modulate P450 activity through induction and suppression of individual P450 isoforms. The biological effects of many therapeutic agents are dependent on the particular cytochrome P450 isoenzyme that may metabolize them to an active or inactive form.

Interaction of Toxaphene and Chlordane with the Cytochrome P450 system:

Chlordane, toxaphene and many polychlorinated pesticides function as potent inducers of hepatic microsomal enzymes (Hodgson *et al.* 1980; Smith, 1991). The induction of hepatic microsomal enzymes by technical chlordane has also been shown to increase the rate of metabolism of many endogenous and xenobiotic compounds, including therapeutic drugs and hormones (Welsh and Harrison, 1966; Welsh *et al.* 1971). Exposure to other pesticides has been shown to alter the metabolism/toxicity of toxaphene and chlordane (Deichmann and Keplinger, 1970) and pretreatment with chlordane has been found to enhance the toxicity of carbon tetrachloride in rats (Stenger *et al.* 1975, Mahon *et*

Figure 5. Polychlorinated pesticide inhibition of human cytochrome P450 2D6 Activity (with ddtc as positive control).

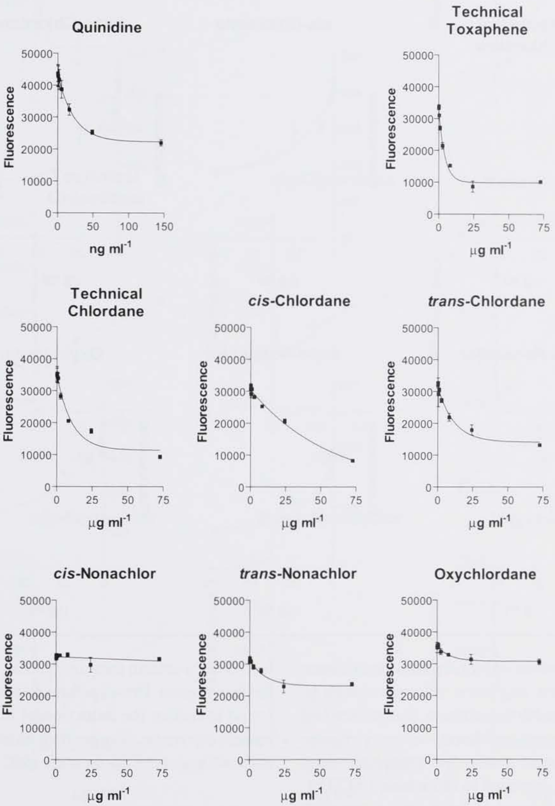
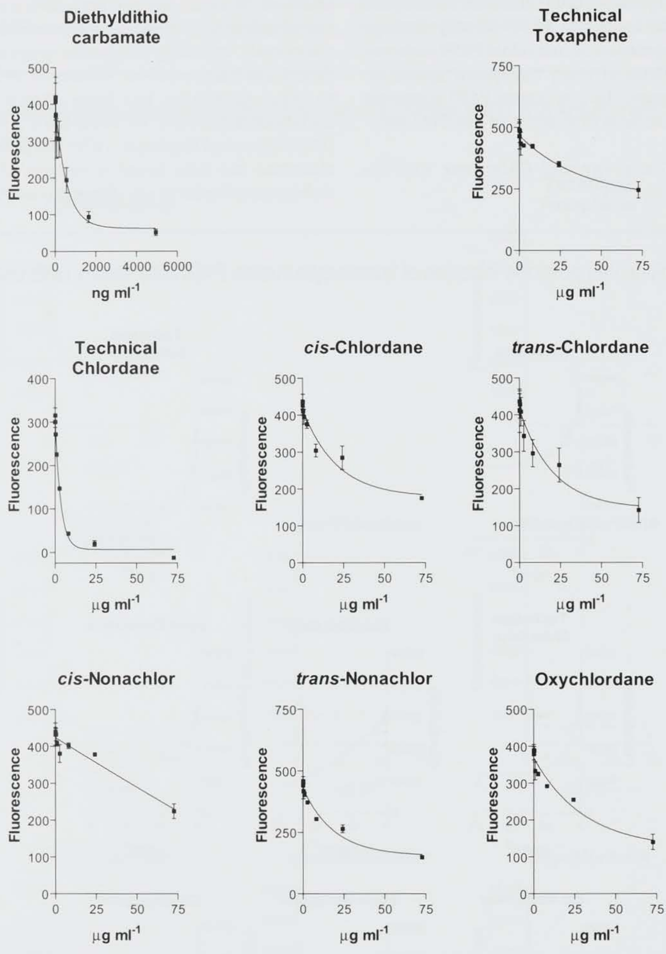


Figure 6. Polychlorinated pesticide inhibition of human cytochrome P450 2E1 Activity (with Diethyldithiocarbamate as positive control).



al. 1978). Even in the absence of human data, the evidence of animal-based studies has been strong enough to promote warnings to health practioners that prescribed doses of therapeutic drugs and hormones may require adjustment in patients case studies on toxaphene-drug interactions published. exposed to chlordane (ATSDR, 1994). Toxaphene exposure has been associated with increased warfarin toxicity (Jeffrey *et al.* 1976) in one of the few human Pre-exposure to toxaphene has also been found to reduce the induction of lung tumours in rats by benzo(a)pyrene, suggesting that toxaphene may be anticarcinogenic (Triolo *et al.* 1982).

Activities

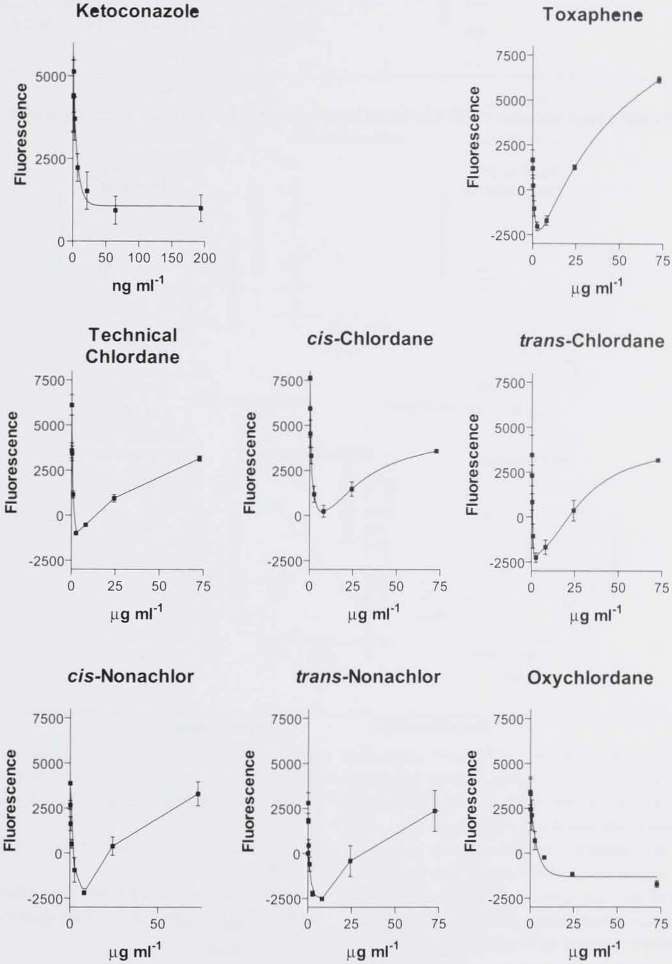
In 2004-2005

The project consisted of *in vitro* studies carried out using commercially available kits used to measure the effect of polychlorinated pesticides on:

a) inhibition of purified, cloned human enzymes

b) induction of enzyme activity in H4IIE rat hepatoma cells, a cell line known to maintain at least some cytochrome P450 inducibility.

Figure 7. Polychlorinated pesticide inhibition of human cytochrome P450 3A4 Activity (with Ketoconazole as positive control).



Studies were carried out by Ms. I. Langlois in the laboratory of Dr. T. Schrader, Toxicology Research Division, Food Directorate, Health Canada, Sir Frederick G. Banting Research Centre, Ottawa, Ont.

Test Chemicals:

The test chemicals included: technical chlordane, *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, oxychlordane, and technical toxaphene (Cerilliant, Round Rock, TX).

Measurement of Enzyme inhibition:

Kits containing purified, cloned cytochrome P450 isozymes (BDGentest) allowed direct testing of test chemicals for inhibition of enzyme activity in a microplate format. The available isozymes provided a comprehension survey of polychlorinated pesticide effects on cytochrome P450 activities and include: Cyp 1A2, Cyp 2A6, Cyp 2B6, Cyp 2C8, Cyp 2C9, Cyp 2C19, Cyp 2D6, Cyp 2E1, Cyp 3A4, and Cyp 19. Briefly, a mix containing the enzyme, fluorescent substrate and necessary cofactors was added to wells containing either a known inhibitor or polychlorinated test chemical and incubated

Figure 8. Induction of cytochrome P450 1A1 in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides

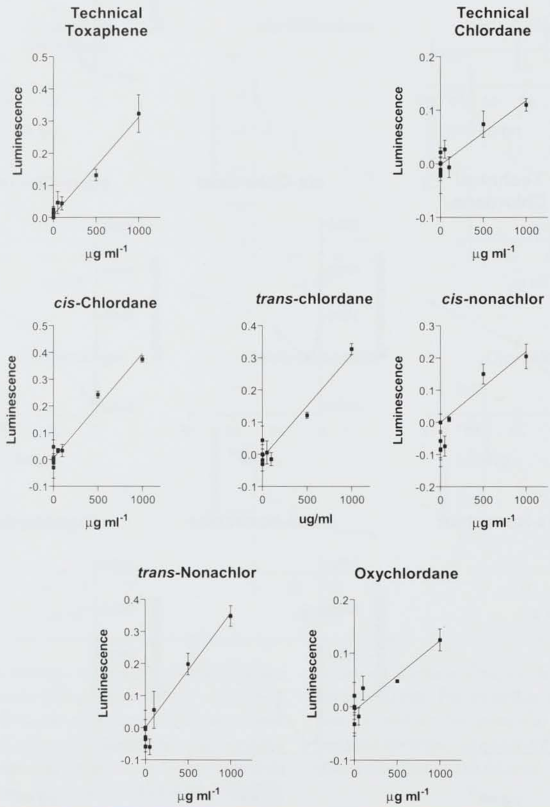
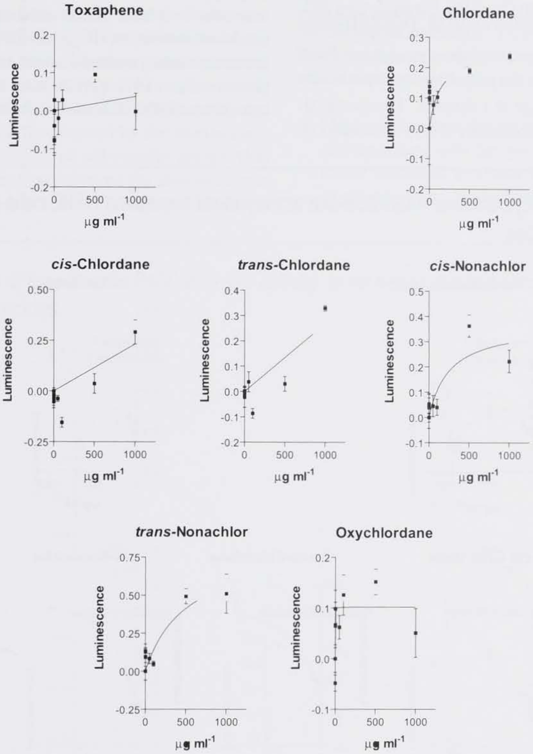


Figure 9. Induction of cytochrome P450 1A2 in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides



for 15 minutes. The reaction was stopped with acetonitrile and the generation of fluorescent product determined on a plate-reading spectrofluorometer (Cytofluor, Millipore).

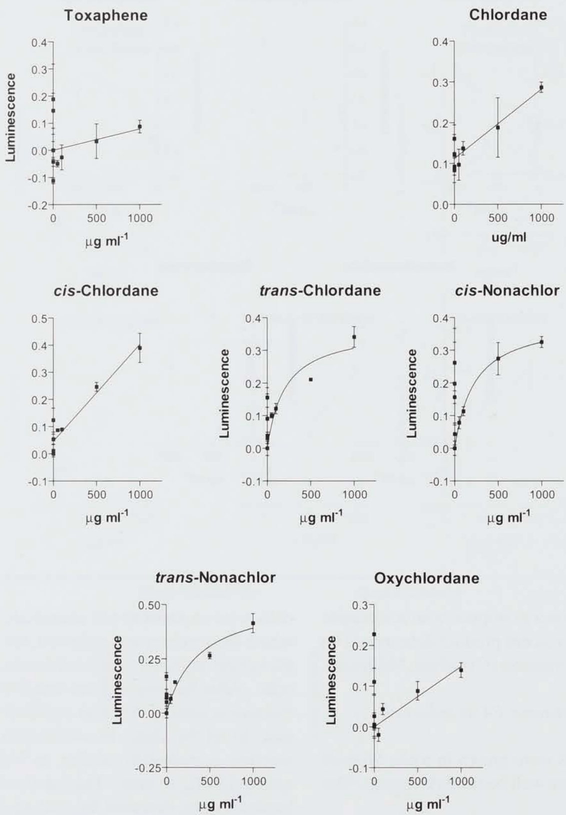
2) Measurement of Cytochrome P450 induction:

Rat hepatoma H4IIE cells were grown in white 96-well microplates with transparent well bottoms (Corning). The cells were exposed to test chemicals for three days after which the medium was removed, the plates washed with phosphate-buffered saline and frozen to permeabilize the cells. After thawing, cytochrome P450 substrate reaction mixture is added. After an incubation period (37°C, 10 min) to all the plates to acclimatize, the luminescence reaction is started by adding an NADPH regenerating system (37°C, 30 min). The reaction is then stopped and luminescence detected by adding luciferin detection reagent.

Results

Results for the effects of the various polychlorinated compounds on enzyme inhibition are presented in graphical form for each of the cytochrome P450 isozymes tested (Cyp 1A2, Figure 1; Cyp 2A6, Figure 2; Cyp 2C8, Figure 3; Cyp 2C9, Figure 4; Cyp 2D6, Figure 5; Cyp 2E1, Figure 6; Cyp 3A4, Figure 7). Evidence supported the general observation that most of the cytochrome P450 isozymes were inhibited by the polychlorinated pesticides with IC_{50}s falling in the range of 1-5µg/ml. The chemicals were generally less potent inhibitors of Cyp 1A2 with *cis*-chlordane and *cis*-nonachlor inactive (Figure 1). *Cis*-nonachlor was also less active in the inhibition of Cyp 2C8 (Figure 3), Cyp 2C9 (Figure 4), and Cyp 2D6 (Figure 5). Oxychlordane was also less inhibitory to Cyp 2D6 (Figure 5). Incubation of Cyp 3A4 with the polychlorinated chemicals in general resulted in a biphasic response in which lower concentrations of chemical-produced inhibition (IC_{50} 300-700 ng/ml) while higher concentrations produced some stimulation of activity (Figure 7). This effect was also observed when cytochrome P450 2C8 was incubated with either technical

Figure 10. Induction of cytochrome P450 2C8-like activity in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides



toxaphene or *trans*-chlordane (Figure 3).

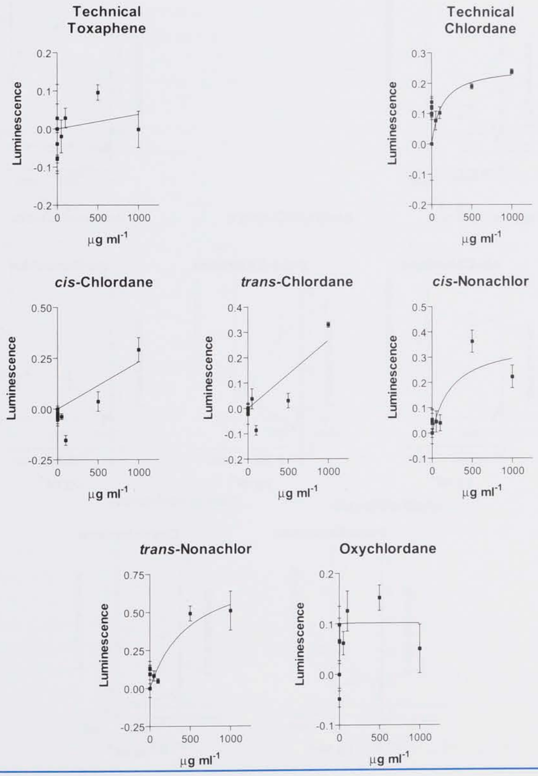
The effect of test chemicals on induction of enzyme activity in rat hepatoma H4IIE cells is also shown (Cyp 1A1, Figure 8; Cyp 1A2, Figure 9; Cyp 2C8, Figure 10; Cyp 2C9, Figure 11; Cyp 3A4, Figure 12, and Cyp 3A7, Figure 13). It should be noted that the substrate specificities used to detect these enzymes are based upon activities characterized with human rather than rat isozymes. Additional experiments will be required using isozyme specific inhibitors to determine which rat 2C and 3A isozymes were actually detected by the luminescent substrates. A comparison of all results shows that cytochrome P450 induction occurred for almost all test chemicals and isozymes at relatively high test chemical concentrations of 250μg/ml to 1 mg/ml. However, biphasis reponses were again found for Cyp 3A4 and Cyp 3A7 where inhibition with IC_{50}s ranging from 35-250 ng/ml was followed by a rebound of cytochrome P450 activity at higher test chemical concentrations.

Discussion and Conclusions

These studies were initiated to address several data gaps which were recognized in the published literature:

A. Most published studies on the interaction of chlordane and toxaphene with the cytochrome P450 system refer to the technical mixtures with little published data available on pesticide subcomponents and

Figure 11. Induction of cytochrome P450 2C9-like activity in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides



metabolites.

B. More recent studies of pesticide effects on cytochrome P450 induction have examined mRNA levels with little accompanying data regarding actual enzyme activities.

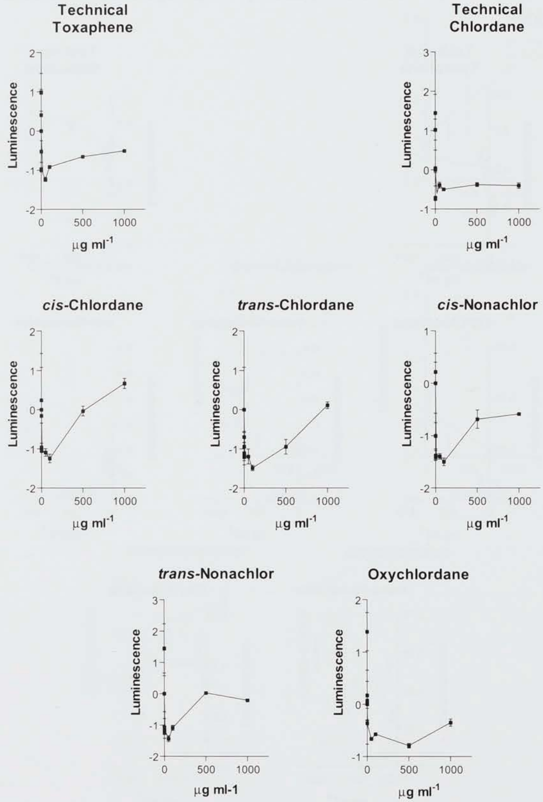
C. Little data is available on the interaction of chlordane, toxaphene or individual components/metabolites with known inducers of cytochrome P450 isozymes.

D. No data appears to be available on enhancement or inhibition of cytochrome P450 isozme activities by technical mixtures of toxaphene or chlordane as well as individual components or metabolites.

The characterization of polychlorinated pesticide interactions with various members of cytochrome P450 families may have important implications for drug interactions, endocrine disruption and carcinogenesis. Interactions could be relatively specific since different hepatic P450 families show some substrate specificity in chemical classes (please refer to table (Adapted from Lewis, 1996) to the right.):

Other studies have found that technical mixtures of chlordane and toxaphene as well as *gamma*-chlordane

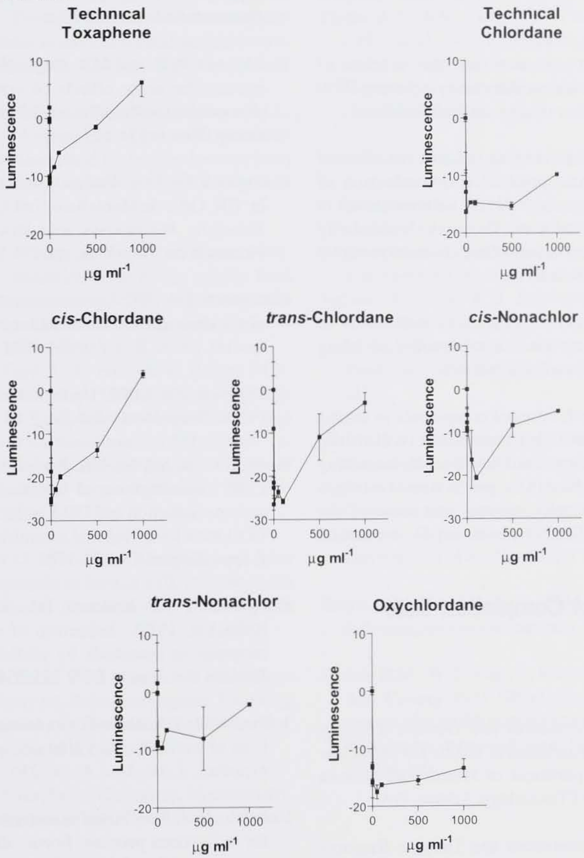
Figure 12. Induction of cytochrome P450 3A4-like activity in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides



and *trans*-nonachlor have induced isozymes typically induced by phenobarbital (cytochrome P450p or Cyp 2B) with a lesser contribution by Cyp 3A (Schuetz *et al.* 1986; Nims and Lubet, 1995; van-Hezik *et al.* 2001). Induction was shown to result from an inhibition of Cyp 2B degradation. Oxychlordane was inactive. The Cyp 2B family has not yet been examined in the present studies but induction was found of Cyp 2A and Cyp 2C families, which are also inducible by phenobarbitol. In contrast, inhibition of enzyme activity was also found when these families were examined.

Cyp family/subfamily	Typical substrates and chemical classes
Cyp 1A1	planar polyaromatic hydrocarbons, nitroarenes
Cyp 1A2	planar heterocyclic and polyaromatic amines and amides
Cyp 2A	7α- and 15α-hydroxylation of testosterone
Cyp 2C	relatively polar compounds possessing non-planar molecules
Cyp 2D	aromatic compounds containing a basic nitrogen atom protonated at pH 7.4 which is [illegible]5-7[illegible] from the site of metabolism
Cyp 2E	small molecular weight solvents
Cyp 3	large molecular weight compounds of diverse structure, including macrolide antibiotics and many structurally diverse pharmaceuticals

Figure 13. Induction of cytochrome P450 3A7-like activity in rat hepatoma H4IIE cells after incubation with polychlorinated pesticides



Estimation of Dietary Exposure to Perfluorinated Carboxylates and Sulfonates via Consumption of Traditional Foods

Project leader(s)

Sheryl Tittlemier, Food Research Division, Health Canada; Laurie Chan, Centre for Indigenous Peoples' Nutrition and Environment (CINE), McGill University

Summary

Liver samples (20) from traditional foods were analyzed for five perfluorinated carboxylates, one perfluorinated sulfonate, three perfluorooctanesulfonamides, three fluorinated telomer carboxylates, and three unsaturated fluorinated telomer carboxylates (see Table 1 for a list of analytes). The samples were extracted using a newly developed solvent extraction method and analyzed using LC-MS/MS.

Introduction

Recent work has described levels of certain perfluorinated compounds (PFCs) in human sera collected from donors in a large number of countries[1] including southern[2] and northern Canada[3]. The routes of human exposure to these perfluorinated compounds have not been well characterized. One possible route is the consumption of foods containing PFCs. Past work on PFCs in Arctic biota[4,5] demonstrates that these compounds are present in the Arctic environment, and in some traditional foods consumed by northern populations. This initial study was performed to examine the dietary exposure of traditional food consumers to PFCs. Portions of liver consumed as traditional food were analyzed for five perfluorinated carboxylates (PFCAs), one perfluorinated sulfonate, three perfluorooctanesulfonamides (PFOSAs), three fluorinated telomer carboxylates (FTCAs), and three unsaturated fluorinated telomer carboxylates (FTUCAs).

Materials and Methods

Liver samples (20 in total) from Arctic char, burbot, caribou, loche, ringed seal, and walrus were collected from various locations in Nunavut between 1997 and 1999 (Table 2). Samples were stored at -20°C prior to analysis.

The samples were extracted using a newly developed solvent extraction method and analyzed using LC-MS/MS[6]. A 0.2 g portion of liver was spiked with recovery internal standards ($^{13}C_2$-PFDA, 4H-PFOS, $^{13}C_2$-6:2 FTUCA, $^{13}C_2$-10:2 FTUCA, and d_5-NEtPFOSA) homogenized with 4 ml Optima grade methanol and centrifuged (10 min. at 3600 x *g*) to obtain supernatant. The extraction was repeated twice more with 2 ml volumes of methanol, and the supernatants were combined and reduced in volume at 37°C to 250 µL using N_2. Aliquots of methanol taken through the procedure were used as method blanks. Instrument performance internal standards were added ($^{13}C_2$-PFOA, $^{13}C_2$-8:2 FTUCA, and d_3-NMePFOSA), and the final solution was centrifuged at 14,000 x *g* for 10 min. A portion of the final solution was transferred to a polypropylene autosampler vial prior to injection on the LC-MS/MS. All PFCs were quantitated using external standard solutions made up in methanol. Method detection limits were estimated to be 0.3 ng/g for PFOA and PFNA, 0.1 ng/g for PFDA, 0.03 ng/g for PFUA, 0.04 ng/g for PFDoDA, 0.02 ng/g for PFOS and 2 and 36 pg/g for PFOSA and N-EtPFOSA, respectively.

Results and Discussion

Tables 2 and 3 list concentrations of PFCs observed in the liver samples. The ringed seal liver contains the greatest amount of PFCs, followed by walrus, caribou, and fish livers. This rank order in ΣPFA concentrations is driven by PFOS concentrations, which are approximately 2 to 10 times higher in ringed seal liver compared to samples from other species. PFCAs were also frequently detected, and were found at the highest levels in caribou and walrus, followed by ringed seal, and then fish. PFOSAs (only perfluorooctanesulfonamide in all but one instance) were only detected in walrus, ringed seal, and the one Arctic char liver sample (Table 3). FTUCA/FTCAs were not detected

Table 1. Perfluorinated analytes and internal standards used.

ompound	Abbreviation	Chemical formula	Analyte/Internal Standard
	Perfluorocarboxylates (PFCAs)		
erfluorooctanoate	PFOA	$C_7F_{15}CO_2$-	analyte
erfluorononaoate	PFNA	$C_8F_{17}CO_2$-	analyte
erfluorodecanoate	PFDA	$C_9F_{19}CO_2$-	analyte
erfluoroundecanoate	PFUA	$C_{10}F_{21}CO_2$-	analyte
erfluorododecanoate	PFDoDA	$C_{11}F_{23}CO_2$-	analyte
C_2-perfluorodecanoate	$^{13}C_2$-PFDA	$C_8F_{17}{}^{13}CF_2{}^{13}CO_2$-	recovery internal std for PFCAs
erfluorooctanesulfonate	PFOS	$C_8F_{17}SO_3$-	analyte
H,1H,2H,2H-etrahydroperfluorooctanesulfonate	THPFOS	$C_6F_{13}CH_2CH_2SO_3$-	recovery internal std for PFOS
	Perfluorosulfonamides (PFOSAs)		
erfluorooctanesulfonamide	PFOSA	$C_8F_{17}SO_2NH_2$	analyte
-methylperfluorooctanesulfonamide	N-MePFOSA	$C_8F_{17}SO_2NH(CH_3)$	analyte
-ethylperfluorooctanesulfonamide	N-EtPFOSA	$C_8F_{17}SO_2NH(C_2H_5)$	analyte
$_3$-N-methylperfluorooctanesulfonamide	d_3N-MePFOSA	$C_8F_{17}SO_2NH(CD_3)$	instrument performance internal std for PFOSAs
$_5$-N-ethylperfluorooctanesulfonamide	d_5N-EtPFOSA	$C_8F_{17}SO_2NH(C_2D_5)$	recovery internal std for PFOSAs
	Unsaturated fluorinated telomer carboxylates (FTUCAs)		
H-perfluoro-2-octenoic acid	6:2 FTUCA	$C_5F_{11}CF=CHCO_2$-	analyte
H-perfluoro-2-decenoic acid	8:2 FTUCA	$C_7F_{15}CF=CHCO_2$-	analyte
H-perfluoro-2-dodecenoic acid	10:2 FTUCA	$C_9F_{19}CF=CHCO_2$-	analyte
H-perfluoro-[1,2-$^{13}C_2$]-2-octenoic acid	$^{13}C_2$-6:2 FTUCA	$C_5F_{11}CF={}^{13}CH{}^{13}CO_2$-	recovery internal std for FTUCA/FTCA
H-perfluoro-[1,2-$^{13}C_2$]-2-decenoic acid	$^{13}C_2$-8:2 FTUCA	$C_7F_{15}CF={}^{13}CH{}^{13}CO_2$-	instrument performance internal std for FTUCA/FTCAs
H-perfluoro-[1,2-$^{13}C_2$]-2-dodecenoic acid	$^{13}C_2$-10:2 FTUCA	$C_9F_{19}CF={}^{13}CH{}^{13}CO_2$-	recovery internal std for FTUCA/FTCA
	Fluorinated telomer carboxylates (FTCAs)		
H-perfluoro-2-octanoic acid	6:2 FTCA	$C_6F_{13}CH_2CO_2$-	analyte
H-perfluoro-2-decanoic acid	8:2 FTCA	$C_8F_{17}CH_2CO_2$-	analyte
H-perfluoro-2-dodecanoic acid	10:2 FTCA	$C_{10}F_{21}CH_2CO_2$-	analyte

Table 2. Liver perfluorinated sulfonate and carboxylate concentrations (ng/g, wet weight)

	Community	Preparation	PFOA	PFNA	PFOS	PFDA	PFUA	PFDoDA	ΣPFAs
Arctic char	Kugluktuk	Raw	0	0	5.4	0	0	0	5.4
Burbot	Aklavik	Raw	26.5	29.2	2.7	10.2	0	0	68.6
Burbot	Aklavik	Raw	0	0	15.4	0	0	0	15.4
Caribou	Pond Inlet	Raw	8.9	26.3	19.8	12.8	7.6	10.8	86.3
Caribou	pooled	Baked	2.1	24.6	19.7	7.8	4.9	6.4	65.5
Caribou	Hopedale	Raw	12.2	17.8	24.4	14.5	11.6	0	80.5
Caribou	Pond Inlet	Raw	5.9	15.5	15.2	4.5	3.9	6.2	51.3
Caribou	Pond Inlet	Raw	3.7	7.7	23.2	0	10.7	0	45.3
Caribou	Kugluktuk	Raw	0	0	3.8	3.2	5.9	0	12.9
Loche	Aklavik-Jackfish Creek	Raw	2.7	0	6.7	5.6	24.3	0	39.3
Loche	Aklavik	Raw	0	0	18.3	0	0	0	18.3
Ringed seal	Igloolik	Raw	0	25.2	86.7	4.4	5.6	2.9	124.7
Ringed seal	Igloolik	Raw	8.7	6.2	74.3	4.2	9.0	0	102.5
Ringed seal	Qikiqtarjuaq	Raw	0	7.1	152.8	3.3	4.9	7.5	175.6
Ringed seal	Igloolik	Raw	2.3	0	291.7	0.7	4.6	13.6	312.9
Ringed seal	Igloolik	Raw	0	9.0	197.9	7.1	0	0	214.1
Walrus	Igloolik	Raw	5.8	18.0	27.7	6.4	3.8	11.1	72.6
Walrus	Igloolik	Raw	0.3	22.3	38.6	2.7	1.8	4.7	70.6
Walrus	Igloolik	Raw	4.5	34.9	8.1	3.5	4.7	4.5	60.2
Walrus	Igloolik	Raw	0	11.1	14.6	0	4.8	8.8	39.3

Table 3. Liver perfluorooctanesulfonamide concentrations (ng/g, wet weight)

Species	Community	Preparation	PFOSA	N-Me-PFOSA	N-Et-PFOSA	ΣPFOSAs
Arctic char	Kugluktuk	Raw	1.6	0	151.0	152.6
Burbot	Aklavik	Raw	0	0	0	0
Burbot	Aklavik	Raw	0	0	0	0
Caribou	Pond Inlet	Raw	0	0	0	0
Caribou	pooled	Baked	0	0	0	0
Caribou	Hopedale	Raw	0	0	0	0
Caribou	Pond Inlet	Raw	0	0	0	0
Caribou	Pond Inlet	Raw	0	0	0	0
Caribou	Kugluktuk	Raw	0	0	0	0
Loche	Aklavik-Jackfish Creek	Raw	0	0	0	0
Loche	Aklavik	Raw	0	0	0	0
Ringed seal	Igloolik	Raw	0	0	0	0
Ringed seal	Igloolik	Raw	0.4	0	0	0.4
Ringed seal	Qikiqtarjuaq	Raw	1.6	0	0	1.6
Ringed seal	Igloolik	Raw	0.2	0	0	0.2
Ringed seal	Igloolik	Raw	2.8	0	0	2.8
Walrus	Igloolik	Raw	3.1	0	0	3.1
Walrus	Igloolik	Raw	3.3	0	0	3.3
Walrus	Igloolik	Raw	0.6	0	0	0.6
Walrus	Igloolik	Raw	1.1	0	0	1.1

Table 4. Average and range (in parentheses) of relative concentrations of selected perfluorocarboxylates and perfluorooctane sulfonate in liver from traditional food samples and archived maternal and cord plasma collected from donors residing in the North.

Samples	PFOA/PFNA	PFOA/PFOS
Metis, Dene, Inuit plasma[a] (n=9)	7.9 (0.2 - 32)	0.35 (0.04 - 1.54)
fish liver (n=5)	0.9 (undefined - 0.9)	2 (0 - 10)
caribou liver (n=6)	0.4 (undefined - 0.7)	0.2 (0 - 0.5)
ringed seal liver (n=5)	0.4 (undefined - 1.4)	0.03 (0 - 0.1)
walrus liver (n=4)	0.1 (0 - 0.3)	0.2 (0 - 0.5)

[a]data is from Tittlemier *et al.* (2004)

in any of the 20 liver samples.

The PFC concentrations observed in this study are generally similar to what has been reported for liver in other ringed seal, walrus, and fish sampled in the Canadian Arctic. Previous work examining PFCs in Arctic biota also found that PFOS was present at higher concentrations than all individual PFCAs in ringed seal[4], walrus[5], and various species of fish[4,5].

Relative concentrations of the PFCA homologues in this limited number of traditional food samples analyzed are different than those observed in the plasma of traditional food consumers (Table 4). PFOS and PFNA are the two most abundant PFCs found in the traditional food samples analyzed in this pilot study (PFOS the most abundant in ringed seal, some walrus and loche; PFNA the most abundant in caribou and some burbot). However, in the plasma pools of donors identified as Dene, Metis, or Inuit, PFOS and PFOA were the most abundant PFCs, followed by PFHpA and then PFNA. PFCAs with perfluoroalkyl chains longer than C_9 were not observed in the human plasma[3], but were observed in almost all of the traditional food samples analyzed.

The results of this pilot study indicate that consumers of liver are exposed to PFCAs, PFOS, and some PFOSAs. Consumption of ringed seal liver will lead to the greatest dietary exposure to PFCs, followed by caribou and walrus liver. However, since liver is not one of the main traditional food items consumed, a wider variety of food items must be analyzed to obtain a better picture of the dietary exposure of traditional food consumers to PFCs. An expanded survey of traditional food items for PFCs will also provide data to assess whether or not PFC concentrations observed in northerners are correlated to PFC concentrations in food.

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Environmental Trends Related to Human Health and International Controls

New Contaminants in Arctic Seabirds

Project leader(s)

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Abstract

This project determined temporal trends of new chemical contaminants in Arctic seabirds. Unlike the persistent organic pollutants (POPs) measured in most previous NCP projects, most of the chemicals determined in this study are in everyday use as flame retardants, stain repellents and lubricants but they have the potential for long range transport to the Arctic and accumulation in top predators. Three major groups of chemicals were investigated, brominated flame retardants (BFRs), chlorinated naphthalenes (PCNs) and perfluorinated acids (PFAs). Since previous analyses showed that short and medium chain chlorinated paraffins (SCCPs/MCCPs) were not detectable in seabird (northern fulmar) eggs and MCCPs were not detectable in any species, this group of compounds was not included in the temporal trend work. Perfluorinated acids clearly increased from 1975 to 2004 in thick-billed murres whereas, in the northern fulmars, there was an increase between 1987 and 1993 but no clear increase between 1993 and 2003. Total polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD) increased significantly in northern fulmars between 1975 and 1998, whereas in thick-billed murres, only PBDEs increased significantly between 1975 and 2003. We have not yet received the PCN data.

Key messages

- The study contributes the first information on temporal trends of HBCD, the PFAs and the PCNs (once received) in arctic seabirds.
- Total polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD) have increased significantly in northern fulmars over the last 2-3 decades whereas, in thick-billed murres, only PBDEs increased significantly.
- Perfluorinated acids have increased over the last three decades in thick-billed murres whereas, in the northern fulmars, the trend is less clear.

Objectives

As part of a larger proposal to investigate the presence and extent of new chemical contaminants in Arctic biota, the sub-component on Arctic seabirds proposes to:

1. Determine the temporal trends of these new or emerging chemical contaminants (such as brominated flame retardants (BFRs), chlorinated naphthalenes (PCNs) and fluorinated sulfonic and alkanoic acids) in Arctic seabirds (2004/05).
2. Determine the geographic/spatial trends of these contaminants (2003/04).

3. Identify and priorize other new contaminants that are entering the Arctic marine and freshwater environments including, if necessary, appropriate analytical methodology.

4. Contribute information to Canadian and International assessments of new candidate POPs.

Introduction

The recent Canadian Arctic Contaminants Assessment Report and the AMAP report on Persistent Organic Pollutants (POPs) have summarized information on a series of new chemical contaminants in the Arctic environment (Alaee et al. 2003; Fisk et al. 2003; deWit et al. 2003). These contaminants include brominated flame retardants (BFRs), perfluorooctane sulfonic acid (PFOS), chlorinated paraffins (CPs) and polychlorinated naphthalenes (PCNs). With the exception of PCNs, these chemicals are widely used in consumer and industrial products in Canada and throughout the world. PCNs are no longer in commercial use. They are, however, combustion byproducts and can, like chlorinated dioxins and furans, be emitted from many sources. The presence of these commercial chemicals and byproducts in the Arctic illustrates the vulnerability of polar regions to contamination by persistent, semi-volatile organic chemicals, particularly those that are used or emitted in relatively large volumes.

NCP Phase II supported several projects which measured "new chemicals" in air (Alaee et al. 2003) and biota (Bidleman et al. 1999; 2000; Martin et al. 2003; Tomy and Helm 2003). PBDEs and SCCPs were detected in archived extracts of Arctic air collected in 1994 at Alert (NU) on northern Ellesmere Island and at Tagish in southern Yukon (Alaee et al. 2003). Levels of total PBDEs were found to have increased significantly in a variety of Arctic biota including ringed seals (Ikonomou et al. 2002), beluga (Stern and Ikonomou 2000), seabirds (Braune and Simon 2003), burbot (Stern et al. 2001) and landlocked Arctic char (Muir and Köch 2003). PCNs as well as SCCPs have been detected in beluga and ringed seals from Cumberland Sound (Helm et al. 2002; Tomy et al. 2000). Fluorinated acids have been detected in liver samples from ringed seals, polar bears, northern fulmars and mink (Martin et al. 2003, 2004).

While much was accomplished under NCP II there are numerous knowledge gaps. Good temporal trend data were developed only for PBDEs in a limited number of species and locations. Other BFRs such as hexabromocyclododecane (HBCD), a chemical that is replacing some PBDEs in Europe, as well as many other semi-volatile brominated compounds that are in commercial use, have not been determined. PCNs, SCCPs and perfluorinated acids were determined only in a very limited number of samples. Neutral precursors of the perfluorinated acids such as perfluoroalkyl-sulfonamides, -sulfonamidoalcohols and telomer alcohols had not been determined. Information on geographic variation of all of these new contaminants was generally not available for any species. Results from 2003/04 (Muir 2004) indicated the presence of perfluoro acids, BFRs and PCNs in the seabirds justifying the analyses of those compounds for temporal trends in year 2 (2004/05) of the project. In fact, the PCN signal for seabird eggs was stronger than in beluga and ringed seal tissues. Chlorinated paraffins, however, were not detected in any of the seabird samples analyzed in 2003/04 and therefore, further analyses of these compounds in seabird samples were not pursued.

Activities

In 2004/2005

The work in 2004/05 focussed on temporal trends of BFRs, PCNs and PFAs in seabirds.

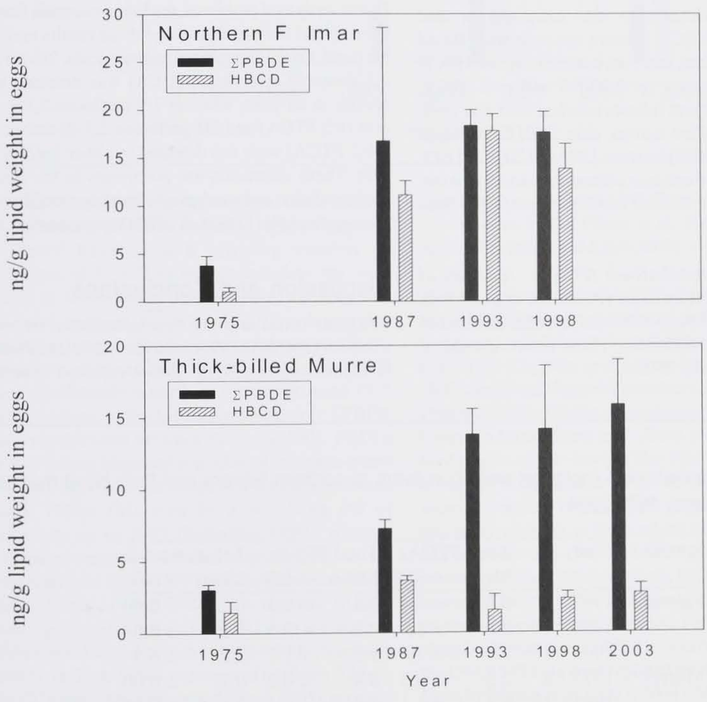
Sample collection/retrieval: Archived individual livers and pooled egg samples (three eggs per pool) of thick-billed murres (*Uria lomvia*) and northern fulmars (*Fulmarus glacialis*) collected from Prince Leopold Island were retrieved from the CWS Specimen Bank for analyses. The following samples were retrieved for the collection years indicated: Eggs - thick-billed murres – 1975, 1987, 1993, 1998; northern fulmars - 1975, 1987, 1993, 1998; Livers – thick-billed murres – 1975, 1993; northern fulmars – 1975, 1987, 1993. Eggs of both species and livers of northern fulmars collected in 2003 were also included in the time trend analyses. The fulmar liver samples collected in 2003 have now been completely used up and no collections of adult thick-billed murres have been made since 1993. Therefore, 10 adult birds each of thick-billed murres and northern fulmars were collected from Prince Leopold Island in 2004 so that recent liver samples will be available for temporal trend comparisons.

Analytical methods: The analytical methods used for each chemical group are outlined in Table 1. Eggs were analysed for BFRs and PCNs, and liver for perfluoro acids. Variability for seabird egg samples was reduced by use of pooled samples (a standard CWS protocol; Braune et al. 2001), however, individual seabird liver samples were analysed for PFAs. In brief, eggs were Soxhlet extracted and lipid was removed by gel-permeation chromatography

Table 1. Analytical methodology for the new chemicals

New chemical	Tissue	Extraction/isolation method	Quantification method
BFRs (Br2-Br8-PBDE, HBCD)	egg	Soxhlet/ASE. GPC to remove lipids.	GC-hi res MS (EI mode) and HPLC/MS/MS
PCN	egg	Soxhlet/ASE. GPC to remove lipids.	GC-lo res MS (NI mode)
Perfluoro acids and neutral precursors	liver	Homogenization with ion pairing reagent.	HPLC/MS/MS

Figure 1. Mean concentrations (± standard error) of brominated flame retardants (ng/g lipid weight) in seabird eggs collected from Prince Leopold Island, 1975-2003. Five egg pools (comprised of 3 eggs each) were analyzed per species for most years with the following exceptions: Northern Fulmar 1987, N=2 egg pools; Thick-billed Murre 1975 &1987, N=3 egg pools per year. SPBDE = Sum of Br_2-Br_7BDEs; HBCD = gamma-hexabromocyclododecane. Results for HBCD are preliminary (see text).



(GPC). Additional cleanup and isolation was accomplished using silica-gel columns. PCNs were subjected to an additional isolation step using carbon columns (Helm et al. 2002). PCNs and PBDEs were quantified by gas chromatography-low resolution mass spectrometry (GC-LRMS) in negative ionization mode. PFAs were extracted by the method of Hansen et al (2001) and quantified by liquid chromatography-tandem mass spectrometry (LC-MS/MS) using electro-spray negative ionization mode. Hexabromocyclododecane was extracted along with other BFRs and quantified by LC-MS/MS and by GC-LRMS (Stuttaford et al. 2004).

Results

***Brominated flame retardants**:* PBDEs (Br_2-Br_7BDEs) and HBCD (gamma-hexabromocyclododecane) were present at low ng/g (lipid weight) concentrations in eggs of both northern fulmars and thick-billed murres as early as 1975 (Figure 1). Results for HBCD are preliminary because the analysis was conducted by GC-MS. Further analyses by LC-MS/MS to determine the proportions and concentrations of HBCD isomers are underway. Based on the preliminary data, however, both ΣPBDE and HBCD increased significantly ($p=0.00078$ and $p=0.00011$, respectively) in northern fulmars between 1975 and 1998, whereas in thick-billed murres, only ΣPBDE increased significantly ($p=0.0039$) between 1975 and 2003. BTBPE (1,2-Bis(2,4,6-tribromophenox)ethane) was detected (0.096 ng/g lw) in only one pool of northern fulmar eggs from 1993.

Polychlorinated naphthalenes (PCNs): Analyses of polychlorinated naphthalenes (PCNs) in eggs of both northern fulmars and thick-billed murres collected between 1975 and 2003 are underway. Those results should be available by September 2005.

Perfluorinated compounds: Perfluorinated carboxylic acids (PFCAs), perfluorosulfonic acids (PFSAs) and telomer acids were determined in liver samples of northern fulmars and thick-billed murres collected between 1975 and 2004 (Table 2). C7 to C15 PFCAs were detectable in both species in all years analyzed, but C11-C15 were the predominant components, particularly in recent years (2003-2004). Perfluorooctane sulfonate (PFOS) was the major PFSA in the murre livers whereas in the fulmars, PFOS and perfluorodecanoic acid (PFDS) contributed equally to total PFSA and perfluorooctane sulfonamide (PFOSA) was the dominant contributor in 1987 and 1993. Perfluorohexane sulfonate (PFHxS) was not detected in any of the murre livers and was only detected in the fulmar livers from 2003. Perfluorinated acids clearly increased from 1975 to 2004 in thick-billed murres whereas, in the northern fulmars, there is an increase between 1987 and 1993 but no clear increase between 1993 and 2003 (Table 2, Figure 2).

Due to analytical problems, the fulmar samples from 1975 have not yet been analyzed and those results may clarify the trend. Of the fluorinated telomer acids, 2H-perfluoro-2,3-decenoic acid (8:2 FTUCA) was detected in both species in all years whereas 2H-perfluoro-2,3-decanoic acid (8:2 FTCA) and 2H-perfluoro-2,3-dodecanoic acid (10:2 FTCA) were not detected in either species in any year. These chemicals are precursors in the microbial biodegradation and atmospheric breakdown of fluorinated telomer alcohols (Ellis et al. 2004; Dinglasan et al. 2004).

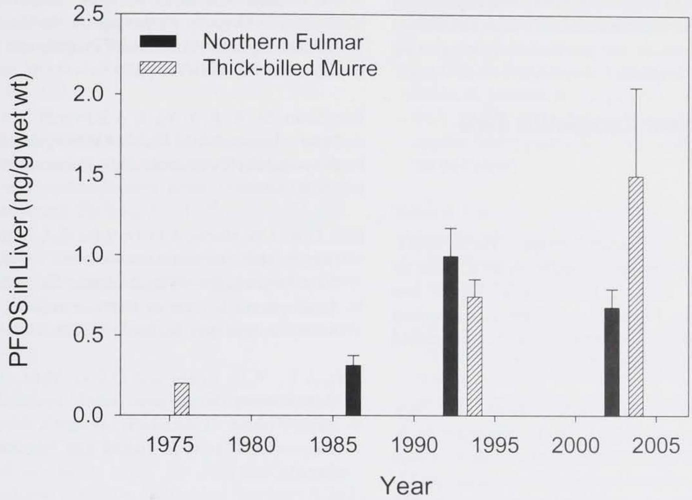
Discussion and Conclusions

The study contributes the first information on temporal trends of HBCD, the PFAs and the PCNs (once received) in arctic seabirds. Muir (2004) reported several new

Table 2. Perfluorinated acids (ng/g wet weight) in livers of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2004

Species	Year	N	Total PFCAs		Total PFSAs		Telomer acids	
			Mean	± SD	Mean	± SD	Mean	± SD
Fulmars	1987	8	6.8	± 3.4	1.4	± 0.3	0.2	± 0.06
	1993	10	30	± 12	4.8	± 2.5	0.2	± 0.08
	2003	15	33	± 38	1.5	± 1.1	2.2	± 6.3
Murres	1975	8	2.5	± 0.3	0.4	± 0.2	0.7	± 0.00
	1993	10	3.1	± 1.1	1.0	± 0.4	0.1	± 0.01
	2004	10	26	± 8.7	2.0	± 1.9	0.2	± 0.05

Figure 2. Mean concentrations (± standard error) of perfluorooctane sulfonic acid (PFOS) (ng/g wet weight) in seabird livers collected from Prince Leopold Island, 1975-2004.



halogenated contaminants in Arctic biota. These include HBCD, an additive BFR that is used in rigid polystyrene foam. There have been a growing number of measurements of HCBD in the environment but none previously in Arctic biota. In this report, we show that HBCD was present at low ng/g (lipid weight) concentrations in eggs of both northern fulmars and thick-billed murres as early as 1975. Both ΣPBDE and HBCD increased significantly in northern fulmars between 1975 and 1998, whereas in thick-billed murres, only ΣPBDE increased significantly between 1975 and 2003. PBDEs were shown to have increased in guillemot (common murre - *Uria aalge*) eggs from the Baltic Sea between 1969 and the early 1980s followed by a levelling off of concentrations up to 1997 (Sellström 1999), whereas HBCD concentrations increased significantly in the guillemot eggs from 1969 to 1997 (Kierkegaard et al. 1999). In Canada, levels of total PBDEs are reported to have increased significantly in herring gull (*Larus argentatus*) eggs in the Great Lakes between 1981 and 2000 (Norstrom et al. 2002), in thick-billed murres and northern fulmars between 1975 and 1998 (Braune and Simon 2003), in ringed seals from Holman Island between 1981 and 2000 (Ikonomou et al. 2002), in beluga from southeast Baffin Island between 1982 and 1997 (Stern and Ikonomou 2000) as well as in burbot (Stern et al. 2001) and landlocked Arctic char (Muir and Köch 2003).

Overall, perfuorinated acids (PFAs) in the northern fulmars and thick-billed murres analyzed in this study were low. Compared with fulmars from the Faroe Islands and black guillemots (*Cepphus grylle*) from Greenland (Bossi et al. 2005), and black-legged kittiwakes (*Rissa tridactyla*) and glaucous gulls (*Larus hyperboreus*) from the eastern Canadian Arctic (Tomy et al. 2004), the PFOS levels in our birds were much lower. The PFOA concentrations, however, were similar. Perfluorinated acids clearly increased during 1975 to 2004 in thick-billed murres in this study whereas, in the northern fulmars, there was an increase between 1987 and 1993 but no clear increase between 1993 and 2003. Similarly, PFOS levels in guillemot (common murre – *Uria aalge*) eggs from the Baltic Sea increased significantly between 1968 and 2003 with a sharp peak observed in 1997 (Holmström et al. 2005). While the C9-C15 PFCAs were reported for the first time in Arctic biota by Martin et al. (2003, 2004), Muir (2004) added to the list with the detection of the fluorinated telomer acids and we have reported further data for these compounds here. With respect to the PFCAs, it is interesting to note that, in the murres and the fulmars, the longer-chained perfluorocarboxylates (C11-C15) dominate the overall profile whereas, in ringed seals (Muir 2004) and most other biota samples, the C8-C11 perfluorocarboxylates dominate. As well, in most biota, PFOS overwhelmingly dominates the perfluorinated acid concentrations whereas, in the seabirds, the profiles are dominated by perfluorinated carboxylates.

Expected Project Completion Date

December 31, 2005

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Northern Contaminants Air Monitoring and Interpretation

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Abstract

Concurrent weekly high volume (HiVol) air samples were collected over one year at two arctic sites: Little Fox Lake (LFL), Yukon, Canada and Point Barrow (PB), Alaska, USA. All samples were analyzed for organochlorine pesticides (OCs), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Preliminary data analysis focuses on selected OCs which show significantly different concentrations and seasonality at the two sites.

Much higher concentrations of á- and ã-HCH and stronger seasonal variation were observed at LFL than at PB. Historically when HCH technical mixtures were widely used, HCHs were transported to the Arctic via long-range transport (LRT), effectively scavenged, and further deposited to soils. Atmospheric scavenging was probably more efficient at LFL than PB because of increased precipitation rate at higher elevation at LFL. The two HCH isomers are subject to re-emission to the atmosphere while temperatures rise above freezing at LFL and after primary emissions have diminished. However, secondary emissions from soils are hindered at PB since snow cover above soils acts as an effective barrier.

Seasonal variation of dieldrin was comparable at the two sites, i.e., higher concentration occurred during summer time and lower concentration in winter. However, elevated concentration of dieldrin in air was observed at LFL compared with PB which could be related to different emission sources. Concentration of endosulfan I was comparable at the two sites during the cold period, whereas nearly opposite trends occurred during the warm period, i.e. elevated concentrations at LFL and lower concentrations at PB. Again, this is probably related to different emission sources. Also, a divergence in temperatures at the two sites may result in different extent of degradation. Relatively high concentrations of pentachloroanisole (PCA) were measured in air at both sites. Monthly average concentrations of PCA were mostly comparable at the two locations, but significant differences occurred during the three summer months of June, July, and August. Specifically, PCA concentrations were much higher at PB during this period of time. This could be a result of regional usage of pentachlorophenol (PCP) and subsequent transformation from PCP to PCA during the summer time at this site. A potential source of PCA at PB could also be increased evaporation from open sea water. Observed low ratio of *trans*- and *cis*-chlordane reflects aged chlordanes in arctic air.

Key Project Messages

1. Concurrent organochlorine pesticide (OC) air concentrations measured at Little Fox Lake (LFL), Yukon, and Point Barrow (PB), Alaska, were compared.

2. Differences in air concentrations and seasonality of α-HCH, γ-HCH, dieldrin, endosulfan I and pentachloroanisole (PCA) were observed at the two sites. Possible explanations for such differences include:
   a) A difference in seasonal snow coverage at the two locations. Snow can act as a barrier to re-emission of previously deposited residue of these chemicals from soils.
   b) A difference in source region of influence to the two sites.

c) Divergence in temperatures at the two locations resulting in different extent of biotic and abiotic degradation of OCs.

d) Regional usage of pentachlorophenol (PCP)-treated wood or building material at PB resulted in elevated summer concentrations of PCA observed at this location. PCA is believed to be an environmental metabolite of PCP.

3. Low ratios of *trans*- and *cis*-chlordane (TC/CC) observed at both locations indicate weathered sources of chlordanes to these areas of the Arctic.

Objectives

1. To measure and understand the occurrence and trends of selected OCs, PCBs, and PAHs in the Arctic atmosphere and to determine whether concentrations are changing in response to national and international initiatives.

2. To provide insight into contaminant pathways (sources, transport, transformation, and removal processes) to the Arctic environment.

3. To enable validation of models of toxic chemicals in the Arctic environment with atmospheric observations.

4. To operate a major long-term trend measurement station at Alert, Nunavut (in operation since 1992), to contribute to future assessments by the Northern Contaminants Program and the Arctic Monitoring and Assessment Programme, and to advise Canadian negotiators in preparing contaminant control strategies.

Introduction

Atmospheric measurements of persistent organic contaminants, including herbicides, pesticides, synthetic industrial compounds and PAHs, have been made on a weekly basis in the Canadian (Alert, Tagish, Little Fox Lake, Kinngait [Cape Dorset]) and Russian Arctic (Dunai, Amderma) since January 1992, and Alaska, USA between March 2002 and April 2003. In the previous Synopsis of Research, long-term trends were derived for the air concentrations of PCBs and OCs at Alert using a digital filtration method; a spatial comparison of OC seasonality at Alert, Tagish, Dunai and Kinngait was given; and, the influence of the Pacific North American (PNA) Pattern on the air concentrations of γ-HCH and PCBs measured at Alert was discussed. In the current Synopsis Report, preliminary results are presented for a spatial comparison of OC air concentrations measured at Little Fox Lake (LFL) and Point Barrow (PB). This work is performed in collaboration with G.W. Patton of Pacific Northwest National Laboratory, Washington, USA, who conducted the measurements at PB.

Weekly high volume air samples were collected between July 2002 and June 2003 at LFL (61.35°N/135.63°W, 1128 m above sea level or m.a.s.l.), Yukon, Canada and between March 2002 and April 2003 at PB (71.32°N/156.60°W, 11 m.a.s.l.), Alaska, USA. The two sampling periods overlapped and all samples were analyzed in the same laboratory, i.e., Freshwater Institute, Canada, thus it is possible to study spatial variation of some organochlorine pesticides (OCs) without considering inter-laboratory correction. Comparison of various compounds can provide insight into their potential sources (e.g., LRT or local secondary emissions) and environmental pathways at the two sites. Preliminary data analysis focuses on selected OCs, i.e., á-HCH, ã-HCH, dieldrin, PCA, endosulfan I, and chlordanes. These compounds show significantly different air concentrations and seasonality at the two sites. Detailed examination of all compounds will be carried out at a later stage by studying usage/emission information of different types of compounds and their potential transformation kinetics, and employing Lagrangian back trajectory to trace air mass origins.

Activities

In 2004–2005

1. Regular weekly atmospheric measurements of OCs and PAHs continued at Alert. This involved the collection, extraction and analysis of air samples.

2. As part of a decision to integrate analytical activities within Environment Canada, chemical analyses have been moved from Fresh Water Institute (FWI), Winnipeg, which is a laboratory of the Department of Fisheries and Oceans, to the National Laboratory for Environmental Testing (NLET), an Environment Canada laboratory. The first round of interlaboratory comparison between FWI and NLET has been completed. The interlaboratory comparison included 3 regular samples and 3 blanks with particle and gas phases separately analyzed and 7 regular samples with particle and gas phases combined for analysis. For most of the PCBs and PAHs, results from the two laboratories compare reasonably well. Various discrepancies were observed for the OC pesticides. A second round of QA/QC assessment has been planned and will commence in the coming fiscal year.

3. Data analysis has been progressing well. Analysis of 1992-2001 data from Alert, 1993-1995 data from Kinngait, Tagish and Dunai, as well as more recently obtained 2000-2002 data from Kinngait is still ongoing.

4. An article summarising findings under this project reported in the Canadian Arctic Contaminants Assessment Report II (CACARII) has been published in the Science of Total Environment in the CACARII Special Issue (Hung, H., Blanchard, P., Halsall, C. J., Bidleman, T. F., Stern, G. A., Fellin, P., Muir, D. C. G., Barrie, L. A., Jantunen, L. M., Helm, P. A., Ma, J., Konoplev, A. (2005) Temporal and Spatial Variabilities of Atmospheric Polychlorinated Biphenyls (PCBs), Organochlorine (OC) Pesticides and Polycyclic Aromatic Hydrocarbons (PAHs) in the Canadian Arctic: Results from a Decade of Monitoring. *Sci. Tot. Environ.*, 342: 119-144.)

5. An article which investigated the influence of climate variation patterns, e.g. North Atlantic Oscillation (NAO), Pacific North American (PNA) pattern and the El Niño-Southern Oscillation (ENSO), on POP air concentrations measured under NCP and the Integrated Atmospheric Deposition Network (IADN), which monitors POP air concentrations in the Great Lakes, has been published in *Environmental Science and Technology*. This work is performed in collaboration with Dr. Jianmin Ma, a meteorologist at MSC. The article was also featured in the *ES&T* News in the same issue.

6. The influence of climate variation patterns on the transport of POPs to the Arctic was further investigated by performing correlation analyses between selected OC pesticides and PCB air concentrations measured at Alert with 10 low-frequency climate variation patterns. These include the PNA, West Pacific (WP), the East Atlantic Jet (EA-Jet) patterns and others. Results have indicated that the seasonal air concentrations of OCs and PCBs measured at Alert were significantly associated with different climate variation patterns. A manuscript to be submitted to *Environmental Science and Technology* is currently being prepared.

7. Considering that there is no comprehensive review of the occurrence of chlordane-related compounds in the Arctic environment, a review paper is currently being drafted. The review paper will contain i) availability of information on current usages and emission inventories; ii) overview of analytical methods that include techniques for identification of individual components and byproducts included in the term "chlordane-related compounds", and any applications which are specific to chlordane-related compounds for analysis of biotic and abiotic samples; iii) assessment of spatial and temporal trends in the environment with the emphasis on the atmosphere of the Arctic region; and iv) identification of knowledge gaps and further monitoring and research needs. The review paper will include all air concentration data previously collected under this NCP project, including those collected from Little Fox Lake (2002-2003), Dunai (1994-1995), Amderma (1999-2001) and Kinngait (2000-2002) which have never been published before.

8. In collaboration with Dr. Crispin Halsall, Lancaster University (UK), the long-term trends of PAHs in Arctic air are being explored. The digital filtration technique developed by MSC, which was used to calculate temporal trends of PCB and OC air concentrations, isn't applicable to PAHs which have extreme seasonality. The air concentrations of PAHs measured in the Arctic are usually high in the winter but mostly below detection limits in the summer. Lancaster University has developed a time series analysis technique, which is also based on digital filters, but is much less sensitive to extreme seasonality. A Ph.D. student under the supervision of Dr. Halsall has used this method to determine the temporal trends of PAHs in air at Alert. It has been found that there is no consistent decreasing or increasing trends for most of the PAHs in Arctic air. This is expected since these compounds are by products of combustion. The air concentrations of PAHs in the Canadian Arctic seem to reflect industrial activities in Eurasia, as well as local incineration activities at the military base at Alert. A manuscript is currently under preparation.

9. The Jul 2002 - Jul 2003 air concentrations of POPs measured at Little Fox Lake were compared with those measured at Tagish between Dec 1992 and Mar 1995. These two sites are very close to each other. A preliminary examination showed that the air concentrations of p,p'-DDE, trans- and cis-chlordane had declined, however, p,p'-DDT and γ-HCH remained more or less unchanged and α-HCH had increased. The air concentrations of PCBs and lighter PAHs, e.g. phenanthrene, also remained more or less unchanged. Fewer high concentration episodes were observed for the heavier PAHs, e.g. benzo[a]pyrene, in 2002-2003 compared to 1992-1995. Five-day Lagrangian back-trajectories have shown that an episode with high air concentrations of several OCs and higher PCBs, which occurred during the week starting Dec 1, 2002, may

carry signals of trans-Pacific transport since greater than 50 % of the back trajectories originated in Asia. However, since the samples were biweekly averaged, such signals may be skewed by transport from western US/Mexico (26 % of the trajectories). Further study of the dataset is required to identify the trans-Pacific versus western US/Mexico transport signature. Results from the preliminary analysis of the Little Fox Lake dataset were presented at SETAC 2004 in Portland, U.S.A..

10. Between March 2002 and April 2003, weekly HiVol samples were collected at PB, Alaska, USA. The sampling period overlapped with sampling campaign conducted in LFL. Moreover, all samples were analyzed in the same laboratory, i.e., Freshwater Institute, Canada. Comparison was performed towards understanding spatial variation of selected OCs and their potential sources and environmental pathways at the two sites. Preliminary data analysis focuses on selected OCs, i.e., á-HCH, ã-HCH, dieldrin, PCA, endosulfan I, and chlordanes. These compounds show significantly different air concentrations and seasonality at the two sites. Detailed examination of all compounds will be carried out at a later stage.

Results and Discussion

The particle-bound phase accounted for only a minor fraction of total concentration for most OCs at the two sites. Gaseous and particle-bound concentrations were combined for individual OCs in the current data analysis in order to circumvent seasonal temperature effect on gaseous/particle partitioning of some OCs. To illustrate the difaference in seasonality of OC air concentrations, monthly average concentrations were calculated by averaging all samples collected in the same month (not necessarily from the same year). The monthly average concentrations were then normalized by the total concentration over the whole sampling period to enhance the seasonal profiles. Several OCs, namely, á-HCH, ã-HCH, dieldrin, PCA, endosulfan I and isomer ratios of HCHs and chlordanes are presented in Fig. 1 to illustrate the difference between the two sampling sites.

Figure 1. Monthly concentrations and seasonal variations of á-HCH, ã-HCH, dieldrin, endosulfan I, and PCA at LFL and PB.

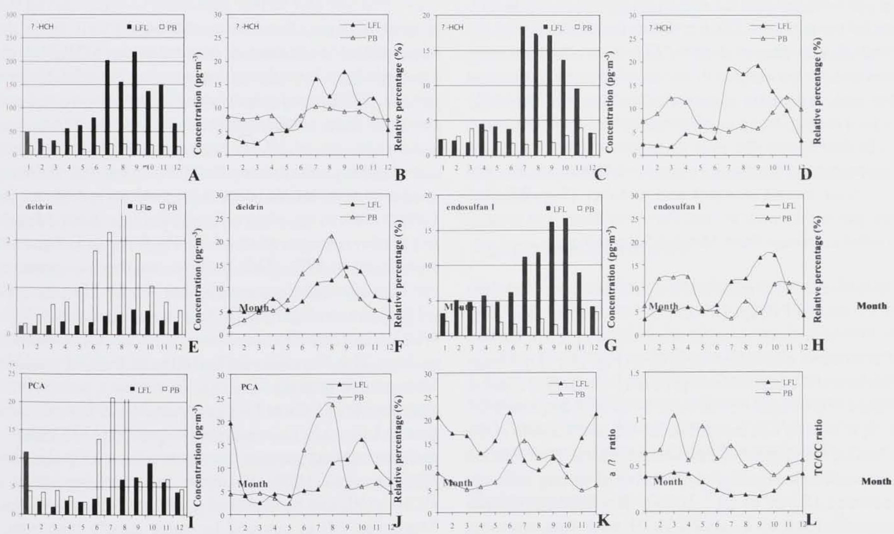

Figure 2. Monthly temperature (°C) and total precipitation (mm) are shown in A and B for both Whitehorse (60.43°N/135.04°W, 703 m above sea level) (http://www.theweathernetwork.com/weather/stats/pages/C02142.htm?CAYT0019) and Barrow (71.18°N/156.47°W, 9 m above sea level) (http://www.theweathernetwork.com/weather/stats/pages/C01873.htm). Monthly rain rate (mm), snow rate (cm), and snow cover (cm) at Whitehorse are indicated in C.

Fig. 2A and 2B show monthly average temperatures and monthly precipitation rates recorded at the meteorological stations of Whitehorse and Barrow (averages from 1961 to 1990), which are the closest meteorological stations to LFL and PB, respectively. Monthly rain rate, snow rate, and snow coverage at LFL are shown in Fig. 2C. In Fig. 2A, the monthly average temperature was approximately 10 °C higher at LFL (or Whitehorse) than at PB (or Barrow). Fig. 2B indicates that the annual precipitation rate at LFL was 2.4 times that of PB. Further examination of Fig. 2C reveals that the precipitation at LFL was mostly from snow between October and April, and mainly from rain between May and September when temperature was generally above freezing, whereas all precipitation was from snow at PB throughout the year. It is noteworthy that snow accumulated between November and March at LFL, and to a lesser extent in April and October (Fig. 2C, "+" indicates snow cover in cm). However, there was usually no snow coverage from May till September.

Both á- and ã-HCH exhibited much higher concentrations at LFL than at PB, specifically in the summer time (Fig. 1A, 1C). Moreover, stronger seasonal variation of the two HCH isomers was observed at LFL (Fig. 1B, 1D). Usage of technical HCH products (generally containing 5 stable isomers of HCHs, α: 55–80 %, β: 5–14 %, γ: 8–15 %, δ: 2–16 %, å: 3–5%) was banned in the US and Canada in the 1970s (Li, 1999) and air concentration of á-HCH is expected to be more or less uniformly distributed among different locations (Shen et al., 2004). Relatively low air concentrations of á- and ã-HCH with less seasonal variation at PB are consistent with this fact. However, elevated concentrations of á- and ã-HCH and strong seasonal variation at LFL suggest that secondary emissions of HCHs were important in this region. Global usage of technical HCH peaked in 1970s and significantly declined in the 1980s and 1990s (Li, 1999); therefore, direct application of technical HCH is currently less important in the global environment. However, historically when the technical mixture was widely used, these compounds were transported via LRT and deposited in the Arctic environment. HCHs can be effectively scavenged by both snow and rain and further deposited to soils. During this period of time, there was net deposition from the atmosphere to soils since air concentrations of HCHs were relatively high. Now that primary emissions of HCHs have ceased, HCH transfer between the atmosphere and soil reversed from net deposition to net evaporation as air concentrations of HCHs have decreased. Fresh snow above soils could act as an effective barrier, reducing evaporation of HCHs during the cold period. When the temperature rises above freezing (i.e., from May to September), evaporation of HCHs from soils becomes significant at LFL. This process can lead to observed elevated atmospheric concentration of á-HCH in this area. ã-HCH shows slightly different seasonal profile at LFL: ã-HCH concentration greatly increased in July compared to June. The elevated concentration of ã-HCH could be from source regions via LRT. In contrast, atmospheric scavenging of OCs at PB is expected to be less efficient than at LFL. LFL is at a higher elevation (1128 m.a.s.l.) and generally experiences more precipitation (Fig. 2B) than PB (Blais et al., 1998). Therefore, historical deposition of HCHs at PB can be expected to be less than that at LFL. Moreover, PB is covered by snow nearly year round which acts as a barrier for HCH evaporation from soil. The observed low concentrations of á- and ã-HCH reflect background air concentrations in this region. The Ration of á-HCH to ã-HCH is calculated for both sites and ranges from 9–21 (mean 15) at LFL and 5–15 (mean 8) at PB (Fig. 1K).

The á/ã ratio of HCH technical mixture is typically between 4 and 7. The á/ã ratio at both sites, specifically at LFL, is much higher than previous observations in the Arctic (Hung et al., 2002; Hung et al., 2005). The surprisingly high á/ã ratio could be from: 1) secondary re-emission of previously applied HCHs with high percentage of á-HCH; 2) reduced usage of ã-HCH or lindane.

Dieldrin is used as an insecticide and could also be a breakdown product of aldrin. Air concentrations of dieldrin at PB were consistently higher than that at LFL, and the difference in concentration was up to a factor of 5–6 during the summer time (Fig. 1E). Temperature at PB was typically 10 °C lower than at LFL; therefore, both biotic and abiotic transformation should be less important at PB than at LFL. The higher dieldrin concentration at PB may also be related to different source regions as a result of LRT. More work is required to investigate this scenario, for example, tracking major source areas using Lagrangian back-trajectory calculations. Seasonal variation of dieldrin is apparent at both sites where concentrations are elevated at higher temperatures and decline when temperatures drop (Fig. 1F).

Endosulfan I differed in both concentration and seasonal profile at the two sites. Concentrations of endosulfan I were comparable during winter and early spring (cold time), but there were significant differences during warmer periods at the two sites (Fig. 1G). At PB, endosulfan I was depleted during the summer time. As mentioned above, secondary emission of OCs from soils was probably less important at PB because of snow cover; therefore, observed endosulfan I could be the result of LRT. During the warm season, less endosulfan I may survive LRT to this remote area because of rapid degradation at relatively high ambient temperatures en route. However, at LFL, higher concentration of endosulfan I occurred during the warmer seasons (i.e., summer and fall) and lower concentrations during the colder seasons (i.e., winter and early spring), which could be a result of seasonal re-emission from secondary sources, which would have been enhanced by elevated temperature and exposed soil with no snow cover. Variation of sources led to different seasonal profiles at the two sites, which showed nearly opposite trends (Fig. 1H).

PCA is one of several OCs that are detected in all samples at the two sites. Generally speaking, higher PCA concentration was observed during fall and winter at both sites relative to that in spring and early summer. However, during three summer months (i.e., June, July, and August), considerably higher concentration of PCA was recorded at PB (Fig. 1I, 1J). Interestingly, the temperature in this location was above 0 °C only during these three months. It is believed that PCA is an environmental metabolite of pentachlorophenol (PCP), which is restrictedly used as a pesticide and a wood preservative. Elevated PCA at PB could be from usage of PCP-treated wood or building material at this site and subsequent transformation. PB is fairly close to the sea and increased evaporation from open water could also lead to higher air concentration of PCA during these three months, however, more study is required to illustrate this issue.

Ratios of *trans*-chlordane (TC) and *cis*-chlordane (CC) (i.e., TC/CC) can provide extra information on whether the presence of these compounds in Arctic air is due to fresh usage or previous application. Technical products of chlordane (TC/CC ~ 1.16) were banned for use in North America many years ago. The observed TC/CC ratios were normally below 1 in arctic air, which is a reflection of aged chlordane (Hung et al., 2002). The TC/CC ratios at the two sites were fairly low. The annual average was 0.30 at LFL and yearly average of TC/CC ratio was 0.63 at PB. Seasonal profile suggests reduced TC/CC ratio during the summer and fall time (Fig. 1L). It is believed that *trans*-chlordane is more susceptible to bio-degradation (Beeman and Matsumura, 1981). Considering 10 °C higher temperature at LFL than at PB, it is understandable that bio-degradation is faster in this location, which could lead to overall lower TC/CC ratio at LFL provided that the two sites have similar emission source (e.g., LRT input). Elevated TC/CC was observed during March and May at PB. This is probably related a difference in source region influence.

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Passive Air Sampling for Persistent Organic Pollutants in Cold Environments

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Abstract

Under NCP, air monitoring for persistent organic pollutants (POPs) has been conducted in the Canadian and Russian Arctic since 1992 using the conventional, active air sampling method. This technique relies on a pump to pull air through the sampler which traps the compounds of interest. However, this approach is expensive, labour intensive and is limited to sampling locations where electricity is available. It is thus difficult to sample in the remote arctic and the high operating costs prevents simultaneous sampling at multiple locations.

In recent years, various passive air sampling (PAS) techniques have been developed to collect chemicals from the atmosphere without the help of a pump, instead relying on the ability of the sampling medium to directly take up chemicals from the air. Previous passive sampler designs, such as those based on polyurethane foam (PUF) disks (Jaward et al., 2004) and XAD-resin (Shen et al., 2004), rely on molecular diffusion for the sampling medium to take up chemicals from the air. Molecular diffusion is a slow process and, as a result, sampling rates of existing PAS designs are quite small, typically on the order of a few m^3 of air per day (Shen et al., 2004; Shoeib and Harner, 2002). Since very low concentrations of POPs in the remote atmosphere often necessitate large air sampling volumes, in the order of 500 m^3 and higher, the low sampling rates of existing PAS designs require long deployment periods on the order of several months to more than a year. Variations in air concentrations on the time scale of months or shorter, thus, cannot be resolved, but are often of considerable interest. Under this project, a flow-through PAS, which can potentially increase the sampling rates of passive air sampling by directing air through the sampling medium, has been developed and tested under laboratory conditions. Two types of sampling media have been tested, namely aluminium honeycomb disks coated with ethylene vinyl acetate (EVA) and polyurethane foam (PUF) disks. It was found that although the former was superior in minimizing flow resistance, significant breakthrough occurred resulting in sample loss. PUF disks were found to be a more suitable sampling medium. The flow resistance introduced by the PUF disks can be adjusted by varying the thickness, number and porosity of the disks used to achieve the desired sampling efficiency.

Key Project Messages

1. A prototype of a flow-through passive air sampler, which can potentially increase the sampling rates of passive air sampling by directing air through the sampling medium, has been built.

2. The prototype has been tested under laboratory conditions using two types of sampling media, namely aluminium honeycomb disks coated with ethylene vinyl acetate (EVA) and polyurethane foam (PUF) disks. It was found that although the former was superior in minimizing flow resistance, significant breakthrough occurred resulting in sample loss. PUF disks were found to be a more suitable sampling medium. The flow resistance introduced by the PUF disks can be adjusted by varying the thickness, number and

porosity of the disks used to achieve the desired sampling efficiency.

3. The flow-through air sampler is currently being tested in the field.

4. Conventional PUF-disk based PAS have been deployed at Alert for 6 months at 13 locations close to the military base and the Global Atmospheric Watch (GAW) Laboratory to assess the spatial variability of POP air concentrations at close proximity. Duplicate samples were also taken at two locations to assess the precision of measurement.

Objectives

1. To test the performance of passive air samplers (PAS) in preparation for their routine use in arctic air monitoring, by:
   a) optimizing and increasing air sampling rates of PAS with the assistance of fluid flow analysis;
   b) conducting wind tunnel experiments to characterize flow rates through PAS;
   c) deploying PAS alongside active air samplers to test for sampling accuracy and to quantify POP uptake kinetics.

2. The long-term objective is to develop a PAS suitable for use under arctic conditions to supplement or to use in place of active air sampling in future arctic air monitoring network(s), and to increase spatial definition of POP air concentrations in the arctic. Such monitoring programs would gather POP air concentration data in support of the Long Range Transboundary Air Pollution (LRTAP) and Stockholm conventions.

Introduction

Air concentrations of POPs have been measured in the Canadian and Russian arctic since 1992 under NCP. This is mainly because air is the major transport pathway for these pollutants to enter the arctic ecosystems. POPs can be transported over great distances and tend to bioaccumulate and biomagnify through food chains resulting in unusually high exposure of northern populations that rely on a traditional, high fat diet.

The conventional technique used to determine air concentrations of POPs involves active sampling. This technique relies on a pump to pass air through the sampler which traps the compounds of interest. The limitation of this approach is that it is expensive, labour intensive and is limited to sampling at locations where electricity is available. It is thus difficult to sample in the remote arctic and the high operating costs prevents simultaneous sampling at multiple locations. In the past few years, various passive sampling techniques have been developed to assess atmospheric levels of POPs. These are simple, cost-effective air sampling techniques that require neither the use of a pump nor electricity, but rely on the devices' capability to directly take up contaminants from the atmosphere.

PAS are promising to address the need for spatially resolved atmospheric concentra-tions of SOCs, because of (1) their capability of time-integrated sampling over extended time period, (2) their independence from power supplies and regular maintenance, and (3) their relatively low production and operating cost. The capability of passive air samplers to provide information on the large-scale variability of atmospheric SOC concentrations has been shown through the results of continental sampling networks in both North America (Shen et al., 2004) and Europe (Jaward et al, 2004). Passive air samplers have also been used to establish urban-rural gradients of SOC concentrations in Southern Ontario (Gouin et al., 2005). In order to reach their full potential, however, the following limitations of existing PAS designs need to be overcome:

- low sampling rates of existing passive air sampling designs. POP air concentrations in remote arctic regions are often low, necessitating large air sampling volumes in the order of 500 m^3 and higher. PAS must therefore either have high sampling rates or be deployed for long periods. For instance, polyurethane foam (PUF) disk sampling rates are approximately 3 m^3/day (Shoeib and Harner, 2002) and XAD-based PAS have sampling rates of less than 1 m^3/day (Shen et al., 2004), which requires deployment periods of about one year at the current analytical detection limits and ambient air concentrations in the arctic. Therefore, seasonal variations in air concentrations are difficult to resolve with the current PAS techniques.
- limited characterization of the precision and accuracy of PAS. A number of experiments on the precision and accuracy of XAD-based passive samplers were conducted under arctic conditions (Wania et al., 2003), but more work is required. Such studies have not been performed under arctic conditions for other types of PAS thus far.
- inability to distinguish between POPs in the gas and particle phases. Existing PAS are designed for sampling POPs in the gas phase. However, at cold arctic temperatures, a larger fraction of POPs is present in the particle-sorbed state than under typical

temperature conditions of mid-latitudes, and sampling only the gas phase may underestimate the true extent of atmospheric contamination by POPs.

In the current project, we attempt to overcome the first and second limitations listed above by designing and developing a PAS suitable for use in cold environments such as the Arctic.

Activities

In 2004-2005

1. Developed and tested under laboratory conditions a new design of PAS, which increases the sampling rate by directing air through the sampling medium.

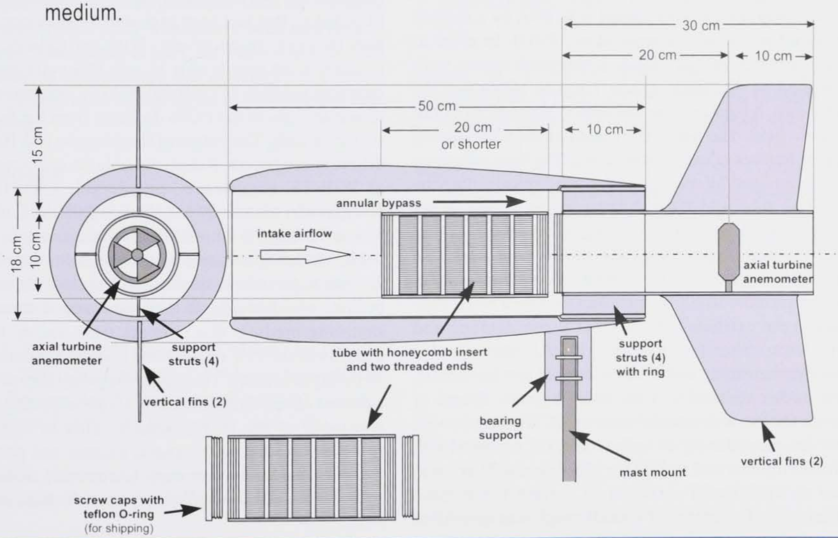
2. Conventional PUF-disk based PAS have been deployed at Alert for 6 months at 13 locations close to the military base and the Global Atmospheric Watch (GAW) Laboratory to assess the spatial variability of POP air concentrations at close proximity. Results of this study will contribute to a global network of air monitoring for POPs using this type of PAS.

New Passive Air Sampler (PAS) Design and Testing Method

In the new PAS design, the sampling rate is increased by forcing wind to blow through the sampling medium. The sampler consists of a horizontally-oriented, aerodynamically shaped, stainless steel flow tube mounted on a post with ball bearings which allow it to turn into the wind with the help of vanes (Fig. 1). The sampling medium is placed into a stainless steel cylinder of approximately 20 cm length and an inner diameter of 10 cm. The cylinder is mounted inside the flow tube assembly on a screw thread. At the same time, it serves as a sturdy storage and shipping container which can be sealed air-tight by screw caps that use the same thread.

By taking advantage of the wind blowing through the sampler, significantly higher sampling rates can be achieved. In contrast to previous sampler designs, however, the sampling rate is no longer a constant but dependent on the wind speed. This means that it is necessary to record the sampled air volume, if the amount of chemical quantified in the sampling medium is to be (1) converted into volumetric air concentrations or (2) compared between locations differing in wind speed. In the prototype sampler, the sampled air volume is recorded by a battery-operated turbine-counter mounted at the exit

Figure 1: Design of the flow-through passive air sampler with EVA-coated honeycomb as sampling medium.



of the flow tube (Fig. 1), which has been pre-calibrated with a hot wire anemometer. The wind speed dependence of the sampling rate further implies that sampling is biased towards time periods with higher wind speeds, i.e. contaminant uptake in the sampling medium is minimal during windstill time periods, but rapid during windy days. The sampler design includes an annular bypass (Fig. 1), which stabilizes the wind speed through the flow tube and reduces the uptake rate during periods of very high wind speeds, thus limiting the extent of sampling bias. Such bias is not a problem if wind speed and POP air concentrations are independent of each other, which often can be assumed to be the case.

To allow air to pass through the flow tube and to collect contaminants quantitatively from the air stream requires a sampling medium that ideally combines low flow resistance with high uptake efficiency. Two types of sampling media were explored:

- aluminium honeycomb disks of 1/8" cell size and 1" thickness, coated with a thin film of ethylene vinyl acetate (EVA). EVA has previously been used in passive air samplers (Shoeib and Harner, 2002; Khaled and Pawliszyn, 2000).

- polyurethane foam (PUF) disks of 1" thickness and different densities (P-10, P-20, P-30 and P-50, corresponding to pore sizes of 10, 20, 30 and 50 pore per inch, respectively). PUF is regularly used as sampling medium for POPs in both active and passive air samplers.

Honeycomb inserts were coated with EVA by a method described previously (Harner et al., 2003). In order to improve the uptake efficiency, honeycomb inserts were separated by half-inch spacer rings to maximize the turbulence. A large box fan was used to generate an indoor air flow field. The mass (thickness) of the EVA coating and the number of inserts was varied. The flow resistance was determined by comparing the wind speed within the sampling tube and through the annular bypass under different wind scenarios. The angles between the wind direction and alignment of the honeycomb were also adjusted to increase wind resistance. Honeycomb samples were extracted with 400 ml methanol for 1 hour twice. PUF disks were extracted by Soxhlet using acetone and petroleum ether (1:1) overnight. All the samples underwent clean-up and were exchanged into iso-octane, then further reduced to 1 ml under a gentle stream of nitrogen before instrumental analysis. PCB concentrations were determined using an Agilent 6890 GC equipped with splitless injector and an ECD or MS detector. Mirex was used as an internal standard to correct for volume differences. The extent of breakthrough was quantified as the percentage of the total chemical amount trapped in the last disk. The effect of sampling time and wind speeds on sampling efficiency was determined for different sampling media.

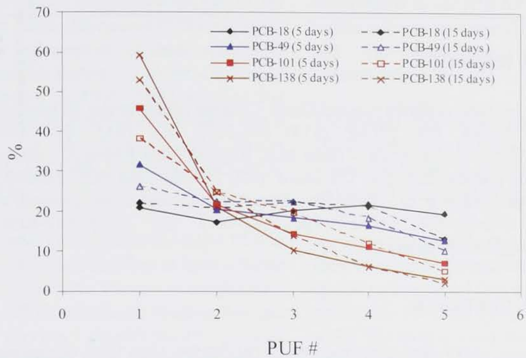
Results and Discussion

Preliminary results from the flow resistance experiments showed that the EVA-coated honeycomb displayed much lower air flow resistance than the PUF disks and that the resistance of the PUF disks depended on its porosity. The wind speed through 5 honeycomb units in series was only three time lower than that through the annular bypass, whereas 5 low density PUF (P10) disks in series decreased the wind speed by about an order of magnitude. Nevertheless, low density PUF-disks (P-10) had a wind resistance sufficiently low to allow for sampling.

PCB concentrations in multiple, serially arranged EVA-coated honey-comb disks were found to be rather uniform. Additional experiments with thicker EVA films and different physical arrangement of the honeycomb inserts did not improve the sampling efficiency. This suggests that the contact time within the honeycomb units is too short (less than 0.1 s) to prevent sub-stantial breakthough. Despite its superiority in terms of flow resistance, the honeycomb inserts were judged not suitable for quantitative measurements of POP air concentrations.

Fig. 2 shows the percentage profile for four selected PCB congeners in two PUF assemblies (five serially-arranged PUF disks), that had been exposed to laboratory air for 5 and 15 days, respectively. With artificially created constant wind speeds of 0.31 m/s, this corresponded to sampling volumes of 1000 and 3000 m^3, respectively. The concentrations of the PCBs decrease from the first to the fifth PUF disk. The extent of the decrease is different for different congeners. Relatively volatile congeners, such as PCB-18, experience considerable breakthrough, whereas less volatile PCBs, such as PCB-101 and PCB-138, are efficiently stripped from the air stream by the first 4 PUF disks. The extent of the concentration decrease appears to be independent of the length of the sampling period, which suggests that wind speed through the sampling medium (i.e. contact time, rather than the capacity of the PUF disks) is the main factor determining sampling efficiency. This opens the possibility to achieve a desired sampling efficiency by simply adjusting the flow resistance of the PUF assembly. This in turn can be achieved by varying thickness, number and porosity of the PUF disks. Further work is currently underway to optimize the sampling efficiency under field conditions at MSC.

Figure 2. Percentage profile of selected PCB congeners through the five serially arranged PUF disks.



Other than the designing and testing of the new flow-through air sampler, previously designed PUF-disk based air samplers (Shoeib and Harner, 2002) were deployed at 13 different locations close to the military base and Global Atmospheric Watch (GAW) Laboratory at Alert to assess the difference in air concentrations of POPs in close proximity to one another. Two sets of duplicate PUF-disk based samplers were also deployed to determine the precision of sampling using PAS under arctic conditions. The samplers were deployed in October 2004 for 6 months. The sampler inserts (PUF disks) have been sent back to Tom Harner's laboratory at MSC for analysis in mid-April 2005. Results of this study will contribute to a global network of passive air sampling for POPs using this type of air sampler.

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Temporal and Spatial Trends of Contaminants in Canadian Polar Bears, Part II

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Abstract

The polar bear (*Ursus maritimus*) is the apex predator of the Arctic marine ecosystem and an integral component of Inuit culture. Due to its position at the top of the marine food web, levels of persistent organic pollutant (POP) and metal contaminants in polar bears are among the highest observed in the Arctic. The last study that examined spatial trends of metals in Canadian polar bears was carried out in 1982 and 1984. Although levels of PCBs and OC pesticides were monitored in western Hudson Bay throughout the 1990s, there has been no temporal or spatial survey of POPs throughout Canada since the late 1990s and early 1990s, respectively. Furthermore, novel and emerging, chlorinated (e.g., methyl sulfonyl-PCB metabolites ($MeSO_2$-PCBs)), brominated (e.g., polar brominated diphenyl ether (PBDEs) and hexabromocyclododecane (HBCD) and fluorinated (e.g., perfluoroalkyl substances (PFAs)) POPs are of environmental concern including in the Arctic, for which there is little or no published data on spatial and temporal trends. To address this knowledge and data gap we determined a suite of legacy (PCBs and OC pesticides) and novel/emerging (PBDEs, PFAs and $MeSO_2$-PCBs) POPs, and metals (e.g., Hg, Se, Rb, Sr, Ba and Mn) that have been identified as important contaminants in the Arctic environment, in tissues of individual polar bears from populations spanning the western hemispheric Arctic in Alaska, Canada, Greenland and Svalbard (Norway). Samples of liver and fat were collected (2001-2002 season) from all polar bears harvested. This allowed for the selection of appropriate bears for the analyses (i.e., female bears between the ages of 5 and 15 years to reduce age effects).

Generally, East Greenland and Svalbard polar bears are at higher exposure risk to (non)legacy POPs and metabolites among Arctic and Subarctic populations. Easternmost populations of the polar bear range were distinguished by higher proportions of DDT-related compounds, nonachlor III, oxychlordane, higher-chlorinated and more persistent PCBs (hepta- to nona-chlorinated), and

$\Sigma MeSO_2$-PCBs and 3-$MeSO_2$-*p,p'*-DDE. Inversely, western polar bear populations of the North American Arctic were characterized by a significantly higher exposure to relatively volatile compounds such as HCHs and PnCBz, and tri- to penta-chlorinated PCB congeners, suggesting a stronger influence of Southeast Asian and North American-sourced inputs for these classes of contaminants. Relative to 1989"1993 studies for comparable female polar bear populations, there was a general decrease for the age-adjusted mean concentrations of ΣCHL, *p,p'*-DDE, Σ_{42}PCB, $\Sigma MeSO_2$-PCB, and 3-$MeSO_2$-*p,p'*-DDE.

Perfluorooctane sulfonate (PFOS) was the major PFA in all liver samples, having concentrations at least a factor of ten higher than all other PFAs. There was a significant geographic trend for PFOS, with South Hudson Bay and East Greenland having significantly greater concentrations than Svalbard, High Arctic, and western NWT, and all having significantly greater concentrations than Chukchi Sea samples. The greater concentrations measured in bears from East Greenland and the South Hudson Bay are possibly due to proximity to sources in Europe and Eastern North America, respectively. If PFAs (and/or precursors) are being transported via wind and/or ocean currents, the prevailing pathways suggest that the source of the PFAs in the European Arctic and eastern Greenland would be attributable to transport from Western Europe and eastern North America, while the western North American Arctic would be influenced mainly by East Asian sources. Temporal trends for PFOS and perfluorocarboxylic acids with carbon chain lengths from C_9 to C_{11} showed an exponential increase between 1972 and 2002 (Northern Baffin Island versus Barrow, Alaska), with doubling times ranging from 3.6 ± 0.9 years for perfluorononanoic acid in the eastern group, to 13.1 ± 4.0 years for PFOS in the western group. Doubling times appear to be short enough to preclude oceanic transport as the major pathway to the Arctic from mid-latitudes.

Fat samples from Canadian arctic and East Greenland polar bears were screened for 33 PBDEs (dibromo- to heptabromo BDEs) as well as BDE209. Only BDE47, BDE99, BDE100 and BDE153 were consistently identified (west to east ΣPBDE concentrations increasing from 7.6 to 70 $ng{\cdot}g^{-1}$ lw), with no detectable BDE209. Total (α) HBCD was present in100% of the East Greenland and Svalbard, and 13% of Bering-Chukchi samples, with concentrations higher than that of BDE47, and thus the highest brominated contaminant in circumpolar polar bears. The geographic trend for PBDE concentrations parallels that of PCBs and PFAs and points to eastern North America and western Europe as source regions.

More than 20 elemental metals were detected in the polar bear livers. Among the Canadian bear populations, Sanikilauq and Southern Baffin Island bears had lower concentrations and relative proportions of Hg and Se but higher concentrations and proportions of Rb, Sr, Ba and Mn. Age was found to influence Hg and Cd concentrations.

The present study on polar bear samples collected in 2001-2002 demonstrated that ongoing assessments are warranted on the spatial and temporal trends of legacy and novel (emerging) POPs and their metabolites, as well as certain metals (As, Cd, Pb, Se and Hg). Clearly there are non-legacy POPs that are bioaccumulative in bears from circumpolar populations, and vary as a function of spatial and temporal factors. These non-legacy POPs are potentially biomagnifying in polar bears and their food webs. The unique trend findings for, e.g., PFAs, PBDEs, total-HBCD and $MeSO_2$-PCBs indicate the necessity for continued vigilance in determining and assessing the trends of other chlorinated, brominated and fluorinated organic contaminants in the Arctic environment.

Key Project Messages

- East Greenland and Svalbard polar bears are at higher exposure risk to (non)legacy POPs and metabolites (PCBs, CHLs, DDTs, PBDEs, total-HBCD, $MeSO_2$-PCBs, 3-$MeSO_2$-*p,p'*-DDE and PFAs) among Arctic and Subarctic populations, with the exception of relatively volatile compounds such as HCHs and PnCBz, and tri- to penta-chlorinated PCB that are higher in concentration in western polar bear populations of the North American Arctic. For bears from Canadian populations, the same is true for metals such as Hg.

- PFOS was the major PFA in all liver samples, having concentrations at least a factor of ten higher than all other PFAs. For South Hudson Bay and East Greenland bears, PFOS concentrations were significantly greater than for Svalbard, High Arctic, and western NWT, and all having significantly greater concentrations than Chukchi Sea samples. Only BDE47, BDE99, BDE100 and BDE153 were consistently identified (no detectable BDE209), with ΣPBDE concentrations in fat increasing from west to east. Regardless of population, total (α) HBCD concentrations in bear fat were highest among the other brominated contaminants including BDE47.

- Relative to previous 1989-1993 studies for comparable female polar bear populations, there has been a general temporal decrease for the age-adjusted mean concentrations of ΣCHL, *p,p'*-DDE, Σ_{42}PCB, $\Sigma MeSO_2$-

PCB, and 3-$MeSO_2$-*p,p'*-DDE. Temporal trends for PFOS and perfluorocarboxylic acids with longer carbon chain lengths showed an exponential increase between 1972 and 2002 (Northern Baffin Island versus Barrow, Alaska), with concentration doubling times ranging from 3.6 ± 0.9 years for perfluorononanoic acid in the eastern group, to 13.1 ± 4.0 years for PFOS in the western group.

- The spatial and temporal trend findings for non (legacy) POPs and metals (e.g., Hg) in polar bears from western hemispheric populations indicate that future assessments are necessary, and future assessments need to include a complete, circumpolar population representation including those from the Russian Arctic.

Objectives

- Interpretation and publication of contaminant data on the spatial and temporal trends of legacy persistent organic pollutants (POPs) (i.e., PCBs and OC pesticides) and metals, and the novel and emerging POPs PBDEs, PFAs and $MeSO_2$-PCBs, determined in the tissues of polar bears (i.e., fat or liver) that were collected across the Canadian arctic in 2001-2002.

- Archive the remaining polar bear tissue samples that were collected as part of this project, at the national specimen bank at the NWRC/CWS in Ottawa.

- Provide information in a timely manner to each Inuit community participating in the study, on the levels and temporal trends of these contaminants in polar bear. This would include translation of documentation and deliverables into Inuktitut.

Introduction

The toxicological significance and spatial and temporal trends of organochlorine contaminants classified as persistent organic pollutants (POPs) and metals in Canadian arctic biota has been discussed in recent assessment reports and publications (Braune et al. 2005; de March et al. 1998; Muir et al. 1998, 2001; Norstrom et al. 2001; Fisk et al. 2005). The OCs in question includes PCB congeners, DDT and metabolites, chlordane compounds, HCH isomers, chlorobenzenes, toxaphene, and a number of miscellaneous compounds (e.g., mirex, endosulfan, etc.). Metals include Hg (organic and inorganic), Ag, As, Ba, Cd, Co, Cr, Cu, Ga, La, Li, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sr, Tl, U, V, and Zn.

In addition to these legacy POPs, there are a number of chlorinated, brominated and fluorinated contaminant classes that are environmentally novel and/or of emerging environmental relevance and concern from both a bioaccumulative and toxicological perspective, but have not been extensively assessed in Arctic biota, including the top marine predator the polar bear (*Ursus maritimus*). Polybrominated diphenyl ethers (PBDEs) are being reported in Arctic biota with increasing frequency, however the focus has generally been on Br_4 to Br_8 PBDE congeners, which largely comprise the PentaBDE and OctaBDE technical mixtures, and continue to be phased out from commercial use. Much less is known about in Arctic biota about higher brominated PBDEs, and especially BDE209, which is the major constituent of the unregulated DecaBDE technical mixture (Braune et al., 2005). Ikonomou et al. (2002) reported exponential increases of PBDEs in Canadian arctic biota measured in samples from 1981 to 2000. PBDEs have been shown to be increasing significantly in ringed seals at Holman (Addison and Ikonomou, 2000). PBDEs in ringed seals were undetectable in blubber samples form the early 1980's but were readily detectable by the late 1990s. Concentrations of total Br_2 to Br_7 PBDEs are in the low ng/g range in ringed seals (Muir et al. 1998; Addison and Ikonomou 2000). The profile of PBDE congeners in ringed seals is dominated by BDE47, 99 and 153/154, which suggests that more highly brominated congeners accumulate in polar bears. Wolkers et al. (2004) reported PBDEs in fat of Svalbard ringed seal, polar bear, and beluga whale. Very recently, Verreault et al. (2005a) reported on PBDEs in plasma of Svalbard glaucous gulls and polar bears. BDE209 was quantifiable in the gull plasma, but at low levels, whereas BDE209 was not detectable in polar bear. There does not exist a published, circumpolar trend study of PBDEs in polar bears.

Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are examples of perfluorinated acids (PFAs) that have recently been identified in liver and blood of polar bears and seals in the Arctic including some samples from Nunavut (Kannan et al. 2001). PFAs are classed as non-mutagenic carcinogens and may cause other effects in wildlife such as liver enlargement and reduction of male sex hormones. Polar bears from Alaska had the highest levels of PFOS of any mammals investigated (175-678 ng/g wet wt in liver) despite their distance from likely sources in urban areas. PFOS is therefore the individual organohalogen of the highest concentration in polar bears. De Silva and Mabury (2004) identified and quantified perfluorocarboxylate anions (PFCAs) in the liver of Canadian arctic and eastern Greenland polar bears. Many compounds in the PFA family were not reported in bears by Kannan et al. (2001) but may be equally bioaccumulative. These findings indicate that the spatial and temporal trends of PFAs, and especially PFOS and related perfluorosulfonates and perfluorocarboxylates, require further investigated in polar bears.

The occurrence of retained OH-PCB and persistent $MeSO_2$-PCB metabolites in wildlife tissues has been of bioaccumulative and toxicological concern from some time(Letcher et. al. 2000a). Regardless, in a limited but growing number of Arctic species (e.g., beluga, bowhead whale and glaucous gull) these novel OCs were, in many cases quite recently, reported in tissues from individuals collected in Alaska, Canada, East Greenland and Norway. In polar bears, $MeSO_2$-PCB and/or OH-PCBs (mainly in blood) have been reported in whole blood, plasma, fat and/or liver of East Greenland, central Canadian arctic and Svalbard polar bears (Letcher et al. 1995, 1996, 1998, 2005; Norstrom et al. 2001; Sandala et al. 2004; Sandau et al. 2000; Sandau 2001), plasma and eggs of Svalbard glaucous gulls (Verreault et al. 2005a, b), blubber and/or liver of Canadian beluga whales (Letcher et al. 2000b; McKinney et al. 2005) and the blubber of Alaskan bowhead whales (Hoekstra et al. 2003), and the blubber of Canadian ringed seal (Letcher et al. 1998). $MeSO_2$-PCB and 3-$MeSO_2$-*p,p'*-DDE have similar bioaccumulative properties as PCBs, and yet only one published study on circumpolar trends in polar bears (collected in 1989-1991) is known, which was on single fat pools for bears from ten Canadian, one East Greenland and one Alaskan population (Letcher et al., 1995).

The last study that examined spatial trends of metals in Canadian polar bears was carried out in 1982 and 1984 (Norstrom et al. 1986, Braune et al. 1991). These studies showed that the levels of many metals, including Cd, Hg and Se varied between different regions of the Canadian Arctic. For example, polar bears collected from the western Canadian Arctic had lower concentrations of Cd but higher concentrations of Hg and Se than those collected from other regions (Braune et al. 2001). In light of the evidence of increasing Hg concentration in Arctic biota and the lack of temporal trend metal data for polar bears there is a need to assess the current levels of metals.

Although levels of OCs were monitored in western Hudson Bay throughout the 1990s there has been no survey of contaminant levels throughout Canada since the late 1980s and early 1990s (Norstrom et al., 1998). Norstrom (2001) measured these contaminants in fat biopsy samples from western Hudson Bay polar bear for every year between 1991 and 1999, except 1996. It was reported for example, that there was no significant decline in total chlordane, total DDT, dieldrin and β-HCH. The rationale for the present circumpolar trend study was based on the need to assess the current spatial trends of legacy (PCBs and OC pesticides) and novel (and understudied) polyhalogenated contaminants in polar bears. For OCs and PCBs, the goal was also to determine if temporal trends of contaminants observed in Hudson Bay polar bears are similar to trends observed in other parts of the Canadian Arctic. This project is part of a larger study on the circumpolar levels of OCs in polar bears that includes samples collected in East Greenland and Svalbard. Samples of liver, fat and muscle were collected from most harvested polar bears during the 2001-2002 season.

Activities

In 2004-2005

This is an ongoing multi-year NCP project which began in 2001. As reported in a 2002-2003 NCP final report, the collection of polar bear samples during the 2001-2002 hunting season was completed, and female polar bears between the ages of 5 and 15 years were selected for the study. Chemical analysis of samples began in April / May of 2002 with the completion of all chemical analyses in 2003. We measured a suite of contaminants (organic and metals) in the fat or liver of polar bears from five Canadian Arctic regions as well as Alaska, East Greenland and Svalbard to assess spatial and temporal contaminant trends. These locations were chosen based on the variability of OC concentrations observed in polar bear populations from the 1980s and early 1990s (Norstrom et al. 1998). As summarized in the 2002-2003 NCP report, the analysis of fat or liver for PCBs, OC pesticides (DDTs, chlordanes, HCHs, CBzs, etc.), $MeSO_2$-PCBs/DDEs, perfluorinated compounds, PBDEs and metals (Hg plus 24 other elements) were completed, and actual data was summarized. In the 2004-2005 period, essentially all of the contaminant data collected has now been compiled and interpreted, and has or is in the process of being disseminated in peer-reviewed, scientific publications. The present findings have also been extensively presented at numerous scientific conferences and workshops. In the original proposal for 2004-2005, we had predicted 4 or 5 manuscripts would be submitted for publication in peer-reviewed scientific journals. We have met these goals. References to publications based on the finding from this study are indicated in the results section.

PCB and OC pesticide data were presented in part at the NCP Workshop held in Sept. 2004 in White Rock, B.C. The metal and PFA results were presented at the Society for Environmental Toxicology and Chemistry (SETAC) meeting in Portland, Oregon, U.S.A. in Nov. 2004. The

PBDE results were present at the SETAC-Europe conference in Prague, Czech Republic in May. 2004. The following is a list of conference and workshop presentations made in 2004-2005.

Remaining polar bear tissues are presently archived at NWRC and NWRI. All freezers are set at least at -20°C, all with individual temperature monitoring and alarms. At NWRC and NWRI there exists the expertise and facilities to properly process and maintain the samples.

This project complements a number of Arctic research initiatives of the project leaders and team members, but in particular that of Muir and Letcher on the dynamic and effect correlations of contaminants in Danish/Greenland polar bears with collaborators (Drs, R. Dietz, F.F. Riget, C. Sonne and M. Kirkegaard) at the Department of Arctic Environment, National Environmental Research Institute, Roskilde, Denmark. Nine papers have be published or submitted for publication based on the results of this research and collaboration (Dietz et al. 2004, 2005; Kirkegaard et al. 2005; Smithwick et al., 2005a; Sonne et al. 2004, 2005a, b, c, d).

Results

PCBs, OC pesticides and $MeSO_2$-PCBs/DDEs (Verreault et al. 2005c)

The East Greenland and Svalbard populations of polar bears were distinguished by higher proportions of DDT - related compounds, nonachlors, oxychlordane, and higher-chlorinated and persistent PCB congeners (hepta- to nona-chlorinated). Conversely, Alaska, the westernmost population of the North American Arctic, was characterized by higher proportions of relatively volatile compounds such as HCHs and PnCBz, lower-chlorinated PCB congeners (tri- to pentachlorinated), and lower proportions of oxychlordane. Geometric mean ΣHCH concentrations were highest in Alaska male polar bear fat samples (593 ng×g^{-1} lipid weight (lw)), ΣDDT concentration were highest in East Greenland female samples (309 ng×g^{-1} lw), and Σ_{42}PCB (5,972 ng×g^{-1} lw) and $\Sigma MeSO_2$-PCB (198 ng×g^{-1} lw) concentrations were highest in female samples collected from Svalbard (Figure 1). The distribution of Óchlordane-related compounds (ΣCHL), ΣCBz, mirex, and dieldrin was relatively uniform among the populations of polar bears investigated.

Perfluorinated compounds (Smithwick et al., 2005b, c)

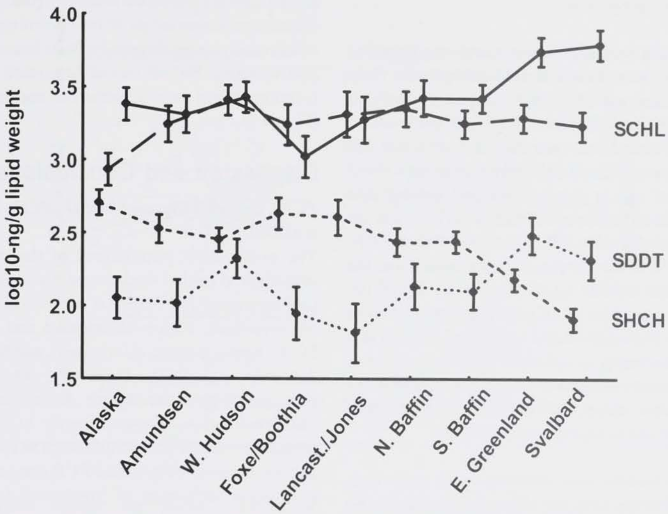
Concentrations of perfluoroalkyl substances (PFAs) were determined in liver tissues of polar bears (*Ursus maritimus*) from five locations in the North American Arctic and two locations in the European Arctic. PFOS, PFHxS, and PFCAs with chain lengths C_8 through C_{13} were detected at concentrations above the MDL at all locations. PFOSA was not detected in the NWT samples, and PFTA was not detected in the Svalbard samples. PFPA was only detected above the method detection limit (MDL) in the Greenland and Svalbard samples.

PFOS was the major contaminant group in all samples, having concentrations at least a factor of ten higher than all other PFAs. There was a significant geographic trend for PFOS, with South Hudson Bay and East Greenland having significantly greater concentrations than Svalbard, High Arctic, and western NWT, and all having significantly greater concentrations ($P<0.05$) than Chukchi Sea samples. The greater concentrations measured in bears from East Greenland and the South Hudson Bay are possibly due to proximity to sources in Europe and Eastern North America, respectively. Only blood plasma was available from the Svalbard bears, and the PFOS concentrations were lower compared to the East Greenland bears. However, the "plasma to liver conversion factor" used on the Svalbard samples was based on the Alaskan samples, and it is highly uncertain whether we can extrapolate to these to other regions.

PFUA (excepting NWT), PFDoA, PFTriA, and PFPA (the only PFPA values above MDL were measured in bears from Svalbard and Greenland) showed similar geographic trends to PFOS, while the remaining PFAs did not show distinguishable geographic trends. PFOS and PFCAs with chain lengths greater than 10 carbons had similar geographic distributions, while PFOA, PFNA, PFDA, PFHxS, and PFOSA are more evenly distributed, or showed higher concentrations in the Western North American Arctic.

In a related study, archived polar bear liver tissue samples from two geographic locations in the North American Arctic, collected from 1972 to 2002 were analysed for the same suite of PFAs as the spatial study (Smithwick et al. 2005c). The eastern group, taken from the vicinity of Northern Baffin Island, Canada comprised 31 samples, and the western group, from the vicinity of Barrow, Alaska, USA, 27 samples. Samples were analyzed for perfluorocarboxylic acids from carbon chain length C8 to C15, perfluorohexane sulfonate, PFOS, the neutral precursor perfluorooctane sulfonamide (PFOSA), as well as 8:2 and 10:2 fluorotelomer acids, and their α, β unsaturated acid counterparts. Concentrations of PFOS and perfluorocarboxylic acids with carbon chain lengths from C_9 to C_{11} showed an exponential increase between 1972 and 2002 at both locations (Figure 2).

Figure 1. Age-adjusted geometric mean concentrations of SPCB and sum of each OC class (plotted with 95% confidence intervals, vertical bars) in polar bear fat in populations in order of longitude.



PBDEs (Muir et al. 2005)

Adipose fat samples were collected by subsistence hunters in the Ittoqqortoormiit/Scoresby Sound area in central East Greenland and in six locations in the Canadian arctic (Amundsen Gulf, Lancaster Sound, Foxe Basin/ Boothia Peninsula, Northeast- and Southeast Baffin Island, Western Hudson Bay). Fat biopsy samples were collected in Svalbard as well as in Southern Beaufort Sea/ Chukchi/Bering Sea regions of northwestern Alaska. PBDEs were isolated along with other OCs and quantified by GC- negative ion low resolution mass spectrometry. Sample extracts from Canadian arctic and East Greenland polar bears were screened for 33 PBDEs (dibromo- to heptabromo BDEs) as well as BDE209. However, only 4 PBDEs (47, 99, 100, and 153) were consistently identified. Samples from East Greenland and Svalbard were screened for BDE209 but it was not detected in any samples (<0.05 ng·g^{-1}). Also identified was total (α) HBCD, which was present in100% of the East Greenland samples that were analysed (11 of 44 females), 100% of Svalbard samples, and 13% of Bering-Chukchi samples.

Geometric mean concentrations of ΣPBDE ranged from 7.6 in the Bering-Chukchi females to 70 ng·g^{-1} lw in East Greenland. BDE47 was the most prominent individual congener with geometric means ranging from 7.6 ng·g^{-1} lw in the Lancaster/Jones Sound group to 50.9 ng·g^{-1} lw in East Greenland females. BDE153 was the next most prominent congener ranging from 0.03 ng·g^{-1} lw in Bering-Chukchi animals to 12 ng·g^{-1} lw in East Greenland bears. BDE99 was more prominent than BDE153 in western North American arctic bears (Amundsen Gulf and Bering-Chukchi). BDE100 was generally present at lower concentrations that the other 3 congeners. Total-HBCD was determined only in a subsample of the Greenland bears (N=11) and in all Bering-Chukchi and Svalbard samples. Total-HBCD geometric mean concentrations were higher than that of BDE47 in the Svalbard and East Greenland samples indicating that it may be the most significant brominated contaminant in polar bears.

Metals (Fisk et al., in preparation)

Total mercury (Hg) in liver and muscle tissue (NLET Method 02-2802) was analysed by cold vapour atomic absorption spectrometry (CVAAS). Analyses of 22 metals in liver and muscle samples (NLET Method 02-2705), were analysed by inductively coupled plasma-Sector Field spectrometry (ICP-SFMS), with 20 metals analysed at low resolution: Ag, Ba, Cd, Co, Cr, Cu, Ga, La, Li, Mn, Mo, Ni, Pb, Rb, Sb, Sr, Tl, U, V and Zn, and the rest at high resolution: As and Se. The instrumental detection limits (IDLs) for most metals were 0.001 i $g \cdot g^{-1}$,wet weight (ww) except for Sr (0.05 $\mu g \cdot g^{-1}$ ww), Pt and Sb (0.01 $\mu g \cdot g^{-1}$ ww), and Pd and Li (0.1 $\mu g \cdot g^{-1}$ ww).

For statistical analysis metal concentrations were log transformed to reduce skewness and heterogeneity. Only multivariate ordination (Principal component analyses PCA, CANOCO 4.5 for Windows, Ter Braak and Šmilauer 1998) were performed both on metal concentrations and metal pattern ([metal]/[Σmetals]) and for all bears without consideration of age or gender (age and gender data lacking for 30 Canadian bears). ΣMetals only include the metals quantified above the IDL. Elements below the IDL in more than 30% of the samples were excluded from the PCA analysis and include Ag, Cr, La, Pt, U, Tl and Pd. Analysis of a larger data set of metals in some of these bears and bears from Alaska and Greenland showed that gender was only found to influence Zn concentrations, an essential element but age was a significant variable for Hg and Cd concentrations, and hence unvariate statistics were not performed to assess spatial trends.

More than 20 elements were detected in the polar bear livers; and for brevity only the elements As, Cd, Pb, Se and Hg are presented (Table 1). These elements were chosen based on concern about their toxicity and because they were listed as elements of concern by AMAP (de March et al., 1998). The PCA assigns scores to the individual samples that are linear combinations of 16 metals, and are presented relative to their ordination axes. Metals are presented as arrows pointing to the direction of increasing value (Figure 3). Polar bears from Sanikilauq and southern Baffin Island separated from the other locations based on concentrations and patterns of metals (Figure 3).

Discussion and Conclusions

PCBs, OC pesticides and MeSO$_2$-PCBs/DDEs (Verreault et al. 2005c)

The easternmost populations of the polar bear range investigated in this study were distinguished by higher proportions of DDT-related compounds, nonachlor III, oxychlordane, higher-chlorinated and more persistent PCBs (hepta- to nona-chlorinated), and MeSO$_2$-PCBs and 3-MeSO$_2$-*p,p'*-DDE. Inversely, western polar bear populations of the North American Arctic were characterized by a significantly higher exposure to relatively volatile compounds such as HCHs and PnCBz, and tri- to penta-chlorinated PCB congeners, suggesting a stronger influence of Southeast Asian and North

Figure 2. Time trends of 4 perfluorinated compounds in archived polar bear liver samples from the North Baffin Bay region (Smithwick et al. 2005c).

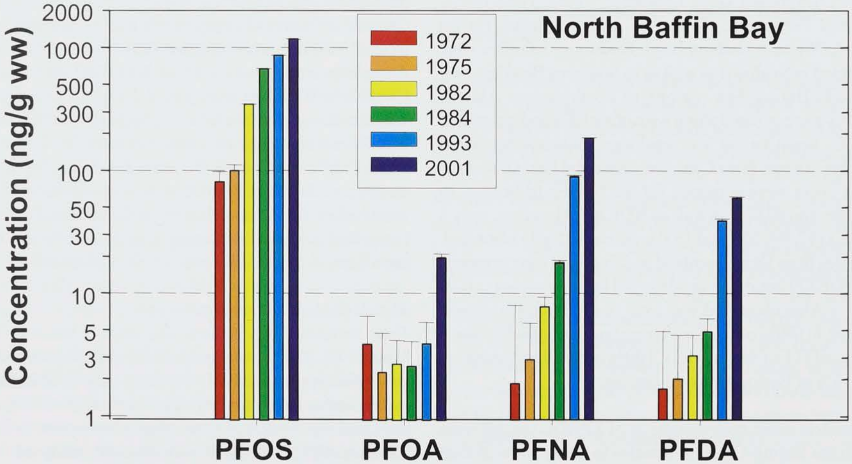
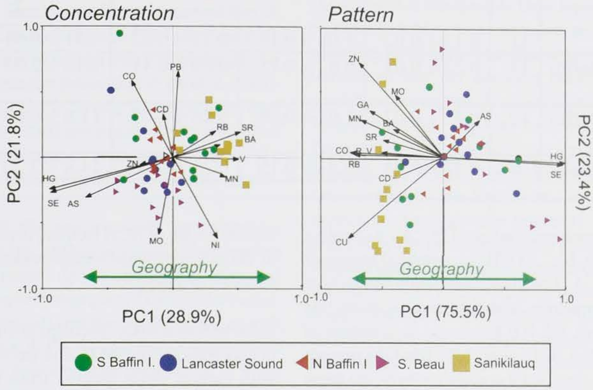


Figure 3: Biplot of polar bear liver scores on the principal components (PC) extracted by principal component analyses (PCA), and the metals' loadings on the PCs for metal concentrations (log $\mu g\ g^{-1}$ ww) and pattern ([metal]/[Σmetals]).



American-sourced inputs for these classes of contaminants.

With respect to adipose tissue samples collected during 1989-1993 from comparable female polar bear populations (Letcher et al. 1995; Norstrom et al. 1998), there was a general decrease for the age-adjusted mean concentrations of ΣCHL, *p,p'*-DDE, Σ_{42}PCB, ΣMeSO$_2$-PCB, and 3-MeSO$_2$-*p,p'*-DDE for the present 1996-2002 female polar bear samples. However, concentrations of dieldrin were unchanged relative to those reported for these female polar bear populations sampled during 1989-1993. Temporal comparisons showed great consistency with temporal trends observed for Svalbard polar bear plasma concentrations of CB153 throughout the 1990s, and ΣCHL, ΣPCB, and dieldrin concentrations measured in East Greenland female polar bear adipose tissue collected during 1999-2001 relative to samples from 1990 (Dietz et al. 2004).

Compared to Norstrom (2001), the Western Hudson Bay female polar bear fat samples of the present assessment displayed trends that were consistent with the apparent non-decreasing trends of ΣCHL, β-HCH, ΣHCH, and dieldrin concentrations over the last 10 to 12 years, and the apparent declining trend for ΣPCB. In contradiction with results by Norstrom (2001), who reported a downward trend for α-HCH and ΣCBz, and no significant change for ΣDDT (mostly *p,p'*-DDE), the concentrations of α-HCH and ÓCBz in the present 2001-2002 survey were elevated compared to the last measurements reported for 1997-1999. For ΣDDT, the present mean concentration in Western Hudson Bay was notably lower than last measured in fat samples collected in 1999.

As a result of their relatively high degree of contamination, East Greenland and Svalbard polar bears are at higher health risk of contaminant exposure among Arctic and Subarctic populations. In addition to continued biomonitoring, further research on health and population status is needed to evaluate the impact from chronic exposure of polar bear populations to CHCs and their metabolites.

Perfluorinated compounds (Smithwick et al., 2005b, c)
Statistically significant correlations were found among concentrations of some PFCAs ($r2 > 0.5$; $P < 0.05$) within location, and the strongest correlation was, in general, between PFDA and PFUA. These correlations suggested a common source within each location. Concentrations of PFOS, FOSA, PFHxS and PFOA were not correlated with any other PFA. Atmospheric degradation experiments by Ellis *et al.* (11) indicated that fluorotelomer alcohols (FTOHs) degrade through reaction with an hydroxyl

Table 1: Concentrations (mean ± 1 SE, ì g·g^{-1} ww) of five metals in the livers of polar bears collected in the Canadian Arctic in 2001-2002 (Figure 3).

Region	N	As	Cd	Pb	Se	Hg
Southern Beaufort Sea	11	0.46 ± 0.07	0.35 ± 0.06	0.06 ± 0.01	21.8 ± 6.0	62.5 ± 16.0
Sanikiluaq	11	0.17 ± 0.02	1.06 ± 0.15	0.12 ± 0.02	3.31 ± 0.61	7.34 ± 1.58
Southern Baffin Island	13	0.22 ± 0.03	0.62 ± 0.11	0.69 ± 0.41	9.16 ± 2.35	28.4 ± 8.47
Northern Baffin Island	12	0.37 ± 0.02	1.02 ± 0.08	0.26 ± 0.05	11.6 ± 0.63	32.5 ± 2.71
Lancaster Sound	13	0.32 ± 0.03	0.87 ± 0.15	0.23 ± 0.06	14.4 ± 2.20	45.2 ± 7.78

radical to yield a homologous series of PFCAs. According to Ellis et al. (2005), 10:2 FTOH is a potential source of both PFDA and PFUA. The strong correlation shown here suggests a common source, and therefore supports this hypothesis. However, 8:2 FTOH should be a source of both PFOA and PFNA (Ellis et al. 2005), but the present study did not find a significant correlation between these two contaminants. Metabolism of 8:2 FTOH to PFOA has been documented in rats and mixed microbial systems and could be a source in the marine food web. Lack of bioaccumulation of PFOA or additional sources of PFNA could further obscure this relationship.

To address the question of sources at different locations, the ratios of adjacent chain length PFA concentrations were calculated, and the arithmetic means and 95% confidence intervals determined. Chukchi Sea samples had a much higher proportion of PFNA to PFOS than in the eastern sampling locations. Similar relationships existed between PFUA to PFDA, PFDA to PFNA, and PFDoA to PFUA. The proportion of PFNA was much greater than PFOA in the Chukchi Sea samples, but lower in the eastern sampling areas. PFTriA and PFDoA were present at similar concentrations within all locations. The resulting patterns could be explained by two different geographic sources of PFAs for the eastern and western locations. The atmospheric processes or chemistry are unlikely to be different between the sampling locations. eastern Greenland would be attributable to transport from Western Europe and eastern North America, while the western North American Arctic would be influenced mainly by East Asian sources (31, 32). No regional emission data are available at this time, but similar geographical source patterns have been presented for PCBs (Verreault et al. 2005c) and PBDEs (Muir et al. 2005). PFHxS and PFNA had a geographic distribution more similar to that of HCH isomers in polar bears (Verreault et al. 2005c), which has been previously shown to be mainly of Asian origin.

In the temporal study described in Smithwick et al. (2005c), concentrations of PFOS and perfluorocarboxylic acids with carbon chain lengths from C_9 to C_{11} showed an exponential increase between 1972 and 2002 at both locations (Figure 2). Doubling times ranged from 3.6 ± 0.9 years for perfluorononanoic acid in the eastern group, to 13.1 ± 4.0 years for PFOS in the western group. PFOSA showed decreasing concentration over time at both locations, while the remaining PFAs showed no significant trends or were not detected in any sample. We concluded that the doubling times determined for these contaminants are short enough to preclude oceanic transport as the major pathway to the Arctic from mid-latitudes.

PBDEs (Muir et al. 2005)

PBDEs have previously been detected in polar bears from Svalbard (Wolkers et al., 2004; Verreault et al., 2005b), but have not been reported elsewhere in the Arctic and geographical trends are unknown. PBDEs were detected in all 204 fat samples with BDE congeners 47, 99 and 153 predominating. Highest mean concentrations of PBDEs were found in Svalbard, East Greenland, Southeast Baffin, and Western Hudson Bay (36-73 ng·g^{-1} lw). Lowest ΣPBDE concentrations were found in the samples from northwest Alaska, Amundsen Gulf and Lancaster Sound (11-17 ng·g^{-1} lw). The geographic trend for PBDE concentrations parallels that of PCBs and PFAs and points to eastern North America and western Europe as source regions.

Metals (Fisk et al. in preparation)
As top Arctic predator, the polar bear is exposed to a wide range of metals and can accumulate high concentrations of mercury due to the process of biomagnification. Sanikilauq and southern Baffin Island bears had lower concentrations and relative proportions of Hg and Se but higher concentrations and proportions of Rb, Sr, Ba and Mn. Similar trend were observed for Cd, Se and Hg in polar bears in 1982 and 1984 (Braune et al. 1991). Levels of mercury in beluga livers were also higher in animals from the Beaufort Sea region (Fisk et al. 2003). Concentrations of As, Cd, Pb, Se and Hg in the polar bear livers collected in 2001-2002 are similar to those reported in 1982 and 1984 (Norstrom et al. 1986; Braune et al. 1991). Age was found to influence Hg and Cd concentrations.

In conclusion overall, the present study on polar bear samples collected in 2001-2002 demonstrated that ongoing assessments are warranted on the spatial and temporal trends of legacy and novel (emerging) POPs (chlorinated, brominated and fluorinated) and their metabolites, as well as certain metals (As, Cd, Pb, Se and Hg). Clearly there are non-legacy POPs that are bioaccumulative in bears from circumpolar populations, and vary as a function of spatial and temporal factors. These non-legacy POPs are potentially biomagnifying in polar bears and their food webs. The unique trend findings for, e.g., PFAs, PBDEs and $MeSO_2$-PCBs indicate the necessity for continued vigilance in determining and assessing other chlorinated, brominated and fluorinated organic contaminants in the Arctic environment. We recommend and are planning on a trend re-assessment in polar bears in the near future (2006-2007), which will include samples from polar bears originating from Russian populations. The present and new collaborators and partners are being approached in the planning of an expanded re-assessment on POP and metal trends.

Expected Project Completion Date

Publications resulting from this project are expected to be submitted or published by December 2005 at the latest. The scientific publications will be made available to, community representatives and the NWT and Nunavut Contaminants Committee once all scientific publications are finalized, which is expected by the end of summer 2005. Results will be provided to the participating communities in the form of posters, which address the issue of new contaminants in wildlife generally. We will work closely with Inuit Tapiriit Kanatami to formulate an appropriate poster and a short report that includes English and Inuktituk.

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We must also thank all the participating and contributing agencies and individuals in the U.S., Greenland, Denmark and Norway. Without their contributions, it would not have been possible to expand the spatial trend assessment into a western hemispheric context, i.e., including bears from Canadian, Alaskan, East Greenland and Norwegian (Svalbard) populations. These individual include Drs. Rune Dietz, Frank Riget, Christian Sonne and Maja Kirkegaard at the Department of Arctic Environment, National Environmental Research Institute, Department of Arctic Environment, Denmark, and Dr. Erik Born at the Greenland Institute of Natural Resources, Nuuk, Greenland, Denmark. In Norway we thank Drs. Geir Gabrielsen and Andrew Derocher (now at the University of Alberta, Edmonton, Canada) at the Norwegian Polar Institute, Tromsø, Norway. We also acknowledge the invaluable involvement of Mr. Jonathan Verreault in the writing of the circumpolar trends paper on PCBs, OC pesticides and $MeSO_2$-PCBs (Verreault et al., 2005c). In Alaska we thank Dr. Thomas Evans at the United States Fish and Wildlife Service, Anchorage, Alaska, U.S.A. Collection and analysis of samples from Alaska, East Greenland and Svalbard received financial support from the U.S. Fish and Wildlife Service, the Danish Co-operation for Environment in the Arctic (DANCEA), and the Norwegian Pollution Control Authority, respectively.

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Digital Arctic for Environmental Study (DAFES): A Continuous Project

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Abstract

The project "Digital Arctic for Environmental Study (**DAFES**)", a project started at the fiscal year 2003/2004, is to integrate all arctic data produced from the Northern Contaminants Program (NCP), the Arctic Monitoring and Assessment Programme (AMAP), and from other publications into one Geographic Information System (GIS) based database. In the fiscal year 2004/2005, all available pollutants data from AMAP assessment reports (AMAP 1998 and 2002) and data from other publications have been collected, carefully processed, and integrated into a standard format. This information was then placed onto a grid system according to its longitude and latitude location using GIS software. The sources for each data have been clearly cited. To date, in the DAFES database, contaminant concentrations are available for over 100 types of POP compounds, 8 heavy metals, and 25 radionuclides generated between 1980 and 2002. There are more than 27,000 records for POPs, almost 19,000 for heavy metals, and more than 2,000 records for radionuclides. Some datasets assembled for this project have been used by national and international institutes.

Key Messages

- All available pollutants data from AMAP assessment reports (AMAP 1998 and 2002) and data from other publications have been collected, and stored in the **DAFES** system. The sources for each data have been clearly cited. The data in the system can be easily searched, queried, downloaded, and displayed using a GIS tool.

- Contaminant concentrations are available for over 100 types of POP compounds, 8 heavy metals, and 25 radionuclides generated between 1980 and 2002.

- There are more than 27,000 records for POPs, almost 19,000 for heavy metals, and more than 2,000 records for radionuclides.

- Metal and radionuclide data from the most recent AMAP assessment Reports were not available when this report was finalized.

Objectives

- To bring as much arctic information as possible into one GIS based system to assist systematic and comprehensive arctic research. Since the arctic environment is a complex system the study of this system for different pollutants in different areas should not be isolated.

- To create a platform that brings public, the Aboriginal people in particular, the policy makers, and the scientists together, and through which communications among the different groups becomes more efficient and transparent.

- Software will be developed that includes relational database management and a GIS tool for visualizing the data. The GIS tool being developed does not include any commercial GIS software, thus the package can be used by any organization and individual at no cost.

Depth(m) – Depth of sea, river, or lake, in meters
Statistic – Method of statistic calculation
Type – Sample type
Layer – Number of layers
Length – Length of animal

Method – Method of obtaining concentration

- The platform created in this project can be modified for other purposes since this package does not include any commercial GIS software. For example, the new package can be used by northerners to develop future Arctic sampling plans and other purposes.

Introduction

Both the Northern Contaminants Program (NCP) and the Arctic Monitoring and Assessment Programme (AMAP) have been carried out for more than 10 years, and a huge set of data is available to the scientific community and public. These data, however, were published in the Annex Tables of the AMAP Reports, and are difficult to search, even by professional scientists. A new concept of "**Digital Arctic For Environmental Study (DAFES)**" is suggested to integrate all Arctic data produced from AMAP and NCP programs, and other programs under the Arctic Council, including inhabitant population, vegetation, land use, ice cover, temperature, along with the level of contamination by all pollutants in both biotic and abiotic environments in the Arctic, into one GIS based database. The data in the system can be easily searched, queried, downloaded, and then displayed using a GIS tool. The database will be created in such way that when one chooses any location in the Arctic, all available information related to that location will be displayed simultaneously, from the land cover to the concentration of pollutants. Specific information (contamination level in wildlife, for example) for a given time period can also be shown for the entire Arctic region.

According to the proposed schedule, a PC-based software package will be made available that includes: a powerful relational database management tool, a geographic information system (GIS) for displaying the data, and an interface linking the GIS AMAP grid system and the database together. This package will not include any commercial GIS software, thus the package can be used by any organization and individuals at no cost.

Activities

In 2004-2005

All available pollutants data from AMAP assessment reports (AMAP 1998 and 2002) and data from other publications have been collected, carefully processed, and integrated into a standard format. This information was then placed onto the AMAP grid system (see Report for the fiscal year 2003/2004) according to its longitude and latitude using GIS software. The sources for each data have been clearly cited. All data have been stored in MS • The platform created in this project can be modified for other purposes since this package does not include any commercial GIS software. For example, the new package can be used by northerners to develop future Arctic sampling plans and other purposes.

The following figures list some concentration datasets for some contaminants in various compartments with the AMAP Grid system:

Discussion and Conclusions

The project **DAFES** was started at the fiscal year 2003/2004. The main purpose of this project is to bring all arctic information produced from NCP and AMAP programs and other arctic programmes into one system. The GIS based and web-based database DAFES can be used as a powerful information source for integral and systematic arctic research, and also a convenient and sophisticated communication tool among aboriginal people, Arctic researchers, and policy makers. By using this system, people can query and search the data, discuss the data, and express their opinions very easily and efficiently. This system can also be made into different versions for different purposes. For example, an arctic education system can be produced from DAFES for the use in high school. It has been suggested that the GIS-database package developed in this project will be modified for the use in planning future Arctic sampling plans.

The datasets created in this project have been used by national and international institutes. For examples, Dr. Derek Muir's group from Environment Canada is using the crop and population datasets for their work on current use pesticides in a glacial snow cores from Svalbard, and Mr. Geir Wing Gabrielsen from the Norwegian Polar Institute used the map of Arctic crop rate in a popular science arctic written in Norwegian.

Project Completion Date

March 31, 2005

Figure 1. Concentrations of α-HCH (ng/L) in arctic waters.

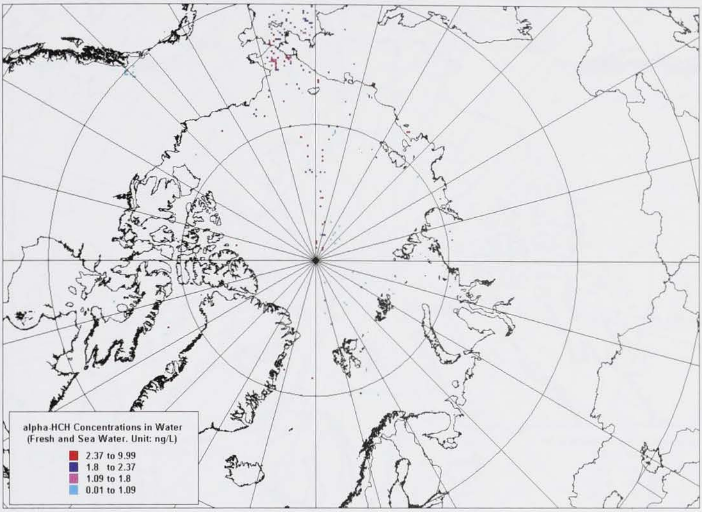


Figure 2. Concentrations of $\sum$DDT (ng/g) in Arctic sediments.

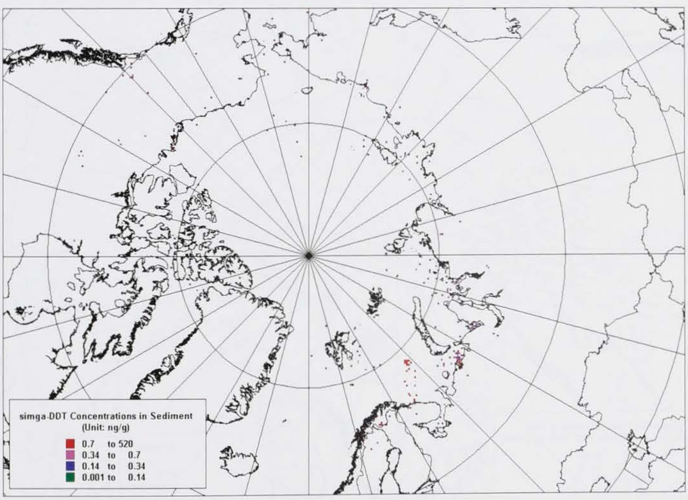


Figure 3. Concentrations of γ-HCH (pg/m^3) in Arctic air.

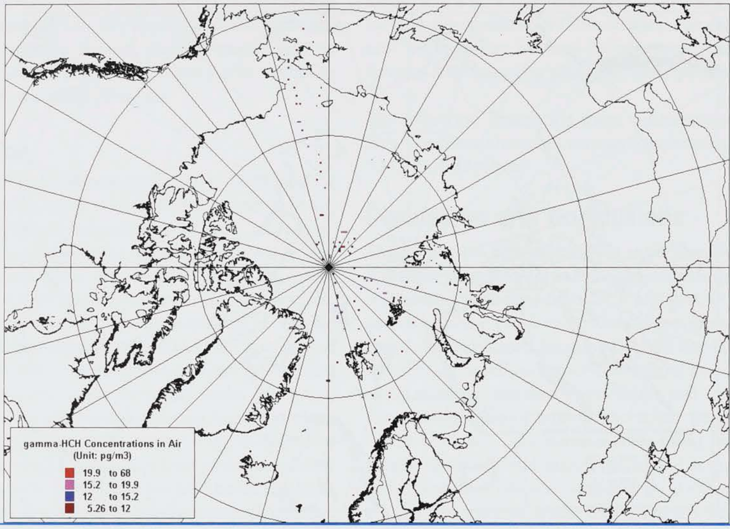


Figure 4. Concentrations of ΣHCH (ng/g ww) in arctic fishes.

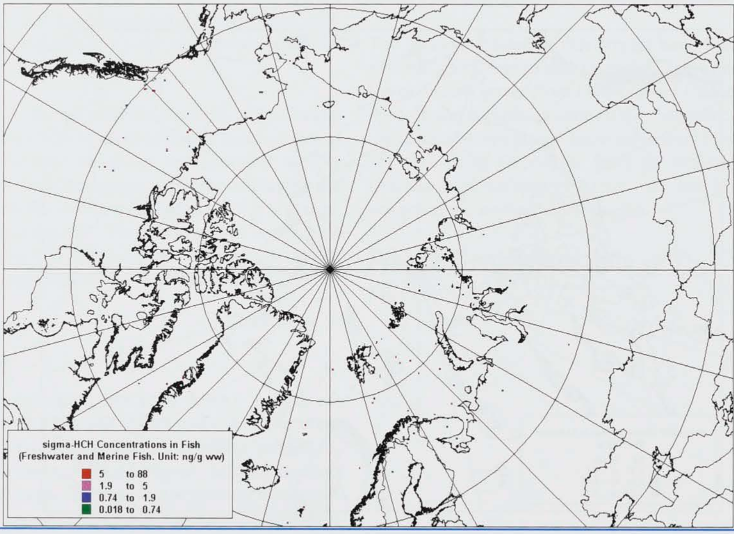


Figure 5. Copper concentrations in arctic sediments.

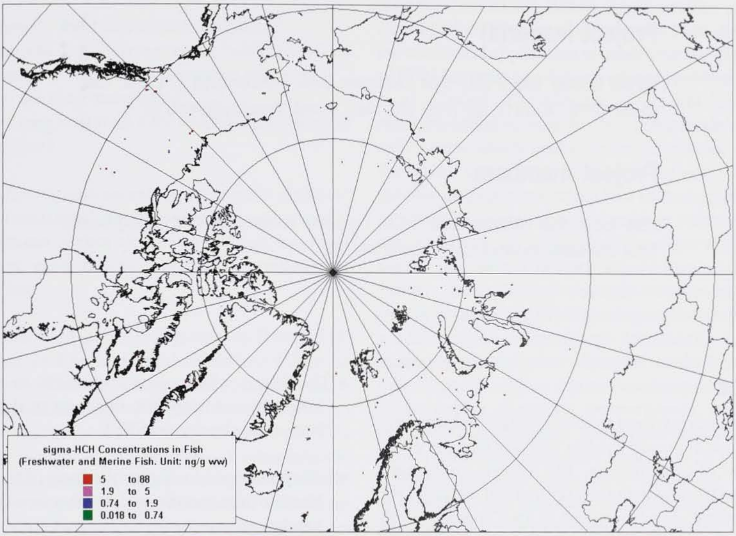
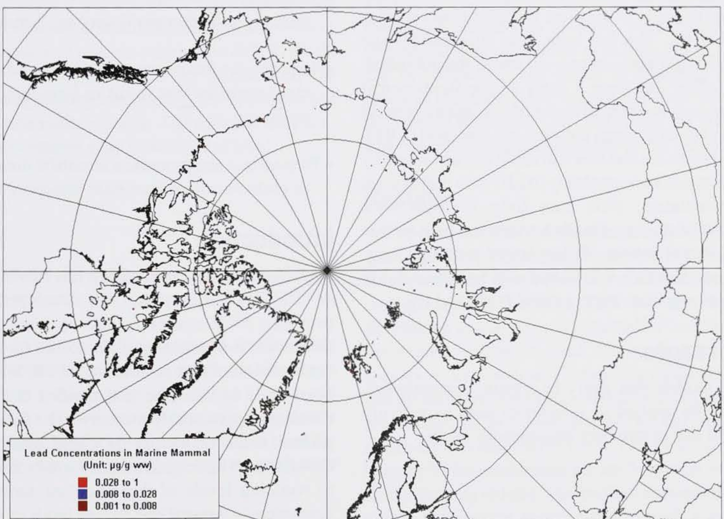


Figure 6. Lead concentrations in arctic marine mammals.



Contributing to International Controls on POPs and Mercury

Project leader(s)

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Abstract

This project has involved the continuing development of mass balance computer models that describe the global distribution of contaminants. The focus is on transport of persistent organic pollutants (POPs) and mercury (Hg) from temperate climatic regions to the Canadian North. The general objective has been to provide scientific modelling information that will contribute to international controls on these substances. The principal effort in 2004-2005 has been to devise a method by which the existing BETR-World model, which was designed for POPs, can be modified to apply to the more complex multi-species chemistry of Hg. This has been done successfully and the new technique has been peer-reviewed and published. A further effort has been a study of the fundamental chemical and environmental factors that cause a chemical to be subject to long-range atmospheric transport (LRT). Early indications are that this will result in a technique by which a chemical's susceptibility to LRT on a global scale can be evaluated. This may help identify new contaminants of concern. Finally a review has been written for the UK Royal Society of Chemistry concerning long-range transport, which it is hoped will be influential in international negotiations to control POPs and Hg.

Key Messages

- Existing models that apply to organic contaminants, can now be applied to substances such as mercury provided that certain key assumptions apply.
- The factors which cause a chemical to be subject to long-range atmospheric transport to the North have been more clearly identified.
- Efforts continue to discuss the issue of transport to the North in the scientific media with a view to influencing foreign governments to support local controls on contaminant releases.

Objectives

- To modify the existing BETR-World model to apply to mercury and other multi-species chemicals.
- To probe the fundamental chemical and environmental characteristics that result in long-range atmospheric transport.
- To maintain and promote a scientific dialog on the issue of global-scale contaminant transport to the North.

Introduction

A global model of contaminant fate (the Berkeley-Trent, or "BETR"-World model) was developed as a result of previous NCP contracts and applied to an organic substance, α-hexachlorocyclohexane (α-HCH). In this continuation of that project the BETR-World model has been used to describe and predict the fate of other chemicals, particularly mercury. The focus has been on global scale transport of chemicals to the arctic ecosystem. It is recognized that the only feasible approach to reducing levels of these contaminants in the arctic ecosystem in general and human foods in particular, is to reduce emissions from all global sources and allow these levels to fall by natural removal processes. Encouraging such reductions internationally requires information such as:

- Where do the contaminants originate?
- What are the differences in "efficiency" of transport from various regions to the arctic?
- How are they transported?
- How long will it take for reductions to become effective?

Answers to these questions enhance Canada's ability to influence international negotiations and agreements. These answers can be provided, at least in part, by global scale dynamic mass balance models of contaminant sources and fate.

This project has been undertaken jointly by DMER Ltd. and the Canadian Environmental Modelling Centre at Trent University. The aim is to generate scientific results and refereed publications which will be influential to international negotiations to reduce emissions of POPs and mercury. Achieving this objective is accomplished by extending the capability of the existing BETR-World single-species model of contaminant fate to address chemicals which co-exist as multiple species. The next step is to apply this multi-species model to historic, current and future scenarios of natural and anthropogenic mercury emissions.

As a supplement to this work on model development and application an exploration was undertaken of the methods by which the results of models such as the BETR-World model can be conveyed to the lay public and the international regulatory community in a simple but scientifically defensible manner. The ultimate aim is to influence policy-makers at an international level.

Activities

In 2004-2005

Two stages of model development were completed in the duration of the project.

First, the multi-species modelling approach for chemicals with constant species concentration ratios was developed and a paper was published in September (Toose and Mackay, 2004). As a result, we are now able to apply the BETR-World global model to substances such as mercury as well as to conventional persistent organic pollutants (POPs).

Second, the multi-species approach developed in the above publication was integrated into the robust framework of the existing BETR-World single-species model. The BETR-World single-species model was developed under a previous contract from the NCP and the successful application to modelling the global fate of α-HCH has been detailed in a refereed publication, Toose et al. (2004). The process of integration required reprogramming sections of the original model to call new subroutines which enable the multi-species version of the model to run in an automated fashion. The model automatically parameterizes how each chemical species, as well as the overall chemical behaves within each region and how they are transported between regions. The model can be run in both steady-state and dynamic modes. The dynamic or unsteady-state model allows the model to estimate the time dependent conditions as contamination increases or decreases. It involves numerical integration in which the results from previous time-steps are used as inputs for subsequent ones, while allowing for changing temperatures, atmospheric chemistry and emissions. The simpler steady-state model shows dominant pathways under which chemical is transported and deposited assuming both the environment and emissions are unchanging. It has the advantage that it is much easier to interpret.

An important issue from the perspective of arctic contamination is the "arctic sunrise" effect during which, in spring, there is increased deposition of ionic mercury. This is believed to be the result of conversion of the elemental mercury to divalent mercury catalysed by organo-halogen substances of marine origin. This effect can be included in the model by adjusting the species ratios at this time. This has not yet been done because the present emphasis is on confirming the mass balance and ensuring that parameter values are reasonable.

Results

We have successfully developed a method by which the existing BETR-World model (which is designed to treat a single chemical species) can be modified to apply to the multiple species mercury. This was accomplished by developing a novel "species multiplier" method in which the existing model is used and applied to one of the species, a "key" species (in this case elemental mercury) and the fluxes of other species (ionic and organic mercury) are quantified as a multiple of the key species. This multiplier can range form 10^{-6} to 10^{6}. This enables a mass balance to be established for each species individually and all species in total. The method requires that the user define the species proportions in each medium, thus circumventing the need to define inter-species conversion rates.

A paper describing the principles underlying this approach has been published in the refereed scientific literature in Environmental Science and Technology (Toose and Mackay, 2004). The multi-species model was then applied in a preliminary fashion to mercury fate on a global scale and promising results were obtained. The model was used to estimate "transfer efficiencies" from various regions to the arctic.

A study was also undertaken to investigate the fundamental determinants of global scale long range atmospheric transport (LRAT) as quantified by Eulerian or multi-box models. The aims are to provide a scientific explanation of the potential that different substances may have for LRAT and provide a method which will be sufficiently simple that it can be explained to a lay audience. It is hoped that this simple and approximate method will be intuitively credible and thus serve to convince participants in international negotiations that LRAT is a real and quantifiable phenomenon and that modelling and monitoring data are mutually supportive. The intention is to develop this concept further in a subsequent study and publish it in a forum that will influence international opinions and activities.

Discussion and Conclusions

Now that we have available a global model applicable to both POPs and mercury, the next task is clearly to apply the models to other existing and "new" substances and seek to establish the model's credibility, or validity. We see the need for both steady-state and dynamic versions of the model. A major task will be compiling information from monitoring programs and emission estimates. The inclusion of the "arctic sunrise" effect for mercury is also required.

A key effort will be to compare how the model quantifies time-trend data and how these "predictions" compare with monitoring data obtained by MSC with NCP support.

We conclude that there is a compelling incentive for Canada to continue to address the issue of the chemical and environmental determinants of long-range atmospheric transport – especially to devise simple and credible methods for identifying new chemicals of concern and to confirm the consistency between these models and the invaluable monitoring data obtained by the Northern Contaminants Program.

Expected Project Completion Date

This modelling work is viewed as continuing indefinitely as long as it proves to be useful to Canadian representatives as a contribution to international negotiations.

Acknowledgements

It is a pleasure to acknowledge the primary support from NCP, but we also gratefully acknowledge additional support Natural Sciences and Engineering Research Council of Canada (NSERC) and the consortium of chemical companies that support research at the Canadian Environmental Modelling Centre. The invaluable cooperation of other scientists, especially at MSC, NWRI, and the DIAND/NCP staff is greatly appreciated.

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Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic

Project leader(s)

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Abstract

Trends in concentrations of PCBs, DDT, and other persistent organic pollutants (POPs), in blubber of female ringed seals from four communities in Nunavut were assessed based on samples collected in 2004 combined with results from previous years. Significant declines in concentrations of ΣDDT (sum of DDT related compounds) were observed in female ringed seals from Arctic Bay, Resolute Bay and Gjoa Haven/Taloyoak (3-4% per year) and there was a shift to more recalcitrant residues, i.e. p,p'-DDE reflecting older "weathered" or degraded sources at all locations. Declines of ΣPCB10 (sum of 10 major PCB congeners) were slower than ΣDDT averaging about 2% per year. Total chlordane (ΣCHL) and ΣHCH also declined significantly at Arctic Bay but not at Resolute. Short chain chlorinated paraffins (SCCPs) increased in concentration in seal blubber between 1992 and 2004. Perfluoroalkyl acids increased in liver of ringed seals from Resolute during the 1990s and the doubling time for perfluorcarboxylic acids (PFCAs) was estimated to be 3.8 years. Mercury and other heavy metals were determined in ringed seal liver collected in 2004 or 2003 from five communities (Arctic Bay, Resolute Bay, Gjoa Haven/Taloyoak, Pond Inlet and Arviat). Mercury concentrations ranged widely at each location but overall averages were similar at all 5 locations ranging from 1.7 ug/g wet wt at Gjoa Haven/ Taloyoak to 4.9 ug/g ww at Arctic Bay. Average cadmium concentrations in liver varied much more widely among locations than mercury; Gjoa Haven had distinctly lower concentrations than all other locations. Mercury concentrations were generally lower in 2003 and 2004 samples than those from the late 1990s/2000. This confirms previous results for ringed seals in which no clear increasing trend of mercury was found. However, this result contrasts with results from seabirds, and for some beluga stocks, where increasing mercury has been observed.

Key Project Messages

- Temporal trends of POPs and mercury were examined in ringed seals from five communities in Nunavut by combining new results from samples collected in 2003/2004 with previous results.
- New chemical contaminants such as fluorinated stain repellants and chlorinated paraffins were found to be increasing in ringed seals
- Mercury concentrations were found to have remained the same or declined at the 5 locations studied.

Objectives

1. Determine temporal trends of persistent organic

pollutants (POPs) and mercury in ringed seals from locations previously studied in the 1970s, 1980s and 1990s.

2. Determine the geographic/spatial and temporal trends of new or emerging chemical contaminants in seals

3. Provide the information on levels and temporal trends of these contaminants to each community participating in the study annually.

Introduction

The ringed seal is the most abundant Arctic pinniped with a circumpolar distribution, making this species an ideal candidate for examining spatial trends of persistent organic pollutants (POPs) and heavy metals in the Arctic. It is identified as a key species for monitoring by the Arctic Monitoring and Assessment Program (AMAP) and for temporal trends monitoring in the previous NCP "Blueprint" (INAC 1999) and current monitoring plan (INAC 2004). As a top predator in nearshore pelagic food webs, the ringed seal prefers land fast ice or multiyear ice. The ringed seal diet consists of fish, mainly Arctic cod (*Boreogadus saida*), polar cod (*Arctocadus glacialis*) and crustaceans (amphipods, mysids and euphausids) (Holst et al. 2001). Ringed seals are relatively sedentary and male ringed seals may occupy the same under ice habitat for up to 9 months (Smith 1987). Ringed seals are hunted throughout the year in virtually all coastal communities of the Canadian Arctic and it is therefore relatively easy to obtain samples with the help of local Hunters and Trappers associations. Because ringed seals are resident top predators they can provide local and regional information on temporal trends of contaminants. Migratory species such as beluga, narwhal, thick-billed murre and blacklegged kittwakes spend much of the year feeding far from the locations they are sampled and thus tend to reflect contaminant trends over much broader areas of the Arctic.

The original rationale for this project was that there could be differences in the temporal trends of POPs and Hg in marine mammals across the Canadian Arctic. Recent seawater measurements show large spatial differences of HCH and toxaphene concentrations in seawater between the Beaufort Sea and Baffin Bay and between those areas and Hudson Bay (Hoekstra et al. 2002; Macdonald et al. 2003). These differences in seawater levels may give rise to differences in contaminant levels in marine food webs and ultimately into marine mammals. In the case of HCH for example, much higher levels are found in ringed seal blubber from the central high Arctic than in waters influenced by the Atlantic Ocean (Muir et al. 2000). PCB153 in seal blubber showed fewer regional differences after adjusting for the effects of age and sex using analysis of covariance (Muir et al. 2000) but levels of PCBs are generally higher in seals in the eastern Arctic (Muir et al. 1997).

Regional differences in concentrations are even more pronounced for mercury (Hg) and cadmium (Cd) than for persistent organochlorines (OCs) in seals. Riget et al. (2005) found the highest Hg concentrations in liver of ringed seals from western Canadian Arctic locations, while Cd in liver was highest in the eastern Canadian and West Greenland locations. This may be due to greater sources of natural Hg in the sedimentary rocks of the western Arctic. Trends in concentrations of mercury in ringed seal liver also vary geographically. During the 1990s/early 2000s, mercury concentrations increased from 2 to 3-fold at 3 locations, declined by 1.5-2x at 3 locations and showed no change at two others, Inukjuaq and Arviat (Muir et al. 2003). There is high year to year variation which suggests that dietary shifts e.g. from macrozooplankton (decapods and large amphipods) to pelagic schooling fishes such as arctic cod (*Boreogadus saida*) that may be related to year to year changes in ice conditions may have a large influence.

The recent Canadian Arctic Assessment Report and the AMAP report on Persistent Organic Pollutants (POPs) have summarized information on a series of new chemical contaminants in the Arctic environment (Alaee et al. 2003; Fisk et al. 2003; de Wit et al. 2004). Temporal trends of polybrominated diphenyl ethers (PBDE) have been examined in seals only at Holman (Ikonomou et al. 2002). They showed that PBDE concentrations were doubling every 4.5 years during the 1990s or about 14% per year assuming a linear trend of log concentrations. Temporal trends of other new, emerging persistent bioaccumulative compounds in ringed seals in the Canadian and circumpolar Arctic are largely unknown. These contaminants include brominated flame retardants (BFRs), perfluorooctane sulfonic acid (PFOS), chlorinated paraffins (CPs) and polychlorinated naphthalenes (PCNs). With the exception of PCNs, these chemicals are widely used in consumer and industrial products in Canada and throughout the world. PCNs are no longer in commercial use. They are, however, combustion byproducts and can, like chlorinated dioxins and –furans, be emitted from many sources. The presence of these commercial chemicals and byproducts in the Arctic illustrates the vulnerability of polar regions to contamination by persistent, semi-volatile organic chemicals, particularly those that are used or emitted in relatively large volumes.

Activities

In 2004-2005

Sample collection: Ringed seal samples were successfully collected with the help of our HTA partner organizations in May-June 2004 from Resolute (N=21), Arctic Bay (N=25), and Gjoa Haven (N=16) and in April-May 2005 from Mittimatalik (Pond Inlet) (N=21). Samples received from Arviat in late 2003 (fall hunt, N=25) were also available. Hunters were provided with a kit and video prepared in Inuktitut and English by the Nunavik Research Centre (NvRC). Collections consisted of blubber, liver, muscle, kidney, tooth/lower jaw (for aging) from 25 seals, most being adults and about half female. Essential data on length, girth, blubber thickness at the sternum, and sex was provided for most animals for all locations. Samples were stored at –20°C and then shipped frozen to NVRC in Kuujjuaq for age determination, processing and metals analysis. Large subsamples of all tissues were archived in walk-in freezers at -35°C in sealed plastic bags (double bagged). Aging was performed on tooth sections at NvRC. Archived samples from Resolute (1972 and 1992) were also provided by the CWS Tissue Bank in collaboration with Birgit Braune.

Chemical analyses: OC pesticides, PCBs and PBDEs in seal blubber were determined with the following general procedure: Blubber samples were homogenized with sodium sulfate and Soxhlet extracted with dichloromethane:hexane (1:1). Following lipid removal by gel permeation chromatography, OCs were fractionated on an activated silica gel column, then analysed by gas chromatography with electron-capture detection (GC-ECD). Separation was accomplished on a HP 6890 GC using a 30m DB-5 column with H_2 carrier gas. PBDEs and HBCD were analysed by low resolution GC-negative ion MS using a HP 5973 MSD in negative ion mode using m/z 79 and 81. All OC analyses were conducted by the National Laboratory for Environmental Testing (NLET) Organics Analysis Laboratory. This lab is certified by Canadian Standards Association and has participated successfully since 1998 in more than 12 QUASIMEME interlab comparisons on PCBs/OC pesticide analysis.
Liver and kidney samples were analysed for heavy metals (cadmium, mercury, lead, selenium and arsenic) at NVRC (Kuujjuaq) using atomic absorption spectrometry (AAS). Samples were primarily digested with nitric acid in Teflon digestion bombs. Cd concentrations were determined by graphite furnace AAS (Perkin Elmer 4110ZL Zeeman). Aliquots of the primary digests were further digested in a mixture of sulfuric and hydrochloric acids at 70°C. Total Hg concentrations of the secondary digests were determined by cold-vapour AAS (Perkin Elmer FIAS-100 and 4110ZL) using 10% w/v stannous chloride in 30% v/v hydrochloric acid as reductant.

Seal liver samples were also analysed for PFAs at the Dept of Chemistry (U of T). Samples were prepared following methods developed by (Hansen et al. 2001). Liver tissue was extracted using MTBE and TBAS as an ion-pairing agent. The MTBE was evaporated and the samples were reconstituted in methanol and filtered through 0.2 ìm nylon filters into plastic lined glass vials. Instrumental analysis was performed by LC-MS/MS following previously described conditions (Martin et al. 2004).

SCCP-MCCP were quantified in the same fractions analysed for PBDEs by GC-high resolution mass spectrometry (HR MS) using MAB-ionization mode. The MAB source was operated with argon (60 mbar, 10–11 mA) in the positive ion mode. analysis of all congeners was done by injecting each sample twice; masses between m/z 208 and m/z 342 were monitored for the first injection and masses between m/z 346 and m/z 458 were monitored for the second injection. One internal standard was used in each injection: ^{13}C12-PCB114 for the first injection and ^{13}C12-PCB157) for the second injection, at 125 pg/ul (Moore et al. 2004).

Quality assurance and statistical analysis: QA steps included the analysis of reference materials for heavy metals and organochlorines, reagent blanks and duplicate samples. The NVRC metals lab and the NLET organics lab have participated in the NCP Quality Assurance Program (Stokker 2003). Organochlorines concentrations in ringed seals were normalized to 100% lipid. Results for both mercury and organochlorines were first tested for normality the Shapiro-Wilk test. All mercury data were $\log_{10}$ transformed to give coefficients of skewness and kurtosis <2 while OC data were not log transformed because of relatively low coefficients of skewness and kurtosis. Geometric means (back transformed log data) and arithmetic means were calculated for mercury in liver. Selected comparisons between years were made with the Students t-test (two tailed, unequal variances) (Excel 2000).

Results and Discussion

Spatial and temporal trends of organohalogens: Samples from female seals from Arctic Bay, Resolute, and Gjoa Haven were selected for analysis in order to minimize the

Table 1. Mean concentrations (ng/g lipid wt ± 95% confidence limits) of major organochlorines in blubber from female ringed seals

	Resolute	2004	Arctic Bay	2004	Gjoa Haven	2004
	Mean	95%CI	Mean	95%CI	Mean	95%CI
N >>>	9		9		10	
Length (cm)	120	8.9	129	11	123	21
Blubber thickness (cm)	5	0.5	5	0.8	4.0	0.9
Age (yrs)	7	0.9	7	2	5	3
ΣPCB	363	80.9	397	83.6	554	199
ΣPCB10	186	44.2	192	50.0	283	121
ΣDDT	159	36.6	188	63.8	134	50.4
ΣCHL	186	39.5	106	18.7	130	46.4
ΣHCH	99.4	13.0	93.2	21.3	75.0	41.9
ΣCBz	30.7	5.6	24.2	5.6	38.6	12.9
SCCPs	188	181	-	-	-	-
SCCPs (Cl_{5-9})	147	158	-	-	-	-

influence of age in the interpretation of temporal trends of OCs (Addison and Smith 1974). Results for major legacy POPs (PCBs and OC pesticides) and SCCPs in samples collected in 2004 are summarized in Table 1. ΣPCB10 represents the sum of CB 28, 31, 52, 101, 105, 118, 138, 153, 156 and 180. Mean concentrations of ΣPCB, ΣDDT, total hexachlorocyclohexanes (ΣHCH), and sum of tetra-, penta- and hexachlorobenzenes (ΣCBz) did not differ significantly between Resolute and Arctic Bay, while ΣCHL were marginally higher at Resolute. PCBs were significantly higher in the samples from Gjoa Haven while ΣHCH was lower.

Results from 2004 from seals collected at Resolute, Arctic Bay and Gjoa Haven are combined in Figure 1 with historical results for preliminary assessment of temporal trends. For comparison with earlier data ΣPCB10 was used rather than all congeners because the results from the early 1980s and 1970s (Muir et al. 1988) did not include as many congeners as later studies. Results from early 1990s are from Muir (1997), Muir (1996), and from 1980s from Weis and Muir (1997). All previous results shown in Figure 1, including the samples from the 1970s and 1980s, were based on capillary GC-ECD with quantification using authentic standards. Temporal trends were examined by calculating the slopes and half-lives using simple linear regression of log of mean lipid weight concentrations versus time.

ΣPCB10 concentrations were generally lower in samples from 2004 than earlier samples at all 3 locations (Figure 1). However, the overall decline in ΣPCB10 was not statistically significant at Resolute, Arctic Bay or Gjoa Haven/Taloyoak and represented <2% per year change in concentrations over the respective time intervals of 20, 29 and 18 years (Table 2). More rapid rates of decline in ΣPCB10 can be calculated for Resolute and Arctic Bay seals using only results from the 1990s, however, statistical power is limited because of few sampling times. The results for ΣPCB10 in seal blubber from samples collected in 1992 at Resolute and archived at the NWRC SCCPs were analysed only in samples from Resolute as part of temporal trend comparison discussed below. C11 and C12 chloroalkanes were the predominant SCCPs present representing 28% and 61% of total SCCPs, respectively. The GC-MAB MS method detected 3 and 4 chlorine containing SCCPs whereas the previous work had determined only chloroalkanes with 5 or more chlorines. Thus SCCPs (Cl5-9) are also reported in Table 1. Concentrations of SCCPs (Cl5-9) averaged about 90% of total SCCPs in the samples from Resolute. However, in 5 samples of male seals from Pangnirtung which were analysed for comparison of the MAB MS method used in these samples and the GC-ECNIMS method used previously (Muir et al. 2004), Cl3 and Cl4 containing C10-

Figure 1. Temporal trends of ΣPCB10 (sum of 10 congeners) and ratio of CB153 to SPCB10, as well as SDDT and ratio of p,p'-DDE to SDDT in female ringed seal blubber from 3 locations in the Canadian Arctic that were sampled in 2004. Bars represent arithmetic mean concentrations (ng/g lipid weight) ± 95% confidence limits. Lines and symbols represent ratios of p,p'-DDE /ΣDDT and CB153/SPCB10.

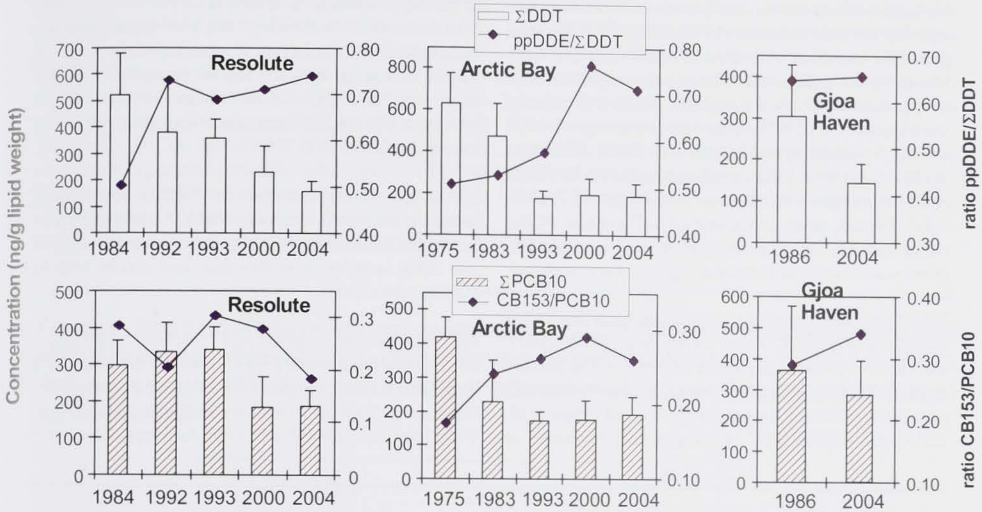


Table 2. Temporal trends of major legacy OCs in female ringed seals from 3 locations studied in 2004-05 expressed as half-lives and % decline per year

	Resolute (1984-2004)			Arctic Bay (1975-2004)			Gjoa Haven/Taloyoak (1986-2004)	
	Half-life (yrs)	P[1]	% per year	Half-life (yrs)	P	% per year	Half-life (yrs)[2]	% per year
ΣPCB10	>20	NS	<2	>20	NS	<3	-	1.2
ΣDDT	12	0.002	4.3	15	0.02	3.3	-	3.1
ΣCHL	>20	NS	<2	19	0.02	2.7	-	2.6
ΣHCH	>15	NS	<3	24	0.05	2.1	-	4.0

[1]Probability of significant slope of log mean concentrations vs time (yrs).
[2]Not calculated since results are available for only 2 years. % declines for this location are based on observed differences divided by number of years.

C12 chloroalkanes represented 75% of total SCCPs.

tissue bank were in very good agreement with those obtained from samples collected in 1993 and analysed in the mid-1990s (Figure 1). This supports the approach used in this study of combining data from previous work with analyses of recently collected samples. For Gjoa Haven we used results from the nearby community of Taloyoak reported by Weis and Muir (1997). CB153/ΣPCB ratios generally increased over time at Arctic Bay and Gjoa Haven but not at Resolute. This indicates a gradual shift to more recalcitrant PCB congeners. We have previously found that CB153/ΣPCB ratios were increasing over time at 8 of 9 locations surveyed (Muir et al. 2003). Addison et al (2005) also did not find significant declines in ΣPCBs in male ringed seals from Holman over the period 1981 to 2000. Indeed, mean concentrations of di-ortho PCBs, which includes the majority of PCB congeners actually remained the same or increased slightly over this period.

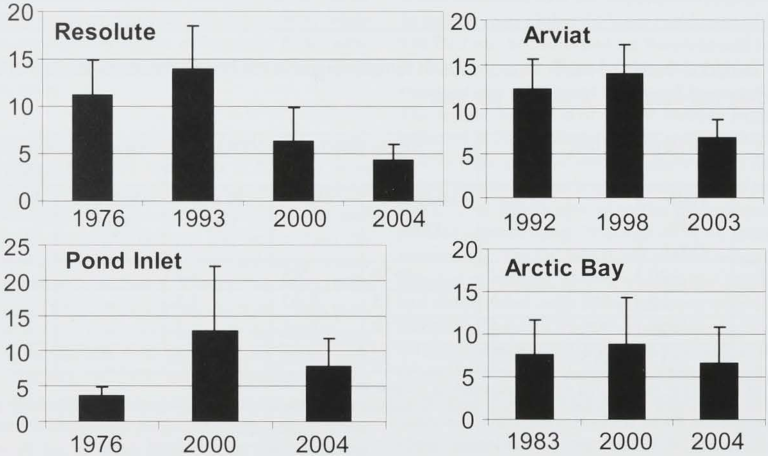
ΣDDT declined significantly in ringed seals from all 3 locations (Figure 1, Table 2) and p,p'-DDE/ΣDDT increased over the same period (Figure 2). The percent decline of 3-4% per year was similar to observations at 3 of 6 other locations we previously studied (Muir et al. 2003). p,p'-DDE/ΣDDT ratios generally increased at Resolute, Arctic Bay and Gjoa Haven . Addison and Smith (1998) found a 3-fold decline for ΣDDT at Holman between 1972 and 1991 which is in general agreement with results from this study.

Total chlordane (ΣCHL) and ΣHCH also declined significantly at Arctic Bay but not at Resolute (Table 2). In general the annual % decline is slower than for DDT-related compounds. Results from 1993-2004 suggest a more rapid decline in the past 10 years especially for HCH. This is consistent with the known reduction in global emissions of HCH (de Wit et al. 2004). β-HCH concentrations actually increased in seals from Arctic Bay over the period 1975 to 2000.

All samples were analysed for PBDEs and HBCD, however, the results are not available for this report due to analytical difficulties. PCNs were determined in archived and 2004 samples from Resolute and results will be available in fall 2005.

Perfluorinated carboxylic acids (PFCAs), perfluorosulfonic acids, PFOSA and telomer acids were determined in liver samples from ringed seals collected at Resolute in 2004 as well as for archived samples from 1972, 1993 and 2000. C7 to C14 PFCAs were not detectable

Figure 2. Temporal trends of mercury in ringed seal liver from 4 locations in the Canadian Arctic. Bars are geometric mean concentrations (ug/g wet weight) + upper 95% confidence intervals except for Pond Inlet where the bars are arithmetic means.



in samples from 1972 while PFOS was above detection limits. However in samples from 1993 and more recent dates, PFCAs were the predominant perfluoro acids. The time trend for total PFCAs in seals at Resolute is shown in Figure 3. Sample sizes for PFCAs are N=2 in 1972 and N=10 for all other sampling times. Doubling time for PFCAs was 3.8 ± 0.4 yrs compared with about 8 years for PFOS. Time trends for SCCPs were determined by analyzing samples from Resolute from 1992 obtained from the NWRC archives and combining with results from 2000 reported by Muir et al (2004). Because only a single archived sample of blubber was available for Resolute in 1972 it was not included in Figure 3 (lower panel). That 1972 sample had non-detect SCCPs. Results for 1992 and 2000 were in reasonable agreement despite being analysed by two different methods (Figure 3, lower panel) However, average concentrations of SCCPs in samples from 2004 were much higher as was the sample variance. Thus although it appears that SCCPs have increased significantly between 2000 and 2004 further analyses will be necessary to confirm this due to high variability in SCCPs among the 2004 samples.

Spatial and temporal trends of mercury and cadmium: Concentrations of Hg in liver of ringed seals from 5 locations are shown in Table 3. Results for both males and female ringed seals were combined because previous studies showed no effect of gender of the animals on Hg concentrations. Hg concentrations ranged widely in adult seals and were highly skewed, however, log transformation reduced skewness and, generally yielded normally distributed data. Thus geometric means are reported and they are similar at all 5 locations ranging from 1.7 ug/g wet wt at Gjoa Haven/ Taloyoak to 4.9 ug/g

Figure 3. Time trend of total perfluorocarboxylates (sum of C7-C14-PFCAs) in ringed seal liver and short chain chlorinated paraffins (SCCPs) in seal blubber from Resolute Bay, NU. A single blubber sample from 1972 had non-detect SCCPs. Symbols represent arithmetic mean concentrations and vertical lines =1 standard deviation.

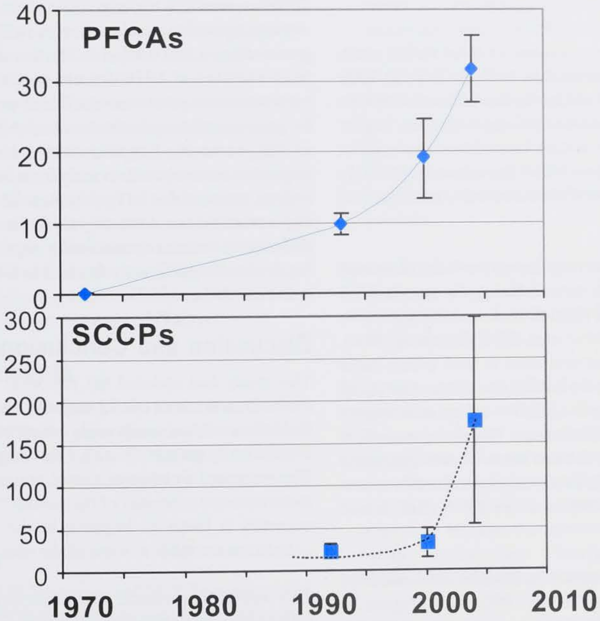


Table 3. Concentrations of mercury and cadmium in ringed seal liver collected in 2004 from the communities of Arctic Bay, Gjoa Haven, Pond Inlet and Resolute Bay and in 2003 from Arviat

Community	N	Statistic	Hg µg/g ww	Cd µg/g ww	Age (yrs)	Length (cm)
Arctic Bay	25	Geomean	4.9	1.8	6	130
		min	0.2	<0.01	2	105
		max	35	9.8	11	150
Arviat	25	Geomean	4.2	7.0	6	109
		min	0.5	0.15	2	86
		max	44	34	12	130
Gjoa Haven	16	Geomean	1.7	0.10	4	119
		min	0.2	0.01	1	97
		max	40	1.5	20	147
Pond Inlet	24	Geomean	2.4	2.9	7	110
		min	0.3	0.25	3	97
		max	34	21	17	141
Resolute Bay	21	Geomean	4.1	3.0	6	120
		min	1.2	1.2	3	99
		max	16	8.9	11	144

ww at Arctic Bay.

Average cadmium concentrations in liver varied much more widely among locations than mercury (Table 3). Seals from Gjoa Haven had distinctly lower concentrations (geomean = 0.1 ng/g ww) than all other locations. Higher concentrations in Cd in seal liver from the eastern Canadian arctic and Greenland have been previously observed by Dietz et al (1998) and recently by Riget et al (2005).

Temporal trends of Hg in ringed seal liver were examined in all four communities by combining the results from 2004 with older data (Smith and Armstrong 1978; Wagemann et al. 1996; Muir et al. 2003; Muir et al. 2004). All of the mercury measurements in seal tissues have been conducted using basically the same analytical methodology (acid digestion followed by cold vapour atomic absorption spectroscopy), therefore, analytical differences are not likely to be an issue. We used geometric means except for Pond Inlet where only arithmetic means were available for samples from 1976 (Smith and Armstrong 1978).

Hg concentrations were generally lower in 2003 and 2004 samples than those from the late 1990s/2000 (Figure 2). At Pond Inlet concentrations increased 3x from 1976 to 2000 but were 50% lower in 2004 than in 2000 even though average ages of the seals collected in 2004 (7 yrs) where greater than in 2000 (4.5 yrs). The raw data from the Pond Inlet samples of 1976 are not available (L.Lockhart, personal communication) and therefore there will always be great uncertainty in the conclusion regarding the size of the increase. For the other 4 locations we used geometric means based on seals from 5 to 15 yrs of age to reduce variance due to age. At Resolute and Arctic Bay, Hg concentrations were slightly lower than in 2000 but differences were not statistically significant. At Arviat, Hg declined significantly from 14 to 6.8 ug/g wet weight between 1998 and 2003.

Discussion and Conclusions

This study has updated the temporal trends of legacy POPs. Slow declines of all 3 major POPs, PCBs , DDT and Chlordane-related compounds are apparent. HCH, which is technically not a POP, is also showing declining trends. The increased number of sampling times is permitting more accurate estimates of the annual % decline and this accuracy is likely to improve in the future as annual collections are made at some of the sites reported on here.

This report also presents, for the first time, temporal trend information on perfluorinated compounds and SCCPs in ringed seals. PFCAs are showing a remarkable rapid rise in concentration in seal liver, outpacing reports for PBDEs in ringed seal blubber (Ikonomou et al. 2002). PFCAs also have shown increasing trends in northern fulmar and thick-billed murres (Braune et al. 2005) although not with the short doubling times found for ringed seals. Doubling times for perfluornonanoic, -decanoic and undecanoic acid in polar bears in the eastern Canadian arctic were also about 4 years (Smithwick et al. 2005). The increasing trend for SCCPs in seals was unexpected because global SCCP production is declining and medium chain chlorinated paraffins (MCCPs) are replacing them (Environment Canada 2004). MCCPs were non-detect in ringed seals from Resolute in samples analysed from 2000 , however, additional analyses by GC-MAB-MS are planned to determine if they are detectable in 2004 samples. There is the possibility that MCCPs are dechlorinated to SCCPs thus helping to explain the observed trend.

The overall decline in concentrations of mercury in ringed seals observed at 4 locations was not entirely consistent with previous work which showed increases of from two to three-fold at three locations (Muir et al. 2003). However, thorough statistical analyses of these trends remain to be done. The variance is high enough within years that only very large trends i.e. >2x are likely to be significant. The results for Hg in ringed seals contrasts with the work on seabird eggs from Prince Leopold Island in Lancaster Sound in which Braune et al (2001) found a significant, approximately two-fold, increase in Hg in thick-billed murre eggs, a 50% increase in northern fulmar eggs and no significant increase in black-legged kittiwake eggs over approximately the same period as several of the ringed seal populations in this study. The explanation for this may be that kittiwakes overwinter at lower latitudes while the murres and fulmars overwinter in northern waters that may not have experienced a decline in Hg. The different overwintering habitat for seabirds compared to seals may also explain differences in trends of PFCAs.

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Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in the High Arctic

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Abstract

This long term study is examining trends over time of mercury and other trace elements, as well as legacy and new persistent organic pollutants (POPs) in landlocked Arctic char from lakes near the community of Qausuittuq (Resolute) and in Lake Hazen, by analysis of annual sample collections. In 2004, arctic char samples were collected from Resolute Lake and from Lake Hazen. To assess temporal trends, results from 2004 were combined with previous results. Concentrations of mercury in the char in Resolute Lake were found to have remained unchanged in 2004 and overall have not declined significantly from 1993 to 2004. At Lake Hazen, mercury concentrations were not significantly different in 2004 from 2003 but year to year variation is evident especially for larger char (>375 mm in length). Time trends of total PCBs (ΣPCB) and total DDT (ΣDDT) were examined in skin-on muscle of arctic char from Amituk, Char, Resolute, and Hazen Lakes. ΣDDT has declined significantly in all 4 lakes over the period 1989 to 2004 (time intervals differ in each lake and vary from 8 to 14 years). The decline of ΣPCB was statistically significant only in Amituk and Hazen lakes at 3 and 5% per year, respectively. Total polybrominated diphenyl ethers (PBDEs) increased significantly in concentration from 1997 to 2004 in Resolute Lake with doubling time of 5 years similar to observations for marine animals in the Canadian arctic.

Key Messages

- Mercury concentrations have not declined significantly in landlocked char from Resolute lake or Lake Hazen from the early 1990s to 2004.
- DDT concentrations in landlocked char have decreased significantly in all 4 study lakes while PCB has declined more slowly or not at all in char from the same lakes
- Total PBDEs increased significantly in concentration from 1997 to 2004 in Resolute Lake with doubling time of 5 years

Objectives

1. Determine long term temporal trends of persistent organic pollutants (POPs) and metals in landlocked Arctic char from lakes in the Canadian high arctic islands by analysis of annual or biannual sample collections.

2. Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet and climate warming.

3. Determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information on a timely basis.

Introduction

Lakes in the high Arctic are replenished annually with snow melt runoff and direct precipitation which represent significant fractions of their water budgets. Changes in concentrations of POPs and Hg (Hg), in air and precipitation should be reflected relatively quickly in changes in levels in food webs and top predator fishes, compared to the vast marine environment. The sedimentary records of POPs and Hg in small arctic lakes show that they reflect global trends in emissions (Muir et al. 1996; Lockhart et al. 1998). Direct precipitation during the open water period and snow melt were important sources of Hg inputs into Amituk Lake (Semkin et al. 2005). About 30% of PCB inputs, and 8-33% of organochlorine (OC) pesticide inputs, to Amituk Lake from snow melt in 1994 were retained in the lake (Macdonald et al. 2000).

As top predators in high arctic lakes, landlocked char are good indicators of changes in inputs of methyl Hg and POPs because of the biomagnification of these contaminants (Köck et al. 2004). Fish accumulate contaminants and metals from their diet and as they pass water over their gills. Unlike mammals, fish have limited capacity to degrade most POPs and excrete many of these chemicals very slowly (Niimi and Oliver 1983). Hg generally enters the food web after conversion to methyl Hg from Hg (II) and Hg(0) (Morel et al. 1998) and concentrations increase with trophic positioning in the food web, with top predators having the highest body burdens of any species in a lake. Mercury is excreted very slowly by fish (Trudel and Rasmussen 1997). In addition, studies have demonstrated that concentrations of Hg from primary to tertiary consumers are significantly related to their trophic position, as determined by $\delta^{15}N$ (Kidd et al. 1995; Power et al. 2002).

The NCP call for proposals for 2004-05 noted that "Landlocked char are an important indicator of atmospheric contaminant inputs in the high Arctic and are also an increasingly important food species to local Inuit. In order to maintain this temporal data set there is a need to assess Hg and POPs in char from Resolute, Amituk, Char and Hazen lakes". The new Northern Contaminants Program's "Blueprint" for "Environmental Trends Related to Human Health and International Controls" which was developed after this project was approved in early 2004, recommended that temporal trend monitoring of Hg and POPs be conducted at "Resolute and Amituk lakes and/or others depending on sample availability". The NCP (2004) blueprint sets an ambitious goal of being able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and confidence level of 95%.

A study of the statistical power of 42 time series data sets for Hg in biota from countries involved in AMAP noted that the consequence of sampling less frequently than once a year was considerable loss of power (Bignert et al. 2004). "Power" is defined as the probability that the data set of interest is sufficiently sensitive to detect a change or trend of a specified magnitude. The study demonstrated that only a few datasets such as those from Sweden had sufficient power to detect annual changes of 5% in Hg in fish.

The value of long term, annual, sampling of fish for measurement of temporal trends of POPs, as well as Hg, has been well illustrated by studies in Sweden. Arctic char have been collected since 1980 in Lake Abiskojaure, 200 km north of the Arctic circle, and northern pike were collected from Lake Storvindeln, a forest lake in northern Sweden since 1978 (de Wit et al. 2004). Each annual sample at a site was represented by 1025 specimens, thus withinyear variation could be estimated. Declines in levels of ΣDDT (DDT + DDD + DDE), PCB, and HCBz, were noted in fish from the Arctic locations (Olsson and Reutergårdh 1986; de Wit et al. 2004). Mercury and HCH isomers showed no significant declines in fish muscle over a 24 year period. Because of annual sampling the Swedish program was also able to detect increases in DDT inputs due to the use of DDT in East Germany in 1984 (Bignert et al. 1993).

Results from our previous study on contaminants in char, which was funded from 1999-2004 in Phase II of the Northern Contaminants Program, have shown that Hg levels have increased marginally Arctic char from Char and Amituk Lakes, remained the same in Lake Hazen, and declined in Resolute Lake over a 9-14 year period (Muir et al. 2001). The slow declining trend in Resolute Lake suggests that these trends can vary widely among lakes. Differences in water residence time and watershed characteristics may help explain this.
Persistent organochlorines were not determined in landlocked char collected by this study in 2003 because

funding was available only for work on Hg. Our previous NCP Synopsis report summarized results for legacy POPs (PCBs, DDT, and other organochlorine (OC) pesticides) and new potential POPs in landlocked char from Amituk, Char and Resolute Lakes based on samples collected between 1993 and 2002 (Muir, Bright et al. 2003) . Char samples had detectable levels of about 85 PCB congeners (ΣPCB) and 30 OC pesticides (DDT, chlordane etc) and OC byproducts (e.g. HCB, octachlorosytrene etc.) related compounds. ΣPCB concentrations showed no significant decline in Char Lake (1993-2000), Amituk Lake (1992-2002) or Resolute Lake (1997-2002). Total chlordane (ΣCHL), total tetra-, penta- and hexachlorobenzenes (ΣCBZ), and total hexachlorocyclohexanes (ΣHCH) declined significantly between 1992-02 (Amituk) and 1993-2000 (Char). ΣDDT (total DDT-related compounds) also declined but the trend was not statistically significant due to small sample sizes. Our previous work also showed significant increased concentrations of tetra- and penta-brominated diphenyl ether (PBDEs) congeners in Resolute Lake (1997-2002).

This study reports on results of continued annual sampling and contaminant analysis of char at Resolute Lake and other lakes on Cornwallis Island, as well as from Lake Hazen.

Activities

In 2004-05

Sample collection:

Samples were successfully collected in August 2004 from Resolute Lakes, as well as from Lake Hazen. Due to ice conditions we were unable to collect adult char from Char and Amituk Lakes (about 90% ice covered). Collection involved the use of gill nets (net size 36 mm and 42 mm) set perpendicular to shore in 1-3 m depth water generally for < 3 hrs. Young char were collected from Char and Resolute Lakes by electrofishing along the shoreline in support of other studies. The sample numbers collected in 2004 and in previous years are listed in Table 1. Samples (skin- on fillets) were frozen in Resolute and then shipped to the National Water Research Institute (NWRI), Burlington, Ontario, and stored at -20°C until analysis. Subsamples were also shipped to J. Reist (DFO Winnipeg). Aging of the char was done by J. Babaluk (DFO Winnipeg). Archived samples of char from Lake Hazen (1992, 2001) were provided by J. Babaluk.

Chemical analysis

Mercury and other elements: Arctic char muscle (skinless) was subsampled and acid-digested in a high-pressure microwave oven. Mercury was analysed by cold vapour atomic absorption spectrophotometry (CVAAS), and 31 elements (Ag, Al, As, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Ga, La, Li, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Tl, U, V, Zn, Pt, Pd, Cs, K) were determined by inductively coupled plasma high resolution mass spectrometry (ICP-HRMS). All analyses were performed by the National Laboratory for Environmental Testing (NLET) at NWRI, Burlington.

Organohalogen compounds: Char (muscle plus skin) samples were homogenized, mixed with pre-cleaned Na_2SO_4 and Soxhlet extracted with dichloromethane:hexane (1:1) using a clean room (carbon and HEPA filtered air) to reduce background contamination. Organohalogens were isolated by gel permeation chromatography (GPC) followed by silica gel cleanup. Lipid was determined using the GPC lipid fraction. The chromatography on silica gel was used to separate PCBs and *p,p'*-DDE from more polar compounds including chlordane and toxaphene components, *p,p'*-DDT and HCH isomers and polybrominated diphenyl ethers (PBDEs). The two fractions from the silica gel column were then analysed by gas chromatography with electron-capture detection (GC-ECD). Separation was accomplished on a HP 6890 GC using a 30 m DB-5 column with H_2 carrier gas. ΣPCBs represented the sum of 103 congeners. Toxaphene, PBDEs and hexabromocyclododecane (HBCD) were analysed by low resolution GC-negative ion MS using a HP 5973 MSD. Selected samples of Fraction 1 were also run to check quantification of toxaphene congener P26. PBDEs were quantified using an external standard consisting of 32 congeners. Gas chromatographic conditions for the PBDEs and HBCD are described by Luross et al (2002).

Stable isotope analyses: Muscle from all fish analysed for Hg and POPs were analysed for stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) at NWRI (Saskatoon) in muscle samples using isotope ratio MS.

Quality assurance (QA): Certified reference materials for heavy metals from the National Research Council of Canada (DOLT-2, DORM-2 and TORT-2) were analysed with each batch of samples (N=2). Average deviations from certified values for the 15 certified elements in DORM-2 (dogfish muscle), 15 elements in DOLT-2 (dogfish liver) and 14 elements in TORT-2 (lobster hepatopancreas) were 3%, 5% and 3%, respectively. Certified reference materials for organochlorines and PBDEs from NIST (National Institute of Standards and Technology, Gaithersburg MD; http://ois.nist.gov/srmcatalog) 1588a cod liver and 1974b mussels were used with each batch of 10 samples. Average deviations for major certified analytes in NIST 1974b ranged from 20-

35% and from 2-35% in NIST 1588a. Reagent blanks were also run with each sample batch of 10 samples. NLET organics and metals labs are participants in the NCP Quality Assurance Program. The NLET organics lab is a participant in the Quality Assurance for Marine Environmental Monitoring in Europe (QUASIMEME) programs for PCBs, toxaphene and PBDEs. The NLET labs are accredited by the Standards Council of Canada through Canadian Environmental Analytical Laboratory program to the standard CAN-P-4D (ISO/IEC 17025).

Statistical analyses: All statistical analyses were conducted using the SYSTAT statistical package (Systat Software Inc., Point Richmond, CA). Non-detect concentrations were replaced with half the instrumental detection limit for calculation of arithmetic and geometric means and standard deviations. Results for each collection year were first tested for normality using the Shapiro-Wilk test. Results for all elements were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2. Geometric mean concentrations and upper/lower 95% confidence intervals were calculated with log transformed data and back transformed for graphical presentation.

Results

Mercury and other elements: Mean concentrations of 18 elements in landlocked Arctic char muscle from Resolute Lake and Lake Hazen for 2004 are presented in Table 1. Of the 32 elements routinely determined, 16 were above detection limits in all Resolute lake samples and 18 in Lake Hazen samples. We have previously noted that Hg was significantly correlated ($P<0.05$) with length, weight, $\delta^{15}N$, Tl and Rb in char from Hazen and Resolute lakes (Muir and Köck 2004).

Table 1. List of Arctic Char samples analysed for mercury and other elements in high Arctic Lakes

Lake	Year	Collected	Analysed for Hg	Analysed for POPs
Amituk [1]	1989	23	23	9
Amituk[1]	1992	15	15	12
Amituk	2001, 2002, 2003	5, 5, 6	5, 5, 6	2,4,5
Char [1]	1993	5	5	5
Char	1999, 2000, 2001	3, 4, 4	3, 4, 4	3,4,4
Char	2003	6	6	6
Hazen [1]	1990	35	35	6
Hazen	1992	20	20	-[2]
Hazen	2001	20	20	-[2]
Hazen	2003	20	20	10
Hazen	2004	16	8	-
Resolute [1]	1993	7	7	-
Resolute	1997	40	10	10
Resolute	1999	21	10	10
Resolute	2000	18	18	8
Resolute	2001	21	17	10
Resolute	2002	19	10	8
Resolute	2003	20	10	10
Resolute	2004	17	10	10

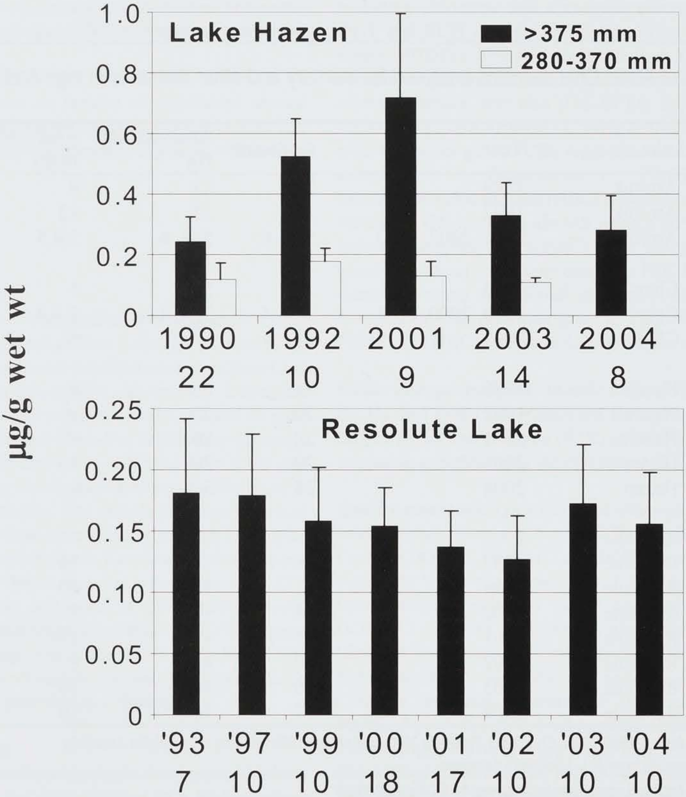
[1] Amituk 1989, 1992, Char 1993, Resolute 1993, and Hazen 1990 samples not available. Used Hg results from W. L. Lockhart's database

[2] Archived samples to be analysed for POPs in 2005-06

The range of $\delta^{15}N$ in char muscle from the 2004 collections varied from 10.6‰ to 14.4‰ in Resolute Lake. Differences of > 3.5‰ in $\delta^{15}N$ indicate that some char were a full trophic level higher than others assuming increases of about 3.5 ‰ with each trophic level (Peterson and Fry 1987). $\delta^{15}N$ was positively correlated ($P<0.01$) with length and weight of char in Resolute lake (data not shown). Thus larger char were feeding at a higher trophic level. Hobson and Welch (1995) associated $\delta^{15}N$ values of 13.7 ‰ with piscivory in char from Char Lake. They also found a significant increase in the $\delta^{15}N$ of these fish with size which they attributed to cannibalism within the population.

Mercury was significantly correlated ($P <0.05$) with age and length of char in Resolute Lake but not in Lake Hazen. Small sample size of the Lake Hazen char may have precluded finding significant relationships. Previous samples from Lake Hazen (2003) showed significant correlations of Hg and fish length, age and $\delta^{15}N$ (Muir and Köck 2004).

Figure 1. Temporal trends of mercury concentrations in arctic char muscle from Lake Hazen and Resolute Lake. Bars represent geometric mean concentrations and 95% confidence intervals on the log transformed data. Horizontal axis shows dates and sample numbers each year.



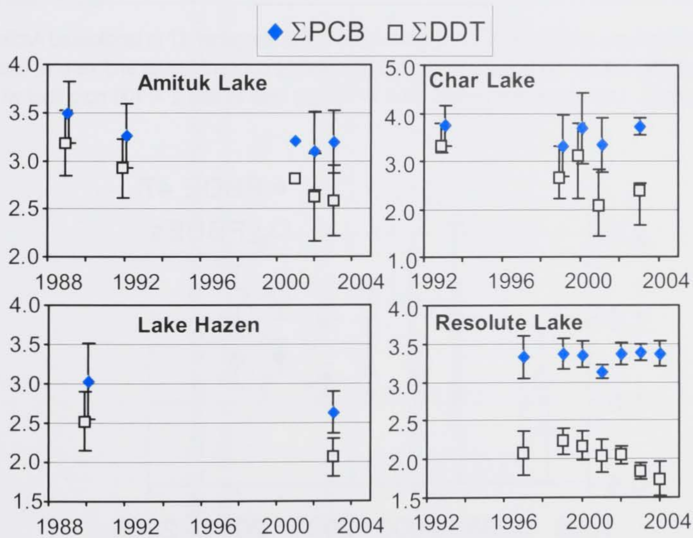
The results for Hg from 2004 are combined with previous results for Hg in landlocked arctic char from Resolute and Hazen Lakes in Figure 1. These are geometric mean concentrations and 95% confidence intervals. No adjustment for weight/length of the char was made because this information is not available for 1993 samples. However, our experience from fishing Resolute Lake since 1997 is that the size range caught each year is very similar. No significant trends over the period 1993 to 2004 are apparent. While mean concentrations of Hg declined about 20-25% from 1993 to 2002, recent mean results (2003-04) have been slightly higher.

For Lake Hazen, two size classes of char were consistently sampled in previous years (1990, 1992, 2001 and 2003). One group from 280-375 mm length generally had $\delta^{15}N$ of 9-12 ‰ while the larger size class (375-680 mm) had $\delta^{15}N >$ 13 ‰. The samples from 2004 were all >370 mm and were therefore included in the "large" category. Arithmetric mean concentrations for 2004 were similar to those for 2003 from the same "large" size class (Figure 1).

Persistent organohalogen compounds:
Char were analysed for legacy OC pesticides and byproducts (29), PCB congeners (104), PBDEs (17) and toxaphene congeners (25). This added to results generated previously for these same analytes from samples collected from 1997 to 2002 (Muir, Bright et al. 2003) and in the early 1990s (Muir and Lockhart 1994; Muir and Lockhart 1996). The combined information enables temporal trends to be examined and for comparison among lakes. In this report we will focus on trends of PCBs and DDT related compounds and on PBDEs.

Trends of total PCBs (ΣPCB) and total DDT (ΣDDT) in skin-on muscle of arctic char from Amituk, Char, Resolute, and Hazen Lakes are presented in Figure 2. These results should be considered preliminary because they represent means of log transformed data using all samples and not considering trophic level of the char. ΣDDT has declined significantly in all 4 lakes over the past 8 to 14 years. Expressed in percentage terms, using the slope of the regression of mean log concentrations vs time, ΣDDT is declining at a rate of 6% per year in Amituk Lake, 17% in

Figure 2. Trends of ΣPCBs and ΣDDT (ng/g lipid weight) in arctic char from Amituk, Char, Resolute, and Hazen Lakes. Vertical bars are upper and lower 95% confidence intervals. Log values are plotted, thus 3=1000; 2=100 ng/g.



Char Lake, 16% in Resolute Lake and 5% per year in Lake Hazen. The decline of ΣPCB was statistically significant only in Amituk and Hazen lakes at 3 and 5% per year, respectively. ΣPCB concentrations have remained constant in Resolute and Char Lakes (Figure 2).

We had previously reported that total PBDEs (ΣPBDE) doubled in concentration from 1997 to 2001 in Resolute Lake (Muir, Bright et al. 2003). The present study has extended this to 2004 and Figure 3 shows mean concentrations of log transformed data using char with $\delta^{15}N$ <13 ‰ (Figure 3). ΣPBDEs in Resolute Lake char were significantly correlated with $\delta^{15}N$ and results from 4 char with $\delta^{15}N$ >13 ‰ were omitted from calculation of mean concentrations in order to use fish that were feeding at the same trophic level. While ΣPBDEs were relatively low (1-5 ng/g wet wt) the concentrations of PBDE congeners 47 and 99 are within the range of the 30 most prominent PCB congeners in the same samples. ΣPBDEs have increased significantly (regression of mean log concentrations vs time; $P<0.05$) with doubling time of 5 years over the period 1997 to 2004. ΣPBDE appear to have levelled off over the period 2001 to 2004 (Figure 3).

Hexabromocyclododecane was also detected in char from Resolute Lake (<0.05-0.25 ng/g wet wt) but not in char from Amituk or Char Lake (<0.05 ng/g wet wt). Decabromodiphenyl ethane and PBDE 209 were not detected in any samples.

Discussion and Conclusions

The results for Hg in landlocked char in this study when combined with previous years work continue to illustrate that there is great lake to lake variation observed in both concentrations and in temporal trends of Hg. Overall, no significant time trends of Hg concentrations were observed in Resolute Lake and in Lake Hazen although significant short term variation seems apparent especially for the large char in Lake Hazen. The presence of small and large char morphotypes (distinctive forms of different size and feeding habits) has been previously reported for Lake Hazen (Reist et al. 1995; Guiguer et al. 2002). Guiguer et al (2002) showed that large char from Lake Hazen (394-642 mm) were feeding at a higher trophic level than smaller char, mainly on juvenile char (113-252 mm length). Our $\delta^{15}N$ for char of 375-680 mm agree with those reported by Guiguer et al. year to year dietary shifts by these piscivorous char could explain the variation.

Resolute Lake has a much higher sedimentation rate than Lake Hazen and because of its small size responds rapidly to changing inputs. Mercury profiles in dated sediment cores from Resolute Lake indicated that historical inputs were greater in the 1960s than in more recent decades

Figure 3. Concentrations of total PBDEs and tetrabromo PBDE congener 47 in landlocked Arctic char from Resolute Lake (1997-2004). Symbols are average lipid weight concentrations and vertical lines are 95% confidence intervals. Log values are plotted, thus 1=10 ng/g lipid wt and 2 = 100 ng/g lipid wt.

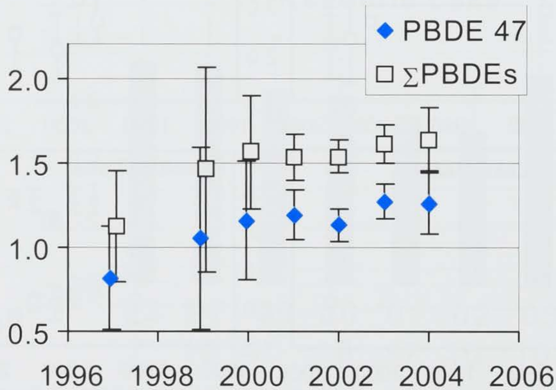


Table 2. Geometric and arithmetic mean concentrations and ranges of length, weight, age major elements (ug/g wet wt) and stable isotope ratios in muscle of landlocked Arctic char from lakes in the Canadian Arctic archipelago collected in 2004

Lake		length (cm)	age (yr)	As	Ba	Cd	Co	Cr	Cs	Cu	Mn	Mo	Ni	Pb	Rb	Se	Sn	Sr	Tl	Zn	Hg	$\delta^{13}C$
Resolute	**GM**	38	19	0.02	0.02	0.002	0.003	0.020	0.001	1.02	0.09	0.004	0.133	0.006	0.69	0.65	0.013	0.111	0.007	7.64	0.156	
N=10	**average**	38	20	0.02	0.02	0.003	0.003	0.027	0.001	1.15	0.09	0.004	0.145	0.009	0.69	0.65	0.017	0.140	0.010	8.21	0.168	-22.0
	min	33	14	0.01	0.01	0.001	0.002	0.004	0.001	0.57	0.05	0.002	0.087	0.001	0.53	0.47	0.010	0.034	0.004	4.59	0.102	-22.8
	max	48	33	0.06	0.06	0.007	0.004	0.061	0.003	2.67	0.14	0.010	0.203	0.022	0.80	0.74	0.050	0.344	0.034	13.1	0.278	-21.6
	% detected[1]			100	100	100	100	100	100	100	100	100	20	80	100	100	100	100	100	100	100	
Hazen	**GM**	44	15	0.02	0.01	0.003	0.009	0.023	0.007	0.36	0.04	0.002	0.040	0.004	1.21	1.46	0.014	0.024	0.010	4.11	0.234	
N=8	**average**	44	15	0.02	0.01	0.004	0.009	0.053	0.007	0.37	0.05	0.002	0.049	0.005	1.23	1.47	0.016	0.031	0.012	4.12	0.280	
	min	37	11	0.01	0.01	0.003	0.005	0.009	0.003	0.22	0.03	0.002	0.009	0.002	0.85	1.02	0.010	0.012	0.004	3.86	0.075	
	max	50	18	0.03	0.02	0.004	0.013	0.298	0.012	0.48	0.07	0.002	0.086	0.008	1.56	1.87	0.030	0.111	0.019	4.51	0.561	
	% detected[1]			100	100	100	100	100	100	100	100	100	100	100	100	100	63	100	100	100	100	

(Muir, Halliwell et al. 2003). Nearby Char Lake also shows declining inputs of total Hg to sediments (Muir, D. and Jackson, T. Unpublished data NWRI 2004). St. Louis et al. (2005) concluded that little of the spring-time oxidized Hg entered lakes via snowmelt due to volatilization and photochemical reduction, however, they did observe a springtime pulse of mono-methyl Hg into high arctic lakes. This may be a significant source for the arctic char food web. Small lakes such as those in the Resolute area that we have been studying since 1997 are thus best suited to detect changes in Hg inputs due to faster response than large systems such as Lake Hazen.

This study has updated the time trends in legacy POPs and new contaminants in landlocked char for the first time since 2002. With the additional data, time trends have greater power and are becoming more amenable to statistical analysis. Observed trends appear to be consistent with observations for marine biota. For example, Ikonomou et al. (2002) observed a doubling time of about 5 yrs during the 1990s for ΣPBDEs in ringed seals from Holman (NT) which is similar to observations in arctic char in Resolute Lake. The AMAP POPs assessment noted that ΣDDT declined by 2.4 to 3.7% per year in Canadian arctic ringed seals and from 3.6 to 7.3% per year in Northern fulmars from Prince Leopold Is (de Wit et al. 2004). ΣPCBs showed generally slower % declines than ΣDDT in seals and seabirds, similar to observations for arctic char. The % per year of decline of ΣPCBs and ΣDDT in char from the most remote lakes, Amituk and Hazen, was most similar to those in marine biota, while results from Resolute and Char showed more rapid decline of ΣDDT and slower decline of ΣPCBs.

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Mercury Measurements at Alert

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Abstract

Mercury is a global toxic pollutant and its impact on the Arctic environment is of great concern. Atmospheric mercury concentration measurements have been made at Alert, Nunavut for the past 10 years and have shown distinct repeatable seasonal and annual patterns in the gaseous elemental mercury (GEM). Research continues into understanding the processes, transfer and impact of atmospheric mercury depletion events (MDEs) in the springtime to the Arctic. An intensive snow sampling campaign was initiated this past year to study mercury in the spring and, for the first time, during the snowmelt period to further understand the potential transport of mercury to the Arctic ecosystem. An international field campaign was held in Barrow, Alaska in the spring of 2004 to further our capabilities of sampling mercury in Arctic environments and to further understand the springtime cycle of mercury in the Arctic.

Key Messages

- Ten years of atmospheric mercury measurements have been made at Alert, Nunavut. This data will establish trends of atmospheric mercury in the Canadian high Arctic
- Continued intensive studies of mercury depletion/deposition episodes and their impact on the Arctic environment were undertaken including sampling of snow during the snowmelt
- Research into the measurement, formation and the fate of the various reactive mercury species continued
- While studies continue to further understand the processes driving mercury depletion events, the cause, effects and implications of these events are still pending.

Objectives

The objectives of this project are to establish baseline concentrations of mercury in the atmosphere and to study the behaviour of mercury in the Canadian high Arctic. By collecting long term information on concentrations of atmospheric mercury, temporal variability, transport events and trends can be established. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives. The behaviour of atmospheric mercury in the high Arctic in the springtime is complex and is currently well studied throughout polar regions. Through the NCP, this phenomenon has been studied at Alert since the beginning of the discovery and has the advantage of long term records and study. This project aims to further elucidate the chemical and physical aspects of atmospheric mercury depletion and deposition events after polar sunrise and the resulting potential link to enhanced Hg concentrations in the Arctic environment.

Introduction

With global climate change considered to occur at a rapid pace in Arctic regions, the atmospheric dynamics and the impacts of pollutants to this environment must be well understood. One priority pollutant of concern in Arctic regions is mercury. Several lines of evidence strongly imply post-industrial enhancement of mercury to the environment and the Arctic appears particularly vulnerable to these inputs (Macdonald et al., 2000). Gaseous elemental mercury (GEM) measurements have been ongoing in the Canadian Arctic at Alert, Nunavut, since 1995. Annual time series of GEM have been produced and show repetitive distinct seasonal cycling of this pollutant. Through analysis of this annual cycling, it was discovered that a substantial amount of reactive mercury is present in the air and on particles during the springtime when levels of GEM in the air are very low (Steffen et al. 2003). A portion of these reactive mercury species remain in the air while a large amount is deposited onto the snow and ice surfaces. It is very likely that this conversion of mercury (and subsequent deposition) after polar sunrise may provide a pathway by which these more reactive (potentially bioavailable) mercury species are introduced into the Arctic environment and thus may be impacting large areas of the Northern Hemisphere (Lu et al. 2001). This project, within the Northern Contaminants Program, provides long term data on the temporal trends and spatial variability of mercury in the High Arctic as well as information concerning the behaviour of mercury that may have a significant impact on the Arctic environment. Results from this project have created international interest and have resulted in similar measurements being made in countries throughout the circumpolar area and in the Antarctic (Schroeder et al. 2003). These data (Canadian and other) will provide important information on the atmospheric transport, transformation and deposition processes of this priority pollutant throughout the Polar Regions.

Activities

In 2004/2005

Ground-based atmospheric GEM, Reactive Gaseous Mercury (RGM) and Particulate Mercury (PM)) measurements continued at Alert. During the spring of 2004, a follow-up international inter-comparative and processes field campaign (Barrow Arctic Mercury Study (BAMS 2004)) was held in Barrow, Alaska to further understand mercury depletion events in the Arctic as well as the methodologies used to make atmospheric mercury measurements. At Alert, snow samples were collected in 4 different ways to support the atmospheric measurements and associated MDE observations.

Results

Ground-level concentration measurements were continued for GEM in ambient air at Alert. The data to the end of 2004 have been preliminarily quality assured. A QC protocol for RGM and PM concentration data was developed for Alert and applied to the 2003-2004 data sets. Results are shown in Figure 1. Results from the BAMS 2004 study are still being worked up.

Four different sets of samples were collected at Alert: 1) snow table; 2) snow melt; 3) over the ocean and 4) snow pit (comparative) samples. Some preliminary results are presented in Table 1. Snow table samples were collected from April until early June. The concentrations were found to range between 2 and 1800 pgg^{-1} and inputs of mercury during this sampling period ranged between 2 and 350 ngm^{-2}. Snow melt (pre-melt, melt and post-melt) samples for total and methyl mercury concentrations were attempted at Alert for the first time in 2004 and preliminary results are shown in Table 1. Part of this initial program involved establishing the required logistics to complete such a task and thus only a few samples were collected this year. Three tributaries near the Alert station were selected for snow and water sampling during the pre-melt, melt, and post-melt periods. Sites 1 and 2 feed into two adjacent lakes and site 3 is an outlet tributary from one of the lakes. Four sets of snow core duplicate samples were obtained for both total and methyl-Hg from June 8 to July 6 for sites 1 and 2, while two sets were taken in June from site 3. Analyses are still ongoing for these samples. Water sampling was limited to three sets from June 29 to July 13 for sites 1 and 2 and two sets for site 3. Methyl-Hg analyses for these water samples are ongoing. Snow and frost flower samples collected over the frozen ocean (for the Out On The Ice (OOTI) 2004 study) were analyzed for total-Hg. Total-Hg results (shown in Table 1) for the frost flowers and artificially created "snow" flowers were low when compared to surface snow results at various sea ice sites. A surface sample collected inland was lower than the sea ice results. Methyl-Hg analyses are ongoing for these samples and integration of the mercury results with other chemical data will be made in the coming months. Snow pit samples were collected for the U of A and the results from the surface snow are shown in Table 1. The concentrations were found to be lower than the table samples and lower than the samples collected over land during OOTI, April 24. Snow table samples were collected and analysed for comparison with

NWRI samples and were found to range between 3 and 600 ng/L.

Discussion and Conclusions

Atmospheric mercury:

10 years of GEM concentration data from this site are now available. This is the longest continuous record of atmospheric mercury measurements made in the Arctic. Using this data set, a comparative analysis of data from several circumpolar sites is underway and is expected to be completed by the end of this year.

Using new technology, RGM and PM concentration measurements have been made on a mostly continuous basis since 2001 to assess the annual signature of these mercury species thought to be key in understanding MDEs. Using the experience gained over the past several years and the data collected, a QC protocol was developed for this data set. This protocol was applied to the 2003 and 2004 data sets (2001 and 2002 are forthcoming) and the final results are shown in Figure 1. This data show the clear anti-correlation between GEM and RGM/PM during the springtime period which has been previously reported (Lindberg et al, 2001; Lu et al., 2001). This figure also shows that towards the beginning of spring the predominant species of mercury during depletion events is PM while towards the end of the season it is predominantly RGM. This is seen in 2003 and is repeated in 2004 suggesting that there is a change each year in the meteorology and/or chemistry at this location throughout the season. RGM/PM concentrations are very low throughout the rest of the year. Some events were found during these low RGM/PM periods of anti-correlations between GEM and PM where the GEM is low and PM is elevated, suggesting depletion events or transport of depletion events occurs in the dark period. Further analysis of this data set is expected this FY.

The BAMS 2004 was undertaken between March and May 2004. This study aimed to further our understanding of mercury cycling in the Arctic region during springtime. As well, the data collected during this campaign will also feed into the circumpolar analysis of mercury. Results from this campaign are still being analysed.

Mercury in snow:

A snow sampling campaign was undertaken this past spring at Alert. 4 types of samples were collected and described above. Concentrations of the snow collected on the table, between April and early June are lower during non-MDEs and higher after or during MDEs which agrees with reported results (Steffen et al., 2002). Samples collected in June may be lower than expected because samples were slushy or partially refrozen, with temperatures hovering around 0°C during sampling. Samples were also collected from the table for analysis at the U of A and were found to be within the same concentration range but a direct comparison is still to be undertaken between laboratories for the total and methyl-Hg samples.

To investigate the effect of snow melt on mercury in the Arctic environment we initiated a pre, during and post snow melt sampling campaign. As shown in Table 1, total-Hg concentrations in water samples were consistent over the three sample sets for sites 1 and 2 showing little variation over the two week period. Concentrations of samples collected at site 3 were lower on average than the inlet sites yet with a larger variation between samples. Further analysis of these and additionally collected samples is required for both total and methyl-Hg and a more intensive sampling campaign is ongoing in 2005.

Frost flowers (halogen enriched frost found on the frozen ocean) are thought to be the initiating factor in the MDE and ozone depletion chemistry. Our goal, as part of the OOTI 2004 study, was to find fresh frost flowers near open leads and measure them and the surrounding snow for total and methyl-Hg. Unfortunately, this study was plagued by a lack of open leads in the sea ice which is required to produce fresh frost flower fields. Two aged frost flower fields were sampled for total and methyl-Hg and a third was artificially created by flooding an area. This yielded some fresh "snow flowers" which were also sampled. Total-Hg concentration in the frost and snow flowers was quite low (as shown in Table 1) compared with the concentration of total-Hg found in the surface snow at various sea ice sites. These data are preliminary and are undergoing further analysis and interpretation.

U of A collected snow pit samples as in previous years at Alert. The concentration of mercury in the surface snow is lower than that reported by NWRI from the table and from surface snow collected on the OOTI study. The 5 surface samples from the snow pits collected show a slight decreasing trend in concentration for both the total and methyl-Hg. This indicates a loss of mercury from the snow pack over the sample time period. It has been suggested, from similar samples collected at Alert in this manner, the concentration of mercury in the snow is low as a result of reduction of the inorganic mercury in the snow to elemental mercury (St. Louis et al., 2005). However, the time that the snow pit samples were collected was around the same time that the snow table samples were reported as "slushy". This might suggest that these samples, similarly to those collected on the snow table, are low because they have been subjected to partial snow melt. This could be part of the reason for these reported low concentration values and suggests an alternate reason for these low concentrations. The post depositional behaviour of mercury in the snow pack, during the melting period, remains questionable and is the focus of our snowmelt study and requires further exploration.

Expected Project Completion Date

Ongoing.

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Temporal Trend Studies of Trace Metals and Halogenated Organic Contaminants (HOCs), Including New and Emerging Persistent Compounds, in Mackenzie River Burbot, Fort Good Hope, NWT

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2004 were analysed for organohalogen contaminants (OCs/PCBs/BFRs/FOCs) and heavy metals (Hg/Se/As). Data from this time point was combined with the existing metal (1985, 1989, 1993, 1995, 1999, 2000, 2001, 2002, Jan 2004 and Dec 2004) and OC (1988, 1994, 1999, 2000, 2001, 2002, Jan 2004 and Dec 2004)) data covering time spans of 19 and 16 years, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. In the males, mean mercury concentrations in muscle increased by 2-fold over the 19 year time period. Mean Hg concentrations in muscle and liver over the entire data sets were 0.317 ± 0.132 (n=231) and 0.078 ± 0.069 (n=223) μg g^{-1}, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale but are at, or exceed, the guideline level of 0.2 μg g^{-1} recommended for fish used for subsistence. PBDEs levels have increase from 3.6-(PBDE 47) to 15.1-fold (PBDE 154) over the 19 year period from 1988 to 2004 but, are currently still about one order of magnitude less than those of PCBs. PFOS was the dominant perfluorinated compound in burbot liver.

Key Messages

- Mean wet weight mercury concentrations in muscle from male Fort Good Hope burbot have increased by almost 2-fold over the 19-year time period from 1985 to 2004.
- Muscle mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale but are at, or exceed, the guideline level of 0.2 μg g^{-1} recommended for fish used for subsistence.
- Significant declines, 6.1- and 4.4-fold, occurred for both α- and γ-HCH over 16 year time period between 1988 and Dec-2004. ΣCBz levels decreased by 2.9-fold over the same time period. No trend in ΣDDT concentration was observed, however, *p,p'*-DDE/ΣDDT ratios increase from 0.39 in 1988 to 0.73 in Dec-2004 suggesting "old" rather than recent inputs of DDT. Oxychlordane levels increased 2.6-fold since March 1988.
- Brominated flames retardant such as PBDEs have increase from 3.6 (PBDE 47) to 15.1 fold (PBDE 154) over the 19 year period from 1988 to 2004.
- Current ΣPBDE levels are approximately one order of magnitude less than those of PCBs.
- PFOS was the dominant perfluorinated compound in burbot liver.

Objectives

To continue to assess long term trends and to maintain current data on levels of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic, lead and cadmium), organochlorine contaminants (e.g. PCBs, DDT, toxaphene) and new contaminants (e.g. brominated flame retardants, fluorinated organic compounds) in Mackenzie River burbot at Rampart Rapids (Fort Good Hope).

Introduction

With a few exceptions, minimal or no direct temporal trend information on organhalogen (OCs/PCPs/BFRs/FOCs) contaminants and heavy metals (Hg/Se/As) in fish are available in either the Arctic marine or freshwater environments. Due to a lack of retrospective samples and of past studies, much of the temporal trend data that are available are too limited to be scientifically credible because they are based on 2 or at most 3 sampling times. In addition, much of this is confounded by changes in analytical methodology as well as variability due to age/size, or dietary and population shifts. By comparison, temporal trend data for contaminants in Lake Ontario lake trout (Borgmann and Whittle 1991) and in pike muscle from Storvindeln Sweden are available over a 15 to 30 year period.

In the Mackenzie Basin over the last 150 years a steady increase in temperatures has been recorded. In particular, over the last 35 years temperatures have increased about a degree a decade, in the centre of the basin (Rouse et al., 1997). Rising temperatures in the region may be responsible for the increasing Hg levels in the FGH burbot (see Results) for several reasons: (a) melted permafrost, increased erosion and forest fires may release increasing amounts of Hg into the river; (b) the rate of Hg methylation processes may have increased due to increasing temperature and nutrients, particularly in the wetlands and peatlands in the basin; and (c) possible changes in food web structure may have an effect on methylmercury (MeHg) biomagnification.

As outlined in the Northern Contaminants Program 2005-2006 Call for Proposals, the goal of temporal trend monitoring is to be able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and a confidence level of 95%. This requires sample collection and analysis of a minimum of 10 fish annually for a period of 10 to 15 years. Because of the importance of burbot to the subsistence diet of northerners residing in the Sahtu Region and because of the availability of current data sets and archived samples (1986-2005), Fort Good Hope (and the continued analysis of burbot) was selected as one of the priority sampling location for long term temporal trend studies.

FWI currently maintains a very extensive archive of Fort Good Hope burbot tissues and data on trace metals (19 years and 9 time points; 1985, 1993, 1995, 1999, 2000, 2001, 2002, Jan04 and Dec04 and POPs (18 years and 9 time points; 1986, 1988, 1994, 1999, 2000, 2001, 2002, Jan04 and Dec04).

Activities

In 2004/05

In December 2005, 35 burbot were collected from the Mackenzie River at Fort Good Hope (Rampart Rapids) by community residents. Heavy metal and HOC analyses for these samples are now complete and the results discussed below.

Results

Hg, Se, As: Currently heavy metal (mercury, selenium and arsenic) time trend data from Fort Good Hope (Rampart Rapids) burbot tissues cover 19 years and 9 time points (1985, 1993, 1995, 1999, 2000, 2001, 2002, Jan04 and Dec 2004). Mean Hg concentrations in muscle and liver over the entire data sets were 0.317 ± 0.132 (n=231) and 0.078 ± 0.069 (n=223) $\mu g\ g^{-1}$, respectively. Muscle mercury levels in muscle are below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g\ g^{-1}$ recommended for fish used for subsistence.

Mean mercury, selenium and arsenic concentrations for burbot muscle and liver samples for each collection year are shown in Tables 1 and 2, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. In the males, mean mercury concentrations in muscle and liver increased by ~1.5- and 3.1-fold, respectively, over the 19 year time period (Tables 1, 2; Figure 1). For selenium and arsenic no trends were observed in either the muscle or liver (Tables 1 and 2). The highest measured As concentration, 17.16 $\mu g\ g^{-1}$, occurred in a muscle sample from a female burbot collected in 1999.

Organohalogens: Tables 3-7 list the mean wet weight concentrations of major HOC groups for collection periods between 1988 and Dec-2004. The high HOC levels of ΣCHL, ΣDDT, ΣPCB and ΣCHB observed in the Dec-2004 samples could possibly be attributed to the higher

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle ($\mu g\ g^{-1}$).

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	10	633 (84)	0.222 (0.035)	0.358 (0.087)	-
Dec-93	M	7	677 (109)	0.231 (0.113)	0.534 (0.163)	2.291 (3.151)
Sept-95	M	2	-	0.265 (0.035)	-	-
Dec-99	M	21	676 (107)	0.286 (0.095)	0.395 (0.107)	0.637 (0.637)
Dec-00	M	21	699 (104)	0.345 (0.097)	0.478 (0.136)	1.333 (1.944)
Dec-01	M	10	720 (164)	0.342 (0.151)	0.581 (0.272)	3.106 (3.897)
Dec-02	M	12	699 (92)	0.297 (0.139)	0.427 (0.132)	1.555 (2.746)
Jan-04	M	9	705 (79)	0.336 (0.179)	0.377 (0.061)	3.324 (4.506)
Dec-04	M	17	681 (112)	0.413 (0.130)	0.523 (0.199)	1.011 (1.680)
Apr-85[1]	F	6	714 (140)	0.337 (0.136)	0.480 (0.126)	-
Dec-93	F	3	812 (133)	0.297 (0.035)	0.321 (0.009)	6.450 (0.984)
Sept-95	F	2	-	0.180 (0.085)	-	-
Dec-99	F	21	735 (101)	0.259 (0.108)	0.219 (0.104)[2]	2.626 (3.815)
Dec-00	F	15	732 (127)	0.364 (0.140)	0.460 (0.175)	1.929 (1.621)
Dec-01	F	10	747 (122)	0.336 (0.180)	0.304 (0.096)	1.098 (1.821)
Dec-02	F	17	727 (118)	0.294 (0.126)	0.400 (.297)	2.704 (3.258)
Jan-04	F	22	726 (98)	0.254 (0.179)	0.376 (0.125)	2.827 (3.425)
Dec-04	F	18	708 (115)	0.432 (0.138)	0.451 (0.114)	1.562 (2.075)

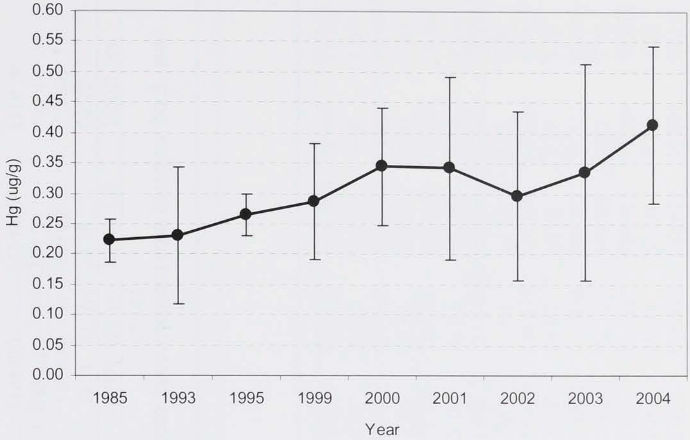
[1]Wagemann 1985; [2]n = 20

Table 2. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot liver ($ug\ g^{-1}$).

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	9	643 (82)	0.044 (0.019)	1.759 (0.558)	-
Dec-88	M	8	706 (84)	0.054 (0.026)	1.230 (0.555)	3.119 (1.725)
Dec-93	M	7	677 (109)	-	-	1.016 (1.328)
Dec-99	M	21	676 (107)	0.046 (0.024)	1.071 (0.628)[2]	0.607 (0.326)
Dec-00	M	21	699 (104)	0.064 (0.026)	1.646 (0.733)	0.585 (0.412)
Dec-01	M	10	720 (164)	0.063 (0.048)	1.434 (1.278)	0.839 (0.822)
Dec-02	M	12	699 (92)	0.063 (0.031)	1.437 (0.808)	0.771 (0.539)
Jan-04	M	9	705 (79)	0.126 (0.179)	1.981 (1.370)	1.994 (1.447)
Dec-04	M	17	681 (112)	0.111 (0.065)	3.267 (2.437)	0.496 (0.605)
Apr-85[1]	F	6	714 (140)	0.097 (0.098)	1.272 (0.715)	-
Dec-88	F	2	623 (86)	0.072 (0.035)	1.460 (1.529)	1.280 (1.018)
Dec-93	F	3	812 (129)	-	-	1.062 (0.546)
Dec-99	F	20	749 (77)	0.064 (0.069)	0.687 (0.552)[2]	1.353 (0.811)
Dec-00	F	15	732 (127)	0.094 (0.056)	1.203 (0.469)	0.632 (0.349)
Dec-01	F	10	747 (122)	0.098 (0.108)	1.235 (0.720)	1.074 (1.227)
Dec-02	F	17	727 (118)	0.082 (0.067)	1.488 (1.203)	1.063 (0.890)
Jan-04	F	22	726 (98)	0.057 (0.033)	1.245 (0.511)	1.522 (1.348)
Dec-04	F	17	700 (112)	0.138 (0.081)	2.616 (2.030)	0.489 (0.335)

[1]Wagemann 1985; [2]n = 19

Figure 1. Mean Hg concentrations in muscle samples from male Fort Good Hope burbot.



water levels (and correspondingly high particulate loadings) observed in the Mackenzie River in spring/summer 2004 (Stern and Macdonald, 2005). After lipid normalization, significant declines, 6.1- and 4.4-fold, occurred for both α- and γ-HCH over this sixteen year time period. β-HCH concentrations were below the detection limit in most samples. ΣCBz levels decreased by 2.9-fold. While no trend in DDT concentration was observed, *p,p'*-DDE/ΣDDT ratios increase from 0.39 in 1988 to 0.73 in Dec-2004 suggesting "old" rather than recent inputs of DDT. Oxychlordane, the principal metabolite of *cis*- and *trans*-chlordane, and second only to *trans*-nonachlor as the most abundant chlordane-related residue in the Fort Good Hope burbot liver, increased 2.6-fold since March 1988. The decreasing *t/c*-CHL ratio suggests "old" rather than recent chlordane inputs.

Major PBDE congener and homologue concentrations in selected burbot liver samples are listed in Table 5. PBDE 47 is the most predominant PBDE congener residue in the burbot liver followed by PBDE 99, 100, 153 and 154. Significant increases were observed for all major congeners over the 12 year time period from 1988 to January 2004.

Mean α- and γ-HBCDD concentrations ranged from 0.177 – 0.290 and 0.104 – 0.314 ng/g, wet weight, respectively (Table 6). β-HBCDD levels in all cases were below detection limits. Only log [γ-HBCDD] from the Jan 04 samples showed any correlation with lipid ($r^2 = 0.23$). No correlation's were observed between log [α-, γ- HBCDD] and age or length.

PFOS was the dominant perfluorinated compound in burbot liver. There were no statistically significant differences in the concentrations of PFOS (or PFOA) in the burbot between 1986 and Jan 2004. There were positive linear correlations between concentration of PFNA (r^2=0.93), PFDA (r^2=0.69) and PFUA (r^2=0.86) and sampling year. No correlations between PFC concentration and age (or length) of fish were observed. PFOS was the dominant perfluorinated compound in burbot liver. There were no statistically significant differences in the concentrations of PFOS (or PFOA) in the burbot between 1986 and 2004.

Expected Project Completion Data

Temporal trend studies are long-term propositions and thus annual sampling is projected until at least 2009 (13 time points covering 21 years for the organohalogen compounds and 14 time points covering a period of 24 years for mercury).

Table 3. OCs in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1}, ww)

Year	sex	n	% Lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	HCBz	Dieldrin
1988	M + F	10	30.20	13.63	5.53	23.83	16.17	58.11	121.66	13.07	2.38
			(13.47)	(4.21)	(1.71)	(7.37)	(5.25)	(18.45)	(38.62)	(4.06)	(0.74)
1994	M + F	9	30.56	8.63	5.13	17.34	18.96	50.05	93.70	8.17	2.02
			(11.59)	(2.63)	(1.53)	(6.14)	(8.28)	(17.55)	(28.92)	(2.48)	(0.62)
1999	M + F	21	42.10	10.04	3.78	21.00	22.84	62.77	108.06	5.43	2.38
			(13.31)	(3.81)	(1.38)	(8.04)	(8.59)	(22.29)	(40.74)	(2.17)	(0.93)
2000	M + F	20	36.22	8.72	3.29	19.02	21.24	54.62	94.02	4.78	2.21
			(15.22)	(5.24)	(1.98)	(12.50)	(14.92)	(36.25)	(58.08)	(2.89)	(1.57)
2001	M + F	20	30.14	6.36	3.79	13.68	8.99	41.88	75.36	4.33	2.37
			(15.00)	(3.06)	(1.67)	(6.99)	(5.96)	(21.26)	(48.54)	(1.90)	(1.31)
2002	M + F	12	27.33	4.69	1.40	17.83	22.18	37.97	143.61	4.54	3.23
			(16.06)	(2.93)	(0.94)	(10.10)	(12.19)	(16.50)	(119.82)	(2.85)	(1.59)
Jan-04	M + F	10	24.90	3.83	1.62	17.25	15.19	29.95	118.13	3.80	2.83
			(5.77)	(3.08)	(0.57)	(18.71)	(12.72)	(21.29)	(109.79)	(3.00)	(2.46)
Dec-04	M + F	9	24.73	4.05	0.87	25.35	35.65	57.62	201.65	3.90	1.96
			(14.27)	(3.72)	(0.45)	(21.84)	(26.15)	(32.22)	(167.60)	(2.66)	(1.56)

Table 4. Major PBDE congener concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, pg g^{-1} ww)

Year	Sex	n	% Lipid	PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154
1988	M + F	10	30.20	226.31	84.54	35.21	29.38	20.53
			(13.47)	(280.28)	(130.65)	(46.69)	(44.66)	(28.95)
1999	M + F	4	35.00	582.83	370.03	207.73	161.33	157.48
			(9.59)	(522.33)	(269.61)	(154.65)	(124.84)	(116.36)
2000	M + F	11	33.31	620.30	319.68	180.47	135.17	81.30
			(13.10)	(628.89)	(273.93)	(182.68)	(133.88)	(84.22)
Jan-2004	M + F	10	28.09*	814.74	745.28	297.72	435.47	311.40
			(11.51)	(618.92)	(583.23)	(190.94)	(330.08)	(216.01)

Table 5. a- and g-HBCDD levels in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1} ww)

Year	Sex	n	% Lipid	α- HBCDD	γ-HBCDD
1986	M + F	8	23.08	0.290	0.154
			(19.56)	(0.190)	(0.204)
1999	M + F	9	42.68	0.177	0.104
			(12.56)	(0.109)	(0.043)
Jan-2004	M + F	9	27.67	0.271	0.314
			(12.13)	(0.198)	(0.229)

Table 6. FOC levels in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1} ww)

Year	Sex	n	% Lipid	PFOA	PFNA	PFOS	PFDA	PFUA	PFDoDA
1986	M + F	10	23.08	4.24	0.30	10.44	1.83	2.21	nd
			(19.56)	(7.07)	(0.93)	(5.90)	(2.20)	(4.92)	
1999	M + F	10	42.68	3.62	3.39	9.98	1.06	1.40	nd
			(12.56)	(6.81)	(9.50)	(10.16)	(1.82)	(2.94)	
Jan-2004	M + F	10	27.67	1.56	7.71	46.55	4.21	5.31	nd
			(12.13)	(3.52)	(8.31)	(95.48)	(4.05)	(3.97)	

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Temporal Trends of Mercury in Beluga, Narwhal and Walrus from the Canadian Arctic

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Abstract

Samples of beluga liver from the eastern Arctic have been analyzed for mercury sporadically since 1981, with a few samples taken even earlier, although age data for those animals were not obtained. These results offer some opportunities to test for temporal changes and these opportunities will grow as future collections add data.

Estimation of temporal change is complicated by the fact that mercury accumulates with age so that older animals often have higher levels. Also, mercury varies considerably from animal to animal and from year to year even without the effect of age. Both of these observations make difficult the detection of temporal changes for a species. Levels appear to vary also among species with walrus generally having lower levels of mercury than narwhal or beluga, presumably reflecting dietary habits of walrus. Levels in beluga liver appear to have behaved differently in different locations signaling the need to consider locations separately. Presumably local conditions are responsible for differing results from different locations, but identifying these variables will require more research. The clearest indications of increasing levels in beluga appear to be the Mackenzie Delta and Arviat, but the change in the Mackenzie Delta appears to be oscillatory rather than linear. Several sets of data suggest a change in the pattern of accumulation of mercury in the early or mid-1990s but the cause of this is speculative.

Key Messages

- Total mercury levels in beluga, narwhal and even walrus liver remain higher than levels used to regulate the sale of commercial fish (0.5 ug g^{-1}).

- Levels of mercury in liver of walrus are lower than those in the whales.

- Levels of mercury in beluga liver have behaved somewhat differently in different locations. In some communities the levels have increased since the mid-1980s but not in all communities. One clear message is the need to consider locations individually. The question of what might be driving changes in beluga from some locations but not others will have to be addressed by future research.

- Year-to-year variation can be quite large (e.g. beluga, Iqaluit, 1993 and 1994), making it difficult statistically to identify any temporal trends.

- Data on narwhal and walrus from the eastern Canadian

Arctic show no clear indication of changing levels of mercury over the intervals sampled.

Objectives

1. To define temporal trends in concentrations of mercury in tissues of narwhal, beluga and walrus from the eastern Canadian Arctic.

2. To develop the data from which to track trends in the levels of mercury on a stock-by-stock basis of beluga, narwhal and walrus.

Introduction

The levels of mercury in organs of northern marine mammals generally exceed the two guidelines used to regulate the sale or domestic consumption of fish (0.5 ug g^{-1} for sale of commercial fish and 0.2 ug g^{-1} for subsistence consumption). The extent to which this results from natural processes acting on the northern geological settings, climate change or from the import of industrial mercury with air and water movements is not clear. Studies of sediment cores suggest that about half the mercury coming into northern lakes is of anthropogenic origin (Lockhart et al., 1998). Mercury has increased in air over the North Atlantic (Slemr and Langer, 1992) and mercury has been measured in air and in snow in the Arctic (Lu et al., 2001). While there is little doubt that industrial mercury is deposited in the Arctic, the fate of that mercury is still under investigation. Processes within the snow suggest that much of the mercury deposited in the Arctic may be volatilized back into the air without actually reaching arctic animals. The question of greatest interest is whether the mercury delivered to the Arctic by the atmosphere is sufficient to cause changes in the levels of mercury in arctic animals. Recently, Stern and Macdonald (2005) postulated that the observed increases of mercury in western Arctic beluga since the early 1990's maybe attributed to recent changes in ice cover and distribution in the western Arctic Ocean.

A previous study of mercury in northern animals pooled data from different locations in the eastern and western Arctic and reported a trend to higher levels in both regions (Wagemann et al., 1996). With growing recognition that arctic populations of marine mammals are composed of multiple stocks that are hunted separately in different communities, the need is for trend data on a stock-specific basis.

Whales may range long distances from the communities where they are hunted, but the hunting itself is usually relatively close to the communities. Here, mammals are described only by the communities where the samples were obtained. Hence two or more communities may hunt the same stock if those communities are relatively near each other.

The raw data from several investigations are archived in the Freshwater Institute and comprise records of mercury levels in over 2300 marine mammals, mostly beluga, ringed seals, narwhal and walrus. Biologists obtain samples from hunter kills and those samples form the basis of most analyses. The archive grows through the collection and analyses of new samples and also through the analyses of archived samples from past collections. Over time, the accumulated data offer increasingly the means to detect geographic and temporal trends.

Activities

In 2004/05

A number of new collections were made during 2003 and 2004 and these are included in this report (Arviat beluga in 2003, Mackenzie Delta beluga in 2003 and 2004, Sanikiluaq beluga in 2003 and 2004, Arctic Bay narwhal in 2004, Pond Inlet narwhal in 2004, Hall Beach walrus in 2004). This report covers data available early in 2005. No report was made for this project in 2004 and this report covers data accumulated through until early in 2005. The collection of samples is done independently of this project and is not described here. The analytical methods have been described in previous reports and have been continued to date. While the project is concerned with mercury, the same samples have analyzed for selenium and cadmium and often for methylmercury. The focus for this report is on total mercury in liver; surveys of mercury in body organs have consistently identified liver as the organ most highly contaminated

In a few instances, the original analyses were reported on a dry weight basis. In these cases, the dry weight unit was converted to wet weight using the formula: Concentration (wet weight) = concentration (dry weight) / (100/(100-per cent moisture)).

Results

The data on age and mercury in liver are listed by location and year of collection for beluga in Table 1, narwhal in Table 2 and walrus in Table 3. In view of the variability in the data, the regression of mercury on age for each combination of location and year of collection was calculated using the "robust regression" technique of NCSS software. This software weights each point in

Table 1. Means of beluga age and levels of mercury in liver. The arithmetic means and standard deviations are listed for age and level of mercury. Geometric means were calculated by converting original concentration units to natural logarithms; geometric means have also been converted back to original concentration units (in parentheses).

Location	Year	N	Arithmetic mean of whale age (yr)	Arithmetic Mean Hg in liver (μg/g wet wt)	Geometric mean (log_e) of Hg in liver	Number of outliers removed
Arviat	1984	20	12.2 ± 6.07	7.61 ± 6.91	1.59 ± 1.05 (4.90)	2
	1986	15	11.5 ± 8.06	7.55 ± 8.44	1.40 ± 1.23 (4.07)	0
	1999	31	11.4 ± 4.86	11.9 ± 8.13	2.18 ± 0.88 (8.83)	5
	2003	28	9.80 ± 5.34	10.4 ± 11.3	1.82 ± 1.03 (6.18)	5
Coral Harbour	1993	8	15.3 ± 2.79	5.05 ± 0.75	1.61 ± 0.13 (5.01)	3
	1997	18	12.9 ± 7.46	12.8 ± 29.8	1.51 ± 1.37 (4.54)	1
	2000	21	9.36 ± 6.03	4.17 ± 1.85	1.35 ± 0.40 (3.85)	3
Grise Fiord	1984	16	5.88 ± 4.85	2.10 ± 1.73	0.44 ± 0.84 (1.55)	1
	2001	5	4.10 ± 1.19	2.08 ± 1.48	0.55 ± 0.66 (1.73)	0
Igloolik	1995	32	11.2 ± 4.25	9.21 ± 5.13	2.08 ± 0.55 (7.97)	3
	2001	11	10.3 ± 2.90	8.02 ± 7.65	1.83 ± 0.68 (6.21)	1
Iqaluit	1993	20	13.4 ± 3.28	7.28 ± 3.10	1.89 ± 0.46 (6.62)	3
	1994	5	15.6 ± 5.22	20.4 ± 6.46	2.98 ± 0.31(19.6)	2
Lake Harbour	1994	18	11.4 ± 6.58	9.23 ± 6.03	1.99 ± 0.76 (7.28)	1
	1997	8	17.1 ± 7.35	12.4 ± 3.93	2.47 ± 0.35 (11.8)	1
	2001	13	14.1 ± 5.97	16.4 ± 9.83	2.58 ± 0.74 (13.2)	0
Mackenzie Delta	1981	24	12.2 ± 4.44	11.1 ± 10.7	1.99 ± 1.02 (7.21)	1
	1984	6	21.8 ± 10.5	22.2 ± 17.1	2.84 ± 0.79 (17.1)	2
	1993	19	22.1 ± 6.23	37.3 ± 28.0	3.25 ± 1.01 (26.7)	3
	1994	40	17.3 ± 5.64	30.0 ± 27.7	2.91 ± 1.13 (18.3)	1
	1995	14	15.5 ± 5.71	38.1 ± 37.4	3.16 ± 1.05 (23.5)	2
	1996	10	14.6 ± 5.68	43.8 ± 31.3	3.51 ± 0.81 (33.4)	0
	2001	23	15.1 ± 5.09	40.2 ± 42.1	3.22 ± 1.02 (24.9)	1
	2002	23	14.3 ± 3.70	26.5 ± 28.2	2.84 ± 0.95 (17.0)	0
	2003	16	16.8 ± 5.64	43.3 ± 35.5	3.41 ± 0.95 (30.1)	3
	2004	26		29.9 ± 28.1	3.00 ± 0.93 (20.1)	0
Nastapoka	1984	12	14.3 ± 7.38	13.3 ± 14.3	2.02 ± 1.14 (7.53)	2
Pangnirtung	1984	11	11.2 ± 3.73	5.05 ± 4.42	1.30 ± 0.83 (3.68)	0
	1993	9	8.11 ± 4.19	8.38 ± 7.53	1.86 ± 0.73 (6.43)	2
	1994	26	8.00 ± 6.07	11.0 ± 13.5	1.97 ± 0.86 (7.16)	1
	1997	22	13.0 ± 4.31	7.68 ± 3.06	1.96 ± 0.40 (7.13)	2
	2002	6	15.2 ± 4.92	16.6 ± 3.06	2.79 ± 0.18 (16.3)	4
Paulatuk	1993	3	14.3 ± 5.13	8.58 ± 10.0	1.67 ± 1.19 (5.31)	0
Repulse Bay	1993	2	8.00 ±	3.42 ±	0.97 ± (2.64)	0
Sanikiluaq	1994	30	13.6 ± 5.56	12.9 ± 9.53	2.27 ± 0.80 (9.71)	0
	1995	14	15.0 ± 7.98	28.6 ± 32.8	2.83 ± 1.03 (17.0)	1
	1998	21	12.7 ± 5.33	21.5 ± 25.8	2.46 ± 1.32 (11.7)	1
	2002	9	12.7 ± 5.01	9.01 ± 8.57	1.85 ± 0.90 (6.33)	0
	2003	8	9.06 ± 5.81	6.04 ± 4.61	1.51 ± 0.87 (4.51)	5
	2004	11		19.1 ± 15.7	2.70 ± 0.71 (14.9)	0
Shingle Point	1993	3	19.7 ± 0.58	42.7 ± 25.3	3.65 ± 0.55 (38.4)	0

accordance with its agreement with the calculated regression line. Points far removed from the line are accorded zero little or no weight and are identified. A few such points were identified in most collections and the number of them is listed in Tables 1 and 3. (Ages cannot be determined reliably for narwhal and so no regression of mercury on age could be calculated.) Once identified outlier points were deleted from the data used for calculation of means.

At least three points are required to suggest a trend. The analyses were restricted to those instances for which we had at least three collections spread over several years. The variation with age and the variation among animals of the same age make detection of temporal changes statistically difficult. The statistical approach used PROC GLM (General Linear Models) of SAS applied to the points remaining after exclusion of outliers. The analysis tested whether means differed in different years for reasons other than differing ages of the animals. The analysis initially included a term of interaction between age and year of collection. If this interaction term was not significant,

Table 2. Means of narwhal lengths and levels of mercury in liver. The arithmetic means and standard deviations are listed for length and level of mercury. Geometric means were calculated by converting original concentration units to natural logarithms; geometric means have also been converted back to original concentration units (in parentheses). Narwhal cannot be aged reliably.

Location	Year	N	Arithmetic Mean Length (cm) and sample number if different from previous column	Arithmetic Mean Hg in liver (µg/g wet wt)	Geometric mean (log_e) of Hg in liver with antilog (µg/g wet wt)	Number of outliers removed
Arctic Bay	1983	15		16.7 ± 4.76	2.77 ± 0.33 (15.9)	0
	1986	3	430 ± 52.8	9.57 ± 2.72	2.23 ± 0.27 (9.68)	1
	1987	9	449 ± 45.8	8.72 ± 3.83	2.07 ± 0.49 (7.94)	2
	1999	25	410 ± 41.7	11.1 ± 7.53	2.25 ± 0.55 (9.44)	2
	2004	11	426 ± 33.1	9.56 ± 6.27	2.12 ± 0.51 (6.72)	3
Broughton Island	1993	11	463 ± 35.6	7.74 ± 2.73	1.99 ± 0.34 (7.35)	2
	1995	23	421 ± 83.1	13.1 ± 7.18	2.42 ± 0.59 (11.3)	4
	1996	8	395 ± 37.0	11.6 ± 7.36	2.18 ± 0.90 (8.86)	0
	2001	25	425 ± 62.6	17.8 ± 24.1	2.50 ± 0.78 (12.2)	0
Clyde River	1993	5	414 ± 92.2	11.7 ± 12.4	1.90 ± 1.28 (6.71)	0
Grise Fiord	1993	3	367 ± 42.9	9.31 ± 6.07	2.01 ± 0.92 (7.43)	0
Pangnirtung	2002	2		10.4	2.05 (7.80)	0
Pond Inlet	1978	38	372 ± 49.6	6.85 ± 2.95	1.83 ± 0.47 (6.23)	5
	1982	23	394 ± 55.3	12.2 ± 7.49	2.23 ± 0.90 (9.31)	0
	1983	15	442 ± 30.2	17.0 ± 7.00	2.75 ± 0.41 (15.7)	0
	1992	9	381 ± 54.9	10.0 ± 5.94	2.10 ± 0.75 (8.14)	0
	1994	18	387 ± 46.3	13.0 ± 10.0	2.20 ± 0.99 (9.07)	1
	1999	17	393 ± 64.7	9.60 ± 8.40	1.91 ± 0.93 (6.77)	0
	2000	11	373 ± 77.4	9.21 ± 6.64	1.93 ± 0.84 (6.91)	4
	2004	7	389 ± 47.8	11.4 ± 6.84	2.30 ± 0.58 (9.94)	1
Repulse Bay	1993	3	398 ± 11.9	8.92 ± 7.92	1.33 ± 2.15 (3.77)	0
	1999	16	365 ± 64.8	12.0 ± 7.20	2.17 ± 1.00 (8.70)	0

then the analysis was repeated without it. If the interaction term was significant, then the analysis was terminated.

Arviat

Four collections were obtained from Arviat over the interval from 1984 to 2003 (Table 1). The mean levels of mercury in liver from Arviat ranged approximately two-fold from 4.07 μg/g in 1986 to 8.83 μg/g in 1999. The average age for the 94 beluga remaining from this location after removal of statistical outliers was 11.1 years. The regression of (log_e) liver mercury on age was calculated for each of the four collection years separately to obtain the mercury levels expected in whales of 11.1 years:

For 1984, age adjusted LnHg = 1.46 (4.32 μg/g)
For 1986, age adjusted LnHg = 1.36 (3.91 μg/g)
For 1999, age adjusted LnHg = 2.14 (8.49 μg/g)
For 2003, age adjusted LnHg = 1.98 (7.26 μg/g).

The analysis of covariance using PROC GLM indicated that there was no significant interaction between age and year and that there were significant differences among years ($F=6.01$, $p=0.0009$). The LSMEANS procedure was run to estimate which means differed and this procedure indicated that the means fell into two pairs; those in 1984 and 1986 differed from those in 1999 and 2003. Inspection of the age-adjusted values shows that the values in the former pair were exceeded by those in the latter pair.

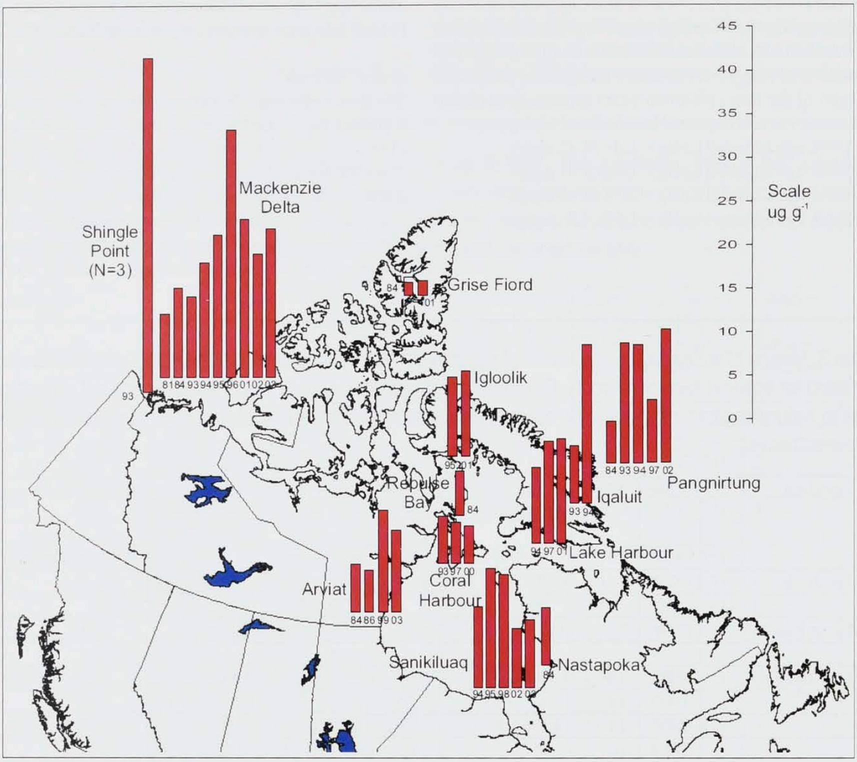
Coral Harbour

The three collections from Coral Harbour were taken over a shorter time span of only 7 years from 1993 to 2000 (Table 1). The arithmetic means show a somewhat distorted pattern because the collection in 1997 included a whale with an unusually high level of 130 μg/g (age 29.5 years) and this individual was not rejected as a statistical outlier. The influence of such an unusual individual was less prominent in the geometric means (Table 1). The levels

Table 3. Means of walrus ages and levels of mercury in liver. The arithmetic means and standard deviations are listed for age and level of mercury. Geometric means were calculated by converting original concentration units to natural logarithms; geometric means have also been converted back to original concentration units (in parentheses).

Location	Year	N	Arithmetic Mean age (yr)	Arithmetic Mean Hg in liver (μg/g wet wt)	Geometric mean (log_e) of Hg in liver	Number of outliers removed
Akulivik	1990	3	5.90 ± 1.47	5.27 ± 0.29	1.66 ± 0.05 (5.26)	1
Grise Fiord	1996	2	10.5	1.26	-0.40 (0.67)	0
Hall Beach	1988	14	9.14 ± 3.37	0.87 ± 0.29	-0.19 ± 0.33 (0.83)	2
	1992	14	11.1 ± 7.32	1.35 ± 1.50	-0.18 ± 1.00 (0.84)	0
	1996	14	14.3 ± 8.84	1.70 ± 1.28	0.22 ± 0.90 (1.24)	0
	2004	16		1.66 ± 0.92	0.35 ± 0.58 (1.43)	0
Igloolik	1982	12	11.8 ± 4.47	1.21 ± 0.82	0.009 ± 0.62 (1.01)	0
	1983	24	12.8 ± 4.28	1.35 ± 1.01	0.12 ± 0.58 (1.12)	0
	1987	14	9.50 ± 4.77	1.07 ± 0.98	-0.13 ± 0.57 (0.88)	2
	1988	11	8.73 ± 6.92	1.18 ± 0.70	-0.04 ± 0.745 (0.96)	1
	1992	6	11.0 ± 5.87	0.78 ± 0.51	-0.48 ± 0.80 (0.62)	0
	1993	5	17.6 ± 4.39	2.02 ± 1.09	0.59 ± 0.53 (1.80)	1
	1996	11	18.5 ± 5.43	1.82 ± 1.17	0.40 ± 0.68 (1.49)	2
Inukjuaq	1990	7	10.9 ± 10.3	1.36 ± 0-.93	0.04 ± 0.85 (1.04)	1
Iqaluit	1984	27	11.4 ± 5.13	1.58 ± 0.97	0.28 ± 0.64 (1.32)	3

Figure 1. Age-adjusted levels of mercury (ug/g wet weight) in beluga liver at locations and years shown. Age adjustment was to 13.2 years, the overall mean age for 650 beluga represented.(The age adjustment for Grise Fiord in 2001(N=5) and Shingle Point in 1993 (N=3)could not be done successfully and the bars shown are the geometric means.)



of mercury were adjusted for an average of 11.7 years with the following results:

For 1993, age adjusted LnHg = 1.73 (5.64 μg/g)
For 1997, age adjusted LnHg = 1.39 (4.02 μg/g)
For 2000, age adjusted LnHg = 1.42 (4.12 μg/g).
Proc GLM of SAS did not detect any significant interaction term and so the procedure was re-run without it and there was no significant effect of year of collection ($F=0.07$, not significant).

Iqaluit

With only two collections from Iqaluit in 1993 and 1994 (Table 1), this location met neither criterion for tests of temporal change. However, this site is instructive for the very large difference in mean levels between the two years. The ages of the whales in the two collections were not very different, 13.4 years in 1993 and 15.6 years in 1994. In addition, neither regression of LnHg on age was significant statistically. It is difficult to imagine such a large apparent change over a single year being the result of any temporal trend. More likely these collections reflect other causes responsible for year-to-year differences. If this interpretation is correct, then it emphasizes the difficulty of being able to detect trends in the presence of such large year-to-year variation.

Lake Harbour

The three collections from Lake Harbour comprised 39 beluga (after removal of two statistical outliers) obtained in 1994, 1997 and 2001 (Table 1). Both arithmetic and geometric means suggest increases in levels over the interval, but the whales were considerably younger in 1994 than in either subsequent collection. The average age for the 39 whales was 13.5 years. The levels of mercury in each collection were adjusted to 13.5 years as follows:

For 1994, age-adjusted LnHg = 2.18 (8.83 μg/g)
For 1997, age-adjusted LnHg = 2.46 (11.7 μg/g)
For 2001, age-adjusted LnHg = 2.51 (12.3 μg/g).

PROC GLM indicated a significant interaction between age and year of collection and so further comparison of means was not attempted. The slopes of the regressions for the three years were:

For 1994, slope of LnHg on age = 0.9143 ± 0.0174 (S.E.) ($p<0.0001$)
For 1997, slope of LnHg on age = 0.0026 ± 0.0194 (S.E.) (not Significant)
For 2001, slope of LnHg on age = 0.1081 ± 0.0182 (S.E.) ($p<0.0001$).

There was no clear pattern in the slopes and no clear conclusion has been drawn regarding temporal change. Since the collection in 1997 had no clear relationship between age and mercury in liver, the analysis was repeated using data from 1994 and 2001 only. In this instance, the interaction term was not significant ($F=0.40$, $p=0.53$). The analysis was run with no interaction in the model and the means fell just short of differing ($F=4.16$, $p=0.051$). This outcome suggests that results in 2001 were probably higher than those in 1994.

Mackenzie Delta

The ten collections from the Mackenzie Delta area from 1981 to 2004 (Table 1) should offer our best opportunity to detect a temporal trend. These values cannot be compared directly with those from the eastern Arctic because these were age-adjusted to the mean age of 16.4 years within the Mackenzie Delta group, an age considerably older than those for the eastern collections. At the time of this report, ages were not available for the collection in 2004. The regression equations were calculated for each collection and then solved for an age of 16.4 years to yield the age-corrected levels of mercury below:

For 1981, age-adjusted LnHg = 2.06 (7.87 μg/g)
For 1984, age-adjusted LnHg = 2.52 (12.5 μg/g)
For 1993, age-adjusted LnHg = 2.57 (13.1 μg/g)
For 1994, age-adjusted LnHg = 2.84 (17.0 μg/g)
For 1995, age-adjusted LnHg = 3.33 (28.1 μg/g)
For 1996, age-adjusted LnHg = 3.72 (41.1 μg/g)
For 2001, age-adjusted LnHg = 3.43 (30.8 μg/g)
For 2002, age-adjusted LnHg = 3.19 (24.3 μg/g)
For 2003, age-adjusted LnHg = 3.34 (28.2 μg/g).

The means could not be compared directly using the analysis of covariance in PROC GLM because the interaction term between age and year was significant ($F=2.30$, $p=0.02$). The slopes of the regression lines were:

For 1981, slope of LnHg on age = 0.0209 ± 0.0488 (S.E.) (not significant)
For 1984, slope of LnHg on age = 0.0588 ± 0.0237 (S.E.) ($p=0.068$)
For 1993, slope of LnHg on age = 0.1072 ± 0.0253 (S.E.) ($p=0.0005$)
For 1994, slope of LnHg on age = 0.0790 ± 0.0299 (S.E.) ($p=0.012$)
For 1995, slope of LnHg on age = 0.1690 ± 0.0130 (S.E.) ($p<0.0001$)
For 1996, slope of LnHg on age = 0.1156 ± 0.0297 (S.E.) ($p=0.0046$)
For 2001, slope of LnHg on age = 0.1657 ± 0.0248 (S.E.) ($p<0.0001$)
For 2002, slope of LnHg on age = 0.1689 ± 0.0419 (S.E.) ($p=0.0006$)
For 2003, slope of LnHg on age = 0.1567 ± 0.0162 (S.E.) ($p<0.0001$)

The slope for 1981 was not significantly different from zero and that for 1984 was only marginally different ($p=0.068$). Whether these two slopes are taken as zero or as the values shown, they are the lowest slopes for this location. Generally the slopes fall into two ranges, those from 1981 to 1994 in the range of 0-0.1972 and those from 1994to 2003 with a range of 0.1156 to 0.1690. These suggest that mercury was taken up more readily during the latter period than during the former.

Since the slope for the collection in 1981 was not significant, the analysis of covariance using PROC GLM was run again excluding that collection. In this case, the interaction term fell just short of statistical significance ($F=2.01$, $p=0.059$) and the analysis with no interaction term indicated significant differences among the means

(F=4.62, p=0.0001). If 1984 is also excluded, the result was similar with no significant interaction term and significant differences among means. The LSMEANS procedure indicated that means in 1993 and 1994 differed from all subsequent means which did not differ from each other. That is, levels were higher in 1995 and later than they were in 1993 and 1994.

Overall, the collections from the Mackenzie Delta suggest that mercury levels in liver have changed over time and that the change occurred in the mid-1990s. The cause of this change is speculative but may have been related to oceanographic changes.

Pangnirtung

The five collections from Pangnirtung included 74 beluga (Table 1) with a mean age of 10.6 years. The age-adjusted means for age 10.6 years were:

For 1984, age-adjusted LnHg = 1.21 (3.36 μg/g)
For 1993, age-adjusted LnHg = 2.23 (9.26 μg/g)
For 1994, age-adjusted LnHg = 2.81 (9.79 μg/g)
For 1987, age-adjusted LnHg = 1.91 (6.74 μg/g) (slope not significant)
For 2002, age-adjusted LnHg = 2.63 (13.9 μg/g)

Again, the means could not be compared in the analysis of covariance because of differing slopes (significant interaction term between age and year of collection). The slopes for the collections were:

For 1984, slope of LnHg on age = 0.1350 ± 0.0594 (S.E.) (p=0.049)
For 1993, slope of LnHg on age = 0.1492 ± 0.0339 (S.E.) (p=0.0031)
For 1994, slope of LnHg on age = 0.1226 ± 0.0142 (S.E.) (p<0.0001)
For 1997, slope of LnHg on age = 1.6683 ± 0.0228 (S.E.) (p=0.2715) (not significant)
For 2002, slope of LnHg on age = 0.0352 ± 0.0034 (S.E.) (p=0.0005)

There was no obvious, consistent pattern to the slopes and so there was no indication that the accumulation of mercury in liver had changed greatly over the interval.

In view of the lack of a relationship between age and mercury in 1997, that collection was excluded and the analysis by PROC GLM was run again. With the remaining four collections, the interaction term was not significant and the difference among yearly means was highly significant (F=12.56, p<0.0001). The LSMEANS procedure indicated that the collection in 1984 differed from the remaining three and that those three (1993, 1994 and 2002) did not differ from each other. This analysis suggests that mercury levels increased sometime between the mid-1980s and the mid-1990s.

Sanikiluaq

The 83 whales from Sanikiluaq over the period from 1994 to 2003 had an average age of 13.1 years. Ages for the collection in 2004 were not available at the time of this report.

The levels of mercury, adjusted to age 13.1 years were:

For 1994, age-adjusted LnHg = 2.22 (9.20 μg/g)
For 1995, age-adjusted LnHg = 2.60 (13.5 μg/g)
For 1998, age-adjusted LnHg = 2.55 (12.8 μg/g)
For 2002, age-adjusted LnHg = 1.91 (6.73 μg/g)
For 2003, age-adjusted LnHg = 2.04 (7.72 μg/g)

As with most other collections, the analysis of covariance using PROC GLM indicated that the interaction between age and year was significant and the analysis was terminated at that point. The slopes of the regressions were:

For 1994, slope of LnHg on age = 0.1060 ± 0.0184 (S.E.) (p<0.0001)
For 1995, slope of LnHg on age = 0.1202 ± 0.0136 (S.E.) (p<0.0001)
For 1998, slope of LnHg on age = 0.2275 ± 0.0229 (S.E.) (p<0.0001)
For 2002, slope of LnHg on age = 0.1327 ± 0.0456 (S.E.) (p=0.0227)
For 2003, slope of LnHg on age = 0.1454 ± 0.0110 (S.E.) (p<0.0001).

Inspection of these slopes suggests no simple trend over the decade. Rather the slopes appear to have increase between 1994 and 1998 and then decreased. All the slopes were significant statistically and so there was no reason to exclude any of them.

Most of the beluga samples could not be analyzed by the conventional analysis of covariance in PROC GLM because of differing slopes of the individual yearly regressions. The exceptions to this were Arviat where levels were higher in the early 2000s than they in the mid-1980s, and Coral Harbour where no change was indicated over the period from 1993 to 2000. The remaining locations with at least three collections, Lake Harbour, Mackenzie Delta, Pangnirtung and Sanikiluaq, all had differing slopes. The differing slopes of mercury on age suggest in themselves changes in the rates of assimilation of mercury into liver. Some of the slopes were not significant; when collections with no significant slope were excluded, the analysis of covariance suggested increases in levels of mercury over time in the remaining collections. Collections suggested either no change in levels or increases; decreases were not suggested. On balance then, our conclusion is that levels of mercury have increased somewhat in beluga from some locations since the mid-1980s.

Narwhal

The narwhal data describe 298 individuals collected over the interval from 1978 to 2004. Narwhal lacking information on length or mercury in liver were excluded. About half of these were from Pond Inlet with smaller numbers from several other communities (Broughton Island, Arctic Bay, Repulse Bay, Clyde River and Grise Fiord). Narwhal cannot be aged reliably; consequently, length was examined as a covariate with mercury. However, the range of lengths in the samples was relatively small. Often regressions of mercury in liver on narwhal length did not have significant slopes and so the value of length as a covariate is limited. Each collection was examined using the "Robust Regression" feature of NCSS software in an attempt to identify statistical outliers. Again, the procedure of removing outliers with narwhal is limited but it was used for consistency with the beluga data. This resulted in removal of 26 individuals, leaving 272 for examination using PROC GLM of SAS. The overall mean length of these 272 narwhal was 404 cm and their average level of mercury in liver was 11.5 μg/g.

Collections from Clyde River, Grise Fiord and Repulse Bay were all made in a single year and so they could not be analyzed for temporal trends.

Arctic Bay

Since length data were not available for the narwhal from Arctic Bay in 1983, they had to be excluded from the analysis of covariance, leaving 48 samples over the period from 1986 to 2004. The initial screening of the data with NCSS software identified several outlier points as listed in Table 2. After removal of outliers, the length-adjusted means were calculated with PROC REG of SAS, using a length of 430 cm, with the results below:

For 1986, length-adjusted LnHg = 2.23 (9.33 μg/g)
For 1987, length-adjusted LnHg = 2.07 (7.92 μg/g)
For 1999, length-adjusted LnHg = 2.25 (9.45 μg/g)
For 2004, length-adjusted LnHg = 2.12 (8.31 μg/g).

The examination with PROC GLM of SAS revealed no interaction was between length and year of collection. When the analysis was repeated without the interaction term, no effect of year of collection was evident ($F=0.64$, $p=0.59$). Hence this analysis offers no indication that levels have changed in narwhal over the interval.

Broughton Island

Four collections were available from Broughton Island: 1993, 1995, 1996 and 2001. The total number of whales was 67 with a mean length of 436 cm and mean mercury in liver of 13.8 μg/g. Two of the four regressions of (Ln) liver mercury on length were statistically significant ($p<0.05$) but the remaining two fell short of significance ($P=0.18$ in 1993 and $p=0.08$ in 1996). When mercury levels were adjusted to the mean length, the adjusted values were:

For 1993, length-adjusted LnHg = 1.84 (6.31 μg/g)
For 1995, length-adjusted LnHg = 2.44 (11.5 μg/g)
For 1996, length-adjusted LnHg = 2.68 (14.6 μg/g)
For 2001, length-adjusted LnHg = 2.51 (12.3 μg/g).

The analysis with PROC GLM revealed no significant interaction term between length and year, and the repeat of that analysis with no interaction term indicated significant differences among years ($F=4.32$, $p=0.0079$). Inspection of the means from the LSMEANS procedure of PROC GLM indicated that the levels in 1993 were lower than all the others. There were no differences among the means from 1995, 1996 and 2001. Thus the pattern is one of a large change between 1993 and 1995 with no subsequent change.

Pond Inlet

The eight collections from Pond Inlet comprise the longest time series we have for marine mammals with collections from 1978 to 2004. The average length of narwhal from this location was 390 cm and the average level of mercury in liver was 10.9 μg/g. When mercury levels were adjusted to a length of 390 cm, the adjusted levels were:

For 1978, length-adjusted LnHg = 1.91 (6.74 μg/g)
For 1982, length-adjusted LnHg = 2.19 (8.96 μg/g)
For 1983, length-adjusted LnHg = 2.52 (12.4 μg/g)
For 1992, length-adjusted LnHg = 2.15 (8.57 μg/g)
For 1994, length-adjusted LnHg = 2.26 (9.62 μg/g)
For 1999, length-adjusted LnHg = 1.89 (6.60 μg/g)
For 2000, length-adjusted LnHg = 2.11 (8.26 μg/g)
For 2001, length-adjusted LnHg = 2.31 (10.1 μg/g).

When these data were analysed with PROC GLM, the interaction term between length and year fell just short of significance ($F=1.90$, $p=0.076$). With no interaction term, PROC GLM indicated no significant effect of year of sampling ($F=0.99$, $p=0.44$). The conclusion drawn was that levels have remained unchanged over the period from 1978 to 2004.

Repulse Bay
Two collections were made from Repulse Bay, a small one of 4 narwhal in 1993 and a larger one of 18 in 1999. However, three of these had no information on length, reducing the total to 19 available for comparison. The average length for these 19 whales 370 cm and the average concentration of mercury in liver was 11.5 µg/g. Adjusting the mercury levels to the average length of 370 cm failed for the three whales in 1993 and gave a clearly erroneous value of only 0.63 µg/g in spite of an arithmetic mean of 8.92 µg/g. The regression technique of adjusting levels of mercury to a common age becomes more and more unreliable as the number of samples gets smaller. For 1999, the length-adjusted mean of LnHg was 2.22 (9.16 µg/g). PROC GLM indicated neither a significant interaction tern nor any difference between years ($F=2.67$, $p=0.12$).

Overall, the narwhal data suggest little or no change in levels of mercury over the period from 1978 to 2004. The only suggestion of any change was in the samples from Broughton Island and the change there was restricted to the period between 1993 and 1995.

Walrus
The number of walrus for which both age and mercury concentrations in liver are available is smaller with 177 samples available (Table 3). These were obtained mostly from Hall Beach and Igloolik with small numbers from other communities. A good sample of 27 walrus was obtained from Iqaluit in 1984 but this has not been repeated yet. Samples were obtained on one occasion only from the communities of Akulivik (1990), Grise Fiord (1996), Inukjuaq (1990) and Iqaluit (1984) and these could not be used for temporal comparison. The levels in walrus liver were consistently lower than those from either beluga or narwhal, presumably reflecting different dietary habits. The three walrus from Akulivik stand out with higher levels of mercury than the walrus from the other collections.

The effect of age on levels of mercury appears to be relatively weak for these walrus. For Hall Beach and Igloolik, a combined total of ten regression equations were calculated and of these only three had slopes significantly greater than zero. Consequently, the adjustment of mercury levels for age in these samples has relatively little effect in most instances.

Hall Beach
Collections of 42 individuals from 1988, 1992 and 1996 are useful for temporal comparisons (Table 3). Ages are not available yet for the collection in 2004. The average for the three earlier collections was 11.5 years and that age was used as the basis for the calculation of the age-adjusted levels of mercury in liver. Two of the three regressions had slopes significantly different from zero (1992 and 1996). The adjusted mean levels of mercury were 0.90 µg/g, 0.87 µg/g and 1.05 µg/g for 1988, 1992 and 1996 respectively. The analysis by PROC GLM of SAS revealed no significant interaction between age and year of collection and the analysis with no interaction term indicated no effect of year of collection. The conclusion drawn was that no significant differences occurred in the levels of mercury in walrus liver at Hall Beach over the period from 1988 to 1996. Future reports will be able to incorporate the data from 2004 after ages are available.

Igloolik
Over the period from 1982 to 1996 we have seven collections of walrus from Igloolik (Table 3). These collections comprise 83 walrus for which both age and mercury in liver have been determined. The overall mean age was 12.5 years and the overall arithmetic average level of mercury in liver was 1.32 µg/g. Of the seven regression equations calculated to adjust the levels of mercury for walrus age, only one (1996) had a slope significantly different from zero and so the adjustment for age had little effect in six of the seven collections. The collections in 1993 and 1996 were composed of animals considerably older than the earlier collections and age was undoubtedly a factor in the higher means in those years. The mean level of mercury in the sample from 1996 declined from 1.49 µg/g (Table 3) when the average age was 18.5 years to only 0.8 µg/g when the age was adjusted to 12.5 years. The adjusted mean levels were:

For 1982, age-adjusted LnHg = 0.03 (1.03 µg/g)
For 1983, age-adjusted LnHg = 0.11 (1.12 µg/g)
For 1987, age-adjusted LnHg = 0.05 (1.05 µg/g)
For 1988, age-adjusted LnHg = -0.10 (0.90 µg/g)
For 1992, age-adjusted LnHg = -0.37 (0.69 µg/g)
For 1993, age-adjusted LnHg = 0.35 (1.42 µg/g)
For 1996, age-adjusted LnHg = -0.22 (0.80 µg/g).

PROC GLM indicated no interaction between age and year of collection and also no effect of year of collection. Our conclusion is that no change in levels of mercury in walrus was evident over the interval.

Hall Beach and Igloolik together
In view of the relatively close geographic proximity of Hall Beach and Igloolik, the data from walrus from those

communities were pooled. The result was similar to the analyses for the communities separately. There was no interaction term between age and year of collection and there was no effect of year of collection. Thus, neither the data from the communities separately nor those from the pooled data suggest a change in levels of mercury over time.

Discussion and Conclusion

Levels of mercury in liver of three species of beluga, narwhal and walrus have been determined at irregular intervals since the 1970s. All mean arithmetic and geometric levels in all three species have exceeded the Canadian consumption guideline of 0.5 μg/g set to regulate the sale of commercial fish. (There is no guideline set specifically for marine mammals.) The predominant form of mercury in liver of beluga is not methylmercury as it is in fish (Wagemann et al., 1998). Regional differences in levels were found in the 1990s in beluga with higher levels of mercury in the animals from the western Arctic than in the Eastern Arctic (Wagemann et al., 1996) but this difference diminished by the early 2000s (Lockhart et al, 2005) suggesting that the levels in the different regions have been driven by different processes. There are quite large differences from one year to the next in some instances. Perhaps the best example of this was from Iqaluit beluga where the mean level changed by more than 2-fold in a single year from 1993 to 1994. In the face of such large year-to-year variation, identification of genuine temporal trends, if any, will be very demanding statistically.

Mercury concentrations are usually expressed as the amount of mercury per wet weight of tissue. This has been common practice in much of the literature and it probably derives from human consumption regulations. However, a sustained effort to detect trends may be facilitated by exploring alternative ways to express concentrations of mercury. For example, organochlorine compounds are commonly expressed on the basis of the amount of fat in a tissue. Similarly, it may be useful to explore techniques for expressing mercury on the basis of total protein, for example, or on the basis of sulfur or protein-bound sulfur. If these or other alternative expressions reduce the variance in the data, then detection of trends will become easier. Biopsy techniques have been used for other purposes to obtain samples without killing animals and these might enable repeated sampling of the same individuals over their lives. With relatively little extension of existing knowledge of mercury in different body organs, it may be possible to express body burdens of mercury rather than concentrations in tissues and this would be useful for modeling and projecting future levels.

There was a clear species differences in levels of mercury in liver. Levels found in walrus liver were consistently lower than those in beluga or narwhal. Probably this difference reflects different feeding habits between walrus and the whales.

Most of the data fail to show a clear temporal trend. Rather they suggest either increases or no change. If the differences simply reflect some source of random variation then one might expect some to show decreases over the intervals. Samples of beluga from the Mackenzie Delta suggest that levels may have been higher in the mid-1990s than in either the 1980s or early 2000s, following an oscillating pattern.

On balance, it seems likely that levels of mercury have increased in some locations. Hopefully future research will be able to identify the processes responsible for this and improved means of detecting changes. Perhaps improved linkages to oceanographic and climatic variables will prove instructive.

Expected Project Completion Date

In view of the statistical difficulties in isolating any temporal trends from other sources of variation, it seems likely that some form of monitoring of levels in marine mammals will be required regularly as long as people consume these animals. It is difficult to predict what, if any, programs will be available to support this work, but the interest in trends in marine mammals and other biota used as human food will continue.

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Temporal Trends of Halogenated Organic Compounds in Arctic Marine Mammals (Beluga, Narwhal and Walrus)

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Abstract

While the levels of major HOC groups and compounds in Arviat and Sanikiluaq have either remained unchanged or have declined since the mid-1980s, the levels in the Hendrickson Island animals have risen significantly over the 15 year period from 1989 to 2004. Interestingly, this result coincides with a similar increase observed for mercury in the same animals and maybe attributed to recent changes in ice cover and distribution in the western Arctic Ocean. HOC concentrations in narwhal from Pond Inlet and Arctic Bay and walrus from Igloolik have declined significantly while, with the exception of ΣCBz, no changes were observed in the Hall Beach walrus.

Key Messages

- HOC levels in Arviat beluga and Arctic Bay narwhal and walrus from Igloolik have declined significantly since the mid-1980s.
- No trends in HOC concentrations were observed in Sanikiluaq beluga or Hall Beach walrus
- HOC levels in the Hendrickson Island animals have risen significantly over the 15 year period from 1989 to 2004. This result coincides with a similar increase observed for mercury in the same animals and maybe attributed to recent changes in ice cover and distribution in the western Arctic Ocean.

Objectives

To continue to assess long term trends and to maintain the current data-base on levels of halogenated organic compounds (e.g. PCBs, DDT, toxaphene) in marine mammals (beluga, narwhal, walrus) from selected locations across the Canadian Arctic

Introduction

Marine animals accumulate (relatively) high concentrations of halogenated organic compounds (HOCs). The objectives of this project, therefore, are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of halogenated organic compounds (HOCs). This will allow us to determine whether contaminant levels in the marine mammals, and hence exposure to Arctic people who traditionally consume them, are changing with time. These results will also help to test the effectiveness of international controls and, in conjunction with projects such as CASES (Canadian Arctic Shelf Exchange Study) and ArcticNet, to understand the effects that climate variation may have on the contaminant levels in these animals and the health of the stocks.

The raw data and samples from previous and ongoing investigations are archived at the Freshwater Institute and represent about 2000 marine mammals, mostly beluga, ringed seals, narwhal and walrus from 23 different locations across the Canadian Arctic. DFO scientists concerned with stock management, animal health and climate change studies obtain various samples from hunter kills and those samples form the basis of most of our analyses. For example, tissues from eastern Arctic and Hudson Bay narwhal and beluga have been collected and analyzed for HOCs as part of DFOs stock management studies since 1996 (Nunuvut Wildlife Management Board and Nunavut Implementation funding to Stern and de March; de March & Stern, 2003; de March et al. 2005). The accumulating data resulting from these studies offer the means to detect both spatial and temporal trends of HOCs and heavy metals in marine mammals across the Canadian Arctic (Stern et al. 2005).

Activities

In 2004/05

With the exception of the 2004 walrus samples from Igloolik (collections were not successful but will be attempted again in summer 2005) all HOC analysis outlined in the 2004/05 proposal has now been completed. The results are reported below in Tables 1-3. Manuscripts outlining factors affecting spatial variation of HOCs in beluga (Stern et al., 2005), the combined use of HOC profiles and molecular genetics for stock discrimination of beluga hunted in three communities on southeast Baffin Island (De March et al. 2004) and a report on narwhal (De March and Stern, 2003) have been now been published .

Results

As part of an ongoing whale sampling and stock identity program, supported by the Nunavut Wildlife Management Board (NWMB) and DFO, samples were collected by hunters during their subsistence hunts using standardized whale kits. Blubber, kidney, liver, ovaries and uterus, muscle and the lower jaw, as well as morphometric data were collected for each animal. All samples were shipped frozen to the Freshwater Institute and stored at - 20°C until analysis.

Beluga: Current temporal trend results for major HOC groups, dieldrin and oxychlordane are presented in Table 1. With few exceptions, HOC levels have declined in the male Arviat beluga over the 17 year time period between 1986 and 2003. The 2003 animals are about twice the age of those collected in 1986 and 1999 but, if corrected for age, would most likely result in even lower levels. Conversely, the levels in the Hendrickson Island animals seem to have increased over the 15 year period from 1989 to 2004 (ages are similar). Interestingly, this result coincides with a similar increase observed for mercury (Lockhart et al. 2005) and could be attributed to recent changes in ice cover and distribution in the western Arctic Ocean (Stern and Macdonald 2005). The levels in the Sanikiluaq animals, taking the ages into account, have not changed significantly over nine year period from 1994 to 2003. HOC levels in the 2004 Hendrickson Island samples are approximately 2-fold higher than those in the 2003 Arviat and Sanikiluaq animals.

Narwhal: Current temporal trend results for major HOC groups, dieldrin and oxychlordane are presented in Table 2. Unlike beluga, narwhal cannot be aged and no correlation between HOC levels and length was observed in males animals for Arctic Bay or Pond Inlet. Over the 17 year period from 1987 to 2004 mean HOC concentrations in the Arctic Bay animals have declined. The high mean HOC levels (standard deviations) in the male 2004 Pond Inlet animals are ascribed to the very high levels measured in two, probably much older, animals. PI samples from 1982, 1992 and 1994 are available and will be analyzed for HOCs in 2005-06.

Walrus: Current temporal trend results for major HOC groups, dieldrin and oxychlordane are presented in Table 3. As was noted by Muir et al. (1995), age was not correlated to HOC concentrations in either the Hall Beach or Igloolik animals. Only ΣCBz showed a significant decline in the Hall Beach animals over the 17 year period from 1987 to 2004.

In the case of the Igloolik animals, levels of contaminant groups and compounds listed in Table 3 declined significantly over the 13 year period from 1983 to 1996 (t-test, $p<0.05$).

A few animals, notably 2 males from Hall beach and one from Igloolik had levels of all major HOC groups and compounds that were approximately 10 fold higher than that of all other males. The $\delta^{15}N$ and $\delta^{13}C$ values for these three animals averaged 12.2 ± 0.25 and -18.1 ± 0.42, respectively, and did not differ significantly from the means outlined in Table 3. Elevated levels were also reported in walrus from Inukjuak, Akulivik (Eastern Husdson Bay) and Loks Land (East Baffin Island) (Muir et al., 2005). It was postulated that the much higher HOC levels in these animals was the result of periodic consumption of ringed seal blubber.

Expected Project Completion Data

This study, in conjunction with the trace metal work, is expected to continue until at least 2009.

Table 1. Mean (stdev) of major HOC groups and compounds in **beluga** blubber (ng g^{-1}, wet wt).

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Dieldrin	Oxychlor
HL	1989	M	12	14.5	90.5	421.5	269.3	1857.6	2930.8	3800.0	4548.0	297.5	487.7
				(7.5)	(3.7)	(185.9)	(111.3)	(667.8)	(1125.8)	(1587.7)	(1462.6)	(112.1)	(143.6)
HI	1995	M	15	16.1	81.3	783.2	211.9	2076.2	3907.7	4176.6	6701.0	287.9	519.1
				(5.2)	(3.3)	(380.4)	(40.6)	(1025.8)	(1753.7)	(1473.3)	(3207.3)	(141.7)	(348.2)
HI	2001	M	19	16.7	82.5	553.8	206.4	2065.4	3593.9	4026.4	6371.5	315.5	555.0
				(5.2)	(3.6)	(224.7)	(42.9)	(976.21)	(1715.1)	(1697.4)	(3561.8)	(129.6)	(328.4)
HI	2004	M	10	nd	85.1	888.0	329.2	2932.8	3747.0	4894.1	7554.1	500.7	744.8
					(6.8)	(189.0)	(50.8)	(535.7)	(1928.3)	(948.8)	(2360.1)	(99.4)	(192.5)
AR	1986	M	9	9.8	94.9	1286.9	464.0	3722.5	11013.7	7128.4	24667.4	1250.0	866.5
				(6.0)	(2.6)	(590.0)	(190.9)	(1048.4)	(6346.5)	(2666.5)	(8436.1)	(366.4)	(226.4)
AR	1999	M	10	12.1	90.3	438.4	455.9	1480.8	2842.2	3086.1	3935.4	240.1	373.6
				(4.8)	(3.3)	(164.8)	(202.0)	(397.3)	(769.8)	(840.7)	(1106.6)	(127.5)	(111.4)
AR	2003	M	18	8.7	79.7	257.8	132.3	1264.8	1332.9	1567.0	4092.2	437.2	296.6
				(4.8)	(14.4)	(169.5)	(63.0)	(539.7)	(786.6)	(620.5)	(1853.4)	(234.2)	(143.7)
AR	2003	F	16	10.2	91.4	219.0	117.0	1320.4	1210.4	1375.7	3453.4	328.0	334.7
				(4.7)	(6.2)	(167.9)	(64.1)	(968.1)	(995.0)	(967.2)	(2137.1)	(216.3)	(304.6)
SK	1994	M	15	15.1	92.5	535.2	440.5	2075.5	2153.7	3481.0	5577.7	441.1	409.4
				(4.9)	(2.7)	(88.7)	(114.4)	(765.4)	(840.7)	(1362.3)	(1571.9)	(139.0)	(196.8)
SK	1998	M	10	12.1	94.4	388.2	374.1	1645.5	1523.3	2856.1	3861.8	268.6	327.4
				(2.8)	(3.9)	(170.6)	(203.7)	(896.6)	(937.9)	(1629.6)	(1830.3)	(201.3)	(194.4)
SK	2003	M	7	8.9	86.9	286.2	154.5	1557.2	2073.0	2422.0	5547.4	571.4	333.3
				(4.4)	(4.7)	(55.8)	(41.0)	(518.1)	(764.9)	(615.4)	(1262.1)	(143.1)	(138.0)
SK	2003	F	3	11.0	85.3	184.8	124.2	1199.9	1543.2	2727.3	7385.8	447.8	217.4
				(8.3)	(2.1)	(237.6)	(94.9)	(1201.2)	(1631.5)	(2883.8)	(5665.2)	(614.8)	(268.2)

HL = Husky Lakes; HI = Hendrickson Island; AR = Arviat; SK = Sanakiluaq; na = not yet determined; SDDT = Sum of *p,p'*-DDT, *p,p'*-DDE, *p p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD; SHCH = a- b- and g-HCH isomers; SCHL = all chlordane related compounds, including heptachlor; SCBz = Sum of 1245TCB, 1234TCB, P5CBz, HCBz; SPCB = Sum of CB1, 3, 4/10, 7, 6, 8/5, 19, 18, 17, 24/27, 16/32, 26, 25, 31, 28, 33, 22, 45, 46, 52, 49, 47, 48, 44, 42, 41/71, 64, 40, 74, 70/76, 66, 95, 56/60, 91, 84/89, 101, 99, 83, 97, 87, 85, 136, 110, 82, 151, 144/135, 149, 118, 134, 114,131, 146, 153, 132, 105, 141, 130/176, 179, 137, 138, 158, 178/129, 175, 187, 183, 128, 185, 174, 177, 171, 156, 201/ 157, 172/197, 180, 193, 191, 200, 170, 190, 198, 199, 196/203, 189, 208, 195, 207, 194, 205, 206, 209

Table 2. Mean (stdev) of major HOC groups and compounds in narwhal blubber (ng g^{-1}, wet wt).

Loc	Year	Sex	n	Length	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Dieldrin	Oxychlor
AB	1987	M	10	459.4	87.2	614.1	139.0	2353.4	9263.7	5269.1	16549.7	582.5	373.3
				(31.9)	(4.10)	(145.1)	(31.7)	(511.3)	(2161.8)	(1119.2)	(4078.3)	(126.7)	(70.0)
AB	1999	M	9	430.8	87.7	371.9	137.0	1629.2	2972.3	4180.5	4455.3	186.6	224.2
				(40.8)	(4.01)	(183.2)	(57.0)	(451.1	(1365.3)	(1755.9)	(1939.8)	(84.0)	(89.6)
AB	2004	M	8	418.2	80.7	257.5	97.5	1449.6	2374.6	2190.6	5820.7	297.0	288.3
				(32.4)	(10.2)	(125.7)	(30.8)	(813.8	(1511.3)	(1260.3)	(3240.1)	(130.1)	(175.6)
AB	2004	F	5	421.6	89.4	385.6	150.4	2309.7	5569.0	3710.9	10705.3	492.2	437.5
				(26.0)	(3.2)	(240.8)	(49.6)	(1486.9	(4707.2)	(2841.3)	(6506.5)	(264.6)	(293.5)
PI	1999	M	8	412.4	88.3	457.1	110.2	1704.9	4857.4	3888.2	8039.3	318.8	370.2
				(34.5)	(3.50)	(134.7)	(34.4)	(483.6)	(1571.0)	(1147.0)	(2430.1)	(85.2)	(114.3)
PI	1999	F	2	353.5	84.8	309.6	75.4	1199.9	3243.9	2660.3	5503.5	229.2	235.8
				(3.54)	(4.45)	(120.4)	(27.1)	(539.8)	(1122.5)	(1044.7)	(2084.9)	(117.2)	(85.6)
PI	2000	M	20	419.2	86.6	364.0	97.1	1438.0	4117.6	3445.4	6812.9	276.1	318.5
				(42.0)	(6.38)	(207.8)	(50.3)	(747.6)	(2152.0)	(1693.2)	(3173.5)	(136.9)	(171.9)
PI	2004	M	8	404.3	92.9	583.8	141.7	3280.3	7680.0	4939.4	14263.6	577.7	648.1
				(49.0)	(1.37)	(217.2)	(41.6)	(1462.0)	(5596.9)	(3116.6)	(11755.4)	(223.5)	(306.0)
PI	2004	F	1	381.0	92.7	55.2	35.1	634.9	977.4	825.8	2540.1	89.7	90.5

AB = Arctic Bay; PI = Pond Inlet; PI samples from 1982, 1992 and 1994 are available and will be run for HOCs in 2005-06.

Table 3. Mean (stdev) of major HOC groups and compounds in walrus blubber (ng g^{-1}, wet wt).

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Dieldrin	Oxychlor	$\delta^{15}N$	$\delta^{13}C$
HB[1]	1987-	M	6	19.7	82.8	20.3	96.5	313.5	37.5	205.7	459.1	143.2	102.2	12.5	-18.9
	1988				(2.4)	(2.2)	(11.1)	(43.7)	(6.1)	(42.5)	(94.6)	(18.6)	(14.6)	(0.3)	(0.4)
HB	1992	M	7	12.3	73.2	6.97	146.0	369.9	41.6	197.6	1054.0	405.0	201.1	13.1	-18.9
				(8.10)	(8.05)	(3.10)	(45.7)	(94.5)	(15.8)	(59.2)	(249.7)	(214.0)	(90.8)	(0.9)	(0.4)
HB	1992	F	2	14.0	62.8	5.02	87.1	253.3	120.2	208.2	1027.7	160.3	105.0	13.7	-18.9
				(4.2)	(20.1)	(2.72)	(22.1)	(247.6)	(68.8)	(205.5)	(1063.3)	(150.8)	(119.0)	(1.4)	(0.7)
HB	1996	M	9	15.3	75.7	2.62	88.9	162.2	24.1	92.5	369.1	95.4	78.0	12.8	-18.5
				(6.7)	(3.25)	(0.85)	(32.5)	(107.2)	(16.5)	(70.3)	(226.8)	(60.9)	(54.6)	(0.7)	(0.7)
HB[2]	2000	M	4	na	75.1	1.88	111.6	271.4	32.3	147.2	625.9	294.3	163.2	na	na
					(9.5)	(0.42)	(8.50)	(43.2)	(18.8)	(44.4)	(212.8)	(71.9)	(29.8)		
HB	2004	M	4	9.5	79.48	1.43	86.4	267.9	29.9	173.9	619.8	194.8	142.1	na	na
				(0.58)	(1.52)	(0.93)	(3.6)	(50.9)	(10.3)	(31.1)	(90.6)	(42.3)	(38.4)		
HB	2004	F	5	9.4	83.6	1.41	72.5	136.0	10.1	77.9	251.4	155.3	85.4	na	na
				(1.1)	(4.93)	(0.16)	(26.1)	(82.9)	(5.02)	(38.2)	(132.2)	(84.9)	(65.7)		
IG	1983	M	9	13.6	74.2	3.50	146.6	350.8	44.0	191.4	1291.4	324.8	215.1	12.2	-18.2
				(5.2)	(4.8)	(0.52)	(43.9)	(82.6)	(20.8)	(44.8)	(445.0)	(154.4)	(59.5)	(0.3)	(0.5)
IG[1]	1987-	M	6	13.3	77.7	26.1	102.4	310.5	28.1	192.5	442.6	165.6	116.1	12.4	-18.9
	1988				(6.4)	(10.1)	(19.0)	(85.0)	(9.1)	(52.8)	(143.3)	(56.8)	(47.8)	(0.3)	(0.3)
IG[1]	1987-	F	12	13.7	81.0	0.37	62.6	165.5	20.8	90.0	201.3	71.8	44.5	12.5	-19.6
	1988				(5.2)	(0.46)	(12.7)	(98.9)	(12.9)	(54.6)	(123.0)	(37.0)	(30.3)	(0.9)	(0.5)
IG	1992	M	4	13.3	68.3	5.45	114.8	242.9	17.2	130.6	566.3	274.7	170.6	12.2	-19.0
				(2.99)	(16.4)	(2.05)	(32.7)	(32.3)	(2.49)	(31.6)	(118.5)	(71.0)	(23.5)	(0.4)	(0.2)
IG	1992	F	2	6.5	79.5	4.53	185.9	408.7	40.4	180.8	889.1	563.4	250.9	13.7	-19.8
				(9.2)	(3.95)	(1.05)	(122.5)	(326.8)	(11.4)	(72.2)	(420.7)	(617.8)	(260.1)	(1.41)	(0.1)
IG	1993	M	5	18.6	79.3	2.07	86.0	184.6	16.6	101.6	497.0	146.3	102.3	12.8	-18.3
				(3.21)	(13.4)	(0.41)	(28.7)	(76.0)	(8.45)	(42.9)	(264.4)	(57.3)	(45.3)	(0.4)	(0.3)
IG	1996	M	7	16.7	78.4	1.81	107.3	237.7	17.5	141.5	606.9	194.6	138.9	12.6	-18.6
				(7.52)	(5.00)	(0.65)	(33.7)	(90.6)	(11.3)	(67.3)	(67.3)	(90.6)	(55.1)	(0.5)	(0.2)

HB = Hall Beach; IG = Igloolik; [1]OC Data from Muir et al. 1995, $d^{15}N$ this study; [2]Blubber from ten animals analyzed but sex has yet to be determined for the remaining six; na = samples not yet analyzed

Trace Metals and Organohalogen Contaminants in Fish from Selected Yukon Lakes: A Temporal and Spatial Study

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Abstract

Lake trout muscle samples collected from two Yukon Lakes, Kusawa and laberge, were analysed for a range of organohalogen (OCs/PCBs/BFRs/FOCs) and heavy metal (Hg/Se/As) contaminants. Currently heavy metal time trend data from Laberge and Kusawa Lake trout muscle cover 11 years, 8 and 6 time points, respectively. Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.46 ± 0.21 (n=84) and 0.40 ± 0.25 (n=55) $\mu g\ g^{-1}$, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g\ g^{-1}$ recommended for fish used for subsistence. In lake Laberge, mercury levels in the trout muscle decreased significantly after 1993 but seemed to rise again in 2003 and 2004. In Kusawa lake trout, levels in the 1993 and 1999 samples were significantly higher than those collected from 2001 to 2004. ΣPCB, ΣHCH, ΣCHB and ΣCBz in Lake Laberge continue to decline since 2003 while in Kusawa, ΣPCB, ΣHCH and ΣDDT concentrations have declined significantly since 2002 and levels of ΣCHL, ΣCBz and ΣCHB remain fairly constant. PFOS was the dominant perfluorinated compound in both the 2000 and 2004 Lake Laberge burbot while PFOA concentrations was the greatest amongst the PFAs in 1996.

Key Messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 11 years, 8 and 6 time points, respectively
- The mean Hg levels in the Laberge and Kusawa trout muscle samples over the entire data sets were 0.46 ± 0.21 (n=84) and 0.40 ± 0.25 (n=55) $\mu g\ g^{-1}$, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g\ g^{-1}$ recommended for fish used for subsistence.
- In lake Laberge, mercury levels in the trout muscle decreased significantly after 1993 but seemed to rise again in 2003 and 2004. In Kusawa lake trout, levels in the 1993 and 1999 samples were significantly higher than those collected from 2001 to 2004.
- Lake Laberge burbot mercury time trend results cover 4 years and time 4 points and 8 year and 4 time points, for muscle and liver tissues, respectively.
- Mean Hg concentrations in burbot muscle and liver samples over the entire data sets were 0.50 ± 0.15 (n=86) and 0.16 ± 0.13 (n=55) $\mu g\ g^{-1}$, respectively.
- The length adjusted mean mercury concentrations in burbot muscle tissues are 0.38, 0.51, 0.60 and 0.45 ($\mu g\ g^{-1}$) for the 2000, 2001, 2002 and 2004 time points, respectively. For liver tissues, the length adjusted were

0.11, 0.13, 0.17 and 0.13 (mg g^{-1}) for the 1996, 1999, 2003 and 2004 time points, respectively.

- In Lake Laberge, ΣPCB, ΣHCH, ΣCHB and ΣCBz continue to decline since 2003. In Kusawa, ΣPCB, ΣHCH and ΣDDT concentrations have declined significantly since 2002. Levels of ΣCHL, ΣCBz and ΣCHB remain fairly constant.

- PFOS was the dominant perfluorinated compound in both the 2000 and 2004 Lake Laberge burbot while PFOA concentrations was the greatest amongst the PFAs in 1996.

Objectives

The objective of this project is to maintain current data on contaminants levels in lake trout from two Yukon lakes (Laberge and Kusawa) to continue to assess the temporal trends of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic), organochlorine contaminants (e.g. PCBs, DDT, toxaphene), selected current use chemicals such as brominated flame retardants (e.g. PBDEs, HBCDD), and fluorinated organic compounds (e.g. PFOS and it's precursors) so as to determine whether the levels of these contaminants in fish (health of the fish stock) and thus exposure to people who consume them are increasing or decreasing with time. These results will also help to test the effectiveness of international controls.

Introduction

Historical studies have demonstrated that halogenated organic contaminants (HOCs) and mercury levels in top predators can vary considerably from lake to lake within a small geographic region but temporal trends of these contaminants have rarely been monitored in a sub-Arctic area for a long period of time. This study examines concentrations of a wide range of HOCs and trace metals in lake trout from two Yukon lakes (Laberge, Kusawa), over a span of 11 years (1993-2004). Recently, Ryan et al. (2005) reported that OC pesticide and PCB concentration were declining at various rates in lake trout (*Salveninus namaycush*) in three different Yukon lakes (Laberge, Kusawa and Quiet). For example, ΣDDT concentrations have decreased 39%, 85% and 84% in Kusawa, Quiet and Laberge lakes respectively. Spatial variations in OC/PCB levels were quite evident as Lake Laberge trout continued to maintain the highest levels over the 10 year period from 1992 to 2003 followed by Kusawa and then Quiet. These differences were related to a variety of factors especially the species morphological characteristics such as log age, log weights and fish lipid content. A decreasing trend in Quiet and Laberge lake trout lipid content, coupled with fluctuating condition factors and increases in body masses, suggest biotic changes may be occurring within the food webs due to fish population variations related to the cessation of commercial fishing or potentially an increase in lake plankton productivity related to annual climate variation.

Because of the importance of lake trout and burbot to the subsistence diet of northerners, the need to continue to assess the effect of climate variation on fish contaminant levels, the availability of current data sets and archived samples, Lakes Laberge and Kusawa were selected as the priority Yukon sampling location for long term temporal trend studies.

Activities

In 2004/5

INAC (Whitehorse)/DFO (Winnipeg) together maintain a very extensive archive of fish tissues and data for Hg, Se, As, and HOCs in Yukon lakes (see Tables 1-7). HOC analysis of burbot liver samples from Kusawa and Laberge (2003 and 2004) are well underway but, are not yet completed. One manuscript is in press (Ryan et al., 2005) and second will is to be submitted for review in mid July 2005.

Results and Discussion

Hg, Se, As: Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 11 years, 8 and 6 time points, respectively (Table 1). Mean Hg concentrations in the Laberge and Kusawa muscle samples over the entire data sets were 0.46 ± 0.21 (n=84) and 0.40 ± 0.25 (n=55) μg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale but are at, or exceed, the guideline level of 0.2 μg g^{-1} recommended for fish used for subsistence. A significant correlation between length and muscle mercury concentration was observed in the Laberge ([Hg] = m*length + b, m=0.0013, b=-0.2926, r^2 = 0.59, p<0.001, n=84) and Kusawa ([Hg] = m*length + b, m=0.0014, b=-0.3489, r^2 = 0.35, p<0.001, n=55) trout. ANCOVA was used to assess the effects of year to year collections (temporal trends), length and length*year were significantly higher than those collected from 2001 to 2004 (1993, 1999 > 2001 to 2004, $p<0.05$, Figure 1). interactions (homogeneity of the slope between length and [Hg]). In lake Laberge, mercury levels in the trout muscle decreased significantly after 1993 but seemed to rise again in 2003 and 2004 (1993>1996 to 2002, $p<0.05$, Figure 1). In Kusuwa lake

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in μg/g.

	Year	n	Length	Hg	Se	As
Laberge	1993	13	483 (110)	0.44 (0.11)	0.45 (0.08)	0.15 (0.04)
	1996	18	472 (93)	0.32 (0.10)	0.32 (0.12)	0.12 (0.06)
	1998	7	700 (125)	0.61 (0.24)	0.42 (0.07)	0.18 (0.12)
	2000	6	590 (108)	0.43 (0.21)	0.66 (0.14)	0.13 (0.04)
	2001	22	639 (92)	0.54 (0.23)	0.57 (0.13)	0.10 (0.04)
	2002	5	570 (120)	0.38 (0.15)	0.61 (0.12)	0.11 (0.05)
	2003	8	593 (98)	0.56 (0.25)	0.47 (0.10)	0.10 (0.03)
	2004	5	614 (68)	0.54 (0.23)	0.38 (0.09)	0.09 (0.04)
Kusawa	1993	3	535 (72)	0.54 (0.21)	0.43 (0.17)	na
	1999	14	515 (106)	0.51 (0.17)	0.46 (0.11)	0.12 (0.07)
	2001	9	551 (108)	0.29 (0.11)	0.52 (0.09)	na
	2002	10	500 (74)	0.29 (0.09)	0.55 (0.07)	0.02 (0.01)
	2003	10	487 (90)	0.35 (0.13)	0.35 (0.24)	0.03 (0.02)
	2004	9	553 (117)	0.39 (0.13)	0.64 (0.14)	0.03 (0.01)

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge and Kusawa (1993 – 2004). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.

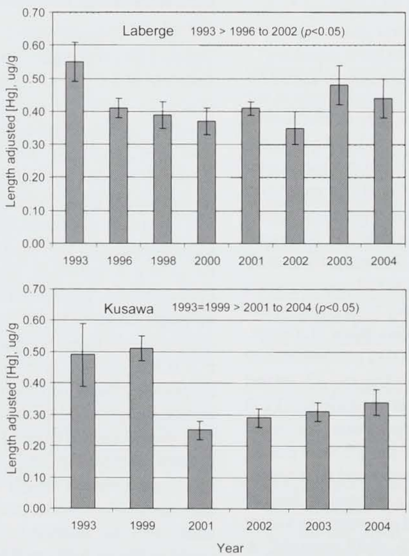

Table 2. Mean (standard deviation) concentrations of mercury, selenium and arsenic in burbot muscle from Laberge and Kusawa Lakes. All levels are in µg/g.

	Year	n	Length	Hg	Se	As
Laberge	2000	18	626 (103)	0.42 (0.14)	0.44 (0.08)	0.11 (0.03)
	2001	30	635 (102)	0.54 (0.15)	0.51 (0.08)	0.13 (0.06)
	2003	13	611 (71)	0.62 (0.12)	0.41 (0.05)	0.13 (0.03)
	2004	25	544 (75)	0.43 (0.12)	0.35 (0.06)	0.10 (0.03)
Ku	2003	14	483 (57)	0.30 (0.08)	0.45 (0.06)	0.04 (0.01)
	2004	1	780	0.42	0.42	0.04

Table 3. Mean (standard deviation) concentrations of mercury, selenium and arsenic in burbot liver from Laberge and Kusawa Lakes. All levels are in µg/g.

	Year	n	Length	Hg	Se	As
Laberge	1996	15	429 (64)	0.08 (0.03)	0.62 (0.45)	0.38 (0.17)
	1999	11	642 (74)	0.21 (0.13)	0.98 (0.53)	0.60 (0.47)
	2003	13	611 (71)	0.25 (0.16)	1.62 (1.01)	0.72 (0.35)
	2004	16	525 (74)	0.15 (0.09)	1.30 (0.48)	0.48 (0.29)
Ku	1999	8	474 (69)	0.05 (0.02)	0.81 (0.29)	0.06 (0.01)
	2003	14	483 (57)	0.09 (0.05)	1.68 (0.82)	0.19 (0.07)
	2004	1	780	0.15	0.55	0.02

trout, levels in the 1993 and 1999 samples Lake Laberge burbot mercury time trend results cover 4 years and time 4 points and 8 year and 4 time points, for muscle and liver tissues, respectively (Table 2). Mean Hg concentrations in the muscle and liver samples over the entire data sets were 0.50 ± 0.15 (n=86) and 0.16 ± 0.13 (n=55) µg g^{-1}, respectively. Significant correlations were observed between length and muscle and liver mercury concentration ($[Hg_{(muscle)}] = m*length + b$, m=0.0006, b=0.1397, $r^2 = 0.14$, $p<0.005$, n=86; $[Hg_{(liver)}] = m*length + b$, m=0.0007, b=-0.2071, $r^2 = 0.35$, $p<0.005$, n=55). The length adjusted mean mercury concentrations in burbot muscle tissues are 0.38, 0.51, 0.60 and 0.45 (µg g^{-1}) for the 2000, 2001, 2002 and 2004 time points, respectively. For liver tissues, the length adjusted were 0.11, 0.13, 0.17 and 0.13 (µg g^{-1}) for the 1996, 1999, 2003 and 2004 time points, respectively.

Organohalogens: Tables 4 and 5 list the mean wet weight HOC concentration in trout from Lake Laberge and Kusawa Lake over the 11 year time period from 1983 to 2004. In Lake Laberge, ΣPCB, ÓHCH, ΣCHB and ΣCBz continued their decline since last reported by Ryan et al. (2005). In Kusawa, ΣPCB, ΣHCH and ΣDDT concentrations declined significantly since 2002. Levels of ΣCHL, ΣCBz and ΣCHB remain fairly constant.

Major PBDE congener and ΣPBDE concentrations in Lake trout from Lakes Laberge, Kusawa and Quite are shown in Table 6. Levels in trout from Quite Lake are 1 to 2 orders of magnitude lower than those from Laberge and Kusawa. Trends were difficult to discern due to the small samples sizes analyzed in this study (n=5).

As was observed in burbot from Fort Good Hope (see report by Stern et al.) PFOS was the dominant perfluorinated compound in both the 2000 and 2004 Lake Laberge burbot (Table 7) while PFOA concentrations was the greatest amongst the PFAs in 1996. The rank order of PFCA concentrations were PFOA>PFNA=PFDA>PFUA. There were no correlations between PFA concentrations and lipid.

Table 4. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

Laberge	1993	1996	2000	2001	2002	2003	2004
N	24	13	6	16	5	8	6
Age	15 (2)	22 (5)	12 (2)	14 (2)	12 (4)	12 (1)	12 (4)
% Lipid	7.9 (0.9)	9.6 (1.4)	3.7 (0.8)	4.9 (0.5)	4.2 (0.9)	4.7 (0.8)	8.7 (3.9)
ΣPCB	328.28 (121.49)	209.32 (52.08)	138.95 (60.89)	139.71 (53.75)	48.60 (8.81)	81.01 (29.83)	48.93 (34.30)
ΣDDT	391.54 (132.69)	236.51 (41.39)	96.46 (14.21)	89.46 (14.04)	54.50 (11.58)	61.48(8.55)	94.09 (60.68)
ΣCHL	47.60 (8.84)	53.38 (13.74)	22.36 (5.84)	26.37 (5.14)	7.26 (1.59)	7.44 (2.24)	7.46 (4.90)
ΣHCH	4.69 (0.78)	6.50 (1.79)	2.30 (1.08)	0.80 (0.07)	1.58 (0.50)	0.54 (0.10)	0.19 (0.09)
ΣCHB	310.96 (62.36)	212.23 (28.31)	207.33 (49.90	154.20 (60.46)	139.23 (16.88)	179.31 (42.79)	79.92 (52.01)
ΣCBz	3.92 (0.57)	4.90 (1.24)	2.26 (0.59)	2.11 (0.17)	1.15 (0.25)	1.21 (0.28)	0.49 (0.28)

Table 5. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

Kusawa	1993	1999	2001	2002	2003	2004
N	10	14	9	10	9	9
Age	19 (2)	18 (1)	12 (1)	12 (1)	9 (3)	13 (4)
% Lipid	1.8 (1.6)	4.6 (3.0)	2.4 (1.4)	1.4 (0.8)	5.8 (3.6)	7.9 (4.7)
ΣPCB	85.62 (26.07)	91.09 (11.85)	48.55 (7.91)	32.45 (3.66)	8.16 (5.86)	11.29 (3.78)
ΣDDT	44.16 (21.50)	139.16 (19.72)	56.58 (15.30)	26.66 (4.15)	8.21 (15.67)	5.70 (3.70)
ΣCHL	17.33 (2.78)	17.82 (2.74)	7.45 (2.35)	3.01 (0.48)	3.50 (2.28)	4.52 (2.16)
ΣHCH	1.21 (0.36)	1.68 (0.23)	0.91 (0.14)	0.62 (0.08)	0.14 (0.08)	0.15 (0.07)
ΣCHB	120.80 (24.94)	148.38 (29.29)	61.03 (8.55)	43.47 (5.02)	45.05 (32.20)	49.73 (30.17)
ΣCBz	1.15 (0.28)	1.52 (0.20)	0.84 (0.14)	0.61 (0.09)	0.44 (0.30)	0.50 (0.27)

Table 6. Mean (S.D.) PBDE levels (pg g^{-1}, wet wt.) in lake trout muscle from Lakes Laberge and Kusawa*.

	Laberge	% Lipid	BDE 47	BDE 49	BDE 99	BDE 100	BDE 153	BDE 154	ΣPBDE
Laberge	1993	1.99 (1.69)	1620 (620)	350 (110)	3240 (1630)	690 (320)	870 (460)	1970 (1010)	9680 (5000)
	2000	0.45 (0.25)	4900 (1680)	2100 (240)	8590 (1170)	3380 (630)	5740 (1320)	4460 (1190)	32280 (41500)
	2003	0.41 (0.19)	3170 (1430)	1290 (750)	5890 (2860)	2450 (1200)	3920(4050)	3200 (2810)	21990 (14030)
Kusawa	1999	3.01 (2.20)	6420 (8440)	1590 (2090)	12070 (16320)	3640 (4820)	3720 (5180)	4.00 (5790)	33950 (45130)
	2001	2.78 (1.63)	700 (990)	130 (160)	720 (1090)	250 (250)	260 (480)	230 (330)	2550 (3650)
	2003	0.16 (1.12)	960 (1220)	360 (47)	2630 (3510)	950 (1260)	1180 (1590)	870 (1150)	7480 (9890)
Quiet	1992	2.52 (0.71)	25 (20)	nd	18 (31)	3 (5)	6 (6)	11 (14)	161 (125)
	2001	0.94 (0.94)	28 (40)	nd	19 (32)	8 (10)	11 (7)	12 (14)	237 (183)
	2003	0.12 (0.09)	51 (106)	7 (4)	127 (273)	18 (41)	32 (71)	17 (35)	293 (581)

*N=5 for both lakes and all year; nd = non detect

Table 7. FOC levels in Burbot liver from Lake Laberge (mean and standard deviation, ng g^{-1} wet wt.)

Year	n	% Lipid	PFOA	PFNA	PFOS	PFDA	PFUA	PFDoDA
1996	5	29.20 (9.12)	14.43 (8.33)	11.89 (11.07)	6.03 (3.92)	6.17 (5.43)	0.93 (2.07)	nd
2000	5	21.75 (6.46)	10.30 (7.30)	6.33 (8.72)	29.99 (22.50)	5.46 (4.36)	0.67 (1.49)	nd
2004	5	20.37 (5.34)	1.56 (2.81)	3.93 (4.67)	30.36 (43.45)	2.20 (2.72)	0.60 (1.34)	nd

nd = non-detect

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected until at least 2009.

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Time-Trend Studies On New and Emerging Persistent Halogenated Compounds in Marine Mammals from the Canadian Arctic

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Abstract

Time trend analyses of new and emerging contaminants were carried out for beluga (Pangnirtung), walrus (Igloolik) and narwhal (Pond Inlet). N-ethylperfluorooctane sulphonamide (N-EtPFOSA) was the dominant fluorinated compound in beluga liver while perfluorooctane sulfonate (PFOS) dominated both narwhal and walrus liver samples. Exponential increases in concentrations of perfluorooctanoic acid (PFOA) and perfluorodecanoic acid (PFDA) were observed in beluga liver with respective doubling times of 6 and 11 years. Mean total polybrominated diphenyl ether (ΣPBDE) concentrations were consistently higher than hexabromocyclododecane (ΣHBCD) in the blubber of all the animals. Walrus show statistically significant ($p = 0.02$, respectively) increasing linear trends in ΣPBDE concentrations. Mean ΣPBDE concentrations in narwhal blubber were found to have increased 3 times between 2000 and 2004. Decabromodiphenyl ethane concentrations were below detections limits in all animals. Mean total short chain chlorinated paraffins (ΣSCCPs) increased exponentially in beluga between 1982 and 2004; medium chain chlorinated paraffins (MCCP) were below detection limits in all the animals.

Key Messages

- N-EtPFOSA, a neutral PFOS precursor, is the dominant perfluorinated chemical in Pangnirtung beluga while PFOS dominated both narwhal and walrus liver tissue;
- PFOA and PFDA are increasing exponentially in Pangnirtung beluga with doubling times of 6 and 11 years, respectively;
- Concentrations of perfluorinated carboxylic acids are increasing in Pond Inlet narwhal;
- ΣPBDE concentrations are greater than ΣHBCD in all animals in blubber;
- ΣPBDE concentrations have increased ~ 3 x in Pond Inlet narwhal between 2000 and 2004;
- ΣHBCD has increased exponentially in Igloolik walrus with a doubling time of 3 years;
- ΣSCCPs concentrations were consistently higher than ΣMCCPs;
- ΣMCCPs concentrations hovered around method detection limits in all the animals;
- ΣSCCPs concentrations have increased exponentially in Pangnirtung beluga between 1982-2004 with a doubling time of 25 years.

Objective

- To construct a chronology of chemical contamination of new and emerging organohalogen contaminants in marine mammals (beluga, narwhal and walrus) from the Canadian Arctic.

Introduction

Changes in the inputs of chemicals into the environment are reflected in changes in concentrations of chemical contaminants in wildlife over time(OSPAR 1999). Because of its unique physical and biological characteristics, the arctic environment has become a sentinel for studies on temporal trends of halogenated organic pollutants.

In this study, three classes of halogenated compounds, perfluorinated compounds (PFCs), brominated flame retardants (BFRs) and chlorinated paraffins are examined in marine mammals. Perfluorinated compounds are a diverse class of compounds which are used as surfactants and as surface protectors(Giesy and Kannan, 2002). Brominated flame retardants are used in a range of consumer products including textiles, furniture and electronics(de Wit, 2002). Short- and medium chain chlorinated paraffins (SCCPs and MCCPs) are complex mixtures used primarily as industrial metal lubricants(Tomy et al., 1998).

Our objective for this research is to determine if there have been changes in concentrations of the PFCs, BFRs, SCCPs and MCCPs in animals from the Canadian arctic over time. The animals chosen were from our archived tissue bank and include: beluga from Pangnirtung, walrus from Igloolik and narwhal from Pond Inlet. Because parse usage and release information exists for these chemicals, constructing historical concentration profiles is the only means of assessing the chronology of contamination.

Activities

In 2004-2005

Beluga from Pangnirtung (1982, 1986, 1992, 1995, 2002), narwhal from Pond Inlet (1982, 1994, 2000, 2004) and walrus from Igloolik (1983, 1992, 1996, 2004) were selected for study. Eight animals were selected for study from each year. Archived liver (for PFCs, $n=8$) and blubber (BFRs, $n=8$ and SCCPs, $n=8$) were extracted and analyzed. Extractions of PFCs from liver were based on a new methanolic extraction method developed in our laboratory(Tomy et al., 2005). BFR and SCCPs and MCCPs extraction and analysis have been described in earlier studies(Tomy et al., 2004, 2000; Tomy and Stern, 1999; and Budakowski, 2003).

Results

Plots of the time-trend log concentrations of PFCs, ΣPBDE, ΣHBCD, ΣSCCP and ΣMCCPs in the animals are shown in Figures 1-3.

Discussion and Conclusions

PFCs. For the Pangnirtung beluga, in which we have the best time resolution, there were exponential increases in both PFOA and PFDA concentrations from 1982 to 2002; respective doubling times are 6 and 11 years. PFUA, the dominant PFCAs in these animals, showed a linear increase throughout the time period. PFOSA and PFOS concentrations increased up until 2002 although there was a small decrease in concentration in 1992 for both compounds. N-EtPFOSA, FTCAs and FTUCAs were below detection limits in all the animals examined. PFCs concentrations which peaked in 1992 for the Igloolik

Figure 1. Change in log concentrations of PFCs in beluga (Pangnirtung, left panel), walrus (Igloolik, middle panel) and narwhal (Pond Inlet, right panel) over time.

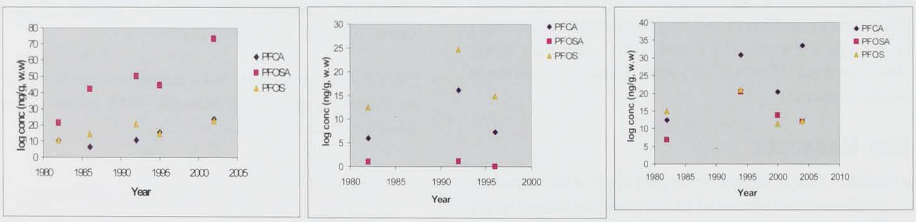


Figure 2. Change in log concentrations of ÓPBDEs and ÓHBCD in beluga (Pangnirtung, left panel), walrus (Igloolik, middle panel) and narwhal (Pond Inlet, right panel) over time.

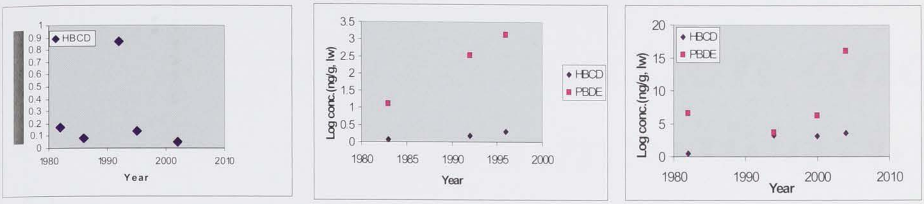
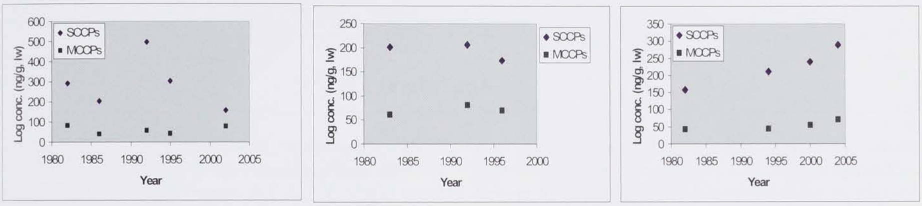


Figure 3. Change in log concentrations of ÓSCCPs and ÓMCCPs in beluga (Pangnirtung, left panel), walrus (Igloolik, middle panel) and narwhal (Pond Inlet, right panel) over time.



walrus appear to have decreased since then. A similar concentration trend was observed for PFOSA and PFOS in Pond Inlet narwhal. PFCAs concentrations were still increasing in 2004 for narwhal.

There were statistically significant relationships between PFOSA and PFOS concentrations and age for the 1995 beluga (*see* Figure 4). There was a decreasing trend in PFOSA concentrations with age of the animals while PFOS concentrations increasing linearly. Taken together, these results strongly support the hypothesis that PFOSA is a metabolic precursor to PFOS in mammals. The fact that PFOSA levels are much greater than PFOS in the younger animals suggests that PFOSA-precursors are likely contributing to the burden of PFOSA at a very young age and that older animals have a greater capacity to biotransform PFOSA to PFOS. No correlation was observed for any of the PFCs and lipid content.

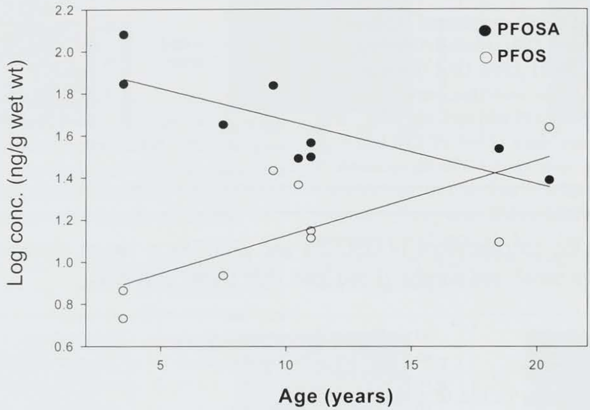
Correlations between PFCA chain length (and PFOS) and concentrations were observed for beluga and narwhal. There were statistically significant positive correlations between PFOS and PFUA concentrations (r^2=0.57, p=0.05) and PFDA and PFUA concentration (r^2=0.64, p=0.05) in beluga from 1982. In narwhal from 1994, positive correlations were observed for the chemical concentrations of the following compounds: PFOA/PFOS (r^2=0.48, p=0.02); PFNA/PFOS (r^2=0.41, p=0.04) and PFDA/PFUA (r^2=0.38, p=0.05).

ΣPBDEs. Walrus show increasing linear trends (p=0.02) in ΣPBDEs concentrations. Between 2000 and 2004, ΣPBDEs concentrations in narwhal increased by 3x. BDE-47 was the dominant congener in narwhal while BDE-99 dominated in walrus. Decabromodiphenylethane (DBDPE) was below the method detection limit in all samples.

ΣHBCDs. For beluga, ΣHBCD concentrations peaked in 1992 and decreased exponential up to 2004. For walrus, there are exponential increases in ΣHBCD concentrations with a doubling time of 3.2 years. ΣHBCD concentrations in narwhal peaked in 1994 where there was roughly an 8x increase between 1982 and 1994; concentrations and have remained steady since then.

ΣSCCPs and ΣMCCPs. Full formulae group profiles for both short- and medium-chain chlorinated paraffins were

Figure 4. Correlation between PFOSA and PFOS log concentration in 1995 beluga and age. Regression analysis: log [PFOSA] = 1.9750 – 0.0302*(age), (r^2=0.63, p=0.01); log [PFOS] = 0.7688 + 0.0356*(age), (r^2=0.51, p=0.03)



determined on an individual animal from each species from each sampling year. SCCPs were consistently greater than MCCPs in all the animals; ÓMCCPs hovered around method detection limits (~ 70 ng/g, lw) in all the animals. ÓSCCPs in beluga peaked in 1992 and have declined since then while concentrations of ÓSCCPs have remained steady in walrus since 1983. In narwhal, ÓSCCPs have increased exponentially from 1982 to 2004 (r^2=0.98, p=0.02) with a doubling rate of ~ 25 years.

Expected Project Completion Date

PBDE analyses in beluga are underway. We hope to have this completed by early Fall.

Acknowledgements

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Education and Communications

Gathering, Disseminating, Developing and Delivering Appropriate Education and Communication Information for the Inuvialuit Settlement Region

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Abstract

In the Inuvialuit Settlement Region (ISR) most communities harvest a variety of marine mammals as an important source of nutritious food. Recent results from CACAR II show that people who rely on marine mammals may be at greater risk for exposure to some environment contaminants. It is vital that people in the ISR get accurate and detailed information about the benefits of country foods and the risk of contaminants in order to make good, informed and educated decisions. In order to provide people with the education tools required to make these decision it was first necessary to understand what people new about contaminants and country foods in the ISR. In 2004-2005 the Inuvialuit Regional Corporation (IRC) and Inuvialuit Game Council (IGC) undertook a project to determine both the short and long-term needs of our communities which began the process of developing our regional strategic plan in order to have a more focused and targeted approach to communication in the ISR.

In 2003-05 a cumulative information initiative took place to assess Inuit comprehension, knowledge and perception of contaminants and health issues in ISR and other Inuit regions. Result were analysed and disseminated and translated into plain language fact sheets for delivery into our individual communities. This process was undertaken with a new Aurora College student-mentoring program to insure lessons learned and the growing network and knowledge trees would be focused on and benefit our Inuvialuit Beneficiaries. This year, we continue on the task of capacity building to empower our people with knowledge. We are also conducting community visits that include attending schools, as well as presentations at the IRC and IGC board meetings. Also, our goal this year was to network with other funding bodies, tasks and projects to build up the position of the Health and Environment Coordinator in order to maximize the knowledge base. We are networking with like organizations, while training our students, allowing for a more sustainable research-liaison position.

Key Messages

- Country Foods continue to be safe, sound choices and offer the best nutrition value
- What do our Beneficiaries know about Contaminants and their health and environment?
- Student Mentoring Program priority and long term planning strategy
- Improved networking tree, and partnered sustainable funding.

Objectives

Short Term Objectives:

- To expand our funding, networking and training opportunities

- To understand how were we going to use the results of the survey into long term planning?

- To inform leaders, frontline workers, educators and community members.

Long-term objectives:

- Enhance and improved well-established communication and networking with a focus on building both the knowledge base and Inuvialuit capacity right down to the community level

- A well developed regional strategic plan in order to have a more focused and targeted approach to communication in the ISR

- A strong student mentoring program to insure lessons learned and the growing network and knowledge trees would be focused on and benefit our youth and Inuvialuit Beneficiaries.

Introduction

What Inuit Want to Know about Their Health and the Environment: Preliminary Results

A survey was developed with input from ITK by Dr. Chris Furgal and his assistant Carrie Gable for all Inuit regions and the Yukon this past year to assess the level of understanding of basic contaminant messages that have been delivered in all regions of the North as well as to identify current perceptions and understandings of contaminant, health and wildlife concepts and issues and information needs related to these topics. The survey was conducted with a representative sample of the regional population 18 years of age or older in Inuvialuit communities. In the ISR, the majority of respondents were concerned about the store foods they ate but not the country foods they consumed. Most had heard about contaminants, but when listing things participants considered "contaminants", local community garbage and pollution issues such as oil drums on the land were also included. An overwhelming majority of people felt that they needed to know more about contaminant issues.

Key Messages

- More Inuvialuit appear to be concerned about the store foods than the country foods they consume;
- Inuvialuit have a number of concerns about their health and the environments around their communities. The issue of environmental contaminants was only mentioned in the context of concerns related to country foods.

Survey Objectives:

The survey proposed to assess the level of recall of some basic contaminants concepts and messages that have been communicated in the ISR under the NCP before as well as collect information on people's concerns and perceptions related to contaminants, food safety and their environment and health information needs. Specifically the project:

- Developed and applied a questionnaire to assess the recall of key NCP developed messages and gather information on health, food and environment concerns and information needs related to these topics;
- The results of this survey will be used to help identify key issues in the regional planning of communication activities at the regional level for contaminants and health issues over the next 5 years.

Activities

In 2004-2005

A common questionnaire was developed in cooperation with Inuit regions and the Yukon to assess the general perception of country food and store food safety and other environment issues in the region. The survey included questions to assess the recall of previously delivered messages under the NCP among other issues. A core group of questions was common to all regions participating in the survey however each region also included questions specific to its own context. The questionnaire was pre-tested, adapted, verified and adapted once again in cooperation with regional researchers. Randomly selected individuals were identified using the resident lists for each community and approximately 1% of the adult population was surveyed in each of the communities. Surveys were conducted face to face by the IRC Health and Environment Coordinator and or a Inuvialuit Joint Secretariat Resource representative during scheduled community visits. All survey responses were entered into a database (excel) for basic quantitative descriptive analysis of results. Analysis of the survey at the regional and national levels is ongoing and is providing information for regional and national communication strategy development. To date quantitative descriptive analysis is complete and analysis of the qualitative data is ongoing. Most importantly, the survey results offered information to produce a 6 page newsletter that is being offered in each of the six ISR communities in both English and translated versions. This newsletter focuses on the benefits of country foods with a variety of everyday comparisons to store bought foods, after a colourful and plain language introduction information sheet that offers results of the survey. (See enclosed example of the English language, community survey results fact sheet).

INUVIALUIT BENNIFICARY MENTORING PROGRAM - HEALTH AND ENVIRONMENT

- Established and maintained a working relationship with the Aurora College Natural Resource Management Program course students and staff to mentor Inuvialuit students regarding Health and Environmental current activities, information and events. Throughout their school term, a number of activities and assignments included class presentations on a variety of Health and Environment projects, assignments relating to all NCP and Nasivvik and ArcticNet research activities, which included proposal-writing instruction, workshops, and community visits and several meetings

- This is the first two year pilot project to offer practical hands on learning and Inuvialuit Beneficiary training to build capacity and promote opportunities to have graduating students with the skills to assume responsibilities for Health and Environment positions in the ISR.

PARTNERSHIP PROGRAM-HEALTH AND ENVIRONMENT (NCP) AND NASIVVIK (ACADRE)

- The IRC secured another 20K from the Nasivvik Center (Total funding for year-35K) to allow for a combined funded position for the Health and Environmental Coordinators position that focus on NCP (95K) and Nasivvik research activities while mentoring Inuvialuit students. In person meetings were attended in Quebec City, in December 2004 which coincided with the first annual ArcticNet Scientific meeting providing an opportunity for regional representatives to exchange with the research community working on Arctic issues and offer lessons learned from the NCP. One student from Aurora College accompanied Barbara Armstrong to this meeting. Activities are ongoing in Labrador, Nunavik, Nunavut and the ISR related to the following issues:
  - Contaminants and Inuit Health
  - Climate Change and Inuit Health
  - Air and water quality and Inuit health
  - Traditional Plant Use and Health
  - Environmental Health Monitoring and Surveillance
  - Inuit Knowledge and Western Science for health research

- The Nasivvik Centre will serve as consultant / advisor for researchers applying for NCP funds this year and provide ideas for training opportunities and capacity building that can be incorporated into their proposals. Further, the Centre will strive to link interested students from the North with research projects funded to provide them experience in Arctic environmental health research to increase our community involvement in research and training by stimulating and supporting interest of communities in obtaining small research grants for community-based projects in our region.

- The Nasivvik Centre took advantage of the ArcticNet / Nunavik Inuit Health Survey ship cruise to all Nunavik communities, on the CCGS, to expose regional trainees from the North to various aspects of Arctic environmental health issues and research techniques. The course was a huge success. Donald Ross (Aurora College), from the ISR, participated in activities ranging from interviewing participants of the Qanuippitaa Survey to collecting water samplings and conducting lab analyses and then he proceeded to give presentations on the experience with other students.

DEVELOPMENT OF REGIONAL / NATIONAL / INTERNATIONAL COMMUNICATION STRATEGIES FOR CONTAMINANTS AND HEALTH IN THE CANADIAN NORTH

- The review of communications materials and activities conducted during Phase II of the NCP, as reported in Knowledge in Action (2003) identified the need for an organized approach to communications activities and research. To date, various forms of evaluation (formal and informal) have documented unique lessons at different times and in different regions regarding methods of best practice or challenges faced in communicating about contaminants and health in our ISR communities. Further, as more is learned about the potential effects of contaminants on Northern Aboriginal health (CACAR II Health Report) the messages are in fact becoming more complex, requiring greater levels of detail to be communicated and therefore understood in order to support truly informed decision and to ensure that information is easy to understand and access.

- A meeting was held in conjunction with the NCP White Rock workshop to begin decisions on how to formulate an appropriate communications plan for the ISR. A second meeting was held in March where discussion took place regarding the Population Survey analysis to formulate results and incorporated them into the working regional plan. Consultations are ongoing as the plan grows and becomes a working document to be incorporated into all aspects of our improved education and communications directive.

All activities were carried out with student participation; monthly tasks are summarized in the list below:

August-December 2004

- NWTECC Conference Calls-review agenda and meeting minutes-student materials created
- Collate 2002-2003 NCP, LCC's, ECC library of information, fact sheets, maps, and posters
- Reviewed and provided the IGC with Fact Sheets, nutritional country food messaging
- Consultations with Roger Connelly, Frank Pokiak and Nellie Cournoyea, Norm Snow and Joe Thrasher-IGC, DIAND and Dene Nation-NWTECC, ITK, Eric Loring, Chris Furgal, John Edwards
- Responded to: IRC, GTC, ECC, ITK, DIAND, IGC, NCP e-mails, phone calls, correspondences
- Prepared the new job description and posting for potential new coordinator Nasivvik position
- Mid Term IRC and GTC board and NCP reporting
- Volunteered to sit on the steering committee to look at the potential for an on-line course to teach frontline health and environment workers about contaminants and nutritional information
- Assisting with coordinating the Nuclear Waste Management Organization (NWMO) dialogues
- Established and maintained a working relationship with the Aurora College Natural Resource Management course students and staff to mentor Inuvialuit students regarding Health and Environmental NCP current activities, information and events
- Arrangements and participation in NCP workshop and meetings in White Rock B.C.
    - Attended several sub meetings during the NCP workshop
- Secured another 20K from the Nasivvik Center (Total funding for year-35K) to allow for a combined funded position for the Health and Environmental Coordinators position that focus on NCP (95K) and Nasivvik and ArcticNet research activities while mentoring Inuvialuit students.
- In person Nasivvik/ArcticNet meeting in Quebec City with Aurora College Student.

January-March 2005

- Consultations with Roger Connelly, IGC-Joe Thrasher and Norm Snow, DIAND, the NWTECC, ITK, Eric Loring and Chris Fugal, ArcticNet and the Nasivvik Center about the ongoing projects
- Responded to: IRC, GTC, ECC, DIAND, IGC, ITK, NCP e-mails, phone calls, correspondences
- Worked on the 5 year regional planning strategy with ITK and local and regional stakeholders
- Attend in-person meeting of the NWTECC,-in January with 2 students from the mentoring program
- Complete year-end funding reports and the 2005 proposal was submitted to the NCP
- Secured funding for partnered funding and created roles and tasks with ArcticNet and Nasivvik
- Ongoing consultations regarding new blood monitoring project (MOM'S)-Alice Thrasher and Barbara Armstrong with reports, updates for both IRC and IGC representatives and board meetings
- Created a new job description and advertised for a new Health and Environment coordinator
- NWTECC Conference Calls - Review Agenda and Meeting Minutes, preparation for meetings
- Presentations at the adult learning center + community college-NCP and Contaminants information
- Continuing the program for an Inuvialuit Beneficiary Mentoring assistant
- Population Survey results/analysis communications information and conference calls
- Create and distribute new communications information under the NCP program and the Contaminants Fact Sheets that included translated Population (Pan Arctic) Survey results
- Organize, translate and print communications materials for upcoming six regional community visits
- Quarterly IRC Board Meetings reports and presentations and continued to write reports and consult with partners regarding all activities with Aurora College student mentors.

Results

This past year, through the successful work of the Health and Environment Coordinator and students from the Aurora College mentoring program, the Inuvialuit Regional Corporation fulfilled the deliverables outlined in the Northern Contaminants Program proposal. Networking was key to this years activities as the position expanded and work on the long term regional and national strategies was conducted and the Pan Arctic Survey results were analyzed, translated and reported back into the communities as plain language summaries to various target groups which increased the knowledge base within the ISR.

Discussion and Conclusions

Ongoing training opportunities and a variety of communications continue to be offered to Inuvialuit Beneficiaries, community representatives, our educators, frontline workers and health professionals regarding a variety of information related to understanding long-range contaminant health and environment issues, and resulting connections and importance of country/traditional food, and healthy lifestyle choices.

Expected Project Completion Date

March 2005

Labrador Regional Contaminants Communication: Assessing Concerns and Learning How to Communicate to Target Groups

Project leader:

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Project Team Members:

Eric Loring , Senior Environment Researcher, Inuit Tapiriit of Kanatami; Chris Furgal, PhD, Research Associate, CHUL Research Centre, Beauport Qc; Labrador Inuit Heath Commission; Libby Dean, School for Resource and Environmental Studies, Dalhousie University

Abstract

In 2004-05 the LIA research office continued to enable communities of the north coast of Labrador and the Lake Melville area to become involved with and learn about contaminant issues affecting the region and supports them in making informed decisions. Additionally, the LIA researcher continued to act as a research liaison with outside researchers conducting work in the region on these issues, supporting their work and aiding them in conducting ethical, effective investigations and communication of these results to regional residents.

In 2003-04, a survey was developed with all Inuit regions and the Yukon to assess the level of understanding of basic contaminant messages that have been delivered in all regions of the North before as well as to identify current perceptions and understandings of contaminant, health and wildlife concepts and issues and information needs related to these topics. The survey was conducted with a representative sample of the regional population 18 years of age or older in all Labrador communities. In Labrador, this survey was titled "What Labradorians Want to Know About Their Health and Environment". The results from this survey was analyzed this year and the majority of respondents reported that they were concerned about the store foods they ate but not the wild foods they consumed. Most had heard about contaminants, but as previous work has shown in this region, local community garbage and pollution issues were included in the definition of what people thought were "contaminants". Additionally, a project was conducted to review the pathways of communication being used for women of child bearing age in the region to assess whether these were more effective lines of communication to use for dissemination contaminants information to these groups.

Key Messages

- The LIA Research Office strives to, in a culturally relevant manner, continue its communication efforts on contaminants, research and the environment, conduct research and promote mutually beneficial relationships between the communities of northern Labrador and outside scientists;

- Labradorians appear more concerned about the store foods they eat than the wild foods consumed although most want to hear more information about contaminants and health in the region

- Labradorians have a number of concerns about their health and the environments around their communities. The issue of environmental contaminants is one of those concerns but is not the most commonly reported concern for either category (health or environment).

Objectives

An objective of the Northern Contaminants Program (NCP) is to reduce or, wherever possible, eliminate contaminants in traditionally harvested foods while providing information that assists informed decision making by individuals and communities related to their food use.

The Labrador Inuit Association Research Officer:

- Assisted residents of Nain, Hopedale, Postville, Makkovik, Rigolet and Happy Valley-Goose Bay by providing information about risks, the means to reduce risks, and information on the benefits of traditionally harvested foods to support residents in making informed decisions;

- Assisted communities of the north coast of Labrador and the Lake Melville area in becoming involved with contaminant issues and activities that affect the people and the region;

- Acted as a research liaison with outside researchers conducting work in the region on these issues, supporting their work and aiding and ensuring that their work is conducted in an ethical, effective manner and that their results are communicated back to the population in a timely manner.

The survey entitled *What Labradorians Want to Know About Their Health and Environment* proposed to assess the level of recall of some basic contaminants concepts and messages that have been communicated in Labrador under the NCP before as well as collect information on people's concerns and perceptions related to contaminants, food safety and their environment and health information needs. Specifically the project:

- Developed, translated and applied a questionnaire to assess the recall of key NCP developed messages and gather information on health, food and environment concerns and information needs related to these topics;

- Is being used to support the identification of key issues in the regional planning of communication activities at the regional level for contaminants and health issues over the next 5 years.

Introduction

Labrador Inuit are sustained by the animals, birds, fish and plants of the region. Research has shown that contaminants are present in these food sources due to the environment being contaminated by varying sources of local and distant pollution which are then transported to the north via atmospheric and oceanic mechanisms. The levels of contaminants in these foods which sustain people in Labrador and potential effects they may have on residents of the coastal communities are of concern to the Inuit of Labrador. The Labrador Inuit Association Research Office helps to ensure that Labradorians are heard and their concerns with regard to both national and local contaminants issues are assessed and communicated. The current issues for Labrador Inuit are similar to those of other Inuit regions, but there are also local concerns that need to be communicated and the minds of Labrador Inuit to be settled with regard to perceived local contaminants. This is especially true when we have just learned that some traditional hunting areas and wildlife in those regions (e.g. Saglek Fjord and its immediate environment) are unsafe for human consumption due to PCBs. As well, greater concern exists for these issues now that studies in Nunavik are showing subtle effects from PCB exposure. In order for Labrador Inuit to be informed about wise food choices the LIA Research Office must coordinate efforts between NCP researchers, Inuit Tapiriit Kanatami and university and government researchers and our communities. Following the objectives of the Northern Contaminants Program, the LIA's Researcher acts as a key resource person and provides information to the population in a culturally relevant and plain language format on contaminant-related issues. This is done by utilizing the guidelines developed through consultation with community individuals in the project *Country Food, Nutrition and Health: Developing Effective Communication Strategies in Labrador* conducted by LIA Research and C Furgal (U Laval) and Lorraine Craig (U Waterloo).

Activities

In 2004-2005

COMMUNICATION

Avativut Newsletter

This newsletter is a quarterly publication that the LIA Research Office has developed and used to communicate to the Labrador Inuit population about the benefits and risks of wild foods, the most recent knowledge on contaminants, health and environmental issues and to update people on current research activities in the region.

The existence of a regional person and their involvement in this publication has enhanced the LIA Research Office's ability to communicate such information in a culturally-relevant and timely manner. Without this person, this newsletter would not be published. The main focus of the Avativut newsletter is on the benefits of consuming wild foods so as to enforce the understanding among the general population that they are still the most nutritious foods for Labradorimiut to eat. Additional updates of new and ongoing research activities and relevant facts about health and environment issues in the region are also provided in this newsletter which is printed in English and Inuktitut (Labrador Dialect) and distributed 4 times a year. A section of the Avativut Newsletter is also set aside for environmental news from each of the north coast communities, giving each community a chance to share their concerns and accomplishments with the coast regarding environment and health issues.

LIAISING/CONTACT PARTICIPATION IN RESEARCH PROJECTS

Communicating in Labrador on Environmental Contaminants: Developing a Strategy to Engage Target Audiences on Contaminant, Food and Health Issues

This project has been looking at what information is currently being distributed to women of child bearing age and through what mechanisms this information is delivered. It is preparing a dissemination framework for reaching this target group with contaminants information using existing pathways. It is expected that this approach will help deliver such information in a proper context, along with other health and nutrition information. This year, Libby Dean of Dalhousie University worked with the LIA research office and conducted key informant interviews in Happy Valley- Goose Bay and Nain, Labrador. Interviews were conducted with local and regional health professionals and educators. Additionally, literature and document sources were identified and gathered for review. Data is now being analyzed and in cooperation with LIA this project will provide recommendations for reaching women of child bearing age with diet and contaminant information in the future. What Labradorians Want to Know About Their Health and Environment

A common questionnaire was developed in cooperation with Inuit regions and the Yukon in 2003-04 to assess the general perception of wild food and store food safety and the population's information needs related to health and environmental issues in the region. A core group of questions was common to all regions participating in the survey however each region also included questions specific to its own context. The questionnaire was pre-tested, adapted, translated, back translated and verified and adapted once again in cooperation with Inuit field assistants in the participating communities. Randomly selected individuals were identified using the Inuit organization membership list for each community and approximately 1% of the adult population was surveyed in each of the north coast communities. Surveys were conducted face to face with the aid of an Inuit fieldworker and were conducted in either English or Inuktitut at the participant's request. All Inuktitut surveys were then translated and all survey responses were entered into a database (excel) for basic quantitative descriptive analysis of results.

Nasivvik Centre for Inuit Health and Changing Environments

This Centre is one of eight established in a network across the country by IAPH (ACADRE Program: Aboriginal Capacity and Developmental Research Environments) to address Aboriginal Health training and research needs. The Nasivvik Centre is based at the Public Health Research Unit, CHUL-CHUQ, Laval University (Quebec).

The Nasivvik Centre and ArcticNet hired Inuit Research Advisors (IRA's) in 4 regions: Labrador, Nunavik, Nunavut and Inuvialuit in September 2004. Elizabeth Ford was hired as Inuit Research Advisor for Labrador. She is currently working out of LIA head office. Mary Denniston, the research office staff member is Acting Board Member and Chair of the Nasivvik Centre. The cooperation between these programs in the LIA Research Office is leading to better overall research coordination among projects funded under the various research programs going on in the North.

ONGOING DAILY COMMUNICATIONS AND RESEARCH COORDINATION

In addition to these specific activities, a number of ongoing communication responsibilities are fulfilled by the LIA Research Office staff. Daily activities of the Research Office include responding to community concerns, providing information to the Labrador Inuit Association, communities, and individuals on issues relating to contaminants, the environment and health, and acting as a liaison for the various people proposing to, and currently conducting research in the region. Additionally, the research staff acts as a liaison for interactions between the regional organizations and ITK and the NCP. This involves regular interaction with various individuals and ongoing communications efforts.

Results

Results of the survey entitled "What Labradorians Want to Know About Their Environment and Health" shows low comprehension of some basic contaminant concepts in some regions; especially among younger women, therefore, the need for a strategy as is being developed under the project "Communicating in Labrador on Environmental Contaminants: Developing a Strategy to Engage Target Audiences on Contaminant, Food and Health Issues" to reach this group is even more obvious. The following is some of the results from the survey, which was also put out in the communities to communicate the results via the use of a fact sheet on this project:

What did Labradorians say about their health, environment and food ?
When asked if they were concerned about the health of the environment or wildlife around their community 43% of participants said "no", 35% said "yes" and 21% were uncertain.

Common environmental concerns were:
- Garbage in communities
- Environmental damage caused by development companies
- Water quality
- Pollution in the region including contaminants like PCBs and mercury

Almost 40 % of participants also said they were concerned about their health or health of others in the community. Almost 50 percent said they were not and the rest were uncertain.

Common health concerns were:
- Cancer, diabetes and other diseases
- Unhealthy behaviours – too many people smoking
- Health of Elders
- Access to good health services

In addition to helping identify needed communications and research on contaminants information dissemination in the region, this project supports the staff in anticipating and reducing the possibility of misunderstandings and mistrust among communities, organizations, researchers and scientists in communication activities in the region.

Discussion and Conclusions

The LIA Research Office staff member continues to be a valuable addition to the LIA Office and regional population. The LIA Office continues to educate and empower the people of Labrador to better understand and deal with contaminants in their environment and traditional foods, and be aware of research and general environmental issues.

The Labrador Inuit Association Research Office continues to:

➢ Support the activities undertaken by LIA Research Staff in providing information on research about contaminants, their effects on wildlife and humans through consumption of wild foods which are based on the varied language and geographic needs of individuals and communities of Labrador;

➢ Enhance decision making abilities of Labrador Inuit through the delivery of information on risks and benefits of contaminants and wild foods relevant to the region in an accurate, timely and accessible manner;

➢ Develop regionally relevant resource materials in consultation with the coastal communities and appropriate agencies (i.e. Labrador Inuit Health Commission, DIAND-NCP, ITK etc.). These materials include educational materials such as posters and a quarterly newsletter; all publications are produced in both Inuktitut and English;

➢ Use the research results from studies conducted in the region, such as the project Country Food, Nutrition and Health: Developing Effective Communication Strategies in Labrador to aid in effective delivery of information;

➢ Be responsible for interacting with and assisting outside researchers with community consultations. This assistance also includes negotiating research agreements between researchers and community organizations and reporting project results to communities in a timely and responsible manner. The Research Office determines, in consultation with community representatives who are responsible for communication on contaminant, health and environment issues, which medium(s) best suit the information needs of the community, etc. This person will continue to assist communities in identifying and prioritizing contaminants issues and assist in communicating community concerns and priorities to appropriate authorities.

- Take part in research projects and communication of research results when appropriate.

Date of Completion

This is an ongoing project in Labrador.

Analysis of the survey at the regional and national levels is ongoing and is providing information for regional and national communication strategy development. To date quantitative descriptive analysis is complete and analysis of the qualitative data is ongoing.

Acknowledgements

The LIA Research Staff would like to thank Dr. Chris Furgal, Laval University Public Health Research Unit, for his invaluable assistance and support in carrying out projects funded under the Northern Contaminants Program. Also, we thank Eric Loring, Inuit Tapiriit Kanatami, for his involvement and guidance in these activities. The support of the Labrador Inuit Association's Executive and its delegates ensures the continuation of the LIA Research Office mandate. We would also like to give special thanks to Louisa Kojak Interpreter/Translator, LIA, and Wilson Jararuse for the translation of communication materials and Katie Harris, Boas Kairtok and Nancy Ikkusek and well as the Labrador Inuit Association's Fieldworkers for their assistance in activities related to the issues discussed in this report.

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Contaminants Workshop in Nunavut: Communication as a Capacity-Building Tool

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Abstract

Nunavut Tunngavik Inc. (NTI) organized a 3-day workshop aiming to build Inuit capacity on contaminants-related issues in Nunavut. Open thematic discussions focused on human and environmental health issues as well as ways to enhance future Northern Contaminants Program activities in Nunavut. While participants expressed concerns regarding the impact of contaminants on the health of Nunavut's wildlife and environment, workshop discussions clearly highlighted that Nunavut Inuit are however not basing their personal food choices on contaminants considerations. Community involvement was seen as the key to progressing towards relevant contaminants research and effective communication, both required for informed decision-making in Nunavut communities.

Key Messages

Workshop discussions revealed that:

- Personal preference, practicality, cost and availability, rather than contaminants, are the main considerations governing the food choices of Nunavut Inuit
- Communications efforts remain a necessity because enduring misinterpretations and misunderstandings potentially hinder informed decision-making

Objectives

To build Inuit capacity on contaminants-related issues by:

- Providing information to, and hearing the concerns of, community resource-people;
- Offering an opportunity for open thematic discussions between holders of community-based and science-based knowledge;
- Linking human and environmental health issues; and
- Supporting community involvement in the design, development and conduct of NCP-sponsored research in Nunavut.

Introduction

Over the course of the Northern Contaminants Program (NCP)'s first two phases, a variety of education and communications initiatives have been delivered in Nunavut communities. More specifically, the Niqiit Avatittinni Committee (NAC), Nunavut's contaminants committee under the NCP, has always made capacity-building and communications the focus of its efforts. Accordingly, the NAC's most recent work (Caughey 2004, Loring 2004) and community tour, which presented

CACAR II results in a balanced manner that considered other health and nutritional issues (Stephens 2004), have highlighted the need to take human health implications into account, to identify community knowledge gaps and priorities, and to generally approach contaminants issues in a broader human and environmental health context. In parallel, preliminary results from the human and environmental health survey entitled "*What do Nunavummiut want to know about their environment and their health?*", described by Furgal (2004), seemed to suggest that Inuit in Nunavut had a perspective that, in at least some respects, diverged from the general Northern outlook on contaminants.

With this in mind, Nunavut Tunngavik Inc. (NTI) wished to shed light on the relevance of contaminants research to Nunavut Inuit and to improve communication lines, both to and from, Nunavut communities. Providing information to, and to hearing the concerns of, community resource-people was seen as a means to build Inuit capacity on contaminants-relates issues in Nunavut. With this in mind, NTI's workshop participant list was to a large extent drawn according to the survey responses to "*Where do you think you can get the most helpful information about wildlife and contaminants?*". The participation of key technical experts and NCP representatives was also seen as essential in encouraging the two-way discussions needed to support informed decision-making by community members and relevant research by contaminants researchers.

Activities

In 2004-2005

From February 15 to 17, 2005, Nunavut Tunngavik Inc. (NTI) hosted a workshop on contaminants in Nunavut. Over 40 people, from Nunavut and Southern Canada, gathered in Iqaluit to take part in this 3-day workshop intended to build Inuit capacity on contaminants-related issues. Participants included Inuit Elders, Hunters and Trappers Organization members, Wildlife Officers, Community Health Representatives along with Health Promotion and Protection staff, delegates from Inuit organizations (Regional Inuit Associations, NTI, Inuit Tapiriit Kanatami and Inuit Circumpolar Conference), Northern Contaminants Program (NPC) and Niqiit Avatittinni Committee (NAC) representatives, as well as technical experts. The workshop was chaired by Thomasie Alikatuktuk, President of the Qikiqtani Inuit Association, and facilitated by Joanasie Akumalik, Director of Government and Public Relations at NTI.

Results

Among the issues that surfaced during the workshop's thematic discussions, the following may be of particular interest to the Northern Contaminants Program:

Contaminants and human health

- Contaminants research needs to look at the overall effect (including benefits) of country foods on the health of Inuit, not just at the potential impacts of the contaminants contained in country foods
- Given researchers' ability to detect trace quantities of contaminants, and the relative lack of knowledge about the effects of these contaminants, is continually searching for contaminants ultimately more harmful than beneficial to Inuit?

Contaminants and environmental health

- Wildlife samples destined to contaminants studies need to come from animals that could normally be harvested by Inuit for their consumption, otherwise results from random or uninformed sampling might not be reflective of the contaminants intake of local human populations
- This being said, the contamination of wildlife is a concern in itself, not just because of its potential repercussions on country foods – the focus of contaminants research should therefore not rest exclusively on human health

Towards relevant contaminants research and informed decision-making

- Contaminants research should not be conducted on the basis that all Inuit eat an average quantity of a given country food every single day of the year – Inuit culture is connected to wildlife and seasonal cycles, and country food consumption consequently varies both throughout the year and across the territory
- If researchers spent more time in Nunavut communities to 'get their bearings', establish links and get to know the communities and surroundings before conducting their study, it might then be easier for community members to consider the researchers' information and for researchers to conduct relevant research and appropriately return results to these communities
- The absence of behavioural change is not necessarily a sign that the contaminants message has not been assimilated – it can also

reflect an informed decision to carry on with personal food choices

Discussion and Conclusions

The cross-thematic nature of discussions throughout the workshop highlighted the extent to which the health of Inuit, of wildlife and of the environment is interconnected. This reality, of particular relevance to the Northern Contaminants Program (NCP) given its interest in country foods, is compounded by the fact that contaminants, and the issue of what is or isn't contaminated, tends to be a very sensitive topic for Inuit. In addition, it is one that is not easily defined for interpreting/translating into Inuktitut and Inuinnaqtun.

It is therefore crucial that accessible, understandable contaminants material and messages be receptive to community concerns and be integrated into a broader human and environmental health context. Further, communications needs to be an ongoing process that will raise the awareness and understanding of contaminants-related issues to a level enabling community members to feel comfortable about their food choices. In this regards, local resource-people are vital for informing community members and want to work more closely with those designing and disseminating contaminants information.

This being said, country foods are generally preferred to store-bought foods and considered more beneficial – to the extent that many think it very unlikely that Inuit in Nunavut would stop eating country foods in response to recommendations or advice based on contaminants research results. Discussions also underlined that although Inuit are undoubtedly concerned about the health of Nunavut's wildlife and environment, personal preference, practicality, cost and availability, rather than contaminants, nonetheless drive the food choices of Nunavut Inuit. Also, since contaminants studies are mainly conducted in Inuit regions, NCP researchers need to improve their understanding of the effects of country foods on the cultural and physical well-being of Inuit before they draw conclusions relating to the impacts of contaminants on Inuit health.

Overall, the workshop was beneficial in that it provided a forum to help the NCP identify issues that are important to Inuit, because contaminants research is still, for the most part, based on questions researchers are asking themselves. As such, when contaminants research doesn't fully involve communities and doesn't genuinely acknowledge that Inuit possess valuable insight and expertise, there is sometimes a perception that researchers are using and abusing Elders and Inuit knowledge to satisfy their own academic agenda. Workshop discussions on healthy choices pertaining to both nutrition and lifestyles emphasized the benefits of bringing community, environmental, wildlife and health expertise to the same table. While progress has clearly been made over the last years towards relevant contaminants research and informed decision-making, many of the conclusions of a similar workshop, held back in 1998 (Nickels et al. 1999), regrettably remain valid today. Further efforts therefore need to be directed at finding the most adequate way to engage Nunavut Inuit on NCP-related contaminants research and issues (contaminated sites being a recurrent source of concern that the NCP does not directly address), and at building on the desire expressed by some community resource-people participating in the workshop to become more involved in contaminants communications.

Lastly, it may be beneficial for the Northern Contaminants Program to take a step back and acknowledge that contaminants are not as crucial an issue to Nunavut community members as they are to contaminants researchers.

Expected Project Completion Date

The workshop was held in February 2005.

Acknowledgments

Nunavut Tunngavik Inc. wishes to thank all workshop participants, especially Elders and community members, for sharing their knowledge and perspectives on contaminants and respectfully welcoming the input of others.

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On-line Contaminant Course for Inuit Students

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Abstract

This unique, Inuit-developed online course explores the issue of contaminants getting into the Arctic. It is meant to introduce the subject to Inuit students at a high school level or for a general introduction to the definitions and issues involved in contaminant education. It can also serve as an explanation for anyone who wants to know more about contaminants in the Arctic.

This online course takes place in a virtual Inuit community in the Arctic – one that doesn't exist in real life but can be used as a "classroom" to learn about contaminants in the Arctic. The many different questions answered in the course are meant to deal with the issue from a general Arctic/Inuit perspective and the virtual Inuit community provides a unique opportunity to bring in the scientists who study contaminants and to present the information with a community perspective in mind.

Key Messages

- In direct response to the success of CINE's online nutrition course, the online contaminant course was developed as a supplementary informational source to provide training about contaminants in the Arctic.
- The development of a relevant and usable resource for Inuit youth about contaminants in the Arctic will assist in further enabling communities to access important information related to food safety, health and contaminants in the Canadian north.

Objectives

Specifically this project:

- Developed a general introductory course about the science and issues concerning contaminants in the Arctic geared to a high school level audience;
- Provided an exploratory and animated context for users (i.e. "the student") to learn about Arctic contaminants and related environmental and health issues;
- Complemented and enhanced existing communication efforts with respect to contaminants in country food, contaminants and health, and food safety and food choice;
- Built capacity to provide community education in these subjects; provide opportunities for Inuit to develop and design their own course curriculum on explaining the complex issues of contaminants to Inuit;
- Further explored the effectiveness of combining the use of online education materials for Inuit regions

Audience:

The general audience for the online contaminant course include Inuit at high school level. It was developed in plain language and is suitable and adaptable for schools, communities, regions or those interested in learning about contaminants.

Introduction

Communicating about the issue of contaminants in the Arctic to Inuit is one that requires many different and innovative approaches. Despite considerable efforts over the past few years to inform Inuit of the health implications of contaminants in country food, many issues remain to be communicated. Community tours, fact sheets, radio programs, face-to-face workshops, radio shows and the development of educational materials have all contributed to increasing the level of understanding of these issues in Inuit communities. However, due to the complex nature of the material and the short exposure (one-time nature) and expense of these methods of communication, not all contaminant communication issues have been explored within Inuit communities. In recent years, the introduction of computers and internet access in Inuit communities has led to the development of material which Inuit can now access via Internet. The broadband initiative in the Arctic is now opening a new door for communicating to Inuit. Although still in its infancy stage with numerous bugs (slow connections speeds, lack of computers, etc) the internet and online courses may be a valuable tool in Arctic education.

ITK is exploring this communication route after extensive community and regional evaluation of using online education. With new knowledge being generated within the Northern Contaminants Program (NCP) concerning the possible health implications of contaminants to Inuit, efforts are now being shifted to focus communication to a much younger Inuit audience. In the past communication was geared to organizations within the communities and to elders. Very little work was done in educating Inuit youth. The community tours of 2003 visited every Inuit high school with the idea to first talk to students about contaminants as well as to engage them in what they would like as communication material. Both online and computer information was overwhelming requested.

The Center for Indigenous Peoples Nutrition and Environment (CINE) had started the process of online course and for three consecutive years, an online (Internet-based) nutrition course have been developed, delivered and evaluated for an audience of community-based health workers in Nunavut through the direction and guidance of a Nunavut-based steering committee. The successes of enrolment and course completion of this course lead to the proposed development of an online contaminants course as a means to educate, inform, and interact with young Inuit on the issue of contaminants in the Arctic.

Activities

In 2004-2005

The development of any collaborative communication or education material requires a series of drafts, development ideas and design; each subsequent meeting working upon the next. This phase of the online contaminant course was no different. A steering committee was struck to design the overall storyboard of what this course would look like, how it would operate, the overall content, who would take the course, etc. The committee wanted a pan-Inuit course that ITK would develop geared towards high school students and front line workers. Once developed it could then be adapted for various regional use. The committee agreed that the course should be housed at ITK, pilot tested and then, if appropriate, adapted to use in the four Inuit regions.

First drafts of the course followed the CINE online nutrition site storyboard of a family discussing contaminants and country foods. This draft was fairly simple, easily downloadable focussing on "storytelling" as the means of navigation. Other ideas were much more ambitious with streaming videos, images, interactivity with more of a video game appearance. What was developed was something in-between a course that was easy to use and interact with but one that was also challenging and engaging.

Learning objectives of the course include:

- Describe the benefits of harvesting and eating country foods
- Recognize the names of some environmental contaminants
- Identify where environmental contaminants come from
- Describe how they get to the Arctic
- Describe the difference between environmental contaminants and contamination at the local dump
- Name the animals most likely to contain environmental contaminants
- Understanding contaminants in Arctic flora and fauna
- Understanding the risk and benefits of country and store bought foods.
- Identify where to go to find more information

Results and Discussion

Through a series of lessons (approximately 20), users will be able to navigate through the course in 2 modes, one tutorial and the other navigational. In the tutorial mode, the user will work through the course linearly accomplishing one lesson before moving to the next. In order to move through the lessons, the user must successfully complete the end of the lesson "quiz" in order to proceed to the next lesson. The navigational mode will be for users who are already familiar (i.e. have completed the course once before) and desire to explore the course at their own leisure.

The course will be based around a virtual Inuit community in the Canadian Arctic. In order to simulate a genuine Arctic town, the design of the "community" will have places (Municipal office, Northern store, Research Office, etc.) and objects (skidoos, water truck, etc.) and characters (Inuk elder, research scientist, young Inuk woman, etc.). Each location, object, and character on the interface will be incorporated into the lesson structure and will be used as a place of information – or a "classroom". Therefore, the user's experience will be largely based upon visiting different classrooms throughout the community, which are incorporated into the lesson structure. Additionally, as required by the content, certain virtual "field trips" (i.e. to research lab in Montreal, pesticide use on cotton field in southern US, or municipal incinerator in Los Angeles) will be integrated into the lessons whereby the users will visit places outside the community via animation or video footage. The course is broken down into 20 work plans (see below). The goal is to acquire 20 dogs to develop a dog team to go out hunting for your family. Each successful completion of each work plan will add another dog to your dog team.

Each lesson included some if not all of the following components:

1) Teacher introduction
2) Assignment
3) Possible Field Trip
4) Report back to the teacher review
5) Misconception
6) Bonus (fun things that are hidden)
7) Discussion Forum
8) Links to glossary / FAQ section
9) Quiz to graduate to next lesson / build dogsled team along the way

The general outline which the course covered is as follows:

1. **Intro: What is this course about?**
   a. About the lessons and field trips (refers back to newspaper article)
   b. Goal of the course: inform people if they hear about contaminants or want to know more, what this means, how it affects everyone's life
   c. Learn the website – what to see and hear and what they'll get at the end

2. **Lesson 1 - What are contaminants? (Classroom)**
   a. What people think contaminants are
   b. General Definition (refer to newspaper)
   c. List of airborne contaminants (i.e. those studied by NCP)
   d. Why are they made? (generally man-made for a reason . . .)
   e. Are contaminants poisonous?
   f. Are contaminants pollutants?
   g. Can you taste or smell or see them?
   h. Bacteria vs. Chemical (contaminant) vs. virus (EAGLE f/s)

3. **Lesson 2: POPs (Classroom / Library)**
   a. Definition of POP
   b. What is "Persistent"?
   c. What is "Organic"?
   d. What is "Pollutant"?
   e. Herbicides / pesticides (types of, sources, uses of)
   f. Industrial byproducts (types of, sources, uses of)
   g. Why is there a concern (love fat, stay in the environment, build up in the food chain)

   Field Trip: Visit with families in South America use pesticides; medical waste burning facility, intensive agriculture in mid-west US

4. **Lesson 3 - Heavy Metals (Classroom / Library)**
   a. Definition
      i. Sources (natural vs. anthropogenic)
      ii. Our bodies need BUT now of concern b/c of anthropogenic sources
   b. What were the levels of these before pollution?
   c. Mercury, lead, and cadmium
   d. Methylmercury
   e. What and why is there a concern? (Mercury problem in food, cadmium only of concern for smokers, lead in shot)
5. **Lesson 4 - Wrap up of what are contaminants** (Now you know what they are, how do they get to the Arctic?)
   a. Sources

6. **Lesson 5 - How do these contaminants get to the Arctic?**

a. Intro – just saw what and where contaminants are used (map), little used in Arctic, so what is concern
b. Local sources
   i. DEW line (Field Trip)
   ii. Mining sites (Field Trip to Nanisivik (zinc))
   iii. Dump burning
c. Long range transport
   i. via air
   ii. via water
d. Why do contaminants stay? Why don't they leave?
   i. Arctic sinkhole
   ii. Climate change impacts
e. Wrap up

Field Trip: Visit with the high Arctic weather Station in Alert: How we measure contaminants in the air

7. **Lesson 6 - Is the Arctic Environment Healthy?**
   a. Air (diagram)
   b. Rivers and Lakes
   c. Drinking water
      i. At Water Truck – Is our water healthy?
   d. Land
      i. Collecting berries with Grandma – are plants healthy?
   e. Ocean
   f. How would you think contaminants would go from air, land, ocean? What's the process?

8. **Lesson 7 - How do contaminants move into the wildlife?**
   a. What they eat: Through food versus through water, environment (i.e. contaminants are not a disease)
   b. Up food chain – biomagnification
   c. Over time – bioaccumulation
   d. Differences between land and sea (animation)
   e. Marine mammals have a lot of fat

9. **Lesson 8 - Where are contaminants located in the animals?**
   a. How do POPS behave in the body of animals?
   b. How do heavy metals behave in bodies of animals?
   c. Organs versus fat
   d. Why is it important to know where contaminants concentrate in an organism?

   Misconception: WORM / BACTERIA

   Field Trip: Out on the ice with a member from the HTO and a research Scientist taking samples for measuring.

10. **Lesson 9 - How do scientists measure contaminants? What do these levels mean?**
   a. What is toxicology?
   b. Sampling methods
   c. What is ppm? Ppb?
   d. Levels – high versus low

   Field Trip: Off to CINE to understand how the seal sample goes from being collected to finding out what contaminants are in it.

   QUIZ: which samples have the highest and lowest ?

11. **Lesson 10 - Is Arctic wildlife healthy?**
   a. How is health measured?
   b. Comparing animals – who has high / who has low levels ?
   c. Regional difference? Why is this?
      i. Beluga lower levels in east than west (due to currents)
      ii. Seal levels from Holman to Kugluktuk to ...
   d. Other places in the world that animals have contaminants

   Field Trip: Maybe we can take them to St. Lawrence seaway with the belugas, or somewhere else where animals are contaminated

12. **Lesson 11 - Are there risks of contaminants to people?**
   a. Everyone has certain amount of contaminants
      i. levels from around the world
   b. Inuit exposure (est. potential risk of contaminants of Arctic/over long period of time low doses)
      i. high dose example (Japan or Grassy Narrows) – do contaminants affect health?
      ii. What does low dose mean?

c. Foods are how most people are exposed to contaminants. This is why Inuit foods are studied.
d. Who is the most sensitive?
e. Who is at risk? (how is it measured)
f. What are some of the risks?
g. What kind of action should Inuit take?
h. Uncertainties but are concerned
i. All the good things to consider about country foods
j. Do contaminants cause cancer?
k. Has anyone ever gotten sick from contaminants?

13. Lesson 12 - What are the benefits of eating country foods?

a. Yes, country foods have contaminants but there are all of these wonderful benefits of country foods.
b. What are all the nutritional benefits of eating country foods?
c. Nutritionist – importance of vitamins / nutrients
d. Breastfeeding
e. CINE – Nutrients studied?
f. What is the Cultural importance?
g. At community hall – sharing eating having fun
h. What is the Economical importance?
i. At grocery store – economic benefits vs. store foods
j. Importance on knowing the benefits in order to make decisions

Radio Station playing PSA

14. Lesson 13 - What about store bought foods?

1. At the store

a. Nutrients / vitamins are different depending on what you eat
b. Types of fats
c. Are there contaminants?
d. What about preservatives / additives?
e. Why can't we eat store foods (beef, pork) raw?
f. How do they compare economically / culturally to country foods?
g. How do we get better store foods?
h. What should we chose? (develop a store food guide?)

15. Lesson 14 - Today's Diet

a. Store Foods
b. Country Foods

16. Lesson 15 - Health Studies / Messages

a. Case of Salluit or Broughton studies
b. Present day Health risk assessments
   i. Health studies (cord blood, hair samples, why its done)
   ii. Dietary Surveys
   iii. Food sampling
   iv. Benefits included
c. Health advisories
d. Public health messages by region
   i. Nunavik

17. Lesson 16 - Talking about Benefits / Risks

a. This is what we know are the good things
b. This is what we know are the potential bad things

18. Lesson 17 - What can I do? What do I need to know to make decisions?

a. Making lifestyle choices
b. Risk of smoking equal to or greater than the risk contaminants
c. Health of gathering / hunting foods
d. Get involved
e. Educate myself
f. Know about Nunavut food guide
g. Public health messages
h. At grandparent's house – benefits

19. Lesson 18 - What is being done?

a. At the Hamlet – What about local issues?
b. At ITK / ICC – what is done nationally, internationally?

Field Trip to Stockholm UNEP meetings

20. Lesson 19 - Conclusions

Conclusion

The Centre for Indigenous Peoples Nutrition and Environment (CINE) has developed and delivered and online nutrition course to frontline health workers in Nunavut and NWT. Through the course evaluations, students expressed their desire to have a similar online course developed to explain the complexities of the "contaminant story in the arctic" to Inuit. Building on the conceptual framework and lessons learned from the CINE online course, an interactive, training course based through the Internet was developed to teach Inuit about contaminants and food safety in the Arctic. The goals for the online course included improvement and/or development of skills and knowledge of the targeted workers, students and other interested parties in the topic areas of contaminants in country food, contaminants and health, and food safety and food choice facing Inuit. Directed by Inuit youth at ITK this course begins to focus teaching more from an Inuit perspective of what youth want to learn and how to learn, rather from a non-Inuit more traditional southern focus.

The ITK online contaminants course has been innovative in its development with Inuit Junior Researchers guiding and directing the development of this course. It explores the issue of contaminants getting into the Arctic through an Inuit perspective. It is meant to introduce the subject to students at a high school level or for a general introduction to the definitions and issues involved. It can also serve as an explanation for anyone who wants to know more about contaminants in the Arctic. It takes place in a virtual Inuit community in the Arctic – one that doesn't exist in real life but can be used as a "classroom" to learn about contaminants in the Arctic. The many different questions answered in the course are meant to deal with the issue from a general Arctic-Inuit perspective and the virtual Inuit community provides a unique opportunity to bring in the scientists who study contaminants and to present the information with a community perspective in mind.

Expected project Completion Date

Final testing September 2005

Acknowledgements

This course could not have been done without the insight and groundbreaking work of Sue Hamilton development of the online nutrition course and from the evaluations and direction from this course and its Nunavut participants, GN-Health and Social Services and Nunavut. Gratitude also goes out to all of those who assisted, reviewed, and commented at all steps of development. Lastly, this could not have been done without the funding and vision of the Northern Contaminants Program.

Providing Contaminants Information in the Context of Regional Environmental Health Initiatives: Communications in Nunavik

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Abstract

In 2003-2004 in cooperation with researchers at the CHUL Research Centre in Quebec City, the Nunavik Nutrition and Health Committee returned results and provided public health messages to communities and the region related to contaminants, country food consumption and child development. Later that year, a small evaluative survey was conducted with a random sample of women in each of the three focus communities for this study to assess their recall and perception of the messages delivered. The NNHC then used feedback documented while in the communities and the results of this survey to develop a fact sheet on this information this year (2004-05). Along with other supporting information on the committee and the issue of contaminants in the region, the NNHC produced an information package that was then distributed to all communities and major organizations in the region in addition to key individuals and researchers interested in this issue. The committee is continuing to manage and disseminate information on health, contaminants and food and the environment in the region in a larger context with other public and environmental health issues and evaluate the effectiveness of its activities in this area.

Key Messages

Results from the Inuit child cohort study conducted in Nunavik were returned via a face to face tour to communities and delivery of public health messages;

Objectives

Specifically, this project:

- Prepared and presented the basic results from a small 3 community evaluative survey on the cohort communication activities done in 2003-04;
- Used community visits conducted in 2003-04 and survey information to finalize a fact sheet on women's and children's health in the region;
- Developed an information package including this fact sheet and other supporting information and distributed it to communities and regional organizations in Nunavik and elsewhere.

Introduction

The management and communication of the risks posed by environmental contaminants in the food chain of northerners comprises a very challenging issue for health and environmental managers and health professionals.

Traditional food is the anchor to cultural and personal well being in the North. For the first time, associations between subtle neurodevelopmental effects in Inuit infants and consumption of country foods by their mothers were reported this past spring in Nunavik (Muckle et al., 2003; NRBHSS, 2003). Acting under the authority of the Public Health Director, the Nunavik Nutrition and Health Committee, in cooperation with researchers conducting this research in the region, have the responsibility of discussing with the population what is being done, why this work is needed, what is being found and what can and will be done about it in order to support informed decision making among Nunavimmiut.

In 2003-04 two initiatives took place to assess Inuit comprehension, knowledge and perception of contaminants and health issues in Nunavik, other Inuit regions and Yukon First Nation communities. This work follows that conducted by Furgal and Myers in Labrador and Nunavut in 2002-03 (Furgal et al., 2005; Myers and Furgal, *in press*). Some standardized questions, which were asked in all Inuit regions and the Yukon in 2003-04, were included in a larger Nunavik Regional Inuit Health Survey. As well, an assessment of reception and recall by a target audience of a specific communication strategy was done in 3 Nunavik communities. The topic of this specific communication strategy was the dissemination of results of the Inuit child development cohort study conducted in Nunavik between 1996 and 2003.

Activities

In 2004-2005

Communications Evaluation Survey

In 2003-04 a tour of three communities was conducted to return results to Nunavimmiut from the Inuit child cohort study. The team involved in this tour included members of the NNHC, the Public Health Director, the researchers leading the Inuit child cohort study, an interpreter-translator and other key Inuit representatives. The findings of the cohort study had indicated potential negative subtle effects on aspects of Inuit child motor and neurodevelopment from exposure to environmental contaminants such as PCBs and mercury. This information was first delivered to the study participants and general public in three participating communities (Puvirnituq, Inukjuaq, Kuujjuarapik) and then to the larger Nunavik population. Key messages delivered and activities for communication focused on the participants of this study, women of child bearing age. In early 2004 a small survey was conducted among this target group in these three communities to document their awareness and recall of some of the basic messages delivered. As well, the survey was done to assess the recollection of where women had heard this information. Questions were developed based on the key messages delivered by the NNHC and Regional Health Board during the community tours. Questionnaires were pre-tested and adapted in both English and Inuktitut prior to application in the three communities.

A random sample of 58 women of child bearing age (18-45 years of age) was selected from all women of child bearing age in the three community populations using community lists with the aid of a local interpreter-translator / research assistant (Babbie, 1990). Women were asked to participate in a survey regarding the issues of contaminants, environment and health and their recollection of the communication events taking place around the Inuit child cohort study in their community that year. Written consent was given and surveys were conducted either in the participant's home or the local health centre (CLSC) and took approximately 25 minutes to complete. The survey was conducted with the aid of a research assistant and interpreter-translator in either English or Inuktitut, at the choice of the participant.

Data was translated, transcribed and entered into an excel spreadsheet for analysis. Descriptive quantitative statistics were calculated using the Systat 11.0 statistics package. Comparisons between age groups and cohort study participants and non-participants are ongoing.

Communications Package

Transcripts of community tour presentations and radio call-in shows conducted to disseminate the results and related public health messages for the Inuit child cohort study were reviewed for key questions related to study findings and relation with other public health issues. Survey results were reviewed for identification of message misconception and strong negative perceptions regarding country food safety and value to women and children's health. Based on this review, a fact sheet was prepared for the final distribution of public health messages related to study findings and other health issues in the region. A comprehensive newspaper communicating results of CACAR II results originally produced in English by Inuit Tapiriit Kanatami (ITK) was translated into Nunavik dialect Inuktitut syllabics. Finally, the NNHC produced an updated brochure to inform the public of their existence, mandate and goals on behalf of Nunavimmiut. All communication material, including a general fact sheet on country foods and health produced by ITK were then packaged and sent to key community and regional organizations and offices for distribution in the region to the general public. As well, key researchers working in the region and individuals with interest in this issue outside of the region were identified and targeted with the delivery of this material.

Results

A total of 58 women were randomly selected from the three communities as shown in Table 1.

Of these women, only 14% (N=8) had participated to the Inuit child cohort study in the previous years. The large majority (81%) had not, but as members of the target population for the communication activities conducted during the community tours, were likely exposed to the messages delivered at that time. However, when asked if they remembered hearing the results or information from the study the majority of participants reported that they did not recall hearing this news (Figure 1).
Among participants, 45% reported that they had heard about contaminants while 52% reported that they had not. When asked what "contaminants" were, the following statements given included:

- "PCBs"
- "I've heard of bacteria in fresh country food, the midwives tell the pregnant women not to eat very fresh fish, fresh caribou, some birds b/c they have bacteria and that can play a role in baby's growth"
- "Mercury, acids (battery), aerosol, other things"
- "Alochol, drugs, smoke"
- "I've seen dead caribou infection on the side of the river"
- "Little infections and bugs"
- "Something in the fish, mercury"

When asked directly if they had heard about PCBs or Hg, 45% and 44% respectively, reported that they had.

Participants were asked, using a 5 point likert scale, if they agreed with a series of public health statements regarding health, food and contaminants. These

Table 1. Participants to communications evaluation

Community	18-25 Years old	26-45 Years old	Total
Inukjuak	14	10	24
Kuujjuarapik	6	8	14
Puvirnituq	6	14	20
Totals	**26**	**32**	**58**

Figure 1. Responses to the question "Do you remember hearing the results or information about what the study on Nunavik women, children and contaminants found?"

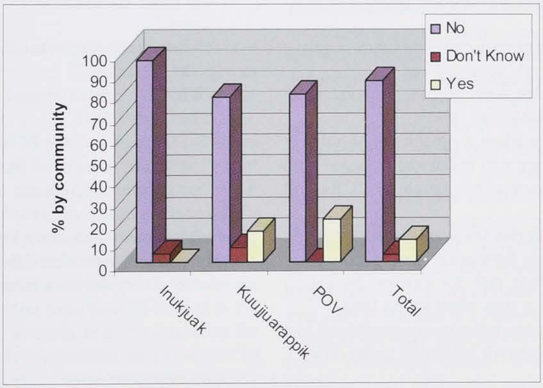
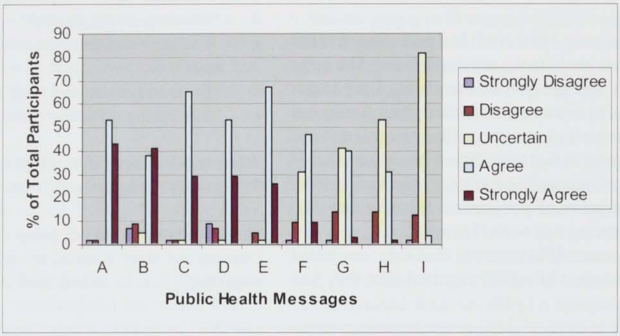


Figure 2. Responses to questions indicating participants' agreement with positive public health messages delivered in the Inuit child cohort communication strategy in Nunavik. Messages are arranged by decreasing agreement ("strongly agree") and increasing uncertainty ("uncertain") as expressed by participants. Letters correspond to the following questions below.



statements had formed the major public health messages of the communication strategy for the Inuit child cohort study delivered in the spring of 2003 (Figure 2).

Questions:

A. Playing, talking, singing and interacting with your baby can have significant positive impacts on your baby's development.

B. Alcohol use during pregnancy can have subtle negative effects on your baby's development.

C. It is very important that women of childbearing age (planning to have a baby or pregnant) eat a variety of nutritious foods in an adequate (good and in an enough) amount.

D. Smoking during pregnancy can have subtle negative effects on your baby's development.

E. While you're pregnant, some country foods are better for you and your baby than others.

F. If you have a choice when pregnant, you should eat country foods that are rich in fatty acids (good fats) and lower in contaminants (such as PCBs and mercury).

G. You can reduce your risk for heart disease by eating country foods rich in fatty acids (good fats).

H. You can reduce your risk for cancers by eating country foods rich in fatty acids (good fats).

I. Nunavimmiut's exposure to some contaminants like PCBs and lead in Nunavik is actually going down.

At the completion of the survey all participants were asked if they had any other questions regarding these issues. The following were some of the most common questions asked or statements made:

- "Women should eat more country food other than just food for their vitamins"
- "If they (researchers) really want to know about country foods they should test them, the protein and stuff like that. They wouldn't have to ask us if they knew the country foods themselves"
- "My girl eats a lot of country foods. Is she getting contaminants from the country foods? I don't have any other comment other than I want to see the report."
- "When I eat goose, what about the meat around the pellet, (is it safe)?"
- "What are contaminants? What are fatty acids? What is mercury?"
- "What are PCBs? Are PCBs in the Hudson coast?"
- "NRBHSS – has no toll free number. Why not?"
- "Researchers/scientists should be more open because a lot of people don't know about contaminants and don't know what's going on. I know they (researchers) are helpful but it would be better if they did something more."

Figure 3. Contents of NNHC communications package distributed this year. Includes (left to right) NNHC brochure, women's health fact sheet, country foods fact sheet, and CACAR II results newspaper. All materials were produced in both Inuktitut and English.

- "Are they still doing more research? I hope that researchers continue this work for the health of the people."

Communications Package

A communications package including the following materials (Figure 3) in both English and Inuktitut was sent to all community and regional organizations dealing with issues related to food, nutrition and health. Additionally, organizations outside the region and researchers regularly working in Nunavik received the package to inform them of how this information is presented to Nunavimmiut in its public health context.

Discussion

The results to date from the survey indicate a low level of recall of the specific event used to return the results from the child development study. Further, as indicated in other work (e.g. Bruneau *et al.*, 2001; Myers and Furgal, *in press*) there appears to be some conceptual confusion regarding the terminology used to communicate about "contaminants" as studied under the NCP (organochlorines, heavy metals and radionuclides). Although there is strong agreement for some of the basic public health messages delivered in the region with the results of the child cohort study, there is increasing uncertainty about some that were directly related to the results of the child cohort study (e.g. messages on the benefits of fatty acids, reduction in exposure to contaminants in Nunavik). Some messages that the majority of participants agreed with are messages that are delivered via a number of other basic public health promotion and education programs in the region (e.g. alcohol and smoking cessation) or are common knowledge among mothers regarding child rearing (e.g. playing with your baby is good for his/her development). Those messages that elicited increasing uncertainty from participants were more complex messages related to concepts of fatty acids and health and trends in contaminants exposure. Further, the remaining questions reported by participants indicate the ongoing need for work on communicating basic fundamental information to build public knowledge on these issues in the region.

The results to date raise a number of questions that must be followed up in future communication efforts and research. Currently it is not possible to determine if the understanding of some issues was positively influenced solely by the strategy and efforts that took place to return results to communities in the spring of 2003 or if this understanding comes from other communication and education efforts in the community. Identifying these other sources and their importance for certain issues and specific audiences within the population may help us determine if this "tour" delivery mechanism is the most effective for returning results and informing the population of the importance of this work for their everyday public health concerns. Without knowing such things as the other source(s) of recalled information and other "contextual factors" is it difficult to know the "effectiveness" of any one activity. If the recall is only strongly associated with other public health communication and education activities then the resources allocated to project specific communication events may require review and / or the specific objectives of such efforts be revisited.

Expected Project Completion Date

The activities reported here are part of the ongoing communications strategy of the Nunavik Nutrition and Health Committee. The final survey results and results of the Regional Inuit Health Survey will be used by the NNHC in the development of a long-term communications strategy in 2005-06.

Acknowledgements

The NNHC would like to thank all Nunavimmiut for their participation in the survey conducted this past year and ongoing Nunavik research on contaminants, health and the environment.

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North Slave Metis Alliance - Contaminants Communications and NWT ECC Participation

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Abstract

The North Slave Métis Alliance received funding for 2004-2005 via the Northern Contaminants Program (NCP) to participate in the NWT Environmental Contaminants Committee (NWTECC), to attend workshops, and to communicate and receive feedback from the NSMA community regarding contaminants information discussed in NWTECC meetings. NSMA continued to provide information regarding the Canadian Arctic Contaminants Assessment Report II (CACAR II).

The North Slave Métis Alliance was an active participant in the Northern Contaminants Program (NCP) throughout 2004-2005. The NSMA works diligently to ensure that members have access to relevant and reliable information about the relative risks and benefits of consuming local country foods as compared to commercially available foods. Particular attention is given to dispelling myths regarding significant health-threatening contaminants in the NSMA community's traditional foods. It is only with the much needed funding and our participation in the Northern Contaminants Program that the NSMA has been able to maintain an active role in dispelling myths and providing accurate, up-to-date information about contaminants to our membership.

Key Project Messages

- The NSMA's participation on the NWTECC is integral to effectively communicating and receiving feedback from the NSMA community regarding contaminant sources, impacts and methods of reduction.
- Traditional North Slave Métis foods remain healthy and nutritious choices compared to easily obtainable commercial substitutes.

Objectives

- To dispel the myth that the country foods the NSMA are consuming contain harmful levels of contaminants,
- To effectively communicate that the country foods the NSMA community are eating are safe, healthy, and nutritious,
- To communicate NSMA community concerns back to the NWT ECC and NCP.
- To actively participate in NWT ECC monthly meetings and related activities

Introduction

Indigenous Métis of the North Slave Region depend on the land and waters of this region for their physical, emotional and cultural survival. As the pace of "development" in the North Slave region continues to increase, and as the volume and type of contaminants introduced or released into the environment also increase, the NSMA community has become increasingly concerned about the safety and security of their traditional food and medicine sources, including air, water, plants, animals, fish, and birds. As a result many members have decreased their consumption of traditional foods in favor of government-inspected products that are expected to be less contaminated.

The Northern Contaminants Program is currently focused on identifying and quantifying long-range contaminants in the northern food chain, and investigating the implications for public health. This year the major initiative was to evaluate research on mercury contamination of fish in NWT lakes to ensure regional relevance. While the identification and quantification of long-range contaminants is of unquestionable value to regulators and policy makers, the community concerns raised about contaminants encompass any and all sources of contamination. In order to adequately inform citizens of the actual risks of consumption of local foods, the cumulative contaminant loads must be known, and interactions between contaminants also need to be considered. In recognition of this information need, the NWT ECC has been instrumental in attracting additional funding for Local Contaminant Concerns projects from Environment Canada and provides advice to community groups on appropriate funding sources.

Activities

In 2004-2005

- Prepared for and participated in NWTECC monthly meetings
- Receive, review, catalogue, and respond to NWT ECC emails.
- Maintain files and folders with northern contaminant information.
- Participate in Local Contaminant Concern proposal reviews
- Participate in social and cultural review of proposed NCP projects.
- Produced NWTECC final report,
- Compile map of locations of contaminant concerns.
- Increase the capacity of the NSMA to deal with contaminants issues.
- Provide the NSMA community with a knowledgeable liaison person and reliable point of contact to discuss and answer questions regarding contaminants in the North Slave Region.
- Inform NSMA staff, directors, and members about the on-going work of the NWT ECC, researchers conducting contaminants research, and contaminants information.
- Help Métis people access contaminants information available to make healthy food choices for their families.
- Inform NWTECC and NCP of NSMA contaminant concerns.
- Attend various workshops.
- Train and orient new staff.
- Participate in the design of the poster "Traditional Foods are Good for You".
- Presented at and attended the annual NCP results workshop, September 28,30, 2004 in Whiterock, BC

Results and Conclusions

The NSMA's participation on the NWTECC has been invaluable to the North Slave Métis People. Although NSMA experienced severe capacity issues throughout the year, including shortage of staff time and money, including a near complete and unplanned turnover of staff following a change in leadership, the work that NSMA has conducted has nevertheless been very effective at providing information to our membership.

Key messages delivered to NSMA Directors, staff, and members, included the following:

- The NSMA's participation on the NWTECC is integral to effectively communicating and receiving feedback from the NSMA community regarding contaminant sources, impacts and methods of reduction.
- Traditional North Slave Métis foods remain healthy and nutritious choices compared to easily obtainable commercial substitutes.
- In spite of information indicating that increasing levels of contaminants are showing up in the northern environment and in country foods and medicines, there is credible research that indicates that the contamination levels remain low enough that they are not considered to pose significant threats to Métis health.
- Preliminary research indicates that nutrients contained in traditional northern foods, combined with the healthy level of activity involved in obtaining, preparing, and distributing country foods, may protect against some effects of Mercury contamination.

Local communities have the ability, and the motivation, to bring contaminant issues to the attention of regulators and managers before the problem becomes so severe that it becomes common public knowledge. The NSMA community has identified the follow contaminant concerns:

• The Bathurst Caribou Herd has decreased in numbers and health. Concerns are that contaminant levels may be impacting the ability of caribou to thrive.

• More information needs to be gathered on how contaminants impact fish, caribou and human health.

• NSMA members identified the need for more Traditional Knowledge to be included in contaminants research as the community's reliance and presence on the land gives them an acute awareness of how the environment functions and changes, they consequently are often the first to point out changes to ecosystem health.

• There is an ongoing need to identify and eliminate long-range and local sources of contaminants to ensure contaminants don't get into the North Slave Métis' food source.

• NSMA members are concerned the contaminants, specifically arsenic, released during Giant and Con Mine's operational years are present in the soils and lake sediments around Yellowknife, a North Slave Métis community. These contaminants have the potential to surface when soils are used for growing vegetables and lake sediments are churned during recreational boating and swimming.

• Increased diamond and other mineral exploration in the NSMA's traditional territory is leaving cuttings from drilling operations on the land, possibility contaminating soils and vegetation, and possibly entering the human food chain. No research has been done to date on the environmental impacts of leaving drill cuttings on the land however, during recent exploration site inspections NSMA members documented dead vegetation resulting from drill cuttings and unsightly discoloring of the soils where cuttings were discharged. The NSMA believe the cuttings are a source of contaminants and are concerned about the cumulative effects of multiple exploration programs releasing contaminated drill cuttings.

• The potential effects of contaminant loads in traditional medicines has not been adequately studied or communicated.

• More information is needed on food storage, preparation and use to minimize harmful effects of possible contaminants.

• More information about contaminants needs to be provided to the NSMA community on an on-going basis to ensure the myth of high levels of contaminants in NSMA traditional foods is dispelled.

Expected Project Completion Date

The NSMA's participation on the NCP NWTECC is an on-going role designed to maintain open communications between the NSMA Board of Directors, membership and the NCP. We will continue in this endeavor to the best of our capacity.

Tlicho Participation in the Northwest Territories Environmental Contaminants Committee (NWTECC)

Project Leader

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Project Team Members

Tlicho Treaty 11, Members of the NWT ECC

Abstract

This 2004-2005 Fiscal Year Report is to record the involvement of Tlicho Treaty 11's involvement as member of the Northwest Territories Environmental Contaminants Committee (NWTECC) commencing April 2004 and ending in March 2005. Dogrib Rae Band (Dogrib Trustco) received funding in 2004-2005 through Northern Contaminants Program so the Tlicho Representative could participate in the NWTECC monthly meetings and communicate any contaminants issues and receive feedback from the Tlicho public.

Tlicho Representative will continue to participate in all NWTECC meetings, participate in NCP and Local Contaminants Concerns proposal Evaluations and keep informed the Tlicho Leadership and public regarding contaminants in the Tlicho Region. The representative, will also continue to conduct two-way transfer of information, to keep the Tlicho public informed of contaminants issues in their region, through the development of proposals and relaying results.

The following report communicates the participation of the Tlicho Representative in the NWTECC and communicating results with the Tlicho public.

Key Project Messages

Tlicho representative participation as member of the NWTECC is a very important part of ways to communicate and receive feedback from the Tlicho communities regarding contaminants in their region. With Traditional foods as Cultural importance to the Tlicho people we continue to seek better ways to communicate the benefits of traditional foods and the concerns of contaminants.

Objectives

- To provide information or seek appropriate resource from members of the Northwest Territories Environmental Contaminants Committee to the Tlicho public.
- To bring to the Tlicho public knowledge on how contaminants are always present in our environment, but also to inform them of harmful contaminants that travel through air and water system to the colder northern parts of the world.
- Wherever possible to seek professional interpreter/ translator assistance to ensure efficient communication is complete so the Tlicho public would understand the issues clearly, and avoid misunderstanding or misinterpretations.
- To continue to participate in activities of the NWT Environmental Contaminants Committee, including monthly meetings and proposal writing and reviews.

Introduction

Through participation of the Tlicho representative as member of the NWTECC, Tlicho public can be provided with accurate contaminants issue information.

Increasingly, through our communications with Tlicho Elders, it becomes apparent our traditional foods like the fish benefits are questioned due to industrial developments within the Tlicho Region.

- Rae-Edzo and other Tlicho community members over the years have expressed their concern regarding drinking water. Because, most of the water within the Tlicho region flows through Rae and into the Great Slave Lake and onto the Mackenzie River, they would like assurance that industrial developments are not adversely affecting their drinking water. More study is wanted in this area.
- Over and over, the Tlicho members are seeking to be involved with research and development regarding contaminants in their area. Additional funding is required to consider this issue.
- Occasionally, issues of contaminants within the community are of concern, but some of the concerns are within the municipal boundaries and local Government. NWTECC need ways to deal with this issue.

The communities want more involvement and it becomes apparent more funding is needed to address many wide verities of concerns.

Activities

In 2004-2005

NWTECC Meetings

March 24, 2005: NCP – Social/cultural review of environmental trends and human health proposals for 2005/06, NCP mercury health risk assessment project – February 22 summary, NEI, LCC projects – updates, etc.

February 23, 2005: NCP – Social/cultural review of environmental trends and human health proposals for 2005/06, Human Health, NWT Education and Communication Proposals, LCC projects – remaining funds/new projects, etc.

January 17, 2005: NCP – calls for proposals 2005/06, NCP mercury health risk assessment project, and LCC projects update/new projects, etc.

December 15, 2004; Northern Contaminants Program – call for Proposals 2005/06, Scott Mitchell, DIAND, explained the Indian and Northern Affairs Canada – Contaminated Sites Program, Lorne Napier, Dene Nation, explained the NCP Denendeh Communications Strategy process, etc.

November 24, 2004: Presentation by Laurie Chan, McGill University, regarding Health risk assessments for mercury levels in fish in NWT lakes/rivers, Chris Paci, Dene Nation, explained the Denendeh Communication Strategy and provided background on the Environment Canada Northern Ecosystem Initiative, LCC projects update, etc.

October 26, 2004: Update on November In-person meeting, NEI for communication of NWT Local Contaminants Concern funding – summary by Chris Paci, Dene Nation, comments on NCP Results Workshop, Whiterock, B.C., Michele provided summary of NCP Management Committee meeting held in Iqaluit in October 19-20, 2004, etc.

September 16, 2004: This Conference Call discusses update on mercury (Hg) research in the NWT presented by Gary Stern/Marlene Evans and to talk about the NCP Results Workshop September 28-30, to be held at Whiterock, British Columbia.

August 12, 2004: NCP Results Workshop September 28-30, Whiterock, BC – update from Simon. LCC projects – brief updates from Pat and George. NCP Education/ Communications projects 2004/05 – brief updates.

June 30, 2004: LCC projects – review of proposals submitted. Long term strategy for Education and Communications – Ottawa meeting. Committee Evaluation Results.

May 25, 2004: Update on the May meeting involving (TCC Chairs and aboriginal partners). LCC projects update. Long term strategy for Education and Communications. Proposals for completing a long term strategy for E&C (~9KI)

April 22, 2004: Update on the management committee meeting. Update on projects funding for the NWT. Update on Education and Communication Projects Funds. LCC projects from 2004-05 update.

Expected Project Completion Date

The Tlicho representative has completed it's responsibilities through participating as member of the Northwest Territories Environmental Contaminants Committee for the Fiscal Year 2004-2005. The Tlicho will continue to participate in the committee for the 2005-2006 Fiscal year.

ITK General Inuit Communications Package on Contaminants

Project Leader

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Project Team Members

Pan Inuit Communication Committee; Carrie Grable, BA, Consultant, Ottawa, ON; Chris Furgal, PhD, Nasivvik Centre, Sté-Foy, QC

Abstract

Since the inception of the Northern Contaminants Program (NCP), many different types and forms of communications materials for Inuit audiences have been developed by the affiliated partners to convey NCP results and information. These printed materials for community use include brochures, fact sheets, posters, newsletters, community reports, posters, curricula, and glossaries. This project has collated all of these various publications into an accessible format from which to develop and ultimately synchronize Inuit communication efforts into a General Inuit Communications website for use by the Pan-Inuit Communications Committee, national, international and regional Inuit organizations, front line workers and high school students in communities.

Key Messages

- An archival record now exists of NCP-related communications materials in both a hard copy binder format and a keyword searchable, 2-disc CD ROM entitled ***"Communicating about Contaminants with Communities: A Collection of Materials from the Northern Contaminants Program and Other Sources"***
- Development of new standardized web based Inuit specific fact sheets is being developed on pertinent subjects to complete an Inuit-general communications package with the same look and feel.

Objectives

Specifically this project:

- Identified and gathered all communications materials for the issues of contaminants and country foods in Inuit regions;
- Reviewed material and identified required new material(s) (done in cooperation with Pan-Inuit Communications Committee);
- Adapted and updated existing material (to provide same look and feel of print material);
- Developed the required new material;
- Assembled information in General Inuit Communications Package;
- Updated annotated database of communications materials in North with new materials.

Introduction

The communication of contaminants information in Inuit regions has involved the development of numerous forms of materials and the use of various methods for their distribution. Some of these materials have been evaluated and shown to be very valuable in communicating specific issues to the general public. Only recently, has material specific to Inuit and some target audiences in Inuit regions been produced (Inuit public Country Food posters, Fact sheet for Women of Child Bearing Age in Nunavik, Fact sheet for Nunavut on Country Food Benefits etc.). These audience-specific materials are showing to be effective in providing detailed information to the intended audiences. However, many of these materials have been produced in one region but are of value to all Inuit regions. It is for this reason, that ITK proposed to gather and review and then develop Inuit specific materials produced to communicate on contaminants and country food issues, adapt and reproduce (including translation) those that were applicable to all Inuit regions, and assemble a general Inuit Communications Package of this material.

Activities

In 2004-2005

By spring 2004, NCP-related materials (e.g. posters, fact sheets, newsletters, curricula, etc.) that had been produced for communication efforts related to contaminants and country foods were identified, gathered, and collated. An inventory of these materials was created in a hard copy format and then transferred into a Microsoft Excel document organized by year, region, organization, type of document, and document title. This collation, due to its immensity and the value of its information, was digitized and inputted into a keyword searchable CD ROM entitled, "Communicating about Contaminants with Communities: A Collection of Materials from the Northern Contaminants Program and Other Sources," produced in winter 2005.

The gathered material was reviewed for content, information gaps were identified, and the fact sheets for the communications package were outlined. Graphic designers have been put in place to ensure continuity and integrity of material. Additionally, the annotated database "Contaminants and Health Communication Materials for the North" was reviewed and updated with new material.

Results

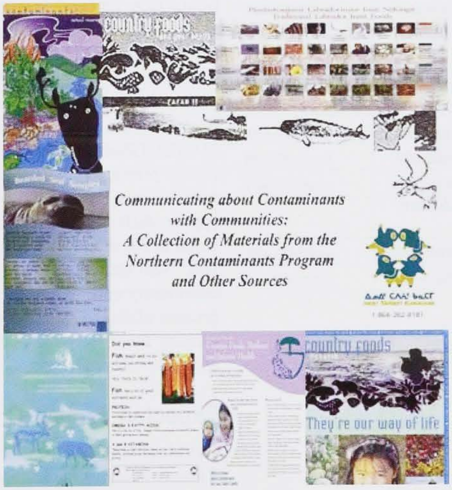
Collation Phase:

In a previous NCP project conducted by Chris Furgal, communications materials produced and used in the North on the issues of contaminants and health were gathered from each northern region health authority, Aboriginal organization, as well as from researchers and national organizations having produced materials. This material was then updated this year by gathering items produced since the production of CACAR II. Once gathered, the title, media type, key words describing its content and the language it was produced in were entered into an Excel spreadsheet.

All materials not previously digitized were then scanned and saved as jpeg and pdf files.

This inventory of material was then linked to the specific digitized PDFs and JPEGs of the documents and this material was saved on a two-CD format. This comprises the CD ROM entitled "Communicating about Contaminants with Communities: A Collection of Materials

Figure 1: Cover sheet for the 2-CD set entitled "Communicating about contaminants with communities: A collection of materials from the Northern Contaminants Program and other sources."



from the Northern Contaminants Program and Other Sources."

Review and Development Phase:
A review of the materials (e.g. fact sheets, brochures, newsletters, posters, curricula) commenced once all material was collated and catalogued. An extensive review of fact sheets was first conducted this year as it was the largest category of items with over 190 pieces. Once categorized (56 were collected on chemical contaminants, of which 12 were on PCBs, 39 described nutrients and nutritional information of country foods, and 17 were on country foods and contaminants-related information) a review of subjects for duplication or gaps was conducted.

The following list of subjects did not exist in fact sheet form for Inuit regions, and the project team identified the need to produce materials on these topics to fill in gaps for the production of a general Inuit communications package on contaminants:

Nutrient Fact Sheets

Store Foods vs Country Foods

Contaminant Fact Sheets

Chlodane
PFOS
Cesium 137
Levels of Contaminants in Air, Snow, Water
Where are they found in the animal? (Front on Marine/Back on Terrestrial)

Species Fact Sheets

Eggs

Health and Country Foods Fact Sheets

Are some country foods safer than others?
Balancing the Benefits and Risks
Is it safe to eat country foods?

Action on Contaminants Fact Sheets

National Initiatives
NCP
AMAP
Stockholm Convention
UNEP-LRTAP
Local Actions (at the dump mercury/PBDEs, PFOS)

FAQ

Cancer and Contaminants-is there a link?
Wildlife Abnormalities
Store Foods vs Country Foods
What you should know about Store Foods in the North?
What are tmeasurements (ppb, ppm)?
What is RDI?

Based on this review of gathered materials and previous experience working in communication efforts with communities, project team members finalized a list of fact sheets to be developed. To aid in this process, a document was created to link the proposed fact sheets to related ones that currently exist (*see Appendix 2-1)*.

Discussion and Conclusion

In fiscal year 2004/2005, over 350 items produced through NCP-related communications activities were collated and catalogued. Building upon the previous database project these materials have been updated and are now in a searchable format by type of publication (e.g. fact sheet, poster, curricula, etc.), year of publication, author, title, keyword, and region.

This has and will continue to provide the groundwork for the continuation of the development of the General Inuit Communications Package.

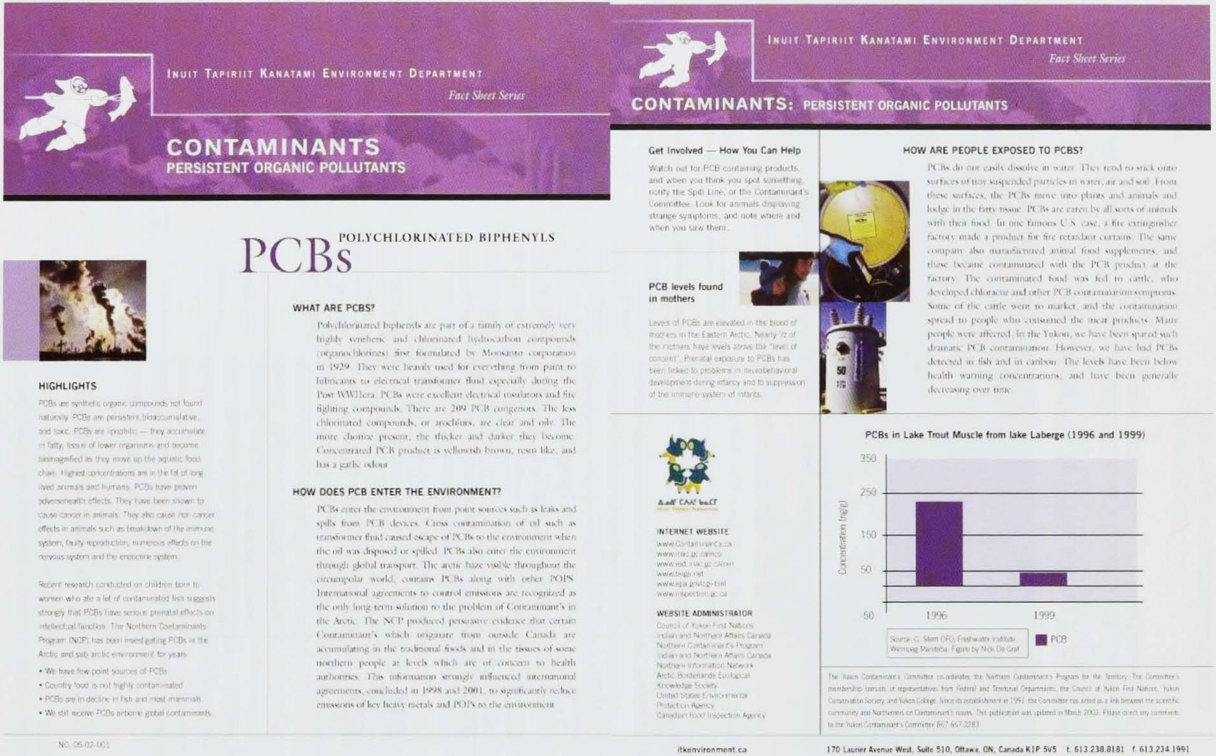
Graphic design work has commenced to ensure that the material developed will be visually appealing, culturally appropriate, and consistent for the information needs of the General Inuit Communications Package. To this end, review by NCP funded scientists and northerners are planned in future steps of materials development and production. Figure 2 is a snapshot of what the new ITK environment fact sheet website will look like. Be able to scroll on topics and choose various fact sheets which will be developed on an ongoing basis for the next few years, or as need arises. The user will be able to choose two options, a quick and fast loading low quality image of the fact sheet for reviewing, and a high resolution PDF file for printing and distributing at meetings or for other needs. Figure 3 shows a draft of how final fact sheets will appear; different subjects will have different icons and colours, but the format will maintain the same look and feel. Next year, review teams made up with researchers, community and regional representatives will begin the process of finalizing the development of fact sheets and looking them over for both community relevance and scientific relevance.

Expected Project Completion Date

Development and production of the General Inuit Communications Package website is an ongoing project

Figure 2: Snapshot of the new look of an ITK fact sheet website.

Figure 3: Draft of the new look of ITK fact sheets



INUIT TAPIRIIT KANATAMI ENVIRONMENT DEPARTMENT

Fact Sheet Series

CONTAMINANTS
PERSISTENT ORGANIC POLLUTANTS

HIGHLIGHTS

PCBs are synthetic organic compounds not found naturally. PCBs are persistent, bioaccumulative, and toxic. PCBs are lipophilic — they accumulate in fatty, tissue of lower organisms and become biomagnified as they move up the aquatic food chain. Highest concentrations are in the fat of long lived animals and humans. PCBs have proven adversehealth effects. They have been shown to cause cancer in animals. They also cause non cancer effects in animals such as breakdown of the immune system, faulty reproduction, numerous effects on the nervous system and the endocrine system.

Recent research conducted on children born to women who ate a lot of contaminated fish suggests strongly that PCBs have serious prenatal effects on intellectual function. The Northern Contaminants Program (NCP) has been investigating PCBs in the Arctic and sub arctic environment for years.

- We have few point sources of PCBs
- Country food is not highly contaminated
- PCBs are in decline in fish and most mammals
- We still receive PCBs airborne global contaminants

PCBs POLYCHLORINATED BIPHENYLS

WHAT ARE PCBS?

Polychlorinated biphenyls are part of a family of extremely very highly synthetic and chlorinated hydrocarbon compounds (organochlorines) first formulated by Monsanto corporation in 1929. They were heavily used for everything from paint to lubricants to electrical transformer fluid especially during the Post WWII era. PCBs were excellent electrical insulators and fire fighting compounds. There are 209 PCB congenors. The less chlorinated compounds, or arochlors, are clear and oily. The more chorine present, the thicker and darker they become. Concentrated PCB product is yellowish brown, resin like, and has a garlic odour.

HOW DOES PCB ENTER THE ENVIRONMENT?

PCBs enter the environment from point sources such as leaks and spills from PCB devices. Cross contamination of oil such as transformer fluid caused escape of PCBs to the environment when the oil was disposed or spilled. PCBs also enter the environment through global transport. The arctic haze visible throughout the circumpolar world, contains PCBs along with other POPS. International agreements to control emissions are recognized as the only long-term solution to the problem of Contaminant's in the Arctic. The NCP produced persuasive evidence that certain Contaminant's which originate from outside Canada are accumulating in the traditional foods and in the tissues of some northern people at levels which are of concern to health authorities. This information strongly influenced international agreements, concluded in 1998 and 2001, to significantly reduce emissions of key heavy metals and POPs to the environment.

NO. 05-02-001

INUIT TAPIRIIT KANATAMI ENVIRONMENT DEPARTMENT

Fact Sheet Series

CONTAMINANTS: PERSISTENT ORGANIC POLLUTANTS

Get Involved — How You Can Help

Watch out for PCB containing products, and when you think you spot something, notify the Spill Line, or the Contaminant's Committee. Look for animals displaying strange symptoms, and note where and when you saw them.

PCB levels found in mothers

Levels of PCBs are elevated in the blood of mothers in the Eastern Arctic. Nearly ½ of the mothers have levels above the "level of concern". Prenatal exposure to PCBs has been linked to problems in neurobehavioral development during infancy and to suppression of the immune system of infants.

HOW ARE PEOPLE EXPOSED TO PCBS?

PCBs do not easily dissolve in water. They tend to stick onto surfaces of tiny suspended particles in water, air and soil. From these surfaces, the PCBs move into plants and animals and lodge in the fatty tissue. PCBs are eaten by all sorts of animals with their food. In one famous U.S. case, a fire extinguisher factory made a product for fire retardant curtains. The same company also manufactured animal food supplements, and these became contaminated with the PCB product at the factory. The contaminated food was fed to cattle, who developed chloracne and other PCB contamination symptoms. Some of the cattle were to market, and the contamination spread to people who consumed the meat products. Many people were affected. In the Yukon, we have been spared such dramatic PCB contamination. However, we have had PCBs detected in fish and in caribou. The levels have been below health warning concentrations, and have been generally decreasing over time.

PCBs in Lake Trout Muscle from lake Laberge (1996 and 1999)

INTERNET WEBSITE
www.Contaminant's.ca
www.inac.gc.ca/ncp
www.esd.inac.gc.ca/nin
www.taiga.net
www.epa.gov/cgs-bin
www.inspection.gc.ca

WEBSITE ADMINISTRATOR
Council of Yukon First Nations
Indian and Northern Affairs Canada
Northern Contaminant's Program
Indian and Northern Affairs Canada
Northern Information Network
Arctic Borderlands Ecological Knowledge Society
United States Environmental Protection Agency
Canadian Food Inspection Agency

The Yukon Contaminant's Committee co-ordinates the Northern Contaminant's Program for the Territory. The Committee's membership consists of representatives from Federal and Territorial Departments, the Council of Yukon First Nations, Yukon Conservation Society and Yukon College. Since its establishment in 1991, the Committee has acted as a link between the scientific community and Northerners on Contaminant's issues. This publication was updated in March 2003. Please direct any comments to the Yukon Contaminant's Committee 867.667.3283

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and will continue into the 2005/2006 fiscal year. Final development on the website are being developed for access of this site please contact ITK for additional information.

Acknowledgements

Website development made possible by Beat Studios in Ottawa and John Albert. Development of the reference CD was made possible by research from Chris Furgal, Tommy Akulukjuk, and Carrie Grable.

Appendix 1-1: Existing NCP Factsheets; broken down by category.

Chemical Fact Sheets: 56 on specific chemical contaminants

4 Contaminants and What you can to REDUCE your Exposure to Contaminants?
A few notes about the 4 contaminants and their possible health effects as relevant to the participants of this monitoring program: Cadmium, Lead, Mercury, PCBs
Arsenic
Bacteria, Chemicals and Viruses
BEWARE: Cadmium Contamination of Deer and Moose Organs
Cadmium
Cadmium
Cadmium
Cadmium
Cadmium
Cadmium and Your Health
DDT
DDT - Dichlorodiphenyltrichlorethane
DDT - Dichlorodiphenyltrichlorethane
DDT and Its Metabolites
Dioxins and Furans
Dioxins and Furans
Heavy Metals
Heavy Metals: What do we know?
Information on Ozone
Metals
Lead
Lead in Household Tap Water in Nunavik
Your Health: Should We Worry About Mercury?
Mercury
Mercury
Mercury
Mercury
Mercury and Your Health
Mercury contamination of the food chain
Mercury Intoxication in Humans: Preventive Measures and Guidelines
Organochlorines: What do we know?
Information on Pesticides
PBDEs - Polybrominated Diphenyl Ethers
PCB concentration
PCBs
PCBs
PCBs
PCBs - Polychlorinated Biphenyls
PCBs - Polychlorinated Biphenyls
PCBs - Polychlorinated Biphenyls
PCBs (polychlorinated biphenyls)
PCBs and Your Health
PCBs and Your Health: Questions and Answers for Participants and Others
Information on PCBs
Advisory: Potential Health Hazard from Burning Wood and Other Materials Coated With Paint Containing PCBs
Persistent Organic Pollutants (POPs)
Petroleum Products
Radiation
Radionuclides
Radionuclides:What do we know?
Selenium
Toxaphene
Toxaphene
Toxaphene
Zinc

Nutrient Fact Sheets: 39 on food sources of nutrients

Country Foods: 20 fact sheets

Arctic Char
Arctic Hare
Beluga
Berries
Caribou
Duck
Fish
Fish
Goose
Goose
Grizzly Bear
Ground Squirrel
Muskox
Polar Bear
Ptarmigan
Seafood Mussels, Clam and Crab
Duck
Seaweed
Walrus
Wild Plant Greens

NWT Contaminant Fact Sheet -17 fact sheet contains both contaminant and nutrient info

Arctic Char, Other Fish and Your Health
Beaver and Muskrat
Beluga and Your Health
Beluga Whale
Berries
Caribou
Caribou and Your Health
Ducks and Your Health
Fish
Moose
Muskoxen
Ptarmigan and Grouse
Ptarmigan and Your Health
Radionuclides
Ringed Seal
Seal and Your Health
Waterfowl

Nutrients/Nutritional Info: 19 fact sheets

Calcium
Fat
Good Sources of Folacin
Good Sources of Iron
Good Sources of Vitamin A
Health, Omega-3 Fatty Acids and Selenium
Healthy Eating for a Healthy Baby
Iron
no title - (nutrients per serving)
Nunavut Food Guide
Nutritional Requirements and Country Foods
Protein
Traditional Food gives you fibre to help prevent cancer
Traditional Food gives you strong blood
Traditional Food gives you strong bones and teeth
Traditional Food makes good snacks
Traditional meat and fat
Vitamin A
Vitamin C

Communicating About Contaminants into the Future: Analysing the Inuit Communications Survey and the Establishment of an Inuit Strategic Plan

Project leader:

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Project Team Members:

Pan Inuit Communications Committee (PICC); Chris Furgal, PhD, Nasivvik Centre, Ste-Foy, QC; Carrie Grable, BA, Consultant Ottawa, ON

Abstract

The Environment Department at Inuit Tapiriit Kanatami supported and helped coordinate the conduct of surveys in each Inuit region under the 2003-04 Northern Contaminants Program to identify information needs related to contaminants and other environmental health issues. The research team entered data, conducted analysis and coordinated the review of preliminary results between and within regions in 2004-05. Initial results fact sheets were distributed and are being used in regions to return the basic results of this work to communities. An Pan Inuit Communications Committee (PICC) was convened and met twice during the year to discuss the survey progress, results and ongoing challenges being faced in communicating about contaminants in these communities. Training and support was provided to this group to begin a process of developing short and long term communication strategies at the regional, national and international levels. Preliminary survey results were used in the development of a national strategy and are now being considered in the development of regional strategies that will then be brought together to develop a new Inuit blueprint for communications and educations. This final product will be used to promote, coordinate and direct needed activities at the regional, national and international levels over the next 3-5 years.

Key Messages

- ITK coordinated and supported the analysis of survey data for each Inuit region to assess information needs and current understandings about contaminant and other environmental health issues;
- An Pan Inuit Communications Committee was established to advise on communicating about contaminants issues in Inuit communities under the NCP;
- A new national Inuit blueprint now exists for Communications and Educations and regional strategies and blueprints are under development that will direct work at the regional level in future years.

Objectives

Specifically this project:

- Collected and analysed data for the Inuit Communications Survey
- Delivered these results to the regional representatives for their dissemination at the regional level
- Developed a long term national Inuit communications strategy for contaminants, country / traditional foods and health
- Convened an Pan Inuit Communications Committee comprised of representatives from each Inuit region, ITK and ICC to develop integrated Inuit communication strategies and to discuss ongoing

challenges to communicating about contaminant issues at various levels.

Introduction

A great deal has been learned about contaminant transport, levels in the Arctic environment, and human exposure to these substances in the past two decades under the Northern Contaminants program. The NCP and participating Aboriginal Partners and regional representatives have delivered much of this information to communities and individuals to support informed decision making in the North. With increasing knowledge regarding the potential effects of these substances on infant health and development in high exposure regions, the delivery of this message has become more complex. The activities used to disseminate this information have been varied, ranging from print media to spoken word and regions are just now conducting evaluative exercises to increase the understanding of successes and challenges related to the delivery of this information. In 2003-2004, a common Inuit Communications Survey was applied in Labrador, Nunavik, Nunavut and the Inuvialuit Settlement region, and in cooperation with the Yukon First Nations communities, and results of this survey will be used to support the identification of communication needs and priorities for coming years in these regions under the NCP. Further, with the establishment of the Northern Contaminants Program as a long term program under Indian and Northern Affairs, some degree of continuity now exists for investigating these issues and determining the best ways to communicate them to northerners in order to support wise food choices in the future. It is for these reasons that the ITK Environment Department supported the establishment of a Pan-Inuit Communications Committee (PICC) this year and helped coordinate the analysis and communication of results from the regional surveys as well as the development of regional, national and international communication strategies for contaminant issues.

Activities

In 2004-2005

Survey Analysis and Dissemination

Survey forms from each region were reviewed and collated. Data for the 72 specific questions (45 quantitative, 27 qualitative) were entered into a spreadsheet and coded and categorized. Question organization and labelling was standardized to enable comparability across regions for similar questions. Basic descriptive statistics were calculated for each quantitative question by region and then among all regions.

An initial presentation of the results was given to Inuit representatives at the second PICC meeting held in Ottawa in winter of 2005. At this time, regional representatives reviewed basic results, posed further questions to analyse and priority questions for their region and suggested methods in which they would like to receive these preliminary results.

Further analysis and verification of the data was conducted for quantitative questions and preliminary fact sheets providing the basic results by region were produced and disseminated to the lead regional representatives (*see regional Inuit synopsis reports from Labrador, Nunavut and the Inuvialuit Settlement Region-Appendices 1-1,2,3*).

Inuit Communications Planning

An initial communications framework and planning background document was produced to guide discussions among regional, national and international Inuit organizations on the subject of developing strategic plans for communicating in Inuit regions on contaminant issues under the NCP (*Appendix 1-4*).

A meeting was convened in Whiterock, BC in association with the Annual NCP Results Workshop at which time the first Pan-Inuit Communications Committee (PICC) met. The document (*Appendix 1-4*) was used to lead discussions and the development process for integrated Inuit communications plans.

Based on the development of a draft National Strategy for communication activities in Inuit regions, the Inuit blueprint was revised for the 2005-06 NCP call for proposals.

The PICC met once again in the winter of 2005 to discuss the results of the Inuit communications survey (see above) and identify ongoing needs related to communications on these issues.

Results and Discussion

A total of 331 individuals were surveyed in Labrador, Nunavut and the Inuvialuit Settlement region. A core group of comparable questions are being asked in Nunavik as part of the Nunavik Regional Inuit Health Survey. Data from this region will not be available until winter 2005-06.

Topics in the survey included:

- Concerns on health and environment

- Personal sources of information
- Risk perception of food safety issues and contaminants
- Recall and comprehension of basic NCP messages
- Information needs and key questions
- Qualitative explanations for the above issues

See regional synopses reports for specific results to date (*Appendices 1-1, 1-2, and 1-3*).

Quantitative analysis is ongoing to determine the relationship between responses to questions and socio-demographic variables collected in the study. This analysis will be done to identify patterns in the concerns, perspectives and information needs reported by participants to help the development of regionally specific communication plans and strategies for future NCP work. As well, analysis of within and between region patterns in responses to qualitative questions is ongoing and being reviewed and managed through the PICC.

A Draft National Communications Strategy was developed in cooperation with regional representatives and included goals, objectives, activities and measurements of success (*see Appendix 1-5*). Regions are continuing their regional planning in 2005-06 and using the planning framework as the basis for their discussions.

Conclusion

The ITK Environment Department has worked to bring together Inuit regions and support them on conducting communication activities related to contaminant issues in their communities. The coordination of analysis of the Inuit Communications Survey and the establishment of the Pan-Inuit Communications Committee are two examples of these efforts to date. Through working together, Inuit regions are striving to join efforts on learning how best to plan for, deliver and evaluate communications on contaminant issues to support informed decision making and action at local, regional, national and international scales.

Expected project Completion Date

Analysis on qualitative aspects of the survey is ongoing and will be completed this fall, 2005. Planning and regional strategy development will be completed this winter in each region and at the national and international levels.

Acknowledgements

The participation and cooperation of the Regional Inuit organizations is greatly appreciated. The work that was conducted by the regional and community-based interviewers for the survey is recognized here as having been critical to the success of this project to date.

Appendix 1-1. What do Labradorians want to know about the environment and their health

What Labradorians Want To Know About Their Health and the Environment

Preliminary Results

What was the survey about ?

A small survey was conducted face to face with a small number of people in each community to learn what people wanted to know and what they thought about the environment and their health. The survey was conducted by LIA, in cooperation with ITK to help these organizations know what information communities want.

Who participated ?

A total of 60 people participated from Labrador. Both men and women over the age of 18 answered the survey. A small number from each community participated. The number that participated from each community was related to the total number of residents in that community. Forty-five percent of participants were men and 55% were women. The average age of all participants was 41 years old.

Table 1. Number of participants in the survey from each Labrador community.

Labrador Community	Total
Hopedale	13
Makkovik	8
Nain	27
Postville	5
Rigolet	7
Total	**60**

What did Labradorians say about their health, environment and food ?

When asked if they were concerned about the health of the environment or wildlife around their community 43% of participants said "no", 35% said "yes" and 21% were uncertain.

Common environmental concerns were:

- Garbage in communities
- Environmental damage caused by development companies
- Water quality
- Pollution in the region including contaminants like PCBs and mercury

Almost 40 % of participants also said they were concerned about their health or health of others in the community. Almost 50 percent said they were not and the rest were uncertain.

Common health concerns were:

- Cancer, diabetes and other diseases
- Unhealthy behaviours – too many people smoking
- Health of Elders
- Access to good health services

Participants also reported concerns they had about store foods and wild foods they ate.

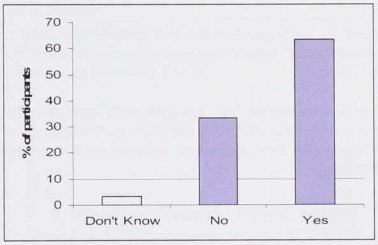


Figure 1. Percent of participants reporting they had concerns about store foods they ate.

Concerns about store foods were:

- Quality (colour, freshness, freezerburn)
- Out of date foods in store
- Food related diseases (botulism, madcow, etc)
- Price

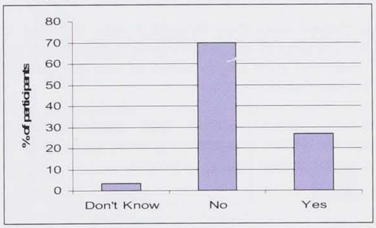


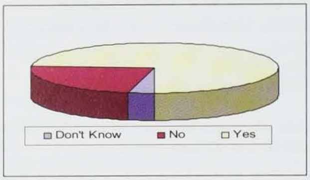
Figure 2. Percent of participants reporting they had concerns about wild foods they ate.

Concerns about wild foods were:

Availability
Animal health (sores on animals etc)
Contaminants (PCBs, mercury etc) in wild foods

Despite concerns almost all participants (87%) reported knowing about the **many benefits** of eating wild foods!

Have Labradorians ever heard of "contaminants"?



Almost all participants said that they have heard of "contaminants" before, as well as the terms "PCBs" and "mercury".

When listing things they thought were contaminants participants also included garbage in the dump, oil drums on the land and other general environmental pollution.

What have Labradorians heard ?

The majority of people were aware that contaminants (things like PCBs and mercury) can be in people, their community, in Labrador, and in southern Canada as well.

When asked if concerned about their health because of contaminants (things like PCBs and mercury), 43% said they were not, 41% said they were, and the remaining 15% did not know.

Most people said they thought it was possible to reduce the amount of contaminants (things like PCBs and mercury) they are exposed to and the amount getting into the environment.

Forty-two percent stated that contaminants (things like PCBs and mercury) were more of a concern for certain groups of people.

The majority of people stated that there were contaminants (things like PCBs and mercury) in both wild and store foods; however, a greater number of participants thought that store foods had contaminants (48%) in them than wild foods (22%).

Thirty-seven percent thought that wildlife in the region had contaminants (things like PCBs and mercury) in them.

Seventy-one percent stated that different species (types of animals, fish, plants) have different amounts of contaminants (things like PCBs and mercury).

Most stated that it had been longer than one month since the topic of "contaminants" had come up in a conversation.

The majority of Labradorians surveyed stated that they pay attention to research done by scientists, feel like it's in an accessible form of information and believe what they hear from these people.

An overwhelming majority felt that they needed to know more about contaminant issues.

Where do Labradorians get their information ?

Most people said they got their information on the environment and wildlife from LIA, a family member of friend or a hunter in the Community. Most people said they got their health information from a Doctor or nurse, LIA/LIHC or a family member or friend.

What's Next ?

These are preliminary results from the survey. You will hear more from LIA and ITK about what people in your region said and how LIA and other organizations will use these results to get you the information you want and in the ways you want to hear them in the near future.

For more information on this survey or other research on environment and health issues contact:

Mary Denniston LIA 1-709-922-2847
Eric Loring ITK 1-866-262-8181

What Nunavummiut Want To Know About Their
Health and the Environment

Preliminary Results

What was the survey about ?

A small survey was conducted face to face with a small number of people in each community to learn what people wanted to know and what they thought about the environment and their health. The survey was conducted by Indian and Northern Affairs (Iqaluit), in cooperation with NTI to help these organizations know what information communities want.

Who participated ?

A total of 201 people participated from Nunavut. Both men and women over the age of 18 answered the survey. A small number from almost all communities participated. The number that participated from each community was related to the total number of residents in that community. Forty-five percent of participants were men and 55% were women. The average age of all participants was 39 years old.

Table 1. Number of participants in the survey from each Labrador community.

Nunavut Community	Number
Arviat	22
Baker Lake	16
Coral Harbour	10
Gjoa Haven	12
Grise Fjord	2
Hall Beach	8
Igloolik	16
Iqaluit	38
Kimmirut	6
Kugaaruk	6
Kugluktuk	16
Pangnirtung	15
Qikiqtarjuaq	6
Repulse Bay	8
Resolute Bay	6
Taloyoak	8
Whale Cove	6

What did Nunavummiut say about their health, environment and food ?

When asked if they were concerned about the health of the environment or wildlife around their community 40% of participants said "no", 37% said "yes" and 23% were uncertain.

Common environmental concerns were:

Garbage on the land
Environmental damage caused by mining
Abnormalities in wildlife
Climate change impacting animals

Thirty-five percent of participants said they were concerned about their health or health of others in the community. Forty percent said they were not and the rest were uncertain.

Common health concerns were:

Healthy behaviours – too many people smoking, poor diet
Cancers
Health of Elders

Participants also reported concerns they had about store foods and wild foods they ate.

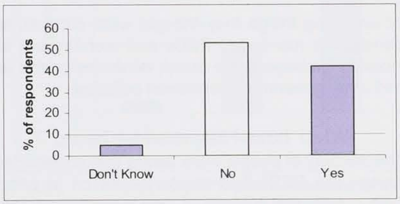


Figure 1. Percent of participants reporting they had concerns about store foods they ate.

Concerns about store foods were:

Quality (freshness, freezerburn, past due date)
Cost
Food related diseases (botulism, madcow, etc)

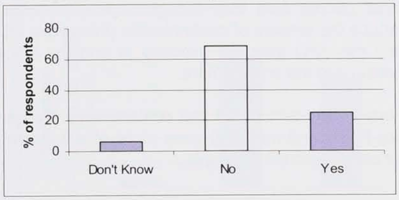


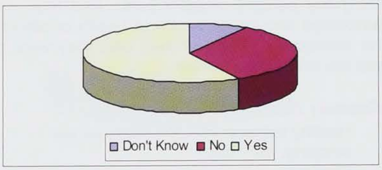
Figure 2. Percent of participants reporting they had concerns about country foods they ate.

Concerns about country foods were:

- Availability
- Animal health (abnormalities in animals etc)
- Contaminants (PCBs, mercury etc)

Despite concerns almost all participants (75%) reported knowing about the **many benefits** of eating wild foods!

Have Nunavummiut ever heard of "contaminants"?



Almost all participants said that they have heard of "contaminants" before, as well as the terms "PCBs" and "mercury".

When listing things they thought were contaminants participants mentioned PCBs and mercury but also included garbage in the dump, oil drums on the land and other general environmental pollution.

What have Nunavummiut heard ?

The majority of people were aware that contaminants (things like PCBs and mercury) can be in people, their community, in Nunavut, and in southern Canada as well.

When asked if concerned about their health because of contaminants (things like PCBs and mercury), 56% said they were not, 31% said they were, and the remaining 13% did not know.

Most people said they thought it was possible to reduce the amount of contaminants (things like PCBs and mercury) they are exposed to and the amount getting into the environment.

Forty-six percent stated that contaminants (things like PCBs and mercury) were more of a concern for certain groups of people.

The majority of people stated that there were contaminants (things like PCBs and mercury) in country foods; however, were uncertain as to whether there were contaminants in store foods.

Twenty-nine percent thought that wildlife in the region had contaminants (things like PCBs and mercury) in them.

Fifty-one percent stated that different species (types of animals, fish, plants) have different amounts of contaminants (things like PCBs and mercury).

Most stated that it had been longer than one month since the topic of "contaminants" had come up in a conversation, or that it never had.

About the same number of people said they did pay attention to research done by scientists, than said they did not. Most said they feel it is sometimes in an accessible form and most believe what they hear from these people.

An overwhelming majority felt that they needed to know more about contaminant issues.

Where do Nunavummiut get their information ?

Most people said they got their information on the environment and wildlife from a family member or friend, the radio or an Elder. Most people said they got their health information from a Doctor or nurse, a family member or friend or the television.

What's Next ?

These are preliminary results from the survey. You will hear more from DIAND, NTI and ITK about what people in your region said and how organizations will use these results to get you the information you want and in the ways you want to hear them in the near future.

For more information on this survey or other research on environment and health issues contact:

Eric Loring ITK 1-866-262-8181

What Inuvialuit Want To Know About Their Health and the Environment

Preliminary Results

IRC-Health and Environment

What was the survey about ?

A small survey was conducted face to face with a small number of people in each community to learn what people wanted to know and what they thought about the environment and their health. The survey was conducted by the IRC, in cooperation with ITK to help these organizations know what information communities want.

Who participated ?

A total of 70 people participated from the Inuvialuit Settlement Region. Both men and women over the age of 18 answered the survey. A small number from each community participated. The number that participated from each community was related to the total number of residents in that community. Fifty percent of participants were men and 50% were women. The average age of all participants was 36 years old.

Table 1. Number of participants in the survey from each ISR community.

Inuvialuit Community	Total
Aklavik	9
Holman Island	9
Inuvik	21
Paulatuk	7
Sachs Harbour	4
Tuktoyaktuk	20
Total	**70**

What did Inuvialuit say about their health, environment and food ?

When asked if they were concerned about the health of the environment or wildlife around their community 70% of participants said "yes", 25% said "no" and the rest were uncertain.

Common environmental concerns were:

- Garbage in communities
- Environmental damage caused by development companies
- Water quality
- Pollution in the region including contaminants like PCBs and mercury

Nearly 70 % of participants also said they were concerned about their health or health of others in the community. Twenty seven percent said they were not and the rest were uncertain.

Common health concerns were:

- Cancer, diabetes and other diseases
- Healthy behaviours – too many people smoking
- Health of Elders
- Access to good health services

Participants also reported concerns they had about store foods and country foods they ate.

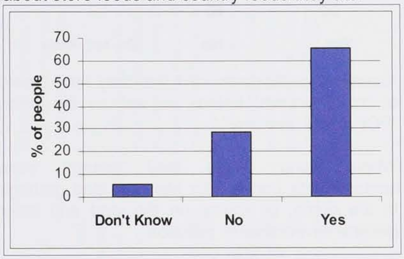


Figure 1. Percent of participants reporting they had concerns about store foods they ate.

Concerns about store foods were:

- Quality (colour, freshness, freezerburn)
- Out of date foods in store
- Food related diseases (botulism, madcow, etc)
- Price

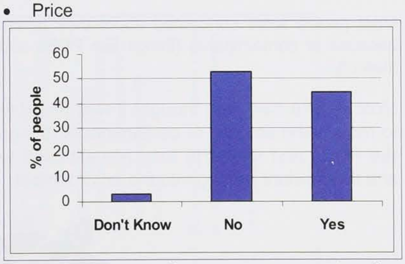


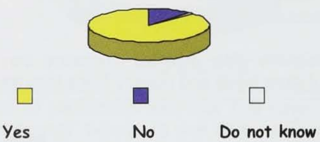
Figure 2. Percent of participants reporting they had concerns about country foods they ate.

Concerns about country foods were:

- Availability
- Animal health (sores on animals etc)
- Contaminants (PCBs, mercury etc) in country foods

Despite these concerns almost all participants reported knowing about the **many benefits** of eating country foods!

Have Inuvialuit ever heard of "contaminants"?



Almost all participants said that they have heard of "contaminants" before, as well as the terms "PCBs" and "mercury".

When listing things they thought were contaminants participants also included garbage in the dump, oil drums on the land and other general environmental pollution.

What have Inuvialuit heard ?

The majority of people were aware that contaminants (things like PCBs and mercury) can be in people, their community, in the Inuvialuit Settlement Region, and in southern Canada as well.

Most people were concerned about their health because of contaminants (things like PCBs and mercury).

Most people said they thought it was possible to reduce the amount of contaminants (things like PCBs and mercury) they are exposed to and the amount getting into the environment.

Most people stated that contaminants (things like PCBs and mercury) were more a concern for certain people.

The majority of people stated that there were contaminants (things like PCBs and mercury) in both country and store foods; however, a greater number of participants thought that country foods had contaminants (65%) in them than store foods (50%).

An overwhelming majority stated that different species (types of animals, fish, plants) have different amounts of contaminants (things like PCBs and mercury).

Most stated that it had been longer than one month since the topic of "contaminants" had come up in a conversation.

The majority of Inuvialuit surveyed stated that they pay attention to research done by scientists, feel like it's in an accessible form of information and believe what they hear from these people.

An overwhelming majority felt that they needed to know more about contaminant issues.

What's Next ?

These are preliminary results from the survey. You will hear more from the IRC and ITK about what people in your region said and how IRC and other organizations will use these results to get you the information you want and in the ways you want to hear them in the near future.

For more information on this survey or other research on environment and health issues contact:

Barbara Armstrong-IRC
*777-2737 or Direct Line-**777 2072***
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Appendix 1-4. Our National Strategy: Communicating about Contaminants in Inuit Communities

Communication / Education Goals	Objectives (Doing, Learning, Developing)	Priority Activities (Projects or mandated activities)	Timeline	Measurement of Success (Evaluation)
1. Inform and educate regional Inuit organizations about the Northern Contaminants Program and pertinent national and international initiatives on Arctic contaminants. *2. Inform and support scientists in engaging communities in meaningful consultation, the responsible return of research results and feasible modes of capacity development in concert with research activities.* *3. Facilitate the exchange and coordination of activities and information among Inuit organizations at various levels* *4. Ensure that the NCP incorporates and addresses Inuit specific concerns/needs related to contaminants research.* *5. Facilitate the awareness of and access to general information on contaminants among Inuit communities.*	1. Act as a liaison and conduit for information between the Northern Contaminants Program managers and scientists and Inuit regions 2. Provide information to inform and educate NCP researchers/scientists on needs and issues of regional Inuit organizations, and appropriate forms of consultation, communication and capacity building in Inuit regions; 3. Facilitate and support the effective management of Inuit specific aspects of the Northern Contaminants Program (e.g. Inuit block within Educations and Communications envelope) and support the understanding and incorporation of Inuit issues in all aspects of the program; 4. Act as a liaison and facilitator to bring together all Inuit representatives involved in the NCP to exchange information and coordinate communication related activities;	1. Develop general Inuit communications materials and messages for key target audiences and issues (e.g. health and contaminants issues for women of child bearing age) and make this material accessible through innovative and appropriate methods at the regional, national, and international levels (meets Obj. 1, 4, 5). 2. Conduct work to identify appropriate national and regionally specific contexts for contaminant messaging and information. Identify and where appropriate, utilize the associated formal and informal pathways for communicating contaminants information in context (meets Obj 1, 5). 3. Conduct evaluative work to increase Inuit organization's knowledge of what NCP researchers and assistants and graduate students want and need to know in order to conduct meaningful consultation, communication, and capacity building with Inuit communities and regions via research funded under the NCP (meets Obj. 2).	Y1–Y5 Y1-Y2 Y1– Y4	1. Existence of materials package 2. Distribution of materials to region, community and international levels 3. Informal feedback 4. In Y3, conduct of evaluative survey or material specific evaluation (e.g. case study review) 1. The existence of a national dissemination tree 2. Identification and use of new pathways for dissemination in association with related topics 3. Development of activities to use and support informal communication networks 1. The success/evaluations at workshop

Effective Translation and Use of Inuit-specific CACAR-II Data in International, Circumpolar, National and Local Fora

Project leader:

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Abstract

NCP Priority Action Plan for 2003-2004 identifies Inuit regions at highest risk of exposure to long-range transport of contaminants of concern. In identifying the new policy thrust priorities to address the human health effects of contaminants in the north, "the evaluation of whether the legal measures of LRTAP and Stockholm agreements are achieving the reductions in human exposures in the Arctic" was identified as an area of interest. In order to assess the performance of international, circumpolar and regional initiatives and provide relevant and useful information on international activities to Inuit communities and the general public, ICC Canada will undertake a series of nested activities. These activities and their products will ensure that the Inuit specific results within CACAR II and the data generated in Inuit communities is fully reflected in international, circumpolar and regional decision-making and that the utility of the data is effectively used to review and move relevant initiatives forward.

Key Messages

The human health and environmental concerns of Inuit regarding contaminants and long range transport were well acknowledged and incorporated into global decision making in the final Stockholm Convention. Regional and international policy instruments and activities are reducing the amount of certain legacy contaminants to the Arctic.

New and emerging chemicals of concern in the Arctic include brominated flame retardants (PBDE and HBCD), fluorinated organic compounds (PFOS and related compounds), chlorinated industrial chemicals (SCCPs and PCNs) and current use pesticides such as endosulfan.

Objectives and Introduction

The overarching objective of this project has been to ensure Inuit are aware of the global, circumpolar and national activities and initiatives regarding contaminants and are in a position to participate where most effective. Further that the regional and international community are aware of the Inuit concerns and Arctic data generated from NCP and use this in negotiations and decision making activities.

The long term goal of this project has been to ensure Inuit (regional, national and international Inuit organizations) have the appropriate information to make informed decisions, to understand the relevance of the data in the larger world, to ensure that Inuit are effective when lobbying for contaminants of concern production and use reduction/control locally, nationally, circumpolar, international.

Activities

In 2004-2005

The NCP programme is of central importance to ICC Canada for it provides the intellectual backing and project specific resources for our work on the international stage with the Arctic Council and North American Commission on Environmental Co-operation. ICC continues to sit on the National Hazardous Air Pollution (HAPs) Working Group as well as the Stockholm Convention, National Implementation Plan Working Group, as a means of bringing forward Arctic and Inuit concerns about contaminants to non-governmental organizations and government agencies and fulfilling Canada's obligations under Stockholm.

ICC Canada has promoted the global acceptance of the following language - Inuit and the Arctic is a "barometer" of the health of global environment and indicators of global environmental change. And has contributed significantly to the preparations for Stockholm Convention COP 1 in Uruguay.

ICC Canada using CACAR II has contributed to the ACAP Mercury Program, the UNEP Global Mercury Progamme and North American Free Trade Agreement (NAFTA) Commission for Environment Cooperation (CEC) Mercury North American Regional Action Plan (NARAP).

ICC Canada has compared Inuit specific CACAR contaminant data (exposure levels, effects) with global data from other indigenous peoples and communities at risk from similar exposure levels, as well as, assessing the regional population specific contaminant levels and the activities and guidelines other regions and countries employ to monitor exposure.

Specific international fact sheets were updated on Stockholm, and the CEC Lindane Taskforce.

ICC continues to develop the CACAR methods and experience into information packages to be used by other countries in developing their National Implementation Plans (NIPs) under Article 7 of the Stockholm Convention. ICC helped plan and participate in the National NIP Consultations.

ICC Canada continues to ensure Inuit data generated in CACAR are considered in international policy decisions/ activities including but not limited to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transbounary Air Pollution (LRTAP) persistent organic pollutants (POPs) heavy metals protocols, Stockholm Convention, the UNEP Global Mercury Programme, the Arctic Council Arctic Contaminants Action Plan (ACAP) Mercury project, and the North American Free Trade Agreement Commission on Environmental Cooperation (NAFTA) North American Regional Action Plan on mercury, lindane, PCBs, chlordane.

ICC Canada continues to publish the quarterly policy journal Silarjualiriniq March 2004 reflects, "Arctic Science and Research Activities" including the NCP.

Results/ Discussion and Conclusions

- **Stockholm Convention**

ICC has undertaken significant international advocacy through letters, speeches, presentations and personal communication with countries to encourage ratification. ICC participated in the National Implementation Plan Stakeholders meetings in Ottawa in February and offered comments on the drfat. ICC continues to prepare for the Conference of the Parties in Uruguay in 2005 and will co-host with AMAP, RAIPON and NCP a lunchtime side event "Results, Capacity Development and The Importance Of Indigenous Involvement in Implementing of the Stockholm Convention: The Russian PTS Report".

- **Arctic Council**

ICC continues to be active within the Arctic Council. ICC continues to participate with AMAP and the Russian Association of Indigenous Peoples of the North (RAIPON) to conclude contaminants in country food and maternal blood project in four Indigenous peoples in northern Russia. The results of this three-year project are to be made public early in the New Year.

- **Mercury**

Reflecting the NCP's conclusions on mercury, which acts in the Arctic very much in the same way as POPs, we are represented on the Mercury Working Group of the Arctic Council's action plan on pollution. This involvement is likely to prove important in coming months and years for it provides a base for us to monitor and participate as best we can in the mercury initiative of Canadian Council of Ministers of the Environment (CCME) Canada-Wide Standards for Mercury; UNEP's Global Mercury Programme; and the Arctic Contaminants Action Plan

(ACAP) Mercury Working Group. Our intent is to translate Arctic science into legally-binding emission control arrangements. ICC would like to become more active on this file and is seeking additional resources and expertise to contribute.

• **North American Commission for Environmental Co-operation Task Force on Lindane**
ICC was represented on the North American Commission for Environmental Co-operation Task Force on Lindane—a pesticide of real concern to Inuit. The draft report is available through the CEC.

Communications
ICC Canada's web site has been improved and new material is being added regularly, including all speeches delivered by the Chair. Sheila Watt-Cloutier was awarded the 2005 UNEP Champion of the Earth and the 2005 Sophie Prize for ICC work on POPs and climate change. ICC presented the importance of Arctic Science to the Northern Strategy meetings on Ottawa March 21-22, 2005. Sheila Watt-Cloutier has spoken at various cities including Toronto, Ottawa, New York, Washington, Winnipeg, Vancouver, Miami and San Francisco on the effects of global contaminants on the Arctic and she is now the acknowledged political spokesperson for Arctic perspectives on climate change and transboundary contaminants. Sheila attended the 2005 February UNEP Governing Council meeting to raise awareness of Arctic environmental issues.

Expected Project Completion Dates

Ongoing

Acknowledgements

ICC would like to acknowledge the support of David Stone, the NCP Secretariat, Cheryl Heathwood (Environment Canada), Barry Stemshorn (Environment Canada), our partners at ITK, Scot nickels and Eric Loring, the regions and the communities for whom we do this work, and John Buccini and UNEP who continue to open doors at the UN for Inuit.

Northwest Territories Environmental Contaminants Committee (NWTECC)

Project leader:

Northwest Territories Environment Contaminants Committee (NWT ECC), Chair: Chris Heron, Northwest Territory Metis Nation, Box 720, Fort Smith, NT, X0E 0P0; phone (867) 872-2770; fax: (867) 872-2772; e-mail: rcc@nwtmn.ca; Co-Chair (Corresponding Author): Michèle Culhane, Indian and Northern Affairs Canada, Contaminants Division, Indian and Northern Affairs Canada, P.O. Box 1500, Yellowknife NT X1A 2R3; phone: (867) 669-2699; fax: (867) 669-2721; e-mail: culhanem@inac.gc.ca

Project Team Members:

Members of the NWTECC: Dene Nation, Inuit Tapiriit Kanatami, Inuvialuit Game Council, Gwich'in Tribal Council, Sahtu Dene Council, Deh Cho First Nations, Tlicho Government, Akaitcho Territory Government, North Slave Metis Alliance, Northwest Territory Metis Nation, Environment Canada, Fisheries and Oceans Canada, Government of the Northwest Territories (GNWT) Resources, Wildlife and Economic Development, GNWT Health & Social Services, Aurora Research Institute.

Abstract

The Northwest Territories Environmental Contaminants Committee (NWTECC) services the Northern Contaminants Committee (NCP) as one of four territorial contaminants committees. It is a multi-party committee that is supported by NCP funding to, amongst other tasks, provide regional coordination for the NCP in the Northwest Territories. There are officially 16 members on the committee representing federal, territorial and aboriginal governments. Several guest organizations also regularly participate in committee meetings. Collectively the NWTECC brings a varied perspective (social, cultural, environmental, technical) to questions related to the occurrence and effects of contaminants in the north.

The NCP's current focus is to understand the relationship between human health effects and exposure to long range contaminants. In this regard the NWTECC undertook a specific project to ensure health risk assessments for mercury levels in fish in NWT lakes and rivers are regionally relevant. Scientific research studies and assessments continue to form the basis of communication and education activities for NWTECC membership, with an emphasis on meaningful two-way communication with Northerners. The NWTECC provides information to all northerners on the presence and possible effects of contaminants in Denendeh and the Inuvialuit Settlement Region (see summary reports from each region on communication/ education activities). The NWTECC facilitates the communication of northern priorities to NCP Secretariat and scientific researchers. The NWTECC produces regionally relevant communications materials. This year the committee produced a poster promoting traditional foods and outlining contaminants research. For the second year, the NWTECC has attracted funding from Environment Canada, Northern Ecosystem Initiative, Contaminants Partner Issue Table, to fund Local Contaminant Concerns (LCC) projects. The NWTECC reviews and approves LCC proposals throughout the year. In 2004-2005, the NWTECC held ten monthly conference calls and two in-person meetings.

Key Project Messages

1. The NWTECC provided a forum for discussion and two-way transfer of contaminants-related information

among aboriginal, territorial and federal governments, residents of the NWT, and contaminants researchers.

2. The NWTECC aided in proposal development and reporting for regional members in order for them to fully participate in the NCP.

3. The NWTECC assisted researchers and community members with information to meet funding requirements and address contaminant concerns/questions.

4. The NWTECC advised the NCP Management Committee of the results of NWTECC social/cultural review process results.

5. The NWTECC lead a project to undertake health risk assessments for mercury levels in fish in NWT lakes and rivers and ensure results are regionally relevant.

6. The NWTECC developed a poster promoting the consumption of traditional foods and highlighting ongoing contaminants research in the NWT.

Objectives

1. To build capacity in the NWT to work on the important issues related to long range contaminants in traditional foods and their human health effects.

2. To facilitate the efforts of northerners to address concerns arising from environmental contaminants in the NWT and identify community priorities and information gaps.

3. To provide a forum for the two-way transfer of contaminants information in the NWT between aboriginal, territorial and federal governments, residents, and researchers.

4. To bridge the NCP with other contaminants related programs in the NWT, i.e. Northern Ecosystem Initiative Local Contaminants Concerns.

5. To serve as a communications network to ensure Northerners are informed and involved in contaminants related activities (e.g. NWTECC poster development).

6. To identify priorities and information gaps related to environmental contaminants research in the NWT (e.g. mercury health risk assessment project)

7. To act as a central repository for environmental contaminants information.

8. To provide advice on appropriate funding sources.

9. To review proposals relevant to the NCP for social/cultural content.

Introduction

Following fourteen years of research the NCP has provided northerners with a valuable balance of human health, environmental trends and education/communication research pertaining to long-range contaminants in the North. The NWTECC has taken a leading role in NCP education/ communication research and communication efforts in all Inuit, Dene and Metis regions of the NWT. This has highlighted the need to have a central coordinating body (through the Yellowknife office of Indian and Northern Affairs Canada) to ensure the highest quality contaminants information is being conveyed in an efficient and timely manner. The NWTECC stimulates important research initiatives by drawing on the expertise of the members. The NWTECC elects a Chair and Co-Chair annually, who are responsible for organizing meetings, activities and distributing information; however, the committee uses a consensus style decision making approach allowing all to speak. For 2004-2005, the Chair/Co-Chair were the Northwest Territory Metis Nation (chair) and Indian and Northern Affairs Canada, NWT Region (co-chair).

The NWTECC provides a forum for researchers and regions/communities to discuss contaminants issues and propose activities to better understand problems and concerns. NWTECC regularly invites guests to discuss important issues of concern to the members. Membership is composed of representatives from three departments of the federal government and two territorial government departments, as well as two national Aboriginal partners, the eight regional Aboriginal governmental organizations, and one government research institute. The committee is well suited to address research priorities and information gaps in the NWT, and has undertaken activities in 2004-2005 in this regard.

Activities

In 2004-2005

The NWTECC met through a combination of conference calls and in-person meetings to discuss various contaminants related issues and education and communication priorities (see Table 1 for summary of meetings). Monthly roundtable discussions and updates helped to keep contaminants workers in Aboriginal, territorial and federal governments, informed of study results, current activities, upcoming proposals, workshops, training opportunities, and conferences.

The NWTECC held a two day in-person meeting in Rae, NT (November 2004) to discuss primarily the NCP Denendeh education and communication strategy. A conference call was held during the meeting to include all NWTECC members in some of the discussion. The meeting provided an opportunity for committee members to learn from each other about their activities and future projects within the NWT.

As in previous years, the Social and Cultural review of NCP projects relevant to the NWT was conducted in person in February 2005. This meeting was scheduled to directly follow a special workshop on mercury health risk assessment lead by Laurie Chan of the Centre for Indigenous Peoples' Nutrition and Environment (CINE) to present health risk assessments on mercury in NWT fish to the committee members and guests. The NWTECC received mid-year funding from the NCP to undertake this project and was fortunate to secure the services of Laurie Chan from CINE to see the project through, and maximized funding allocations by combining the workshop with the annual proposal review meeting (one day each).

The NWTECC provided valuable comments and input in designing a poster titled "Traditional foods are good for you!" distributed to all Aboriginal governments in the NWT, schools, health centres as well as several other governments and organizations. In addition, the committee continued to review Local Contaminants Concerns proposals funded by Environment Canada's Northern Ecosystem Initiative. They also sought important information on other funding sources such as Environment Canada's EcoAction fund and Building Environmental Aboriginal Human Resources (BEAHR) program. A presentation on the Indian and Northern Affairs Canada Contaminated Sites program was made to clarify differences between various contaminants related programs and answer questions of committee members.

Results and Conclusions

The NWTECC secured resources under the national and regional coordination envelope of the NCP which allowed the committee to meet in-person twice, and allowed for representation at the NCP Management Committee meetings, and the development of an NWTECC poster. The funds represent a fraction of the actual costs, as many of the members contribute their representation in-kind, causing a strain on representatives and their organizations. In addition, while participant funds are provided to the Aboriginal governments participating at the NWTECC, these funds do not represent the full costs of participation.

As in 2003-2004, the majority of NCP funding is being allocated to high risk regions exposed to international/transboundary contaminants (these being regions with elevated consumption of marine mammals) in 2004-2005. In Denendeh the regions are identified as low to medium risk, and are funded under the Denendeh block for education/communication projects. In the Inuvialuit region communities are seen as medium to high risk, and are funded under the Inuit block. Dene Nation lead the development of the 5 year Denendeh Communication Strategy in November which provided guidance for developing proposals under the Denendeh block this year. The NWTECC co-chair has provided a great deal of assistance in ensuring Denendeh members submitted proposals to the Denendeh block of funds. The Inuit block funding is managed through Inuit Tapiriit Kanatami and are not discussed in detail at the NWTECC. Results of individual projects will be summarized in the education and communication section of the NCP Synopsis report. Capacity building is an outcome of the funding mechanisms, but the main goal for capacity building is to provide northerners with the best information possible, in accessible and relevance ways, in order that northerners can make informed decisions about their food choices (as they related to traditional/country foods and long range contaminants). NWTECC continues to provide important information and guidance to the regions.

The continued need to train and orient NWTECC members will be an important matter for NCP to consider. Finding innovative ways to build capacity, including on-going training (i.e. Taiga lab training), will be a consideration in future years. The full cost to regions, governments, and all participants in the NWTECC should be accounted for, demonstrated and communicated. There is a very real dependency on the NCP to fund all activities of the NWTECC; however, as with the move to NEI funding of local contaminants concerns, there are contaminants related activities in the NWT that could possibly be funded from other sources. The NWTECC co-chair acted as a support to regions conducting their own NCP education/communications projects and Local Contaminants Concerns proposal development (non-NCP funded).

Table 1. Meetings held by the NWTECC during 2004-2005 fiscal year.

Meeting #	Date	Key agenda items
53	April 22,2004	Update on NCP Management Committee meeting proposal review Update on education/communication project funds NEI LCC projects from 2003/04 and 2004/05 update Roundtable Discussions
54	May 25, 2004	Update on May meeting of TCC chairs and Aboriginal partners Proposal for completing a long term strategy for ed/com Review of terms of reference for NWT ECC Elections for Chair/Co-chair Roundtable Discussions
55	June 30, 2004	Committee evaluation results NWT ECC poster Long term strategy for education and communication LCC projects – review of proposals submitted Roundtable Discussions
56	August 12, 2004	Finalize NWTECC poster text NCP Education/communications projects updates LCC projects – brief updates Roundtable Discussions
57	September 16, 2004	Discussion on mercury research in the NWT Discussion on upcoming NCP results workshop Sept 28-30 LCC projects – brief updates Roundtable Discussions
58	October 26, 2004	Denendeh communication strategy planning Guest from Building Environmental Aboriginal Human Resources (BEAHR) briefly introduced the program Summary of NCP Management Committee meeting Oct 19/20 Summary of NCP results workshop Sept 28-30 Roundtable Discussions
59	November 24, 2004 (combination of conf call and in person in Rae, NT)	Denendeh communication strategy meeting (in-person) Discussion of health risk assessments for mercury in fish – Laurie Chan, CINE NEI LCC projects – Dene Nation LCC communication project Roundtable Discussions
60	December 15, 2004	NCP call for proposals for 2005/06 Contaminated sites program – Scott Mitchell, INAC NT NCP Denendeh Communication strategy –update by Dene Nation NEI LCC projects – brief updates/new projects Roundtable Discussions
61	January 17, 2005	NCP call for proposals for 2005/06 NCP mercury health risk assessment project update NEI LCC projects – brief updates/new projects Taiga lab training update Roundtable Discussions
62	February 23, 2005 (in-person, Yellowknife)	NCP proposal review of human health and environmental trends proposals for social/cultural criteria Discussion regarding upcoming NEI LCC projects (note: meeting followed mercury HRA meeting February 22)
63	March 24, 2005	NCP mercury health risk assessment project update Overview of NWTECC social/cultural proposal review NEI LCC project updates Roundtable discussions

Meetings

Monthly conference calls have kept communications flowing among regions, scientists, government organizations and Aboriginal partners. These meetings are important to discuss media reports, scientific research, sample collection, workshops, training, and presentations. They are a good opportunity to meet and talk about health advice, new contaminant findings, environmental issues, and community concerns. Minutes of each meeting were produced by the co-chair summarizing the discussions, activities, and decisions of the Committee. Minutes are archived by the Contaminants and Remediation Directorate, INAC (Yellowknife). Representation by Aboriginal Partners, such as Inuit Tapiriit Kanatami (ITK) and Dene Nation, in the committee is essential to ensure effective communications of NCP information to their regions.

Social/Cultural Review

During the social/cultural review by the NWTECC, the committee went through each proposal at a level of detail, ranking projects based on the following criteria: their involvement with the regions/communities on communications, consultation, capacity building/training and priorities in the north. The review process increased the NWTECC understanding of the NCP, specific projects, and human health research. It also provided the community members greater knowledge of the responsibilities and obligations researchers are taking to their communities. This meeting allowed for regional representatives to comment on whether they felt the researcher was fulfilling their requirements and to communicate their comments to the Management Committee. These views were reinforced by the NWTECC co-chair and Aboriginal Partners participation in the review process and they were brought forward to Management Committee.

Education and communication proposals were not reviewed by the NWTECC. For the first time an independent technical review team set up by the NCP Secretariat ensured an unbiased formal review of all education and communication proposals from every NCP region. The comments from this review were well received by the Management Committee. The NWTECC co-chair did ensure a coordinated approach to Denendeh block proposals was put forward, thus strengthening the value of the proposals at the technical review and management committee level.

Mercury health risk assessment project

The mercury health risk assessment project funded with mid-year NCP funds was an extremely valuable NWTECC activity this year, and will continue to provide a basis for future discussions. The one day workshop lead by Laurie Chan, CINE, served as a training opportunity for NWTECC members and guests. Laurie provided easy to understand explanations of mercury, toxicology, benefit/risk balance concepts, and summaries of mercury levels in fish in the context of fish consumption by residents of the NWT. It is hoped that GNWT Health and Social Services will strongly consider the results of this project, and re-evaluate its present mercury health advisories in the NWT to ensure they are regionally relevant.

NWTECC poster

The development of an NWTECC poster was a successful product of the committee this year. All committee members provided input and comments at many stages in the poster development process. The poster highlighted a positive message – that traditional foods are good for you. It was very widely distributed and has been spotted in band offices, schools, and health centers.

Expected Project Completion Date

The NWTECC will continue to meet throughout 2005-06 by monthly conference calls and twice in person. The role and terms of reference for the committee will continue to evolve.

Yukon Contaminants Committee 2004

Project Leader:

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Project Team:

Yukon Contaminants Committee: DIAND; Council of Yukon First Nations; Environment Canada; Yukon Environment; Yukon Health and Social Services; Yukon Education; Yukon Conservation Society; Yukon College, and Yukon Education

Abstract

The Yukon Contaminants Committee (YCC) was established in 1992 to direct research in the Yukon and to coordinate the communication of information on contaminants. Since that time the Committee has produced a large number of communications vehicles; including fact sheets, videos, educational material, booklets, brochures, radio and television ads. In 2004, the Committee focussed on developing a five year communications strategy, worked with CHUL and Yukon Education on a school survey of the Contaminants Found Me curriculum, updated the Yukon Contaminants Database, and produced a workshop "package" for delivery in the communities over the next five years.

Key Project Message

The Yukon Contaminants Committee has reviewed the results of NCP research and International contaminants studies and communicates this information to the Yukon public in a culturally appropriate manner.

Objectives

- Produce a five years communications strategy for the Yukon;
- Review the Contaminants Found Me curriculum for relevance through a survey of students and teachers exposed to the material;
- Produce a package of material to be delivered in Yukon communities over the next five years;
- Review and update the Yukon Contaminants Database;
- Communicate the results of contaminants research to the Yukon people in a culturally appropriate and relevant manner.

Introduction

The YCC produces and delivers communications for the NCP in the Yukon in close cooperation with CYFN. This has been the case for the existence of the NCP and it continues to be an effective and cost effective relationship. The Committee is composed of a diverse group of stakeholder representatives, who provide perspective from across the Yukon cultural and political landscape. The Council of Yukon First Nations is a member of the YCC and it insures cultural concepts are included in the communications process and provides invaluable contact within the Aboriginal communities within the Yukon. While the YCC and CYFN often undertake separate initiatives, they are with the full knowledge of both partners.

Activities

In 2004

This year the Committee concentrated on the development of a five year communications strategy.

Five Year Strategy

Short Term Goals

As always, our short term goal is to assure the Yukon that our traditional foods continue to be monitored, so that we can confidently say they are safe to eat. Finding novel and effective methods of communicating the monitoring program results and keeping the Yukon current on our knowledge of contaminants from NCP and International research are the primary short term goals. Rather than limit ourselves to defined components, the YCC will seek to find new methods and take advantage of communication opportunities as they arise. This has been our focus in the past and we have achieved some success with this approach. The primary messages are: that we are monitoring; that our traditional foods are safe to eat; and that we are here to contact for information. Our strength as a Committee has been our close association with CYFN in communicating these messages.

Long Term Goals

The long term goal is to add detail to the short term efforts of promoting the traditional foods as safe to eat. This will include raising the level of understanding within the Yukon on what contaminants are and why traditional foods remain a healthy and safe choice. Included in the long term component is participation as a Territorial component of NCP that feeds into International initiatives. This is the way we can have an impact on insuring that our traditional foods remain safe to eat. Inherent to the success of the long term strategy is the information obtained through the 2003 surveys, by YCC and CYFN. The survey results were not definitive, but provided a window on what the strengths were in our past communications, and where we were not successful.

It appears that we have effectively communicated messages on contaminants and that traditional foods are safe. What we have not been effective at is the direct connection to the NCP and that the YCC is a prime source of information on contaminants in the Yukon. The survey method will be used again in five years to compare results and judge progress.

Results

School Survey

What do Yukon students know about the environment and their health?

- Random, stratified sample
- 10 Questions – total of 31 specific responses
  - 20 quantitative responses
  - 11 qualitative responses
  - presented as a survey on environment and health issues not specifically on contaminants
- Socio-demographic data
  - Age, gender, grade, school, reception of contaminants teaching, interest in science class

Issues included in the Survey

- Concerns on food, health and environment
- Sources of information
- Awareness of basic contaminant concepts
- Risk perception of food safety issues and contaminants
- Comprehension of basic contaminants information
- Qualitative explanations

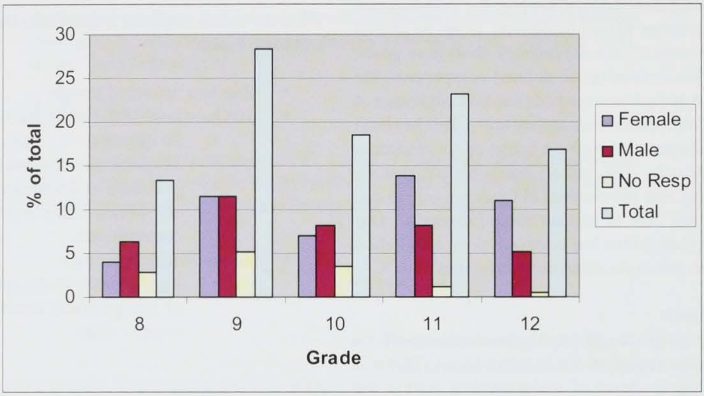
Basic Groups of Data

- Perception of food, health, environment issues
- Awareness of issues
- Comprehension of issues

Table 1. Yukon Participation in the Survey

	Female	Male	No Response	Total
FH Colins	36	27	12	75
Tantalus	9	2	1	12
Vanier	20	28	8	56
Watson Lake	18	11	2	31
Total	83	68	23	174

Figure 1. Education Levels of Survey Participants



Awareness - Contaminants

Figure 2: Response to the Question "Have you heard of contaminants?"

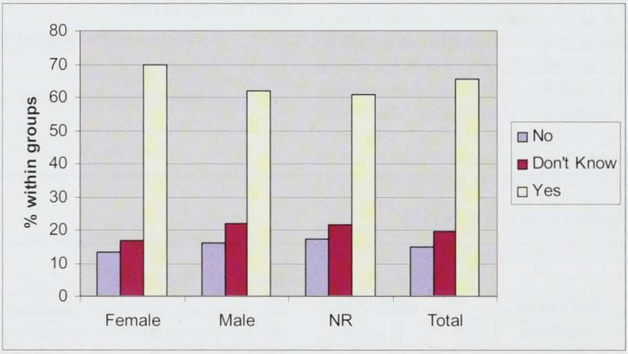


Figure 3: Response to the Question "Have you heard of PCBs?"

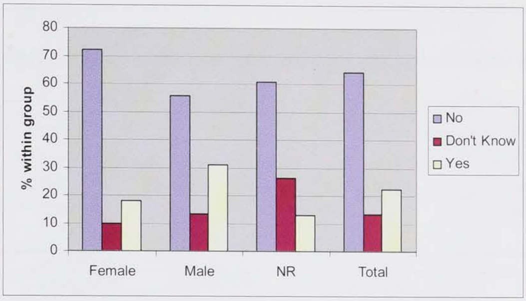


Figure 4: Response to the Question "Have you heard of mercury?"

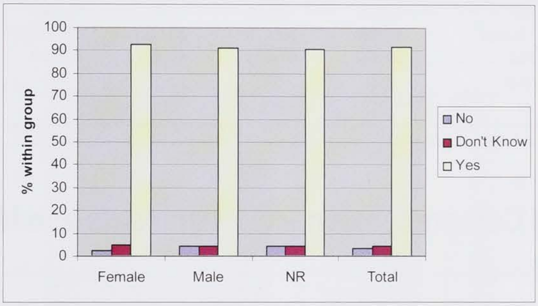
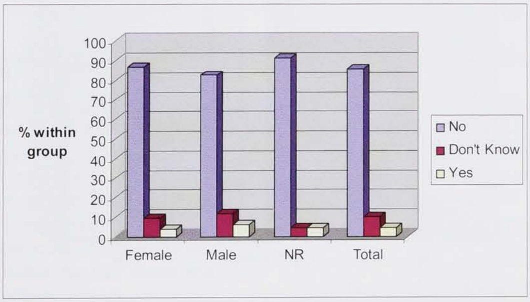


Figure 5. Response to the Question "Have you heard of the NCP?"



Perception / Awareness - Contaminants

Table 2. Response to the Question "Do you think there are contaminants in the Yukon?"

	Female	Male	NR	Total	N
No	3,704	4,478	4,348	4,094	7
Don't Know	17,284	8,955	39,13	16,959	29
Yes	79,012	86,567	56,522	78,947	135
Total	100	100	100	100	
N	81	67	23		171

Table 3. Response to the Question "Are there local sources of these contaminants?"

	Female	Male	NR	Total	N
No	5,085	2,174	0	3,333	4
Don't Know	35,593	30,435	53,333	35,833	43
Yes	59,322	67,391	46,667	60,833	73
Total	100	100	100	100	
N	59	46	15		120

Perception and Comprehension – Contaminants and Health

Figure 6. Response to the Question "Do you think wildlife in the YK have contaminants in them?"

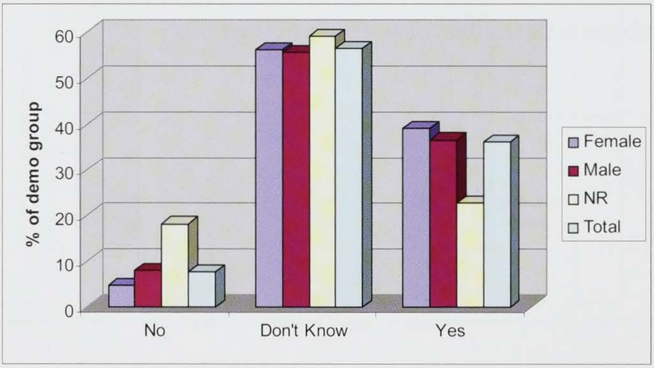


Figure 7. Response to the Question "Do you think there are contaminants in store bought foods?"

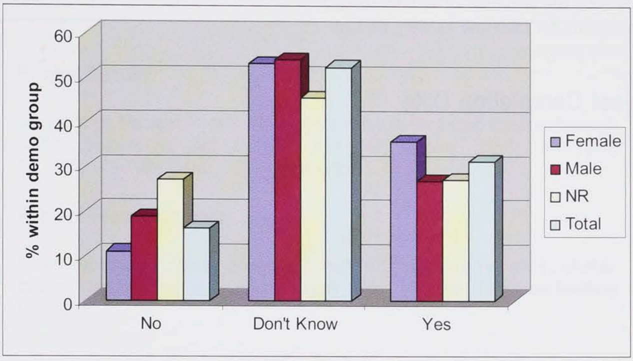
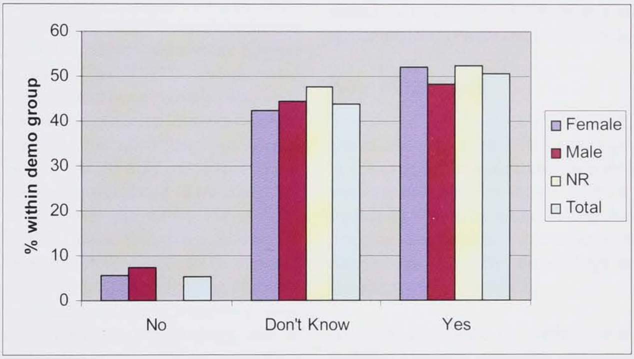


Figure 8. Response to the Question "Do you think that different species and animals have different levels of contaminants in them?"



Communications Package for Workshops

As part of the five year strategy, a communications package was developed for the YCC that could be delivered in the communities as a stand-alone unit and modified to suit each community. This package is currently under review and revision by the YCC.

As usual the YCC provides answers to community and First Nation queries related to contaminants and traditional foods and acted as a source for fact sheets and other communications commodities.

Yukon Contaminants Database

During the update of the database, a number of errors and problems with the search engine were encountered, which has led to essentially recreating the database from the raw data sets. This is a current work in-progress.

Discussion and Conclusions

There have been no projects under NCP for the Yukon which have not originated with the YCC in conjunction with CYFN. Communications by the Committee also includes providing information for Yukon State of the Environment reports, local media, schools, and communities. Recently, the YCC has been involved with our neighbours in Alaska, and provided an assortment of communications materials for their use as they initiate their own Contaminants program.

Expected Project Completion Date

This project is on-going.

Katigsuiniq: A Compilation and Review of Inuktitut Terminology Relating to Environmental Contaminants

Project Leader

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Project Team Members

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Abstract

Inuktitut interpreter-translators (ITs) enable virtually all dialogue and information exchange between Inuit residents of Nunavut and Nunavik (who speak Inuktitut) and NCP researchers and managers (who speak English or French). Over the course of the NCP, ITs have translated thousands of pages of text, and have provided hundreds of hours of simultaneous interpretation (at workshops, at meetings). However, there has never been any formal assessment under the NCP of how effectively contaminants terminology is translated to Inuktitut, nor any examination of the roles played by ITs in NCP communication efforts. Contaminants terminology is highly technical, abstract and very difficult to translate accurately and consistently in Inuktitut. The Nunavut Research Institute initiated a project to compile a range of existing sources of Inuktitut terminology, and to identify sources of translation error (and how to minimize them). 11 sources of Inuktitut terminology were identified and 180 terms compiled in a reference glossary for interpreter translators. Inuktitut terms in 3 widely used glossaries were back translated to English revealing numerous errors and inconsistencies. Grammar differences between English and Inuktitut, translators' familiarity with English and scientific terminology, and translators preconceptions and opinions about contaminants emerged as key potential sources of translation error. This study recommends that NCP representatives soliciting translation and/or interpretation take measures to minimize translation error. Inuktitut translations should be proof-read and back translated (from Inuktitut to English) to detect and correct any errors corrected, prior to dissemination. There is also a need for Inuktitut language experts and NCP researchers and managers to collectively develop a standardized set of environmental contaminants terminology in Inuktitut.

Key Messages

Translated information should not immediately be assumed to be accurate. Simple measures can be employed to detect and minimize translation errors. For example, translated documents should be back translated (from Inuktitut to English) and carefully reviewed for quality prior to circulation. Presenters should meet with interpreters to clarify terminology prior to beginning simultaneous

A forum is needed for collective discussion among Inuktitut language specialists and contaminants scientists leading to the development of standardized Inuktitut contaminants terminology (with appropriate provision for dialect differences).

Objectives

The objectives of the project are to:

1)Identify and compile sources of Inuktitut terminology related to environmental contaminants and make these resources available to ITs who currently support NCP initiatives;

2) Review the quality of Inuktitut contaminants terminology to identify sources of translation error;

3) Identify potential measures to improve the accuracy and precision of Inuktitut interpretation and translation in the context of the NCP.

Introduction

In communities of Nunavut and Nunavik, virtually all forms of communication between NCP scientists and Inuit residents must be processed and relayed by interpreter translators (ITs) who are literate in both languages and able to relay complex terms and concepts between Inuktitut and English. Over the course of NCP, ITs have translated literally thousands of pages of written information in various formats (project proposals, fact sheets, posters, brochures, research results, advisories, etc.) to Inuktitut, and have provided hundreds of hours of simultaneous interpretation at NCP training courses, workshops and meetings. ITs are literally the cross-cultural communication between Inuit and NCP researchers and managers, and without their support, communication would be impossible. Their job is far from easy. Much of the terminology surrounding contaminants is abstract and complex, and very difficult to translate to Inuktitut. Certain basic concepts have no equivalent in Inuktitut and when translated to Inuktitut can easily lose their intended meaning. For example, the Inuktitut word for 'contaminants' can easily apply to parasites, diseases, and garbage – things that fall well outside the scope of contaminants as defined by the NCP. Recent surveys in Nunavut have revealed that local understanding of the risks of contaminants in country food is affected by language gaps between English and Inuktitut and amongst Inuktitut speakers, and by the lack of consistent Inuktitut terminology for scientific concepts (Myers and Furgal 2004).

Over the past 10 years, a variety of glossaries, wordlists and other reference material have been developed through the Northern Contaminants Program to help northern community residents understand scientific terminology and concepts related to contaminants research. However, these resources were never widely distributed to interpreter-translators in Nunavut, nor were they made available from a central location. As a result, interpreter-translators who work on contaminants issues may not be aware that terminology resources exist and/or where they may be obtained.

Results

The project leader (J. Shirley) initiated a contract with the project researcher (C. Grable) in early 2004 to identify terminology sources and develop a master list of terms. 11 written sources of Inuktitut contaminants terminology (glossaries, wordlists, and dictionaries) were identified and collected. These documents were all produced within the past 15 years by a wide variety of agencies - the Northern Contaminants Program, Nunavut Arctic College, Nunavut Government departments (Environment and Education) and the Federal Government (INAC). Terminology from these various sources was compiled in a reference glossary that provides one or more plain language definitions (in English and Inuktitut) for approximately 180 technical terms related to northern environmental contaminants and research. A variety of definitions were included to provide interpreter-translators with thorough, clear explanations will reduce the need for guesswork or speculation in the choice of appropriate Inuktitut terminology to define English terms. To help ensure its utility, the glossary is being distributed directly (in electronic and hard copy form) to interpreter-translators who currently support NCP research in Nunavut. The document is also meant to serve as a reference tool for future workshops aimed at developing and refine Inuktitut contaminants terminology.

The range of agencies and institutions that have developed Inuktitut contaminants terminology was broader than anticipated, and some very useful terminology was identified from unlikely sources (e.g. generic Inuktitut dictionaries). The content and format of these documents varied. In some, both the terms and definitions were translated, in others, the definitions were provided in one language only (English or Inuktitut). In one source, the English back-translation of the Inuktitut translation was provided in addition to the English definition. The regional dialect of the Inuktitut translations was also not identified in most sources. English definitions for key terms were fairly consistent between glossaries.

The reference glossary is being produced as a spiral bound hard copy and as a PDF document on CD ROM by AtiGo multimedia; an Iqaluit based, Inuit owned multi-media production company. An electronic version of the final proof will be saved for potential reprinting/recirculation.

In late 2004, Inuktitut language specialists in Iqaluit were contracted to review the accuracy and precision of Inuktitut translations of contaminants terminology in the

CACAR II glossaries, and Nunavut Arctic College Environmental glossary. Terms were "back-translated" to assess how closely the Inuktitut translations match the original English definitions, and sources of translation error were identified. Results of the assessment are discussed below.

Discussion and Conclusions

Our assessment of the Inuktitut terminology identified several important sources of translation error that warrant further investigation. The most basic errors involved basic spelling mistakes in the syllabic text, and the use of incorrect Inuktitut terminology (e.g. in the CACAR II glossary, "liver" was incorrectly translated as "kidney"). These errors reflect poor understanding of Inuktitut terminology on the translators' part. Formatting errors in the conversion of syllabic font are also important. When documents created using one syllabic font are converted to a different font, errors often appear in the syllabic text.

Grammatical and linguistic variation between Inuktitut and English were a far more significant source of error in translation. Sentences are constructed differently in Inuktitut than in English, and as a result, word for word translations are meaningless.

In part because Inuktitut grammar is so precise and specific, the wrong Inuktitut term is often chosen for concepts that have no existing terminology in Inuktitut (e.g. chemical is translated as liquid in the CACAR II glossary). Literal interpretation of English terms was also an important source of error, especially where the English term is itself an analogy for an abstract process (e.g. "half life" was translated to mean "partly human"). One of the language specialists reviewing the CACAR II glossary remarked "I think the main issue was {the Inuktitut translations} were so literal that you couldn't make out the meaning until you saw the English, which is very typical of a translated version in general". Translators must often apply their judgment and discretion to find appropriate ways to express terms in Inuktitut; sometimes terms lose their intended meaning in this process. In some cases, translated terms assumed new meanings and connotations that might reflect the translators' personal perceptions and opinions about the subject matter. In the CACAR II glossary for example, radionuclides, were translated as "burning things that move around", however, the corresponding English definition contained no reference to heat or burning.

It may be impossible to create concise (1-2 word) Inuktitut names for abstract concepts like brominated, flourinated, biphenyl, etc. In this case transliterating / borrowing English terms but translating the definitions is sometimes more appropriate than creating a new Inuktitut word. Definitions/explanations translate more accurately and consistently than terms (less need for "guesswork" by individual translators). In many cases a single generic Inuktitut term is used to categorize classes of substances (e.g. qupiruijaup - meaning something to remove bugs - is used in one glossary to describe both toxaphene and chlordane). Use of generic terminology is often too imprecise to allow for necessary differentiation among different concepts.

Discussions with interpreter translators during the course of this research have identified simple but effective means by which errors in translation and interpretation of contaminants information can be minimized. Just as scientific articles are peer-reviewed prior to publication, written Inuktitut translations of contaminants information should be reviewed prior to finalization by a translator (not the same person who prepared the original translation). One effective means for detecting errors in a translated document is to back-translate from Inuktitut to English, and compare to the original English version. Well prior to utilizing simultaneous interpretation, researchers should meet with interpreters to review the content and explain any technical terminology. Copies of presentation slides, and a written transcript of the presentation, should also be provided to the interpreter in advance. The Nunavut Interpreter Translator Society recommends that people using simultaneous Inuktitut interpretation to present technical information should:

- speak slowly, clearly, and directly in the microphone (pause every couple of sentences to let the interpreter catch up)
- use simple, straightforward English with complete sentences
- avoid using words that require explanatory definitions, and avoid using puns, idiomatic expressions, aphorisms, and acronyms (this applies to written documents also)
- budget for two interpreters if the presentation will exceed half an hour; simultaneous interpreters cannot interpret for more than 30min at a time accurately, and its unfair to expect them to do so

There is also a need for Inuktitut language experts and NCP researchers and managers to collectively develop a standardized set of environmental contaminants terminology in Inuktitut.

Expected Project Completion Date

The Inuktitut translation assessment component of this project will be complete by August 2005. In Oct/Nov 2005 a series of informal telephone interviews will be conducted with several interpreter-translators who have received the glossary, to determine if and how the glossary has been used, to and how it should be revised or improved in future editions. A detailed on the terminology assessment, and feedback received during the evaluation will be reported to the NCP managers, the NAC membership, and other interested parties in Nov 05.

References

Myers and Furgal, 2004. *Long range transfer of Information: are Arctic residents getting the message about contaminants?* Presentation to the 14th annual Inuit Studies Conference, Calgary Alta, Aug. 2004.

Akaitcho Territory Government Participation in the NCP and NWT ECC

Project Leader

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Project Team Members

Deninu Kue' First Nation; Lutsel Ke' First Nation; Yellowknifes Dene First Nations (Ndilo); Yellowknifes Dene First Nations (Dettah); NWTECC; Dene Nation; National Water Research Institute; Akaitcho Territory Government participation in the NCP and NWT ECC

Abstract

The Akaitcho Territory Government continues to participate in the NWT Environmental Contaminants Committee monthly meetings and in-person meetings. The Committee is responsible for providing information to Northerners on the presence and possible effects of contaminants in the environment and the Dene traditional lifestyle and consumption. Finally, the Akaitcho Territory Government continues to support, foster and build on relationships and partnerships between all Akaitcho Dene First Nations and the NCP-NWTECC by partnering with their respective participants in continuing to improve greater understanding through internships and communication strategies directly speaking to our First Nations.

The purpose of my role in the NWTECC is:

- to represent the interest of the Akaitcho people for the Chiefs of the Akaitcho Territory Government,
- to make known the Akaitcho's issues, concerns and projects in terms of contaminants as it 1. To promote the results of CACAR II and recent relates to our traditional lifestyle and consumption,
- to participate in the review and recommendations of contaminants proposals to the Management Committee of NCP, and
- to report the activities and projects of the NWTECC to the Chiefs of the Akaitcho Territory Government.

Key Project Messages

- The Akaitcho Territory Government provided information to its Dene First Nations about the results of CACAR II and recent NCP research, and general information on contaminants.
- The Akaitcho Territory Government attended NWT Environmental Contaminants Committee meetings to bring forward contaminants concerns and proposals from the Akaitcho and to review Northern Contaminants Concerns proposals and other information.

- The Akaitcho Territory Government initiated and partnered with NWTECC participants to scientific results back to Akaitcho Dene First Nations.

Objectives

- To promote the results of CACAR II and recent NCP research through the use of the NWT fact sheets and other communication avenues.
- To assist Akaitcho First Nations to identify concerns related to environmental contaminants.
- To inform and educate the public about contaminants in the Akaitcho territory.
- To coordinate regional and First Nation contaminant studies.
- To review NWT Proposals related to the NCP.
- To coordinate and facilitate the Akaitcho's internship with the National Water Research Institute.
- To participate in Dene Nation NCP Communication Strategy development.

Introduction

The focus of the Northern Contaminants Program (NCP) is to address issues surrounding contaminants in traditional/country foods in the Canadian Arctic (e.g. persistent organic pollutants, mercury, dioxins, etc.). The long-term goal of the NCP and ultimate solution to the contaminants issue is controls on chemical releases that reach the Arctic from source countries around the world. However, the immediate concerns of the program, which must be addressed now, are associated with the risk of current human exposures to contaminants in the Arctic food chain.

A key NCP objective is to ensure that Northerners have the appropriate information on the risks and benefits ciated with contaminants and traditional/country foods so that they can make informed decisions about harvesting and consumption. The Akaitcho Territory Government also strives to provide the best information possible on contaminants to its Dene First Nations through participation in the NCP and NWT ECC.

Activities

In 2004-2005

Given, the description of the roles of the NWTECC as it relates to NCP and the partnerships with the Akaitcho Territory Government, funding was secured for the 2004-2005 fiscal year. With this funding, we have been and will continue to be busy doing the following, as identified in my Akaitcho Summary of Activity submission to the Northwest Territories Environment Contaminants Committee for 2004 – 2005.

1. Monthly conference calls.
2. In - person meeting in Yellowknife (February 22-24, 2005)..
3. NWTECC Results Workshop in White Rock, B.C. (September 28-30, 2004).
4. NWTECC Dene Nation Communication Strategy session (November 22-24, 2004)
5. This year's final report and next years work plan and budget.
6. Proposing, facilitating and reporting the Deninu Kue' Internship project.
7. Proposing, facilitating and reporting the Deninu Kue' Berry project (Local Contaminants Concerns project).

Results

The Deninu Kue' First Nation in partnership with the Akaitcho Territory Government, NWTECC and Marlene Evans of the National Water Research Institute (NWRI) proposed and facilitated and a Deninu Kue' Internship. We have identified Maurice Boucher an Akaitcho Member to go through an internship with the NWRI. They will assist and train him on interpreting, developing and presenting (in a plain language summary) all the results the NWRI have in the Akaitcho Territory (in terms of Contaminants). Because of scheduling difficulties we have slated this to begin in the first week of April 2005. Subsequent reports will then follow.

The Northwest Territories Environment Contaminants Committee in partnership with the Dene Nation held a Communication Strategy Session at Rabessca Resources camp near Fort Rae on November 22-24, 2004. The Akaitcho Territory Government sent their NWTECC representative Patrick Simon to participate, support and assist in the development of this strategy. This session was successful in supporting Dene Nation to complete a Denendeh Communication Strategy for the NCP.

The Northern Contaminants Program (NCP) held their 2004 Results Workshop in White Rock, British Colombia on September 28 – 30, 2004. The Akaitcho Territory

Government sent the Cumulative Effects and Management Steering Committee Representative, Maurice Boucher and the NWTECC Representative, Patrick Simon to the NWTECC 2004 Results Workshop as registered participants. Patrick Simon presented the results of the 2003/04 NCP education and communication project by the Akaitcho Territory Government.

Other activities:

- Acted as a point of contact for contaminants concerns in the Akaitcho territory.
- Learned about CACARII through the NWT Fact sheets and CACARII reports and helped provide this information to Akaitcho community members.
- Provided input to the NWT ECC on Akaitcho contaminants concerns.
- Provided input to the development of the NWT ECC Traditional Foods are Good For You poster.
- Coordinate Akaitcho proposals to the NWT ECC and act as their liaison.
- Report to the Akaitcho Territory Government and the Deninu Kue' First Nation on the NWT ECC
- Conducted an Northern Ecosystem Initiative local contaminants concern project approved by the NWT ECC on heavy metal levels in berries and soil near Fort Resolution (Deninu Kue' First Nation in partnership with Akaitcho Territory Government, NWT ECC and Centre for Indigenous Peoples' Nutrition and Environment (CINE))

Discussion and Conclusions

I feel that this year we took a little more advantage of the benefits of the Northwest Territories Environment Contaminants Committee and the Northern Contaminants Program. We began by attending, participating, reporting and promoting the NWTECC in the annual Akaitcho Assembly and Executive Meetings. Our First Nation of Deninu Kue' was involved with a berry contaminants project. The Akaitcho Territory Government took part in the Dene Nation's communication strategy. The Akaitcho Territory Government initiated an Akaitcho Contaminants Results Internship. Finally, the Akaitcho NWT ECC and CEAMF representatives participated in the NCP annual results workshop.

We still need to look at and continue to work at improving communications and understanding between the NWTECC and the Akaitcho Dene First Nation. As the Akaitcho Dene become more aware of the potential of NWTECC and NCP partnerships then we can reap the benefits, as well as addressing the issues and concerns in our respective First Nations as it relates to Contaminants and our traditional lifestyles and consumption within the Akaitcho Territory. This year we struggle with our projects in terms of timelines and deadlines, it seems that given all the activities and issue on all our First nation's plates the NWTECC seem to be a low priority. I feel that if we continue to make known opportunities and benefits of the NWTECC then more emphasis will be put on this relationship. Good communications and good benefits make for more willingness to buy into this partnership.

Expected Project Completion Date

The Akaitcho Territory Government will continue to be represented on the NWT-ECC, and address concerns and communicate information relating to contaminants in the Akaitcho Territory until this program/committee has ended. The Akaitcho Territory Government has submitted a proposal to NCPs education and communication envelope for 2005/2006.

Sahtu Dene Council Participation with the Northwest Territories Environmental Contaminants Committee (NWT ECC) and Translating NCP Public Service Announcements into Kahsho Gotene

Project Leader

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Project Team Members

Sahtu Dene Council, the members of the NWTECC

Abstract

The Sahtu Dene Council focused this year on the following areas:

1. Participation in the NWTECC. This committee represents the communications network for obtaining contaminant concern information and relaying community concerns to governing bodies, scientists committed to Northern research and the research institutes in the NWT. The committee is also responsible for approving research carried out under the NCP, as it relates to proper consultation and communications of results.

2. Public service announcements in Kahsho Gotene related to the NCP. These announcements encouraged people in the NWT to eat more country foods.

Key Project Messages

1. Environmental contaminant concerns brought to the attention of the Sahtu Dene Council Executive Director will be discussed with other regions, scientists and government workers to address in any means allowable.

2. Any information provided to the Sahtu Dene Council Executive Director from the NWTECC will be shared with the communities

Objectives

1. To provide two-way transfer of contaminants information between Sahtu communities, NWTECC, researchers, the Northern Contaminants Program (NCP) and other contaminants related programs.

2. To establish a communications network that ensures communities are informed and involved in contaminants related activities that occur in their area.

3. To facilitate the efforts to address concerns arising from environmental contaminants in Sahtu.

4. To identify priorities and information gaps related to environmental contaminants research including consultation and communities in Sahtu.

5. To act as a central repository for environmental contaminants information in Sahtu.

6. To review NWT research proposals for social/cultural content and provide acceptance/denial on behalf of the communities in Sahtu.

Introduction

The Sahtu Dene Council office in Deline has received research documentation and other related contaminant information that is available to Sahtu people. The office, at this time, represents the point of main contact for information and literature regarding contaminant issues. It is a known fact that contaminants are slowly but surely getting in to the northern food-chain. The question that everyone is asking is: how much? Research tells us that contaminants in the northern food-chain are low in the Denendeh area. Most of the contaminants found in northern wildlife do not exceed health guidelines. Smoking cigarettes causes many more toxins in the body than eating country foods. The project for 2003-2004 was to convey this information to the public, using the dialect Kahsho Gotene. The Kahsho Gotene is one of four dialects used in the Sahtu region. Unfortunately, majority of public service announcements tend to only use the Neye Gotene dialect, which neglects to convey information to the all people in the Sahtu.

Activities

In 2004-2005

- Attended several monthly meetings of the NWTECC by phone and two in-person meetings (November 2004 in Rae to discuss the Denendeh Communication Strategy and February 2005 in Yellowknife to review NCP proposals).
- On-going communication of the results from the CACAR II as well as the NWT Fact Sheets. This will be on going in 2005-2006.
- Continued to transfer information from Sahtu communities to the NWT ECC, which will relay major concerns to the NCP management committee and vice versa.
- A mid-year report of activities was submitted to the NCP for 2004/05.
- A proposal was submitted to NCP for continued participation of the Sahtu Dene Council in NCP activities and the NWT ECC in 2005/06, also working within the Language terminology project.
- A public service announcement in Kahsho Gotene was developed and delivered to all the regions in the Mackenzie Valley. This PSA informed the public that country foods are good for you, and encouraged the consumption of traditional foods.

Results

Participation in the NWTECC meeting

Provided a to-way transfer of information to/from the NWTECC and communities within Sahtu. Learnt about the programs background and focus for the future in order to become more affective in participation and proposal development for the region.

Translation of NCP Public Service Announcement
The PSA were delivered to the Mackenzie Valley region. A compact disc with all the information used for the PSA was sent to the Sahtu Dene Council.

Discussion and Conclusions

Working for the Contaminants program in the Sahtu region means that there are long periods of time when there is no money, and it is a job that is hard to keep up unless the person has a long term commitment to their land and people. The work is based on people's commitment to keep our environment healthy and clean. The work is slow, sometimes at a snail's pace, and the results and efforts are not always easy to see. The communication gaps between scientists, researchers and communities are still an issue; the language terminology project will help in addressing the gap of translation.

Dehcho First Nations: Communicating and Filling the Gaps of CACAR II

Project Leader

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Project Team

Northwest Territories Environment Contaminants Committee Dehcho First Nations

Abstract

The Dehcho First Nations hired a member as the Local Contaminants Coordinator to communicate and fill the gaps of CACAR II and Contaminants in the Dehcho II. The coordinator presented information on the presence of contaminants in traditional foods, address community concerns and identified research priorities in the Dehcho. In addition, the coordinator was trained in a variety of environmental activities and participated in regional workshops.

The coordinator continues to develop a database and support materials, and to give advice to Dehcho members. These efforts strengthen the message of the Northern Contaminants Program for target groups in the communities.

The Dehcho First Nations continue to participate in the Northwest Territories Environmental Contaminants Committee's monthly meetings. The Coordinator is responsible for providing Dehcho members on the presence and possible effects of long-range transport of contaminants in the environment and traditional foods.

Key Project Messages

- Communicated results of CACAR II relevant to the Dehcho region
- Communicated that contaminants are low in traditional foods
- Participated in monthly NWT ECC meeting

Objectives

- To transfer long-range environmental contaminants information to traditional food consumers.
- To conduct community visits that bring relevant information to the communities and provide opportunity for feedback regarding research priorities in the Dehcho.
- To communicate traditional foods are low in contaminants, and the benefits of traditional foods still outweigh the risks.
- To co-ordinate Northern Contaminants Program Projects with the Northern Water Research Institute and Renewable Wildlife and Economic Development data bases and other Dehcho Training, environmental monitoring and resource management initiatives.
- To network partnerships with other governments' contaminants divisions.
- Communicating an environmental contaminants program to the Dehcho First Nations community governments and its' people.
- To gather and organize community feedback concerning contaminants.
- To distribute resource materials on contaminants, research and results.
- To identify research priorities
- To continue to actively participate in NWTECC monthly meetings in traditional food and the possible effects of these contaminants on the environment. Throughout this project, Dehcho First Nations provided a two-way transfer of community concerns and the NCP. The Dehcho First Nations continue to inform and educate its members about contaminants

through the participation on the Northwest Territories Environmental Contaminants Committee.

Activities

In 2004 – 2005

- Community Visits to provide opportunity for feedback on contaminants.
- Monthly NWTECC conference calls.
- Presented Contaminants in the Dehcho project results at the NCP annual workshop in White Rock, B.C, September 28 – 30, 2004.
- Trained at the Taiga Lab on water sampling and lab analysis
- Prepared the 2005/06 NCP proposals
- On-going communication with the communities
- Maintain filing system on communities and concerns.
- Communication with various agencies regarding community contaminants concerns
- Participated in the Hg workshop with other NWTECC members
- Assisted in the design of the Traditional Foods is good for you poster
- Reviewed Local Contaminant Concern proposals as an NWTECC member.

Results

- Contaminants in the Dehcho gap analysis of CACAR II
- CD, Poster, Internet site
- Interim and Final report to the Northern Contaminants Program, DIAND
- Addressed community concerns about contaminants
- Distributed NWT ECC poster on traditional foods as well as phamlets, fact sheets, and research results to the communities of the Dehcho.
- Increase awareness of contaminant in Dehcho communities
- Provide input to the NWTECC on Dehcho community concerns
- Respond to local request for information on contaminants:
- Ensure that relevant regional/community organizations are kept informed.

Introducation

The Dehcho First Nations want to ensure that its residents are informed about the possible presence of contaminants

- Partnerships with various government department back to NCP
- Assist community/regional organizations to develop research ideas and proposals for funding
- Provide updates on the NWTECC during meetings
- Provide information on the NCP at assemblies, meetings and community visits.
- Develop regionally-relevant resource materials to communicate NCP messages
- Attend and present regional reports at the annual fall NCP results workshop
- Participate in monthly NWTECC meetings

Discussions and Conclusions

The Dehcho First Nations has communicated CACAR II and now is working on terminology with other Denendeh members of the NWTECC. The community members continue to be concerned about their traditional foods.

Resources used to communicate are the internet, emails, and files.
Deh Cho First Nations Staff and Resources, CACAR II , NCP Blueprints, NCP frontline training course by Dene Nation, Synopsis of research 2001 – 2004, NCP Summary of projects, NWT contaminant fact sheets, CACAR II Fact Sheets, NCP Minutes, and the resource people available through the Northern Contaminants Program and community members of the Deh Cho Region.

Clients/Partnerships:
- Indian and Northern Affairs Canada/Northern Contaminants Program
- Resources Wildlife and Economic Development, Government of the NWT
- Northern Water Research Institution, Environment Canada
- Katlodeeche First Nation
- Liidlii Kue first Nation
- Pehdzeh Ki First Nation
- Jean Marie River Dene Band
- Ka'a'gee Tu First Nation
- Deh Gah Gotie Dene Council
- Nahanni Butte Dene band
- Sambaa K'e Dene Band
- West Point First Nation
- Fort Simpson Metis Local
- Fort Providence Metis LocalAcho Dene Koe First Nations

Gwich'in Tribal Council - Communication & Education of the NCP-CACAR II

Project Leader:

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Project Team Members:

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Abstract

The Gwich'in consumes traditional/country foods as a main staple of their diet. Due to concerns from the Gwich'in regards to contaminants in the food chain, the Gwich'in Community Liaison (GCL) position was established. This position enabled the Gwich'in to be a member of the NWT Environmental Contaminants Committee and participate in research programs established by the Northern Contaminants Program (NCP).

The GCL has continued to promote dialogue and information between the Gwich'in communities, Gwich'in Organizations, NCP representatives, and NCP scientists.

The GCL has participated in monthly NWTECC meetings including proposal reviews and communications material reviews, and provided relevant contaminant information materials to Gwich'in communities and organizations. The GCL also attended and made a presentation at the NCP annual results workshop held in Whiterock, BC, in September 2004.

Key Project Messages

- The Gwich'in Community Liaison (GCL) has continued to promote dialogue and information exchange between the Gwich'in communities, Gwich'in Organizations, NCP representatives, and NCP scientists.
- The GCL had the opportunity to attend workshops (e.g. NCP results workshop) and training courses to enhance capacity to carry out the duties of the GCL position.
- The GCL actively participated in both in-person and conference call meetings of the NWT ECC throughout 2004/05.

Objectives

The objectives of this project are to facilitate the process of collaborative study, assessment and communication of information to residents of the Gwich'in Settlement Area (GSA) about the presence and possible effects of contaminants in the air, land, water and wildlife. GCL goals are to:

1. To promote the role of the Gwich'in Tribal Council (GTC) as a partner in the NCP
2. To assist the Gwich'in Communities to identify research and development
3. To inform and educate the public about contaminants within the GSA.
4. To increase capacity at the regional / local level
5. To coordinate regional contaminant studies

6. To identify complementary environmental issues and funding sources

7. To review Local Contaminant Concerns proposals throughout the year as a member of the NWT ECC.

8. To review NWT Proposals for the NCP for social/cultural criteria prior to full technical reviews.

9. To actively participate in all NWT ECC meetings and related tasks.

Introduction

This was the sixth year that the GTC has been actively involved in the Northern Contaminants Program. Over the course of involvement with the NCP the Gwich'in representative for the GTC has established a very good track record. The Gwich'in are concerned about long range contaminants and want to continue to be well informed about levels of contaminants in their traditional foods. Participation in the NCP and NWT ECC provides a valuable opportunity for two-way communication about contaminants in the GSA and the NWT.

Activities

In 2004-2005

- The GCL attended several monthly meetings of the NWTECC by phone and two in-person meetings (November 2004 in Rae to discuss the Denendeh Communication Strategy and February 2005 in Yellowknife to review NCP proposals).

- The GCL attended and made two poster presentations at the NCP results workshop in Whiterock, BC, in September 2004. One poster was on the participation of the GTC in the NCP, and the other poster was on the Martinhouse local contaminants concern project funded by Envrionment Canada's Northern Ecosystem Initiative.

- On-going communication of the results from the CACAR II as well as the NWT Fact Sheets was initiated. This will be on-going in 2005-2006.

- Continued to relay information to the Gwich'in communities through the GCL and Aboriginal partners to the NWT ECC, which will relay major concerns to the NCP management committee and vice versa.

- The GCL completed community tours during the week of March 7 – 11, 2005 to discuss the NCP with the community members and to continue to relay the importance of the NCP to community members. Communities visited were Fort McPherson, Tsiigehtchic and Aklavik. A meeting was also held with the Nihtat Gwich'in Council of Inuvik on March 14, 2005.

- A mid-year report of activities was submitted to the NCP for 2004/05.

- A proposal was submitted to NCP for continued participation of the GTC in NCP activities and the NWT ECC in 2005/06.

Results

In addition to the activities outlined above, the Gwich'in Community Liaison highlighted several concerns from Gwich'in communities and organizations.. These concerns ranged from long term monitoring of contaminant levels in important traditional foods such as caribou, to local contaminants concerns and water quality issues, to relationships between contaminants and human health concerns.

The NCP poster prepared for the NCP results workshop in September 2004 is also available to the NCP and has been provided to the Indian and Northern Affairs Canada office in Yellowknife.

Discussion and Conclusions

In 2004/2005, the GCL has continued to address concerns of the residents of the Gwich'in Settlement Area by gathering, organizing, and distributing information, and initiating research programs. The GCL attended workshops, and meetings to enhance his capacity to carry out the duties of the GCL position. The GCL has had personnel turnovers during the 2004/2005 year, and the GCL continued to represent the GTC for the NCP and NWTECC. Furthermore, based on requirements of the information by the residents of the Gwich'in Settlement Area, it has been demonstrated that this position is an integral part of the NCP and the Gwich'in Settlement Area. The GTC is confident that the GCL will continue this successful relationship in the future with NCP.

Expected Project Completion Date

The GCL will continue to represent the Gwich'in Beneficiaries by continuing to be a part of the NWT ECC, and address concerns relating to Contaminants in the Gwich'in Settlement Area.