# Synopsis of Research

Conducted under the 2003-2004 Northern Contaminants Program



Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Canada

# Synopsis of Research Conducted under the 2003-2004 Northern Contaminants Program

Editors: Simon Smith, Jason Stow, and Farah Carrillo

Published under the authority of the
Minister of Indian Affairs and
Northern Development
Ottawa, 2004
www.ainc-inac.gc.ca
1-800-567-9604
TTY only 1-866-553-0554

QS-8602-030-EE-A1
Catalogue No. R71-19/76-2004
ISBN 0-662-36210-1



This report was prepared under the Northern Contaminants Program, coordinated by the Northern Science and Contaminants Research Directorate, Department of Indian Affairs and Northern Development.

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

# Table of Contents

# Foreword

This report provides a summary of the progress to date of research and monitoring studies on contaminants in northern Canada, and related education, communications and policy activities that were conducted in 2003-2004 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 modelling, 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 surveillance 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 2003-2004. Ces études et activités ont été menées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). Ces projets, tels que décrit dans les plans directeurs liés au programme, représentent tous les aspects portant sur les contaminants, incluant la santé humaine, la surveillance de la santé des habitants et des écosystèmes de l'Arctique et de l'efficacité des mesures de contrôle internationales (surveillance et modélisation milieux abiotiques, et surveillance - milieux biotiques), l'éducation et la communication, la politique internationale et la gestion des programmes.

Ces projets ont été examinés par des pairs, des comités d'examen technique, un comité d'examen social et culturel, les comités territoriaux / régionaux sur les contaminants environnementaux, et le comité de gestion de la PLCN afin de s'assurer qu'ils répondent 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 2003-2004. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2003-2004 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

# Perinatal Organochlorine Exposure in Rats: Effects on Humoral and Cellular Immune Parameters


## Project leader(s)

Pierre Ayotte, Ph.D., Professor Université Laval Unité de recherche en santé publique CHUQ-CHUL Direction de la Toxicologie Humaine-INSPQ 945, avenue Wolfe Sainte Foy, QC G1V 5B3; phone: (418) 650-5115 ext. 4654; fax: (418) 654-2148; e-mail: pierre.ayotte@inspq.qc.ca

## Project members

Unité de Recherche en Rhumatologie et Immunologie, Centre de Recherche du CHUL-CHUQ; Project Co-Investigator, Raynald Roy, Ph.D.; Marthe Belles-Isles, Ph. D.; Division d'Hématologie-Oncologie, Hôpital Sainte-Justine, Montréal Éric Wagner, Ph.D; Centre de Recherche en Biologie de la Reproduction ; Département des sciences animales, Université Laval ; Janice L. Bailey., Ph.D., Professor ; Anas Idris, D.V.M., Ph..D., postdoctoral fellow


## Abstract


Inuit people are exposed to unusually high doses of several organochlorines (OC) through their traditional diet. Epidemiological studies conducted in Nunavik revealed that prenatal exposure to OC was associated with increased incidence of acute otitis media in Inuit infants. We assessed the effects of *in utero* and lactational exposure to an OC mixture, similar to that found in sea mammal fat consumed by the Inuit, on specific elements of the immune system in 90-days-old F1 male rats. In last year's synopsis, we reported that exposure to the mixture induced activation-like changes in surface markers of splenic dendritic cells (DC). Here we report an increase in the expression of IL-1β, IL-18 and IL-10 in splenic DC from rats belonging to the medium dose group compared to controls. The C3 component of the complement system was also decreased by the OC treatment. Cytokine expression pattern is coherent with an inappropriate stimulation of DC that may lead to their premature deletion, altered survival of T cells and dysregulation of the immune system.


## Key Project Messages

1. *In utero* and lactational exposure of rats to the environmentally-relevant organochlorine mixture induces a pattern of cytokine expression that is indicative of inappropriate activation of dendritic cells. These cells are involved in initiating normal immune response following exposure to an antigen.

2. Altered dendritic cell activation may represent a novel mechanism by which developmental exposure to organochlorines induces immunosupresssion.

## Objectives

1) To assess the effect on the immune system of rats following developmental exposure to a complex organochlorine mixture, similar to that found in the Arctic aquatic food-chain, by measuring:

   a) cytokine gene expression in splenic DC and peripheral blood mononuclear cells;

   b) complement system components C2 and C3.

2) To determine the effects of the OC mixture and its main components on the expression of specific maturation markers (CD86, MHCII, CCR6 and CCR7) in a monocytic cell line (THP-1).

## Introduction

Because of their high consumption of sea mammal fat, the Inuit people living in Nunavik display a body burden of organochlorines (OC) that exceeds that of inhabitants of Southern Québec. In both laboratory animal models and human studies, members of the organochlorine compound family have been shown to affect reproductive neuroendocrine and immune High incidences of infectious diseases have been reported in Inuit infants of Nunavik. These include meningitis, broncho-pulmonary infections and middle-ear infections (Dufour 1988; Duval and Thérien 1982; Proulx 1988). Otitis media is a serious problem in this population since hearing loss in one or both ears is observed in as many as 25% of school age children (Julien et al. 1987; Proulx 1988). While genetic and lifestyle factors may be implicated in this unusually high susceptibility displayed by Inuit infants to infectious diseases, we hypothesized that developmental exposure to OC could suppress immune system function and decrease resistance to infectious diseases. Indeed, a first epidemiological study conducted by our group in Nunavik showed that the risk of otitis media increased with prenatal exposure to some organochlorines (Dewailly et al. 2000). This association was again noted in the course of the infant development study also conducted in Nunavik (Dallaire et al., *unpublished data*).

In order to increase the biological plausibility of this association and investigate possible mechanisms of action, we initiated experimental studies in animal models featuring developmental exposure to an organochlorine mixture designed to approximate that found in marine mammal fat consumed by Inuit people. The composition of the OC mixture is presented in Table 1. Using a vaccination protocol against *Mycoplasma hyopneumoniae* in pigs exposed to this OC mixture *in utero* and through lactation, we observed a low antibody production in piglets from the highest exposure group compared to animals in the other treatment groups, indicating that the humoral immune response was affected by developmental exposure to the mixture (Bilrha et al. 2004). These findings are in agreement with those of a study in rats showing that perinatal dioxin exposure was associated with suppression of specific antibody response (Ross et al. 2001).

Dendritic cells (DC) have the capacity to induce the primary immune response to a foreign antigen and therefore are important in generating the immune response to infection (Bancherau et al. 2000). DC are the most effective antigen-presenting cells (APC) to promote activation of cytotoxic T cells and natural killer (NK) cells. Because the cytotoxic cells are implicated in the defence system against microbes, DC function constitutes a critical endpoint to be measured in the immunotoxicological evaluation of xenobiotics.

When exposed to an antigenic stimulus, DC are induced to migrate to the spleen or draining lymph nodes and to undergo a maturation process (Banchereau et al. 2000). Mature DC are able to up-regulate a variety of cytokines and ultimately promote the differentiation of Th1 vs Th2 cells. Following xenobiotics exposure, disruption in DC maturation could have a predominant effect on regulation of humoral and cell-mediated immunity.

Several immunotoxicity studies have focused on the effects of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), which induces specific responses mediated through binding to the aryl-hydrocarbon receptor (Whitlock 1991). It was shown that TCDD induced a lower resistance to infectious diseases, suppression of cell mediated and thymus-dependent humoral response in mice (Kerkvliet and Burleson 1994). More recently, it was also shown that although treatment of mice with TCDD lead to a lower level of DC *in vivo*, increased expression of ICAM-1, B7.2, CD40 and IL-12 was observed (Vorderstrasse and Kerkvliet 2001). Since activation of naive T cells is initiated primarily by DC, as mentioned earlier, these cells represent a potential target for dioxin-like compound immunotoxicity. Dioxin-like compounds are important constituents of the OC mixture found in the Arctic aquatic food web.

In the present study, we examined the effect of prenatal and lactational exposure to the OC mixture on the expression of cytokine genes in DC-enriched splenic cells and on complement system components involved in humoral response. We also began testing the capacity of the OC mixture to activate the monocytic cell line THP-1 *in vitro*.

## Activities

## In 2003-2004

Five-week-old Sprague-Dawley female rats were housed, two per cage, in a university facility with 12 h light cycle (6:45-18:45), 22±1°C temperature and 46±10% humidity. After 10 days of acclimatization, the rats were randomly assigned to four groups (10 per groups) and were administered the organochlorine mixture thrice weekly by gavage (corn oil as vehicle) to yield the following daily doses of polychlorinated biphenyls (PCBs): 0 (control group), 0.05, 0.5, 5 mg $kg^{-1}$ body weight (BW) $day^{-1}$. Doses of other OC that are part of the mixture can be calculated from composition data presented in Table 1. After five weeks of treatment, each pair was housed with an unexposed male for 10 days. Mating was confirmed by the presence of a vaginal plug. OC administration continued throughout gestation until parturition.

Male pups were sacrificed at PND90. Blood was collected by cardiac puncture in a tube containing heparin and PBMC were isolated using Ficoll-hypaque gradient centrifugation. The serum was stored at –70°C for complement analysis. Functional titrations of complement components C2 (classical pathway) and C3 (classical and alternative pathways) were performed according to established methods (Rapp and Borsos 1970; Wagner et al. 2001).

DC were enriched from spleens using the method described by Vorderstrasse and Kerkvliet (2001). Briefly, splenic tissues were digested with collagenase D (Boehringer Mannheim) at 37°C for 45-60 min to release DC from the capsule and to increase recovery. Cell suspensions were then diluted in Ca-/Mg-free HBSS and pelleted. Recovered cells were spun over a bovine serum albumin gradient and cells in the low-density fraction were collected. RNA was extracted from these freshly isolated DC-enriched populations and PBMC. Total cellular

**Table 1.** Composition of the organochlorine mixture.

| Compound | CAS number | % weight |
|---|---|---|
| PCB mixture[a] | | 32.59 |
| Technical chlordane | 57-74-9 | 21.3 |
| *p,p'*-DDE | 72-55-9 | 19.24 |
| *p,p'*-DDT | 50-29-3 | 6,79 |
| Technical toxaphene | 8001-35-2 | 6.54 |
| α-HCH | 319-84-6 | 6.17 |
| Aldrin | 309-00-2 | 2.52 |
| Dieldrin | 60-57-1 | 2.09 |
| 1,2,4,5-tetrachlorobenzene | 95-94-3 | 0.86 |
| *p,p'*-DDD | 72-54-8 | 0.49 |
| β- HCH | 319-85-7 | 0.46 |
| Hexachlorobenzene | 118-74-1 | 0.35 |
| Mirex | 2385-85-5 | 0.23 |
| γ- HCH | 58-89-9 | 0.20 |
| Pentachlorobenzene | 608-93-5 | 0.18 |

a. Mixture containing 2,4,4'-trichlorobiphenyl (320 mg), 2,2',4,4'-tetrachlorobiphenyl (256 mg), 3,3',4,4'-tetrachlorobiphenyl (1.4 mg), 3,3',4,4', 5-pentachlorobiphenyl (6.7 mg), Aroclor 1254 (12.8 g) and Aroclor 1260 (19.2 g).

Wagner, É., H. Jiang and M.M. Frank. 2001. Complement and kinins: mediators of inflammation. In: J.B. Henry (ed.), 20th ed., *Clinical Diagnosis and Management by Laboratory Methods*. Philadelphia, PA: W.B. Saunders Company. pp. 892-913.

Whitlock, J.P. Jr. 1991. Mechanism of dioxin action: relevance to risk assessment. In: M.A. Gallo, R.J. Scheuplein and K.A. Van Der Heijden (eds.), *Biological Basis for Risk Assessment of Dioxins and Related Compounds*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. pp. 351-366.

Zitvogel, L. 2002. Dendritic and natural killer cells cooperate in the control/switch of innate immunity. *J Exp Med.* 195: F9-14.

# Effects of an Environmentally-pertinent Mixture of Organochlorines on Reproductive Development and Health in the Porcine and Rat Models


## Project leader(s)

Janice L. Bailey, Ph.D., Professor Centre de Recherche en Biologie de la Reproduction Département des sciences animales, Université Laval Pavillon Paul-Comtois, local 4147 Ste-Foy, QC G1K 7P4; phone: (418) 656-2131 ext. 3354; fax: 418-656-3766; e-mail: janice.bailey@crbr.ulaval.ca

## Project members

Pierre Ayotte, Ph.D., Professor, Public Health Research Unit, Université Laval; Christine Guillemette, M.Sc and Anas Idris, D.V.M., Ph..D., postdoctoral fellow, Centre de Recherche en Biologie de la Reproduction, Département des sciences animales, Université Laval, Research Associate



## Abstract

Traditional foods of Northern aboriginal populations are persistently contaminated with endocrine-disrupting PCBs and chlorinated pesticides. The toxicity of these organochlorines on human health, reproduction and development remains unclear. The fetus is particularly sensitive to organochlorines, since much reproductive development occurs during gestation. Our working hypothesis is that in utero and lactational exposure to a mixture of organochlorines that contaminates the Arctic food chain harms the development and post-pubertal function of the reproductive system. Our current study has used the rat as a model and our focus was on reproductive health. Marked adverse affects on the male reproductive system were apparent, including a reduced percentage of male pups born, delayed puberty, reduced sperm motility, impaired spermatogenesis and abnormal weights of the reproductive organs. We also observed unexpected effects on the development and function of the female reproductive system, including delayed puberty, abnormal estrous cycles, reduced ovulation rates and abnormal oocyte development. Moreover, we were surprised to observe direct affects on the treated dams manifest as reduced fertility and gestational growth rates.


## Key Project Messages

Our rat study showed that exposure to environmentally-relevant levels of an organochlorine mixture induces:

- Smaller offspring size at birth;
- Reduced weights of testicles and accessory sex glands in male offspring;
- Impaired sperm motility in male offspring;
- Retarded and abnormal oocyte maturation in females;
- Abnormal hormonal profiles in male and female offspring.

These data support the hypothesis that this organochlorine mixture has adverse effects on reproductive development and function in animal models, supporting concerns that human health might also be impacted by dietary and maternal exposure to similar compounds.

## Objectives

Since 2002, our overall objective was to determine the effects of *in utero* and lactational exposure to the environmentally relevant organochlorine mixture on the reproductive ontogeny and function of male rat pups. We have also examined the impact of such exposure on female offspring in 2003-4. Our objectives from 2002 through 2004 were to:

- Indicate the impact of the organochlorine mixture on female reproductive function (i.e. maternal competence);
- Demonstrate the effect of the mixture on foetal development (e.g. foetal size, anogenital distance, sex ratio, presence of nipples);
- Assess the impact of the treatments on offspring growth and onset of puberty;
- Determine effects of the organochlorines on the reproductive parameters of post-pubertal male rats (sperm quality);
- In 2003-4, to determine the effects of the organochlorines on the reproductive parameters of post-pubertal female rats (oestrous cycle patterns, oocyte number and quality);
- In 2003-4, evaluate the hormone profiles on the dams and pups (thyroid hormone levels, prolactin, sex steroids and gonadotrophins);
- In 2003-4, conduct histological evaluation of reproductive organs (testicles, epididymis, seminal vesicles in the males and ovaries in the females).

## Introduction

The traditional diets of Northern populations are persistently contaminated with a complex mixture of organochlorines. Consequently, this unusually high exposure has elevated the levels of these compounds in various body tissues. Persistent organochlorines found in highly exposed human populations contain a variety of compounds, including substances with estrogenic (e.g. *o,p'*-DDT, β-HCH), anti-estrogenic (e.g. dioxin-like polychlorinated biphenyls, PCBs) or anti-androgenic capacities (e.g. *p,p'*-DDE). These environmental contaminants alter the normal function of endocrine and reproductive systems by mimicking or antagonizing endogenous hormone action, modulating the synthesis and metabolism of endogenous hormones, or altering hormone receptor production (Sonnenschein and Soto, 1998). Since steroid hormones regulate the development and maintenance of reproductive tissues, real-life mixtures composed of numerous compounds can interact with different receptors involved in cell differentiation, growth and affect reproduction.

In men, declining sperm counts, testicular cancer, hypospadias, cryptorchodism and small penile size have all been related to endocrine disruption by organochlorines (reviewed by Cheek and McLachlan, 1998). In a study by our group, we showed that non-occupational DDT exposure was associated with poor sperm motility, abnormal sperm morphology and incomplete sperm DNA packaging in men from rural Mexico (de Jager et al., 2002). Similar findings were reported for men presenting at a Boston fertility clinic (Hauser et al., 2002). A recent investigation of young Swedish men showed that serum levels of 2,2',4,4',5,5' -hexachlorobiphenyl was negatively correlated with sperm motility and free testosterone levels (Richthoff et al., 2003).

In women, Trapp et al. (1984) reported the presence of various organochlorine compounds in human follicular fluid. Exposure of the gametes and the embryo/fetus to these endocrine disruptors is assured by the presence of environmental contaminants in the female reproductive tract and amniotic fluid (Foster et al., 2000). Granulosa cells, which surround the oocytes, are highly susceptible to endocrine disruptors (Campagna et al., 2001). In various species, *in vitro* oocyte maturation, fertilisation and embryo development are compromised in the presence of certain organochlorines (Kholkute et al., 1994; Lindenau and Fischer, 1996; Kholkute and Dukelow, 1997; Alm et al, 1998; Campagna et al., 2002). Finally, an increased risk of spontaneous abortion is associated with maternal serum DDE levels among textile workers in China (Korrick et al., 2001).

Reproductive abnormalities in Northern animal populations that are important traditional foods are concerning. Backlin et al. (2003) speculated that the development of uterine leiomyomas in northern seals is associated with organochlorines and low reproductive activity and as early as 1986, Reijnders reported reproductive failure in seals in Northern Europe was linked to pollution. Polar bears have alarming body burdens of organochlorines and it was suggested that the Svalbard polar bear populations are threatened by contaminant-related effects leading to reproductive impairment of females, lower survival rates of cubs, or increased mortality of reproductive females (Derocher et al., 2003). Moreover, extensive observation of killer whale pods showed that the dominant males who mated most frequently had the highest body burdens of organochlorines (Ylitalo et al., 2001), which could lead to male-mediated effects on their offspring or reduced population growth should these males be less fertile than non-contaminated males.

Therefore, an increasing body of literature indicates that exposure to organochlorines negatively impacts male and female reproductive function. However, little data is available on the impact of organochlorines on the reproductive parameters of people (or animal species that serve as traditional foods) in Northern Aboriginal populations.

# Activities

## In 2003/2004

The present study was carried out to test the hypothesis that *in utero* and lactational exposure of rats to an environmentally relevant mixture of organochlorines modulates their reproductive development and function. The study was initiated in 2002 and completed in 2004. The organochlorine mixture was designed to correlate to the levels found in Ringed Seal blubber from Northern Québec. Organochlorine compounds and technical mixtures were dissolved in corn oil to give the proportions listed in Table A.

*Maternal rat treatment, mating and gestation*

Five-week-old female Sprague-Dawley rats were housed two per cage in a room with 12 h light cycle (6:45-18:45), 22±1 Ċ temperature and 46±10% humidity. Animals were given free access to food and chlorinated water ad libidum. Animal care and handling were in accordance with the guidelines of the university committees for animal care, chemical safety and ethics.

**Table A.** Composition of the organochlorine mixture.

| *Compound* | CAS number | % weight |
|---|---|---|
| PCB mixture[a] | | 32.59 |
| Technical chlordane | 57-74-9 | 21.3 |
| *p,p'*-DDE | 72-55-9 | 19.24 |
| *p,p'*-DDT | 50-29-3 | 6,79 |
| Technical toxaphene | 8001-35-2 | 6.54 |
| α-HCH | 319-84-6 | 6.17 |
| Aldrin | 309-00-2 | 2.52 |
| Dieldrin | 60-57-1 | 2.09 |
| 1,2,4,5-tetrachlorobenzene | 95-94-3 | 0.86 |
| *p,p'*-DDD | 72-54-8 | 0.49 |
| β- HCH | 319-85-7 | 0.46 |
| Hexachlorobenzene | 118-74-1 | 0.35 |
| Mirex | 2385-85-5 | 0.23 |
| γ- HCH | 58-89-9 | 0.20 |
| Pentachlorobenzene | 608-93-5 | 0.18 |

a - Mixture containing 2,4,4'-trichlorobiphenyl (320 mg), 2,2',4,4'-tetrachlorobiphenyl (256 mg), 3,3',4,4'-tetrachlorobiphenyl (1.4 mg), 3,3',4,4', 5-pentachlorobiphenyl (6.7 mg), Aroclor 1254 (12.8g) and Aroclor 1260 (19.2 g).

After 10 days of acclimatization, the rats were weighed, randomly assigned to four groups (n=10) and dosed the organochlorine mixture thrice weekly by gavage with equal volume of vehicle (1 ml corn oil/100 grams body weight) to give the following three daily intakes of PCBs: 0.05 mg/kg body weight, 0.5 mg/kg body weight and 5 mg/kg body weight. The daily intakes of the other organochlorines can be calculated from proportions listed in Table A. The fourth group of rats was fed an equal volume of oil and used as controls. After 5 weeks of treatment, each pair of female rats was housed with an unexposed male rat for 10 days and mating was confirmed by the presence of a vaginal plug. Organochlorine treatment continued through mating and gestation until terminated at parturition.

Parturition and weaning

The day of the parturition was considered to be postnatal day (PND) 1. On PND2, dam and pup body weights, numbers of litter, litter size, sex ratio and the percentage of live offspring were determined. Rats were left with their litters until PND21, at which time terminal body weight was recorded and blood samples were collected from the dams by cardiac puncture after been anesthetised with ketamine and xylazine. Serum and plasma were separated by centrifugation at 900 g for 30 minutes and kept frozen at –20 Ċ until the time of organochlorine analysis. Rats were then sacrificed by cervical dislocation and their livers, spleens, uteri and ovaries were collected, cleared from the surrounding fat and weighed. The number of implantation sites in the uteri was also counted.

Development of male offspring

This next portion of the study was, therefore, carried out to test the hypothesis that *in utero* and lactational exposure of male rats to an environmentally relevant mixture of organochlorines modulates their reproductive development and function.

The day of parturition was considered to be postnatal day (PND) 1. On PND2, pup body weights were determined, and litters of more than 10 pups were culled to 10 (male and female) and those with less than 7 pups were excluded. Because only two of the dams from the 5 mg PCBs treatment retained some of their live pups on PND2, the male offspring from this group were statistically excluded from this study. Pups remained with their mothers until weaning (PND21), at which time blood samples were collected from some of the males. Serum and plasma were kept frozen at – 20$^{o}$C until the time of hormone and organochlorine analyses. Their livers, spleens, testes and epididymides, ventral prostates and seminal vesicles were collected, cleared from the surrounding fat and weighed. Preputial separation in the remaining male rats was examined daily from PND35. Half of these were killed on PND60 and the remainders killed on PND90. Again, blood samples were collected for hormone and organochlorine analyses, and livers, spleens and reproductive organs were removed and weighed. The right cauda epididymides from some of the rats were used for examining sperm motility and morphology.

Development of female offspring

A third portion of study was conducted in parallel to the male rat pup development to test the hypothesis that *in utero* and lactational exposure to an environmentally relevant organochlorine mixture affects reproductive development and function in female offspring using the rat as a model.

Together with the male pups, the female pups remained with their mothers until weaning (PND21), at which time blood samples were collected from some of the females by cardiac puncture. These rats were then sacrificed by cervical dislocation and their livers, spleens, uteri and ovaries were collected. The vaginal openings of the remaining female rats were examined daily after PND26. Half of these rats were sacrificed on PND60 and the remainders were killed on PND90. Blood samples were collected for hormone and organochlorine analyses, and livers, spleens and reproductive organs were removed and weighed.

Starting on PND50, the estrous cycle of the female pups was examined daily by vaginal smears for 25 days. The stage of the cycle was identified by the cell type found in the vaginal fluid. The number of days spent at each stage of the cycle was recorded.

Ovulation rate was examined between PND80 and PND90. On the morning of estrus, as identified by vaginal smears, rats were killed and ovaries and oviducts were removed. The ovary and oviduct were separated and cumulus-enclosed oocyes were dissected out of the oviducts, counted, and the morphology of cumulus cells was examined with a phase contrast microscope. Oocytes with partial or full degree of expansion were considered expanded.

## Results

<u>Effect of treatment on the reproductive competence of the dams and neonatal parameters</u>

No significant differences in the mating, fertility and pregnancy indices were observed between the treated and untreated rats (Table 1). The highest level of exposure (5 mg PCBs) reduced the number of pups per litter and the percentage of live offspring ($P<0.05$). Male pup weight on PND2 was significantly lower in the 0.5 and 5 mg PCBs groups than the control ($P<0.05$). Similarly, all female pups from rats receiving the organochlorines (at all levels of exposure) had lower body weights than the control ($P<0.05$). Postimplantation mortality was also higher in rats from 5 mg PCB group than the control ($P<0.05$). No significant differences in the number of implantation sites, sex ratio and duration of gestation were observed among treatments. None of the females has died until the termination of the experiment. In sum, it appears that there was no apparent direct affect of the 0.05 and 0.5 mg treatments on dam reproductive function, although pup development (weight) was reduced. As discussed later, physiological parameters of the dams treated with 5 mg PCBs indicate a direct toxic response, resulting in reduced fertility.

There was no difference in the body weight gain of dams after 5 weeks of treatment, but 5 mg PCBs treatment reduced the body weight gain at the time of parturition ($P<0.05$; Fig. 1). The maternal body weight gain was also reduced at the time of weaning with all levels of organochlorine treatment ($P<0.05$).

Rats exposed to 5 mg PCBs had relatively higher weight of liver and significantly lower spleen weight in comparison to the control (Fig. 2) suggesting acute toxic effects of the mixture at 5 mg:

**Table 1.** Fertility data of the rats orally exposed to the organochlorine mixture.

| Treatment (mg/kg) | No. dams | No. mated (%)[a] | No. preg. (%)[b] | No. litters (%)[c] | Pups per litter | Implantation sites [d] | Postimplant. mort. (%)[d] | Gestation length (days)[d] | % live pups[d] | % males | Male pup weight (g)[d] | Female pup weight (g)[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 10 | 9 (90) | 9 (90) | 9 (100) | 10.1±2.2[a] | 12.6±1.5 | 19.02 | 22.4±0.7 | 92±2.2[a] | 43.2±0.2 | 7.32±0.08[a] | 7.23±0.08[a] |
| 0.05 | 10 | 9 (90) | 9 (90) | 9 (100) | 10.6±1.9[a] | 12.4±1.7 | 15.01 | 22.0±0.0 | 98±0.1[a] | 53.5±0.2 | 7.21±0.09[ab] | 6.64±0.06[b] |
| 0.5 | 10 | 10 (100) | 9 (90) | 9 (100) | 12.4±2.1[a] | 13.9±1.5 | 9.8 | 22.1±0.3 | 97±0.2[a] | 55.9±0.1 | 6.99±0.09[b] | 6.64±0.07[b] |
| 5 | 10 | 8 (80) | 8 (80) | 8 (100) | 6.3±1.0[b] | 11±1.9 | 39.21[a] | 22.0±0.0 | 73±0.3[b] | 42±0.1 | 6.0±0.09[c] | 5.8±0.09[c] |

[a] Mating index
[b] Fertility index
[c] Pregnancy index
[d] Data are means±SEM
[a,b,c] Different superscripts within the same column are significantly different ($P<0.05$).

**Figure 1.** Oral treatment with organochlorines reduces the body weight gain of the dams. Data are means ± SEM; letters indicate SD due to treatment (P<0.05; n = 9).

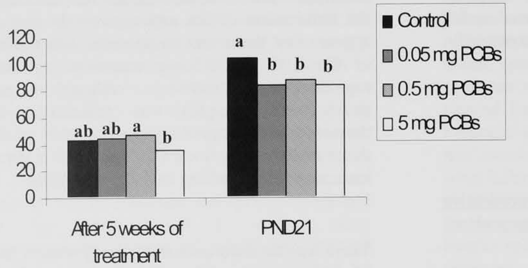
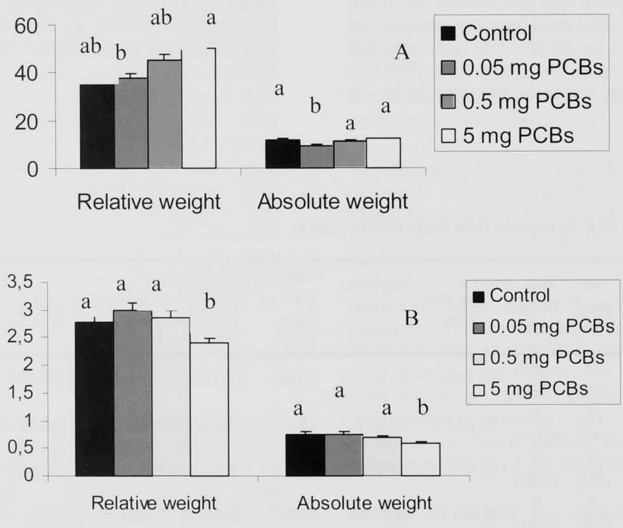



**Figure 2.** Relative (g/kg body weight) and absolute (g) weights of livers (A) and spleens (B) from female rats treated with various levels of organochlorines and sacrificed after weaning. Values are means+SEM. Letters indicate significant difference due to organochlorine treatment (P<0.05).



No differences in the uterine or ovarian weights were observed as a result of the organochlorine treatment (data not shown), suggesting no direct affect of the subchronic exposure on reproductive tissues.

The concentrations of various organochlorines and their metabolites in plasma samples collected from dams on PND21 were assayed. Aroclor 1260, and congeners 101, 138, 153, 170, 180 and 187 as well as p,p'-DDE and hexachlorobenzene were detected in plasma samples from the control group (Table 2):

Aldrin, alpha-chlordane, hepta-chlorepoxide, pentachloro-benzene, toxaphenes, and PCB congeners 28 and 52 were not detected in any sample. With the exception of alpha-HCH and hexachloro benzene, the plasma levels of all other detected organochlorines increased with treatment in a dose-dependant manner (Table 3).

Development of male offspring

Only three rats from the 5 mg PCB treatment group survived beyond PND2, and we feel that this dose induced acute toxicity. Therefore, observations of this group after PND2 were not included in the statistical analysis. Data from this group, however, are presented separately in Table 4.

Table 5 presents the effect of organochlorine exposure on the anogenital distance measured on PND2, the number of retained nipples counted on PND13, the age of preputial separation and body growth of the male pups. Anogenital distance (AGD) was shorter in rats from the 5 mg PCBs ($P<0.05$), but the relative AGD (AGD/body weight) was not different among groups. Nipple retention was also not affected by the organochlorine exposure. However, the age of preputial separation, the primary indicator of puberty, was effectively delayed in rats exposed to the organochlorines ($P<0.05$). The weight of the pups exposed to the organochlorine mixture at 5 mg PCBs was lower than that of the other groups when recorded on PND2 ($P<0.05$). The body growth of the pups thereafter was not affected by the organochlorine exposure.

**Table 2.** PCB congeners levels (µg/L) in plasma of female rats exposed to organochlorines*

| | Control | 0.05 mg PCB/kg bw/day | 0.5 mg PCB/kg bw/day | 5 mg PCB/kg bw/day |
|---|---|---|---|---|
| Aroclor 1260 | 0.21±0.13 | 14.98±13.26 | 68.6±49.68 | 2272.6±1521.5 |
| 28 | ND | ND | ND | ND |
| 52 | ND | ND | ND | ND |
| 99 | ND | 0.21±0.32 | 1.33±1.78 | 47.3±39.83 |
| 101 | 0.004±0.009 | ND | 0.06±0.14 | 2.14±1.76 |
| 105 | ND | 0.1±0.23 | 0.29±0.48 | 14.76±11.71 |
| 118 | ND | 0.34±0.61 | 1.42±1.63 | 52.54±41.46 |
| 128 | ND | 0.07±0.15 | 0.41±0.29 | 18.94±14.54 |
| 138 | 0.02±0.01 | 1.16±1.10 | 5.36±4.34 | 188.4±129.0 |
| 153 | 0.03±0.02 | 1.74±1.49 | 7.88±5.21 | 248.8±163.95 |
| 156 | ND | 0.41±0.21 | 1.06±0.71 | 32.82±23.98 |
| 170 | 0.01±0.01 | 0.66±0.40 | 3.84±2.13 | 83.00±50.88 |
| 180 | 0.07±0.07 | 1.63±0.87 | 9.18+4.12 | 186.8±106.5 |
| 183 | ND | 0.4±0.23 | 2.34±1.14 | 47.4±26.9 |
| 187 | 0.02±0.01 | 0.99±0.63 | 5.24±2.41 | 113.8±63.6 |

ND: not detected.
*Values are means ± SD; n=5

The effect of the organochlorine treatment on the development of male reproductive organ as indicated by their relative weights (g/kg body weight) is shown in Fig. 3. On PND21, testes weights were higher in pups exposed to 0.5 mg PCBs (P<0.05) but not on PND60 or 90. PND60 ventral prostate weights were lower with the 0.5 mg PCBs exposure (P>0.05). As well, PND90 weights of the epididymides, ventral prostate and seminal vesicle were effectively decreased with organochlorine exposure (P<0.05). As for the liver and spleen, the only significant effect was an increase in the PND21 weight of liver from rats exposed to 0.5 mg PCBs (P<0.05; data not shown).

The effect of the organochlorine exposure on the motility of the caudal epididymal sperm is presented in Fig. 4. When examined on PND60, the percentages of motile and progressively motile sperm were not significantly affected by orgnochlorine exposure. At PND90, however, the percentages of motile and progressively motile sperm were decreased in rats exposed to the organochlorine mixture (P<0.05), which might reduce the fertility of the males, though this was never investigated. For the 0.05 mg PCBs group, the decrease was significant after 60 minutes of incubation. The decrease was apparent at all tested time periods for rats from the 0.5 mg PCBs group. Among the other examined parameters, ALH and BCF were higher in rats from the 0.5 mg PCBs treatment group (P<0.05; data not shown). The morphology of the sperm was not affected at any level of organochlorine exposure (data not shown).

The effects of the organochlorine exposure on male rat serum hormones are presented in Fig. 5. Rats from the 0.5 mg PCBs treatment had relatively low levels of serum testosterone than the control, however,

**Table 3.** Concentrations (µg/ml) of various organochlorines and their metabolites in plasma of female rats exposed orally to the organochlorine mixture*

| | Control | 0.05 mg PCB/kg bw/day | 0.5 mg PCB/kg bw/day | 5 mg PCB/kg bw/day |
|---|---|---|---|---|
| *p,p'*-DDT | ND | 2.58±2.74 | 12.78±11.99 | 232.81±146.13 |
| *p,p'*-DDD | ND | ND | 0.26±0.58 | 16.44±19.31 |
| *p,p'*-DDE | 0.13±0.12 | 6.44±7.02 | 15.34±9.45 | 1259±949.04 |
| Aldrin | ND | ND | ND | ND |
| Dieldrin | ND | 0.18±0.41 | 0.22±0.09 | 27.2±45.79 |
| Lindane | ND | ND | ND | ND |
| Mirex | ND | 0.44±0.13 | 2.92±1.03 | 41.2+21+55 |
| Alpha-chlorodane | ND | ND | ND | ND |
| Gamma-chlorodane | ND | ND | ND | 0.47±0.57 |
| Oxy-chlorodane | ND | 0.11±0.24 | 0.2±0.41 | 33.73±37.4 |
| Hepta-chlorodane | ND | ND | ND | 3.38±4.54 |
| Alpha-BHC | ND | 0.09+0.13 | ND | 9.47±16.65 |
| Beta-BHC | ND | ND | ND | 12.57±10.06 |
| Cis-nonachlor | ND | ND | ND | 0.42±0.94 |
| Trans-nonachlor | ND | ND | ND | 8.84±19.1 |
| Hepta-chlor- epoxide | ND | ND | ND | ND |
| Hexa-chloro-benzene | 0.01±0.01 | 0.12±0.19 | 0.07±0.17 | 20.42±19.42 |
| Penta-chloro-benzene | ND | ND | ND | ND |
| Toxaphenes | ND | ND | ND | ND |

ND: not detected.
*Values are means ± SD; n=5

the differences were not significant at any tested time. Serum FSH, LH and thyroxin levels were not affected by the organochlorine treatment at all tested times (not shown).

Fig. 6A shows the testicular histology. Testes from 0.05 and 0.5 mg PCBs groups were morphologically similar to the control, and had 100% seminiferous tubules showing differentiating germ cells. Some of the seminiferous tubules from the 0.5 mg PCBs, however, had relatively fewer sperm in the lumen than the controls. In contrast, severe histological changes were observed in testes from rats exposed to 5 mg PCBs. In these testes, germs cells appeared to be degenerated as all had large pyknotic nuclei and were undistinguishable. A higher percentage of smaller size tubules, fewer Sertoli cells, and several vacuoles were also some features of testes from the 5 mg PCBs. Additionally, the lumens of the seminiferous tubules were deprived of sperm and contained fibrins.

The morphology of the epididymides also appears normal in rats from 0.05 and 0.5 mg PCBs groups compared to the control with the exception that sperm in epididymal lumens from 0.5 mg PCBs treatment are less abundant, confirming observations of the seminiferous tubules (Fig. 6B). However, epididymal morphology was apparently affected by exposing to 5 mg PCBs; changes include reduced tubule size, absence of sperm, and the presence of fibrins and cellular debris in the lumen.

The concentrations of various organochlorines and their metabolites in blood plasma samples collected from the male rats on PND21, 60 and 90 are presented in Table 6. Aroclor 1260, and congeners 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187 as well as p,p'-DDT, p,p'-DDE, oxychlorodane and hexachlorobenzene were detected in plasma samples from the

**Table 4.** Reproductive and developmental data of rats from the 5 mg PCBs group

| Characters | Values |
|---|---|
| PND13 Nipple retention | 1.00±1.00 |
| Age at preputial separation (days) | 57.0±3.74 |
| PND21 body weight (g) | 33.9±3.00 |
| PND60 body weight (g) | 165±33.2 |
| PND90 body weight (g) | 241±35.8 |
| Liver weight (g/kg body weight) | 24.1±1.50 |
| Spleen weight (g/kg body weight) | 2.88±0.33 |
| Testis weight (g/kg body weight) | 2.18±0.77 |
| Epididymis weight (g/kg body weight) | 0.70±0.10 |
| Ventral prostate weight (g/kg body weight) | 0.26±0.02 |
| Seminal vesicle weight (g/kg body weight) | 1.31±0.88 |
| % Motility[a] | 0 |
| % Progressive motility[a] | 0 |
| % Normal sperm[b] | 0 |

Relative organ weights were measured on PND90.

Values are means±SD (n=3)

[a] No of sperm counted was 32, 29 and 17 for the first, second and third rat, respectively.

[b] No of sperm examined was 18, 16 and 15 for the first, second and third rat, respectively.

control group. Aldrin, dieldrin, lindane, alpha-chlordane, gama-chlordane, heptachlor, alpha-BHC, cis-nonachlor, trans-nonachlor, hepta-chlorepoxide, pentachloro-benzene, and PCB congeners 28 and 52 were not detected in any sample. Plasma levels of all detected organochlorines increased with treatment, and drastically decreased with the age of rats.

Development of female offspring

As mentioned for the male rat pups, only 2 rats from the 5 mg PCB treatment group retained some live pups beyond PND2, therefore, observations of this group recorded after PND2 were not included in the statistical analysis. Table 7 presents the effect of organochlorine exposure on some of the developmental traits in female pups. Anogenital distance in the female pups was not affected by the exposure. The age of vaginal separation was effectively delayed in rats exposed to the organochlorines ($P<0.05$). Vaginal separation is an indicator of puberty; therefore, as observed for the males, even the lowest treatment doses effectively interrupted puberty in these animals. All levels of organochlorine exposure significantly reduced PND2 body weight compared to the control ($P<0.05$), a likely consequence of the poor gestational weight gain of the dams (Fig. 1). Rats from the 5 mg PCBs group had even lower body weights than the 0.05 and 0.5 mg PCBs groups on PND2 ($P<0.05$). The body growth of the pups thereafter was not affected by the organochlorine exposure, so a direct toxic effect of the exposure was unlikely.

Uterine, ovarian and spleen weights were not affected by the organochlorine exposure at all ages tested (data not shown). For the liver weights, the only significant difference was an increased weight due to the 0.5 mg PCBs treatment on PND21 ($P<0.05$; data note shown).

Organochlorine exposure disrupted the estrous cycle of the female offspring. Rats from the 0.5 mg PCBs group spent significantly more days in diestrus stage of the cycle than those from the control and 0.05 mg PCBs groups ($P<0.05$; Fig. 7). On the other hand, both levels of organochlorine exposure (0.05 and 0.5 mg PCBs) significantly shortened the duration of the estrus (i.e. sexual receptive and ovulatory) stage relative to controls ($P<0.05$).

**Table 5.** Developmental data of male rats exposed *in utero* and during lactation to the organochlorine mixture

| Parameters | Control | 0.05 mg PCBs | 0.5 mg PCBs | 5 mg PCBs |
|---|---|---|---|---|
| Anogenital distance (mm*) | $2.49\pm0.06^{a}$ | $2.45\pm0.05^{a}$ | $2.34\pm0.04^{a}$ | $2.1\pm0.03^{b}$ |
| AGD/body weight* | 0.34 | 0.34 | 0.33 | 0.34 |
| Nipple retention** | 0 | 0 | 0 | ND |
| Age at preputial separation (days)*** | $42.05\pm0.25^{a}$ | $43.14\pm0.25^{b}$ | $44.19\pm0.19^{c}$ | NA |
| PND2 body weight | $7.32\pm0.08^{a}$ | $7.21\pm0.09^{a}$ | $6.99\pm0.09^{a}$ | $6.05^{b}$ |
| PND21 body weight | $54.03\pm0.65$ | $53.68\pm0.69$ | $52.42\pm0.51$ | NA |
| PND60 body weight | $311.49\pm4.55$ | $308.27\pm5.05$ | $305.61\pm3.93$ | NA |
| PND90 body weight | $374.14\pm9.93$ | 365.38 | 369.94 | NA |

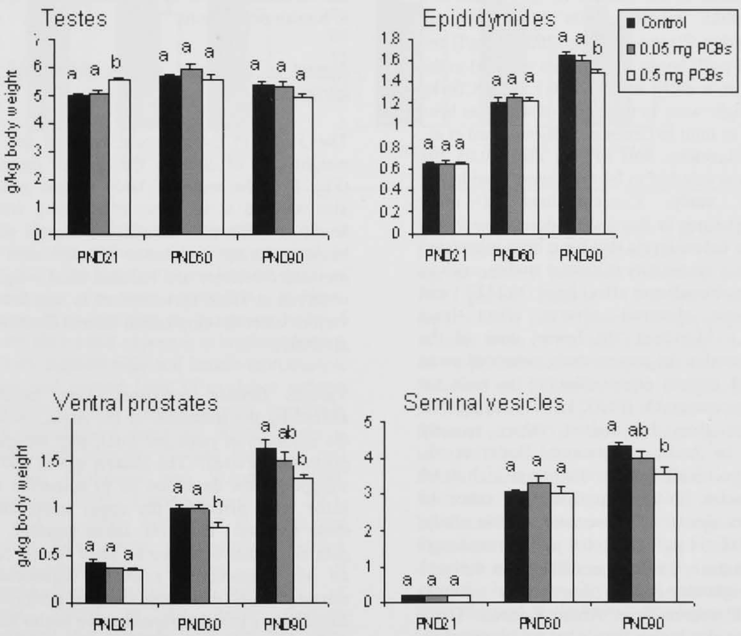
Values are mean±SEM.
* PND2 (n=37,51,52 and 13 for control, 0.05 mg and 0.5 mg PCBs groups, respectively).
** PND13 (n= 37, 51, 52 for control, 0.05 mg and 0.5 mg PCBs groups, respectively).
*** n=20
[1] n=37, 51 and 52 for control, 0.05 and 0.5 mg PCBs groups, respectively.
[2] n=33,42 and 51 for control, 0.05 and 0.5 mg PCBs groups, respectively
[3] n=16,18 and 20 for control, 0.05 and 0.5 mg PCBs groups, respectively
[4] n=8,11 and 11 for control, 0.05 and 0.5 mg PCBs groups, respectively

As shown in Table 8, organochlorine exposure had no effect on ovulation rate of the female rat offspring. The number of the collected oocytes per ovulated rat was also not altered by the organochlorine treatment. In contrast, the process of cumulus expansion was severely affected in oocytes collected from the exposed rats as indicated by the significantly low percentage of oocytes that had expanded cumulus cells ($P<0.05$; Table 8). Figure 8 shows the morphology of the oocytes, indicating that the 0.5 mg group has very condensed cumulus relative to the others.

Estradiol (E2), thyroxin (T4), follicle stimulating hormone (FSH), luteinising hormone (LH) and prolactin were measured by radioimmunoassay. As shown in Fig. 9, at PND21, serum E2 levels of the treated rats did not differ from levels in the untreated controls. On PND60, however, serum E2 level significantly declined in rats exposed to the organochlorine mixture ($P<0.05$). On PND90, concentration of serum E2 again did not differ among treated and control rats. Serum FSH, LH and prolactin was not affected by organochlorine exposure at all ages tested (not shown). Fig. 7 shows also that female rats from the 0.5 mg PCBs group had significantly lower serum T4 concentration than the other groups on PND21. In contrast, PND60 and 90 serum T4 levels of the treated rats were not different from those of the control rats.

The concentrations of various organochlorines and their metabolites in plasma samples collected from the male rats on PND21, 60 and 90 are presented in Table 6.

**Figure 3.** Development of reproductive organs from male rats exposed *in utero* and during lactation to an organochlorine mixture at PND 21, 60 and 90. Data are shown as absolute organ weights/body weights (g/kg). Values are means±SEM. Different letters indicate significant differences due to treatment within each PND ($P<0.05$; n=12, 10 and 10 for PND21, 60 and 90 respectively).



## Discussion and Conclusions

The data obtained from this study clearly indicate that in utero and lactational exposure to organochlorines designed to mimic real-life contaminants in the Far North adversely affect neonatal characteristics, puberty and reproductive function in the rat model. At present, there is no evidence of fertility problems in Northern populations because it has never been studied, but they might start to be observed over the next several decades. Moreover, reproductive problems in the affected food sources (seals, polar bear, and beluga) have been documented and might result in future difficulty for the human populations in obtaining these nutritionally and culturally important traditional food sources (Reijnders, 1986; Ylitalo et al., 2001).

*The treatment doses are pertinent*

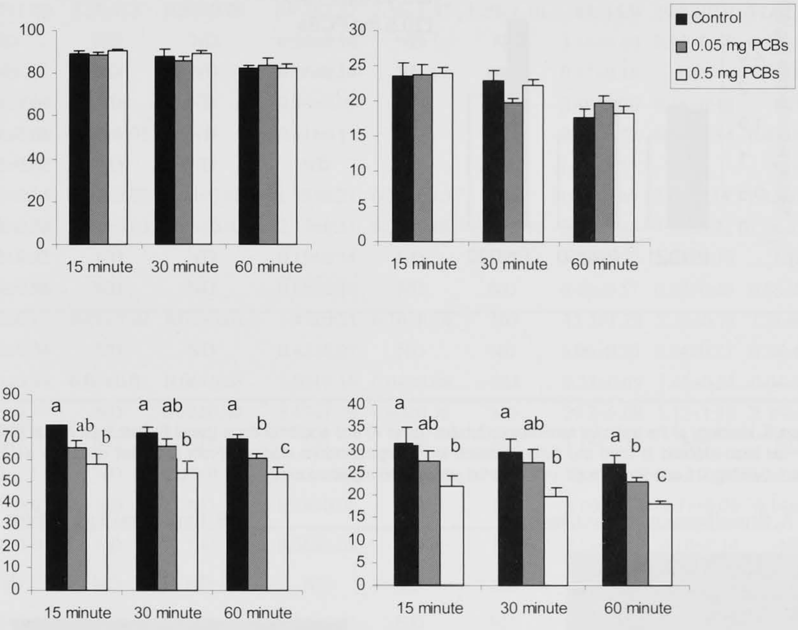
The lowest mixture dose used in this study was based on the results of our preliminary experiment (not shown) in which female rats were exposed to the mixture for five weeks at a daily intake ranging from 0 to 10 mg PCBs/kg/day. Plasma Aroclor 1260 (48 μg/l) and DDE (15 μg/l) levels in these rats exposed to the mixture at a daily intake of 0.1 mg PCBs/kg body weight were in the range of what has been reported in Inuit in Greenland (Bjerregaard et al., 2001). Therefore, half of this dose (0.05 mg PCBs) was selected to be the lowest dose in our principal study. Concentrations of other organochlorines in this lowest dose were in the ranges or below levels that have been associated with low or no toxicity in animal studies, such as no observable adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL). Moreover, the lowest dose of the mixture used in the present study generated mean values of plasma organochlorines in male rat offspring comparable (PND21 DDT; 5.5 μg/l) or far lower than the highest values recently reported in Arctic populations (Butler et al., 2003). Specifically, concentrations as high as 60 μg/l Aroclor 1260, 21 μg/l sum of other 14 congeners similar to those used in this study, 3μg/l DDT, 34 μg/l DDE, 0.8 μg/l mirex, 6 μg/l oxychlorodane, 38 μg/l beta-BHC and 4.5 μg/l hexachlorobenzene were detected in maternal blood of women from Arctic Canada. These values are also higher than what we observed on PND60 and PND90 in the rats treated with 0.5 mg PCBs in the present study. However, on PND21, rats from this group had three-fold higher PCBs, 10-fold higher DDT, two-fold higher DDE and four-fold higher mirex plasma levels than what was reported for the Arctic maternal blood levels. As well, PND90 plasma PCBs and mirex mean concentrations in male rats from the highest level of exposure group (5 mg PCBs) in this study were five- and two-fold higher than the highest levels reported in the Arctic study (Butler et al., 2003). Other detected plasma organochlorines in this group were either around the same level (DDT and DDE) or less (oxychlorodane and hexachlorobenzene) than those of the Arctic (Butler et al., 2003). In addition to what has been reported in Arctic, as high as 47 μg/l and 95 μg/l of Aroclor were detected in human blood from Montrealers of Asian origin (Kosatsky et al., 1999) and Greenland (Bjerregaard and Hansen, 2000). These observations indicate that the mixture used in this study generated blood concentrations of organochlorines in the male rat offspring comparable to the levels in the blood of highly exposed humans. Therefore, the treatment used can be considered to be environmentally relevant to human populations.

*Impact of treatment on the dams and litter parameters*

The 5 mg PCBs treatment reduced the body weight gain of dams at the time of parturition (Fig. 1). The maternal body weight gain was also reduced at the time of weaning with all levels of treatment. Insufficient weight gain in humans during pregnancy is associated with premature delivery and reduced natal weight (as observed in Table 1), which are in turn linked to various other developmental issues (Ehrenberg et al., 2003).

Various fertility outcomes were negatively altered by the treatment of the dams, including the numbers of pups per litter, pup weight and postnatal survival. The altered spleen and liver weights in the dams led us to suspect a slight acute toxic affect of the upper treatments on these females. However, taken together, these data show that exposure of adult female rats to an environmentally relevant organochlorine mixture alters their reproductive performance, suggesting a possible reproductive health hazards for human and other animals.

**Figure 4.** Percentages of motile and progressively motile sperm from rats at PND60 (n=10) and PND90 (n=10) that had been exposed *in utero* and during lactation to the organochlorine mixture. Cauda epididymal sperm were incubated in TCM-199 at 38C in CO2 for 15, 30 or 60 minutes, at which time motility was assessed using a Hamilton-Thorne analyser. Values are means±SEM. Letters indicate significant differences due to treatment within each incubation period (P<0.05). Sperm motility was not affected due to treatment at PND60 (P>0.05).




Despite the declining organochlorine levels in the North, the children that were exposed *in utero* and during lactation to the highest levels of contaminants are just approaching puberty. However, it is clear that an increasing body of literature shows that exposure to organochlorines negatively impacts male and female reproductive function and several lines of evidence support the hypothesis that organochlorines negatively affects reproductive function. Firstly, there is overwhelming amounts of data from our and other labs (Solomon and Schettler, 2000; McLauchlan, 2001; Campagana et al., 2001, 2002; AMAP, 2002; Adeeko et al., 2003 and references within these documents) indicating that environmentally relevant levels of organochlorines (individual pollutants or mixtures) found in the Arctic disrupts development (for example birth size, sex ratio, gestational weight gain which is in turn linked to complications) and reproduction (for example age at puberty, hormone dynamics, conception rate, gamete quality). Secondly, numerous reports show that exposure to similar pollutants in other areas of the world have negative effects on reproductive development (for example Solomon and Schettler, 2000; Longnecker et al., 2001; Hauser et al., 2002; Rogan et al., 2003; Swan et al., 2003). As well, other health effects in Arctic peoples such as neurodevelopmental delays, osteoporosis and immunosuppression have been suggested to occur via molecular or hormonal alterations due to organochlorine exposure. To suggest that reproductive development, which is intricately regulated by steroid hormone dynamics during foetal, perinatal and peripubertal development, would

Figure 5. Serum testosterone from male rats exposed *in utero* and during lactation to organochlorine mixture and sacrificed at PND21, 60 and 90. Values are means+SEM (n=4 for PND21, and 7 for PND60 and 90). No significant differences were observed due to the organochlorine exposure.

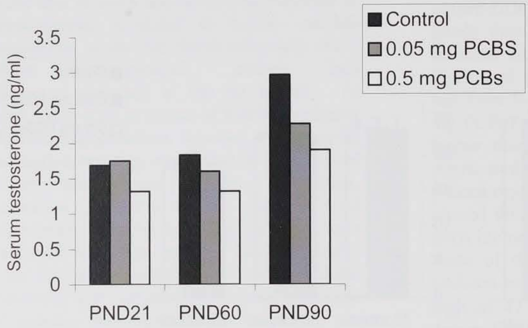
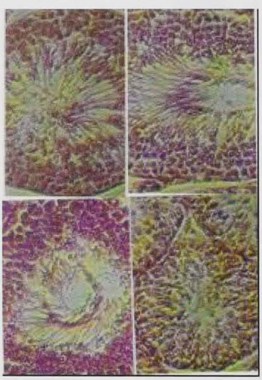



Figure 6. Histology of the testicular seminiferous tubules (panel A) and epididmal ducts (panel B) from male rats at PND90 that had been exposed *in utero* and during lactation to the organochlorine mixture. From upper left clockwise are from control, 0.05 mg, 0.5 and 5 mg groups. (n = 10 for all groups but 5 mg where n = 2).

A. Seminiferous tubule sections

B. Epididymal duct sections



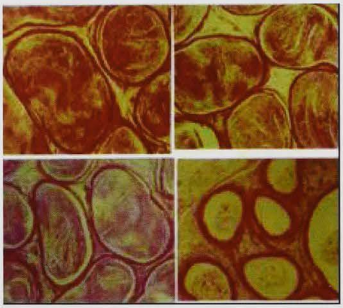


**Table 6.** PCB congener and organochlorine levels (μg/L) in plasma of male rats exposed *in utero* and during lactation to organochlorine mixture

| | Control | | | 0.05 | | | 0.5 | | | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (mg PCBs/kg body weight/day) | | | | | | |
| | PND21 | PND60 | PND90 | PND21 | PND60 | PND90 | PND21 | PND60 | PND90 | PND90 |
| roclor 1260 | 2.57±1.70 | 0.24±0.3 | 0.32±0.20 | 19.3±2.52 | 2.36±1.47 | 1.20±1.10 | 183±18.9 | 29.8±12.9 | 17.0±3.32 | 277±121 |
| 99 | ND | ND | ND | 0.52±0.14 | ND | ND | 5.18±0.60 | 0.95±0.58 | 0.21±0.30 | 4.83±1.82 |
| 101 | ND | ND | ND | 0.16±0.14 | ND | ND | 0.17±0.19 | ND | ND | ND |
| 105 | 0.04±0.04 | ND | ND | 0.34±0.03 | ND | ND | 2.40±0.20 | 0.16±0.16 | ND | 0.87±0.46 |
| 118 | 0.11±0.08 | 0.01±0.01 | ND | 0.81±0.11 | ND | ND | 7.00±0.72 | 0.80±0.34 | 0.43±0.08 | 3.73±1.99 |
| 128 | 0.03±0.02 | ND | ND | ND | ND | ND | 1.43±0.21 | ND | ND | 0.41±0.31 |
| 138 | 0.21±0.14 | 0.02±0.02 | 0.03±0.02 | 1.53±0.21 | 0.21±0.13 | ND | 14.5±1.00 | 2.52±1.18 | 1.32±0.26 | 22.3±9.02 |
| 153 | 0.28±0.20 | 0.02±0.03 | 0.03±0.02 | 2.17±0.31 | 0.29±0.08 | 0.13±0.12 | 21.0±2.45 | 3.24±1.32 | 1.96±0.39 | 31.3±14.0 |
| 156 | 0.03±0.02 | ND | ND | 0.15±0.14 | ND | ND | 1.98±0.22 | 0.24±0.15 | ND | 2.90±1.51 |
| 170 | 0.09±0.06 | ND | ND | 0.68±0.10 | ND | ND | 6.40±0.57 | 0.97±0.40 | 0.56±0.10 | 9.33±5.22 |
| 180 | 0.20±0.14 | 0.01±0.02 | 0.03±0.02 | 1.47±0.21 | 0.10±0.14 | ND | 13.5±1.29 | 2.16±0.78 | 1.36±0.26 | 20.3±10.1 |
| 183 | 0.05±0.04 | ND | ND | 0.42±0.07 | ND | ND | 3.90±0.39 | 0.54±0.21 | 0.34±0.07 | 4.43±2.26 |
| 187 | 0.13±0.09 | 0.01±0.01 | 0.06±0.08 | 1.02±0.16 | 0.04±0.09 | ND | 9.23±0.69 | 1.45±0.54 | 0.94±0.18 | 12.3±5.10 |
| p,p'-DDT | 0.86±0.91 | ND | 0.02±0.04 | 5.47±1.79 | 0.60±0.35 | ND | 29.3±5.68 | 3.12±1.10 | 2.36±0.31 | 3.30±1.31 |
| p,p'-DDD | ND | ND | ND | ND | ND | ND | 1.15±1.33 | ND | ND | ND |
| p,p'-DDE | 1.62±1.13 | ND | 0.07±0.10 | 11.0±0.00 | 0.63±0.40 | 0.13±0.29 | 72.3±15.3 | 2.62±0.77 | 1.42±0.55 | 34.7±28.0 |
| Mirex | 0.03±0.03 | ND | ND | 0.29±0.06 | ND | ND | 3.00±0.54 | 0.31±0.09 | 0.14±0.13 | 1.97±1.12 |
| Oxy-chlordane | 0.04±0.04 | ND | ND | 0.36±0.02 | ND | ND | 2.28±1.10 | 0.10±0.14 | ND | 0.19±0.18 |
| ß-BHC | ND | ND | ND | ND | ND | ND | 1.48±0.31 | ND | ND | ND |
| Hexachlorobenzene | 0.05±0.04 | ND | ND | 0.24±0.03 | ND | ND | 2.05±0.42 | 0.09±0.12 | ND | 0.89±0.19 |

ND: not detected. Values are arithmetic means±SD (n=5 for the control, 0.05 mg and 0.5 mg PCBs groups, and 3 for 5 mg PCBs group).
Male rats were exposed in utero and during lactation to the organochlorine mixture and plasma samples were collected at PND21, PND60 and 90. Aldrin, dieldrin, lindane, alpha-chlordane, gama-chlordane, hepta-chlorepoxide, pentachlorobenzene, Cis-nonachlor, alpha-BHC, heptachlor, trans-nonachlor and PCB congeners 28 and 52 were not detected in any sample.

not be affected by these chemicals would be misleading to the Northern communities and other exposed populations until solid research demonstrates otherwise.

*Treatment adversely affected male offspring development*

The age of preputial separation was later in all rats exposed to the organochlorines, indicating that puberty was effectively delayed due to treatment and is suggestive of endocrine abnormalities or a retarded activation of the hypothalamo-hypophoseal-testicular axis. Although Figure 5 shows no significant difference in serum testosterone among the groups, our previous pig study revealed reduced testosterone levels in juvenile male offspringe. However, we are reluctant to conclude that the endocrine systems of these male rats are unaffected because the pulsatility of reproductive hormones makes it difficult to accurately compare animals. In retrospect, we should have sampled at least 10 to 15 males per age group to have made a more precise comparison, although we did not have enough animals to have conducted such an assay. Furthermore, as shown in the next section, the female offspring (i.e. the sisters of these males) have disrupted endocrine responses due to maternal treatment. Moreover, the significantly decreased weights of the androgen-dependent organs (Figure 3) reflect abnormal androgen function or a feminisation (due to the estrogenic influences of the organochlorines).

Adult male offspring from the 0.05 mg and 0.5 PCBs groups showed poorer sperm motility compared to controls, which could indicate poorer fertility in the males. However, the motility decline might not be manifest as reduced fertility, since the number of sperm per ejaculate (not measured in this study with rats) would likely compensate for a moderate decline in quality. Some of the seminiferous tubules from the 0.5 mg PCBs, however, had relatively fewer sperm in the epididymal lumen than controls or 0.05 mg group, which could more conceivably result in reduced fertilising efficiency relative to controls.

**Table 7.** Developmental data of female rats exposed *in utero* and during lactation to the organochlorine mixture.

| Treatment* | Anogenital Distance (mm)[1] | Age at vaginal opening (days)[2] | Body weight (g) | | | |
|---|---|---|---|---|---|---|
| | | | PND2[1] | PND21[3] | PND60[4] | PND90[5] |
| Control | 1.13±0.03 | 31.64±0.23[a] | 7.23±0.07[a] | 52.5±0.63 | 185.7±2.29 | 238.4±3.55 |
| 0.05 mg PCBs | 1.13±0.02 | 33.36±0.32[b] | 6.64±0.10[b] | 49.7±0.69 | 181.2±3.36 | 243.8±5.99 |
| 0.5 mg PCBs | 1.1±0.03 | 33.93±0.32[b] | 6.64±0.10[b] | 50.1±0.53 | 177.6±3.24 | 232.1±3.52 |

Values are means±SEM. Different superscripts within the same column are significantly different ($P<0.05$).

[1] n=51, 44 and 49 for the control, 0.05 and 0.5 mg PCBs groups, respectively.

[2] n=14; [3] n= 34; [4] n=14; [5] n=7.

**Figure 7.** Effect of *in utero* and lactational exposure to organochlorine mixture on estrous cycle duration. Rats were daily examined for 25 days for their cycles and the number of days spent in each stage of the cycle was counted. Data are means±SEM (n=7). Different letters indicate significant differences due to treatment within each stage ($P<0.05$).

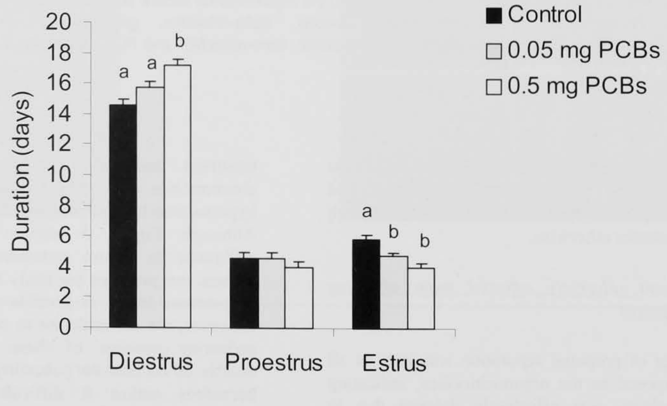
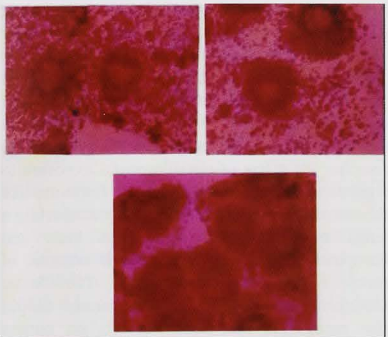


**Table 8.** Ovulation rate, number of oocytes collected and oocyte cumulus expansion in female rats exposed in utero and during lactation to the organochlorine mixture.

| Treatment* | No. of examined rats | No. of ovulated rats | No. of oocytes/ovulated rat | % of oocytes with cumulus expansion |
|---|---|---|---|---|
| Control | 4 | 3 | 15.5±0.3 | 77.8[a] |
| 0.05 mg PCBs/kg/day | 3 | 3 | 15.3±0.3 | 80.7[a] |
| 0.5 mg PCBs/kg/day | 3 | 3 | 14.7±0.3 | 19.1[b] |

[a,b] Different superscripts within the same column are significantly different (P<0.05).

**Figure 8.** Oocytes from female rats exposed *in utero* and during lactation to organochlorine mixture and sacrificed at PND90 (n=4). From upper left clockwise are oocytes from control, 0.05 and 0.5 rats.

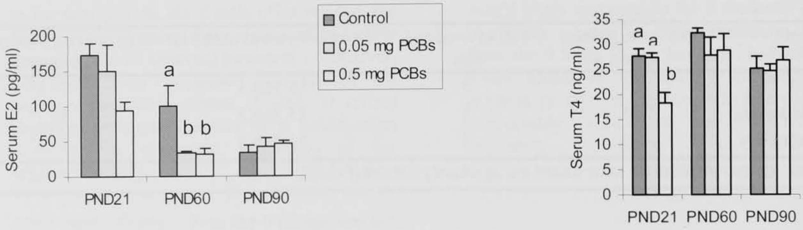


Also of interest was the altered pattern of sperm motility observed in the treated rats. The elevated ALH and BCF are suggestive of premature sperm activation and might result in reduced fertility, as has been observed in other cases of precocious sperm activation (Cormier et al., 1997).In addition, the few surviving males from the 5 mg PCBs group were clearly negatively altered by maternal exposure to the organchlorines as noted by severely abnormal testes and lack of sperm in the cauda epidiymis. Again the mechanism of such dysfunction is likely attributable to endocrine disruption.

Adverse affects of treatment on female offspring

Striking similarities between male and female development were observed. Vaginal separationis an indicator of puberty in female rats and as for the males, even the lowest treatment doses effectively interrupted puberty because the age of vaginal separation was delayed in rats maternally exposed to the organochlorines. The mechanism underlying the delay is also likely related to endocrine abnormalities or a retarded activation of the hypothalamo-hypophoseal-ovarian axis. Indeed, estrogen levels of the pubertal females (PND60) were reduced due to treatment, which might explain the retarded puberty. The reduced T4 levels might indicate a certain degree of hypothyrodoism, although we did not have the

**Figure 9.** Serum E2 (estrogen) and T4 (thyroxin) from female rats exposed *in utero* and during lactation to organochlorine mixture and sacrificed at PND21, 60 and 90. Values are means±SEM (n=4 for PND21, 7 for PND60 and 4 for 90). Different letters indicate significant differences due to treatment within age (P<0.05).




resources to conduct complete thyroid hormone profiling (including thyroid stimulating hormone assays). Hypothyroidism from infancy in humans, if untreated, delays puberty (Larsen et al., 1998).

Organochlorine exposure disrupted the estrous cycle of the female offspring, resulting in longer diestrus and shorter estrus phases. An impact of a longer diestrus period could be increased oocyte apoptosis or reduced oocyte competence due to improper DNA structure shorter. Likewise, a shorter estrus phase could reduce fertility, simply because the number of matings permitted by the female would be limited relative to controls as estrus is the period of sexual receptivity.

Organochlorine exposure had no effect on ovulation rate of the female rat offspring, however, the morphology of the ovulated oocytes was abnormal. The normally expanded cumulus was markedly inhibited in the 0.5 mg group. These results are strikingly similar to what we have previously observed with pig oocytes *in vitro* (Campagna et al., 2001, 2002). The degree of cumulus expansion is known to be related to the competence of the oocyte to develop into a healthy embryo. Therefore, the ability of these female rats to produce a competent embryo is questionable, although we did not directly test their fertility *in vivo*.

*Concluding remarks*

To the best of our knowledge, no data are available on the impact of organochlorines on the reproductive parameters of people (or animal species that serve as traditional foods) in Northern Aboriginal populations. One might speculate that reproductive function has never been studied because no one feels that it is a problem. However, some sexual development data are being collected in an on-going cohort study in Nunavik. Moreover, the European Commission has initiated the INUENDO to decipher the effect of environmental exposure to organochlorine compounds with hormone-like actions on human fertility. They are conducting a series of interrelated studies in Inuit and European populations with a high contrast of exposure test this hypothesis. The Arctic Monitoring and Assessment Programme (2002) also recognises that subtle effects on human health are occurring in the Arctic due to exposure and that foetal and neonatal development is of greatest concern. Finally, it is interesting to note that the Canadian Institute of Child Health released a study in 2002 entitled *The Health of Canada's Children*, which concluded that "Today's children are born with a body burden of synthetic, persistent organic pollutants – the consequences of which will not be know for another 50 years or so."

## References


Adeeko A, Li D, Forsyth DS, Casey V, Cooke GM, Barthelemy J, Cyr DG, Trasler JM, Robaire B, Hales BF. Effects of in utero tributyltin chloride exposure in the rat on pregnancy outcome. Toxicol Sci. 2003;74:407-415.

Alm H, Torner H, Tiemann U, Kanitz W. Influence of organochlorine pesticides on maturation and postfertilization development of bovine oocytes in vitro. Reprod Toxicol 1998 12:559-63.

AMAP (Arctic Monitoring and Assessment Programme). 2002. Arctic Pollution 2002. AMAP, Oslo, Norwary. 111 pages.

Backlin BM, Eriksson L, Olovsson M. Histology of uterine leiomyoma and occurrence in relation to reproductive activity in the Baltic gray seal (Halichoerus grypus). Vet Pathol. 2003; 40: 175-80.

Bjerregaard P, Hansen JC. Organochlorines and heavy metals in pregnant women from the Disko Bay area in Greenland. Sci Total Environ 2000;245:195-202.

Bjerregaard P, Dewailly E, Ayotte P, Pars T, Ferron L, Mulvad G. Exposure of Inuit in Greenland to organochlorines through the marine diet. J Toxicol and Environ Health 2001;62 :69-81.

Butler Walker J, Seddon L, McMullen E, Houseman J, Tofflemire K, Corriveau A, Weber JP, Mills C, Smith S, Van Oostdam J. Organochlorine levels in maternal and umbilical cord blood plasma in Arctic Canada. Sci Total Environ 2003;302:27-52.

Campagna C, C Guillemette, R Paradis, MA Sirard, P Ayotte & JL Bailey. An environmentally-relevant organochlorine mixture damages sperm function and fertility in the porcine model. Biol. Reprod. 2002; 67: 80-87.

Campagna C, MA Sirard, P Ayotte & JL Bailey. Impaired maturation, fertilization and embryonic development of porcine oocytes following exposure to an environmentally-relevant organochlorine mixture. Biol. Reprod. 2001; 65: 554-560.

Cheek AO, McLachlan JA. Environmental hormones and the male reproductive system. J Andrology 1998 19:5-10.

Cormier N, M-A Sirard & JL Bailey. Premature capacitation of bovine spermatozoa is initiated by cryopreservation. J. Androl. 1997; 18:461-468.

de Jager C, MS Bornman & JL Bailey. Male reproductive health and DDT: Sufficient evidence to discontinue its use? In: Proceedings of the 9th International Symposium on Spermatology, G van der Horst, D Franken, R Bornman, T de Jager, S Dyer (Eds.), Monduzzi Editore, Bologna, Italy. 2002. Pages191-196.

Derocher AE, Wolkers H, Colborn T, Schlabach M, Larsen TS, Wiig O. Contaminants in Svalbard polar bear samples archived since 1967 and possible population level effects. Sci Total Environ. 2003; 301: 163-74.

Foster W, Chan S, Platt L, Hughes C. Detection of endocrine disrupting chemicals in samples of second trimester human amniotic fluid. J Clin Endocrinol Metab. 2000; 85:2954-7.

Hauser R, Altshul L, Chen Z, Ryan L, Overstreet J, Schiff I, Christiani DC. Environmental organochlorines and semen quality: results of a pilot study. Environ Health Perspect. 2002; 110: 229-33.

Kholkute SD, Dukelow WR. Effects of polychlorinated biphenyls (PCB) mixtures on in vitro fertilisation in the mouse. Bull Environ Contam Toxicol 1997 59:531-536.

Kholkute SD, Rodriguez J, Dukelow WR. Reproductive toxicity of Aroclor-1254 : effets on oocytes, spermatozoa, in vitro fertilization, and embryo development in the mouse. Reprod Toxicol 1994; 8:487-493.

Korrick SA, Chen C, Damokosh AI, Ni J, Liu X, Cho SI, Altshul L, Ryan L, Xu X. Association of DDT with spontaneous abortion: a case-control study. Epidemiol. 2001; 11: 491-6.

Kosatsky T, Przybysz R, Shatenstein B, Weber JP, Armstrong B. Contaminant exposure in Montrealers of Asian origin fishing the St. Lawrence River: exploratory assessment. Environ Res. 1999:80:159-165.

Larsen PR, Davies TF, Hay ID. The thyroid gland. In Williams Textbook of Endocrinology eds J. D. Wilson, DW Foster, HM Kronenberg, PR & Larsen, 9th edition WB Saunders, Philadelphia 1998 p. 389-515.

Lindenau A, Fischer B. Embryotoxicity of polychlorinated biphenyls (PCBs) for preimplantation embryos. Reprod Toxicol 1996 10:227-230.

Longnecker MP, Klebanoff MA, Zhou H, Brock JW. Association between maternal serum concentration of the DDT metabolite DDE and preterm and small-for-gestational-age-babies at birth. Lancet 2001; 358:110-114.

McLachlan JA. Environmental signaling: what embryos and evolution teach us about endocrine disrupting chemicals. Endocr Rev. 2001;22:319-341.

Muir D. Spatial and temporal trends of organochlorines in Arctic marine mammals. in Environmental Studies No. 73, Synopsis of Research Conducted Under the 1994/1995 Northern Contaminants Program., J. Murray, R. Shearer and S. Han, Editors 1995 143-147.

Reijnders PJ. Reproductive failure in common seals feeding on fish from polluted coastal waters. Nature. 1986; 324: 456-7.

Richthoff J, Rylander L, Jonsson BA, Akesson H, Hagmar L, Nilsson-Ehle P, Stridsberg M, Giwercman A. Serum levels of 2,2',4,4',5,5'-hexachlorobiphenyl (CB-153) in relation to markers of reproductive function in young males from the general Swedish population. Environ Health Perspect. 2003; 111: 409-13.

Rogan WJ, Ragan N. Evidence of effects of environmental chemicals on the endocrine system in children. Pediatrics 2003; 112: 247-252.

Solomon GM, Schettler T. Environment and health: 6. Endocrine disruption and potential human health implications. CMAJ. 2000: 28;163:1471-1476.

Sonnenschein C, Soto AM. An updated review of environmental estrogen and androgen mimics and antagonists. J Steroid Biochem Mol Biol 1998 65:143-50.

Swan SH, Kruse RL, Lui F, Barr DB, Drobnis EZ, Redmon JB, Wang C, Brazil C, Overstreet JW, the Study for Future Families Research Group. Semen quality in relation to biomarkers of pesticide exposure. Environ Health Perspect 2003; 111:1478-1284.

Trapp M, Baukloh V, Bohnet H-G, Heeschen W. Pollutants in human follicular fluid. Fertil Steril. 1984 42:146-8.

Ylitalo GM, Matkin CO, Buzitis J, Krahn MM, Jones LL, Rowles T, Stein JE. Influence of life-history parameters on organochlorine concentrations in free-ranging killer whales (Orcinus orca) from Prince William Sound, AK. Sci Total Environ. 2001; 281: 183-203.

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


## Project leader(s)

Laurie Chan, Ph.D., Associate Professor and, NSERC Northern Research Chair,Centre ForIndigenous Peoples' Nutrition and Environment (CINE), McGill University, 21,111Lakeshore Road, Ste-Anne-de-Bellevue, QC H9X 3V9; phone: (514) 398-7765; fax: (514) 398-1020, e-mail: Laurie.Chan@McGill.ca; Rekha Mehta Ph.D., Chief, Toxicology Research Division, Bureau of Chemical Safety, Food Directorate, Health Canada

## Project members

Eric Lok, Santokh Gill, Dawn Jin, Toxicology Research Division, Bureau of Chemical Safety, Food Directorate, Health Canada



## Abstract

It is been shown that some Inuit populations are exposed to higher levels of methylmercury. It is important to characterize the risk by studying whether other components of the Inuit diet may offer protective effects against the methylmercury toxicity. This project is a follow-up study on the effects of nutrients on toxicity of methylmercury using rat as an animal model. Our previous study funded by NCP II has shown that nutrients such as vitamin E and selenium may have protective effects against the toxicity of the methylmercury on the newborn rats. This follow-up study is to investigate whether vitamin E and/or selenium, or phytate, a dietary fibre, will affect the accumulation of orally ingested methylmercury in different organs or change the toxic effects of methylmercury. This is a laboratory-based toxicology experiment and a collaboration between researchers from the Centre for Indigenous Peoples' Nutrition and Environment at McGill University and the Toxicology Research Division, Bureau of Chemical Safety of Health Canada. Results of the study will help to characterize the risk of mercury exposure from the consumption of the traditional Inuit diet.


## Objectives

To study the effects of dietary factors on methylmercury toxicity.

*Specific Objectives (2003-2004):*

1. To complete the pathology examination of rat tissues from the previous experiments studying the effects of protein and lipids on methylmercury.
2. To study the effects of selenium on methylmercury kinetics and toxicity in adult rats.
3. To study the effects of vitamin E on methylmercury kinetics and toxicity in adult rats.
4. To study the effects of phytate on methylmercury kinetics and toxicity in adult rats
5. To use state-of-the-art endpoint measurements to characterize the toxicity of methylmercury.

## Introduction

Northern Contaminants Program (NCP) Phase II concluded with the release of the Canadian Arctic Contaminants Assessment Report II (CACAR II) that there is a need to characterize the risk of Hg exposure among Inuit communities because some Inuit populations are exposed to higher levels of methylmercury. A recent report published by the United States National Research Council (US NRC) on the toxicological effects of methylmercury concluded that dietary nutrients and supplements might protect against toxicity of methylmercury (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 mercury 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 other components of the Inuit diet may offer protective effects against the methylmercury toxicity. This project was a follow-up study on the effects of nutrients on toxicity of methylmercury using rats as an animal model. Our previous study funded by NCP II has shown that nutrients such as vitamin E and selenium may have protective effects against the toxicity of the methylmercury on the 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 methylmercury in different organs and/or change the toxic effects of methylmercury. This is a collaboration between researchers from the Centre for Indigenous Peoples' Nutrition and Environment 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 mercury exposure as well as beneficial effects from the consumption of the traditional Inuit diet.

## Activities

### In 2003/2004

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 fund to be transferred to Toxicology Research Division, Food Directorate of Health Canada (HC) for the work that was going to be done at HC. Thus, a lot of energy was spent in figuring out the financial aspects before the diets and other materials could be purchased and planned studies could begin. Despite these set backs, the following activities were undertaken:

1. Completion of pathological examination of rat tissues from the previous experiments studying the effects of dietary protein and lipids on methylmercury toxicity.
2. Completion of experimental design and preparation of diets, and dosing solutions. Commencement of animal treatments, and sample collections and analyses to study the effects of selenium, vitamin E, and phytate on methylmercury kinetics and toxicity in adult rats.

## Results

**I. *<u>Pathological Findings from the Previous Study:</u>***

Tissues for microscopic examination, fixed in 10% neutral buffered formalin were embedded in Paraplast wax, sectioned at 4 microns and stained with hematoxylin and eosin. Kidney, liver, and spleen were evaluated for any pathological changes. In addition a few random sections of thyroid from vehicle and high dose animals were examined. The histopathology examination is complete and a pathology report has been generated for inclusion in a publication that is currently *in preparation.* Data on the kidney lesions have been *submitted* for discussion among pathologists at a web conference organized by the Registry of Toxicologic Pathology for Animals, Armed Forces Institute of Pathology, Washington, DC.

Focal mild lesions of chronic nephritis were observed in the vehicle treated rats in all diet groups. Such lesions are consistent with the common spontaneous disease, chronic progressive nephropathy (Chandra *et al.*,1993). Mild subclinical hydronephrosis was also observed at a low incidence spontaneously in these rats as previously been shown to occur in Sprague Dawley rats (Chandra *et al.*, 1993). One of the vehicle treated rats had small numbers of basophilic tubules in the OSOM, similar to those in mercury treated rats. Generally among the 8 diet groups for both doses (1 and 3mg/kg/day) the lesions of methylmercury nephrosis were very similar in extent and severity. The 1 mg/kg/day fish protein group had slightly milder kidney lesions than the other 1 mg/kg/day groups. Overall the 8 different diets did not significantly alter the morphologic expression of methylmercury nephrosis at the light microscopic level.

No significant liver lesions were seen. Mild thyroid follicular hypertrophy and hyperplasia were seen in a few vehicle treated rats in the fish and whey protein diet groups; this non-specific lesion is evidence of a mild goitrogenic effect caused by some dietary components (Gopinath *et al.*,1987). The same thyroid changes were widespread among all diet groups treated with 3 mg/kg/day MeHg. Rats with these thyroid lesions may or may not be clinically hypothyroid. In spleens there was mild atrophy of B- and T-dependent regions in all diet groups receiving 1 mg/kg/day MeHg; qualitatively similar but slightly more severe combined atrophy occurred in all diet groups receiving 3 mg/kg/day MeHg.

***II. Progress of the Follow-Up Study:***

Two of four groups of animals have been treated to study the effects of selenium, vitamin E, and phytate on methylmercury kinetics and toxicity in adult rats since March 29, 2004. The first set of necropsies occurred on May 11-13, and tissues, urine, and blood were collected for analysis of various toxicological parameters. The treatments of other groups of animals will occur on June 7 and June 28 and be completed by August 12, 2004. Analysis of tissue, urine, and blood has commenced as these were collected, and are expected to be completed by December 31, 2004.

## Expected Completion Date

The expected project completion date is now December 31, 2004 instead of the proposed date of March 31, 2004. This is due to late receipt of NCP funds (See above under **(8)**). A request to carry over the NCP funds into the new fiscal year was rejected by FNIHB, which meant that all of the NCP funds received had to be spent by March 31, 2004. These funds were used wherever possible to purchase the reagents required to complete the toxicological analysis. However, the animal maintenance costs could not be paid in advance and will now have to be covered as part of the in kind contribution by Health Canada.

## References


Beyrouty, P. 2002. *Effects of methylmercury on reproduction and offspring development and potential benefits of supplemental selenium and vitamin E intake in rats*. M.Sc. thesis, Department of Natural Resources Sciences, McGill University, Montreal, Québec, Canada.

Castoldi A.F., Coccini T, Ceccatelli S, and Manzo L (2001). Neurotoxicity and molecular effects of methylmercury. *Brain Research Bulletin*, 55(2);197-203.

Chakrabarti SK, Loua KM, Bai C, Durham H, Panisset JC. (1998) Modulation of monoamine oxidase activity in different brain regions and platelets following exposure of rats to methylmercury. *Neurotoxicol Teratol* 20(2):161-8

Chandra, M.and Frith,C.H. (1993) Non-neoplastic renal lesions in Sprague-Dawley and Fischer-344 rats, *Exp Toxic Pathol,*45:439-447.

Chan, H.M. 2000. Dietary Effects on Methylmercury Toxicity in Rats. In: *Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program*. S. Kalhok (ed.). Department of Indian Affairs and Northern Development, Ottawa, Ontario, Canada. pp. 11-15.

Faro L.R.F., Nascimento, J.L.M. do, Alfonso, M., Duran, R. (2002) Mechanism fo action of methylmercury on *in vivo* striatal dopamine release: Possible involvement of dopamine transporter. *Neurochemistry International* 40; 455-465.

Gopinath,C.,Prentice, D.E.and Lewis, D.J.(1987) *Atlas of Experimental Toxicological Pathology, Lancaster: MTP Press,* p.112.

Jin, X., Lok E., Chan L.C., and Mehta R. (2003) Effects of dietary fats and proteins on methylmercury-mediated oxidative stress in rats. *Proceedings of the Canadian Federation of Biological Societies, 46th Annual Meeting, Abstract # T069, p. 81, Ottawa, Ontario.*

Jin, X. Lok E., Laurie H.M. Chan, and Mehta R. (2003) Effects of dietary fats and proteins on methylmercury-mediated oxidative DNA damage. *Northern Contaminants Program. Canadian Arctic Contaminants Assessment Symposium, Abstract P-H12, Ottawa, Ontario.*

Rowland IR, Robinson RD, Doherty RA. Effects of diet on mercury metabolism and excretion in mice given methylmercury: role of gut flora. *Arch Environ Health.* 39:401-8 (1984).

Rowland IR, Mallett AK, Flynn J, Hargreaves RJ. The effect of various dietary fibres on tissue concentration and chemical form of mercury after methylmercury exposure in mice. *Arch Toxicol* 59:94-8 (1986).

US NRC. 2000. *Toxicological Effects of Methylmercury.* National Academy Press, Washington, D.C., U.S.A.

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


## Project leader(s)

Laurie Chan, Ph.D., Associate Professor and, NSERC Northern Research Chair,Centre ForIndigenous Peoples' Nutrition and Environment (CINE), McGill University, 21,111Lakeshore Road, Ste-Anne-de-Bellevue, QC H9X 3V9; phone: (514) 398-7765; fax: (514) 398-1020; e-mail: Laurie.Chan@McGill.ca

## Project members

Donna Mergler, Professor, Université du Québec à Montréal; Amy Caughey, Health Promotions, Nutrition Specialist, Health and ocial Services, GN); Eric Loring, Senior Environment Researcher, Inuit Tapiriit Kanatami; Co-researchers from 2 communities



## Abstract

Previous study has shown that Inuit in Nunavut may be exposed to elevated levels of mercury through traditional food consumption. This study seeks to characterize the risk to human health by examining the relationships between diet and body burden of mercury. Study in the next two years will further study effects of dietary contaminants and lifestyle on early alterations of health and quality of life within the target communities. The key research questions are: 1) What is the best approach to measure mercury in the body and its effects in the Inuit communities? 2) Are there individuals who have more than acceptable levels of mercury in their body? 3) Which traditional food items are the main sources of mercury of these individuals? 4) What are the effects of contaminant exposure on the health and lifestyle of the individuals? 5) Is it possible to maximize the use of traditional food and minimize toxic risk by dietary intervention? A pilot study was conducted in 2003-2004 to address the first 3 questions. A follow up study will be conducted in the following years to address questions 4 and 5. This pilot project will develop methodology and research partnership that can be used to measure contaminant exposure and health effects that are culturally acceptable. Every effort will be made to take into account the Inuit traditional knowledge and to integrate community needs and values into the research partnership.


## 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 maximizing 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 and toenail samples for biomonitoring of mercury.
2. To estimate dietary intake levels of the participants.
3. To correlate Hg burden with dietary intake.

4. To explore the feasibility of obtaining blood samples to measure mercury and potential benefit nutrients such as fatty acids, vitamin E and selenium.
5. To report test results to each participant and discuss the potential health implications.
6. To discuss with the community representatives on the follow-up study.

## Introduction

There have been extensive studies of population groups, including 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 ug/kg-body weight/day (ATSDR, 1999). Results of the dietary study conducted by CINE on 18 Inuit communities show that the average intake of Hg is 0.6 ug/kg-body weight/day (n=1875) and the $95^{th}$ percentile exposed group have intake level at 3.0 ug/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 correlate the data with estimate dietary exposure followed by neurobehaviour testing of the subjects (if warranted). Dewailly et al. (1999) reported the mean Hg concentrations in hair samples collected in 1999 in Salluit region to be 5.7 mg/Kg. No similar data were collected by NCP in Nunavut.

Recently, a case–control study conducted in eight European countries and Israel (684 men with a first diagnosis of myocardial infarction and 724 men as control) showed toenail Hg level was directly associated with the risk of myocardial infarction, and high Hg content may diminish the cardioprotective effect of fish intake (Guallar *et al.* 2002). However, another study published in the same issue of the journal reported contradictory results and found no association between Hg in toenail and risk of coronary heart diseases using a nested case–control study with 33,737 male health professionals between 40 to 75 years of age (Yoshizawa *et al.*, 2002). Further studies are clearly needed. However, there are no data on toenail Hg levels available in Arctic Canada for comparison.

Neurobehavioral studies have shown that subtle changes in performance, measured in exposed populations, represent not only warning signs of possible increased risk for future illness, but just as more important, diminished capacity with potential long lasting effects (ex. increased lead exposure *in utero* is associated with decrease in children's intellectual ability and increased delinquent behaviour as adolescents (Needleman et al. 2002). Health studies on Hg have recognised the importance of not only looking at illness as a outcome, but also early changes in physiological functions, notably in relation to the nervous system which is the initial target organ of methyl Hg toxicity (Mahaffey, 2000). Cross-sectional studies of children and adults have observed dose-related deficits in nervous system functions in relation to methyl Hg exposure through fish and marine mammal consumption (Grandjean et al, 1999; Dolbec et al, 2000; Cordier et al, 2002; Weihe et al, 2002; Grandjean et al, 2003). Batteries of testing for neurobehavioral outcomes have been shown useful to detect early effects of Hg in adults and children; subtle changes in nervous system functions can have important repercussions on a community in terms of learning capacities, behaviour and adaptation to stress.

## Activities

### In 2003/2004

Extensive consultations were made with the Niqiit Avatittinni Committee on the need, 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 community 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 will be collected from about 160 participants in the 2 communities. A M.Sc. student Partricia Solomon has been recruited as the project coordinator. At least two research assistants have been hired in each of the two communities. Data have been collected in Igloolik and Repulse Bay, and samples were sent to CINE for Hg analysis. Dietary Hg exposure will be estimated using food frequency questionnaire and body burden of Hg will be assessed by measuring toenail and hair samples. The relationship between dietary patterns, Hg concentrations in foods and in humans will be studied. Temporal trend of Hg body burden will be explored. We plan to discuss the results and health implications with the communities in December 2004.

## Expected Completion Date

The expected project completion date is now December 31, 2004 instead of the proposed date of March 31, 2004. This is due to the prolonged period of the review of the human ethics review process.

## References

ATSDR 1999. Toxicological profile for mercury. Agency for Toxic Substances and Disease Registry. Available at http://www.atsdr.cdc.gov/toxprofiles/tp46.html.

Cordier S, Garel M, Mandereau L, Morcel H, Doineau P, Gosme-Seguret S, Josse D, White R, Amiel-Tison C. 2002. Neurodevelopmental investigations among methylmercury-exposed children in French Guiana. Environ Res.89 (1):1-11.

Dewailly É, Laliberté C, Lebel G, Ayotte P. 1999. Évaluation de l'exposition prénatale aux organochlorés et aux métaux lourds et des concentrations et oméga-3 des populations de la moyenne et de la Basse-Côte-Nord du Saint-Laurent. Unité de recherche en santé publique du CHUQ, Centre de Toxicologie du Québec, Departement of Nutrition Sciences, University of Guelph, 87 p.

Dolbec J., Mergler D., Sousa Passos C.-J., Sousa de Morais S., and Lebel J. 2000. Methylmercury exposure affects motor performance of a riverine population of the Tapajos river, Brazilian Amazon. *Int Arch Occup Environ Health* 73: 195-203.

Grandjean P, White RF, Nielsen A, Cleary D, de Oliveira Santos EC. 1999. Methylmercury neurotoxicity in Amazonian children downstream from gold mining. Environ Health Perspect. 107(7):587-91.

Grandjean P, White RF, Weihe P, Jorgensen PJ. 2003. Neurotoxic risk caused by stable and variable exposure to methylmercury from seafood. *Ambul Pediatr*. 3:18-23.

Guallar E, Sanz-Gallardo MI, van't Veer P, Bode P, Aro A, Gomez-Aracena J, Kark JD, Riemersma RA, Martin-Moreno JM, Kok FJ. 2002. Mercury, fish oils, and the risk of myocardial infarction. *N Engl J Med*. 347:1747-54.

Kehrig HA, Malm O, and Akagi H. 1997. Methylmercury in hair samples from different riverine Groups, Amazon, Brazil. Water, Soil Air Pollut 97:17-29

Kuhnlein, H.V. and H. M. Chan. (2000). "Environment and contaminants in traditional food systems of northern indigenous peoples." Annu. Rev. Nutr. 2000. 20:595-626.

Kuhnlein, H.V., Receveur, O., Chan, H.M., Loring , E. (2000). Assessment of dietary benefit/risk in Inuit communities. Research Report. Centre for Indigenous Peoples' Nutrition and Environment (CINE). Macdonald Campus, McGill University, Ste. Anne de Bellevue, QC.

Mahaffey KR. 2000. Recent advances in recognition of low-level methylmercury poisoning. Curr Opin Neurol 13(6):699-707

Needleman HL, McFarland C, Ness RB, Fienberg SE, Tobin MJ. 2002. Bone lead levels in adjudicated delinquents. A case control study. Neurotoxicol Teratol. 24(6):711-7.

Lebel J, Mergler D, Lucotte M. *et al.* 1996. Evidence of early nervous system dysfunction in Amazonian populations exposed to low-levels of methylmercury. NeuroTox 17:157-168

Lebel J, Roulet M, Mergler D, *et al.* 1997. Fish diet and mercury exposure in a riparian Amazonian population. Water, Air Soil Pollut 97:31-44

Tsubaki T, and Irukayama K. (eds). 1977. Minamata Disease. Methylmercury Poisoning in Minamata and Niigata, Japan. Elsevier/North Holland, New York

Weihe P, Hansen JC, Murata K, Debes F, Jorgensen P, Steuerwald U, White RF, Grandjean P. 2002. Neurobehavioral performance of Inuit children with increased prenatal exposure to methylmercury. *Int J Circumpolar Health*. 61:41-9.

Yoshizawa K, Rimm EB, Morris JS, *et al.* 2002. Mercury and the risk of coronary heart disease in men. N Engl J Med 347: 1755-1760.

# Dissociation of the Neurotoxicological and other Health Effects of Major Components of a Chemical Mixture Based upon Exposure Profiles in Arctic Human Populations Following *In utero* and Lactational Exposure in Rodents


## Project leader(s)

Ih Chu, Environmental and Occupational Toxicology Division, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, ON K1A 0L2; phone: (613) 957-1837, fax: (613) 957-8800, e-mail: ih_chu@hc-sc.gc.ca

## Project members

Wayne Bowers, Jamie Nakai, Al Yagminas, David Moir. Environmental and Occupational Toxicology Div, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, K1A 0L2


## Abstract


This study compared the effects of a chemical mixture (based on Arctic maternal blood profiles) against effects of major components of the mixture. Rats were exposed *in utero* and during lactation to the mixture (0.05 and 5.0 mg/kg), methylmercury (MeHg: 0.02 or 2.0 mg/kg), PCBs (0.011 or 1.1 mg/kg) or organochlorine pesticides (OCs: 0.019 or 1.9 mg//kg). Blood mercury levels were comparable in mixture and MeHg-exposed animals. High dose mixture or MeHg comparably decreased maternal and offspring body weight with no recovery of weight loss in mixture-exposed animals. Only female offspring recovered from high dose MeHg-induced weight loss. MeHg increased post-weaning mortality in males but this mortality was eliminated when MeHg was part of the mixture. Mixture-induced hyperactivity can be attributed to MeHg but MeHg masked the decreased activity produced by PCBs and OCs. The mixture-induced decrease in neuromuscular function in young rats reflects the combined impact of all mixture components while increased startle in high dose mixture offspring is not associated with any mixture component or additive effects of the components. These results indicate that some specific mixture effects can be attributed to specific mixture components while other effects are uniquely associated with combined exposure to mixture components.


## Key Project Messages

1. This study compared the toxicity of a chemical mixture based on blood contaminant profiles in Canadian Arctic populations with toxicity of major components of the mixture of chemicals

2. Maternal weight loss and reduced body weight in young offspring produced by the mixture can be accounted for by the methylmercury component of the mixture

3. Persistent body weight reductions after exposure to the mixture can be accounted for by methylmercury only in male offspring

4. Exposure to methylmercury alone increases post-weaning mortality in male offspring but methylmercury as part of the mixture produces no post-weaning mortality

5. The role of specific components of the mixture in mediating the effects of the mixture on neurobehavioural function depends on the specific behavioural function

6. The mixture produces neurobehavioural effects that are not evident after exposure to single components of the mixture and neurobehavioural effects of specific components of the mixture are not always evident after exposure to the mixture.

## Objectives

1. Compare the neurotoxicity of a chemical mixture based on profiles of these chemicals in blood of Arctic populations against the toxicity of major chemical components of this mixture (PCBs, organochlorine pesticides and methyl mercury).

2. Determine if developmental, systemic and neurotoxicological effects of the chemical mixture can be attributed to specific components of the chemical mixture.

3. Determine if concurrent exposure to all components of the mixture alters the toxicity of specific components of the mixture.

## Introduction

Canadian Arctic populations are exposed to a range of persistent environmental pollutants and many of these pollutants are suspected of producing neurotoxicological effects. Studies in human populations have identified relationships between exposure to persistent organic pollutants and neurological and behavioural disturbances in infants and children (Jacobson and Jacobson, 1997;Koopman-Esseboom et al., 1996;Stewart et al., 2003). Studies in animals have confirmed that contaminants like polychlorinated biphenyls (PCBs), mercury, and organochlorine (OC) pesticides can disrupt a variety of neurobehavioural functions. Examples include PCB-induced deficits in motor activity (Hany et al., 1999), learning (Lilienthal and Winneke, 1991), memory and attention (Schantz et al., 1997), neuromuscular development (Bernhoft et al., 1994), and sensory functions (Crofton and Rice, 1999).

While Canadian Arctic populations are exposed to environmental contaminants similar to other populations, the exposure profile differs from southern populations and there is relatively little toxicological data on the effects of combined exposure to the mixture of chemicals found in this population. Previous work that we have conducted (Bowers et al., 2003) examined the toxicological effects in rodents of *in utero* and lactational exposure to a mixture of 26 chemicals (PCBs, organochlorine pesticides and methyl mercury) found in maternal blood of Canadian Arctic populations. Results indicated that the chemical mixture altered growth and development, appearance of early neurodevelopmental measures, and produced changes in behavioural performance in young and mature animals. The mixture also reduced both maternal and offspring serum thyroid hormones $T_4$ and $T_3$ levels. Dosing with the mixture produced dose-dependent increases in blood mercury concentrations in both pregnant rats as well as their offspring and the lowest mixture dose produced offspring blood mercury levels (13 ug/L) that approximated concentrations of mercury found in umbilical cord blood in Arctic infants (22.7 ug/L). Analysis of organochlorine residue levels in maternal blood revealed that the chemical profile in maternal blood was comparable to the original dosing mixture which was based on blood profiles from Arctic maternal blood.

Epidemiological studies in this population has provided some evidence suggesting that specific neurobehavioural disturbances may be differentially correlated with specific contaminants. For instance, (Muckle et al., 2003) have reported preliminary results that prenatal PCB levels are negatively correlated with infant performance on tests of memory (visual recognition memory test) but prenatal methyl mercury levels are negatively correlated with a separate measure (the A-not-B test) that is thought to reflect early executive functioning. Further, while PCB 153 is correlated with reduced birth and a small decrease in gestation period, lead appears to be correlated with measures of information processing speed. Though intriguing, these correlations between specific chemicals found in maternal blood and specific neurobehavioural measures in infants cannot dissociate the impact of other chemicals found in maternal blood. Laboratory studies, however, can control chemical exposures and thus can directly evaluate the relationship between specific components of the chemical mixture found in Arctic maternal blood and specific behavioural functions. The current study was designed to determine if specific

**Table 1:** Blood Mercury levels in offspring dosed during gestation and lactation (ug/L whole blood)

| | Days of Age | | |
|---|---|---|---|
| **Dose** | **5** | **22** | **30** |
| **Vehicle** | 10.72 (1.46) | 3.914 (0.43) | 11.241 (0.93) |
| **0.02 Hg** | 328.12 (31.87) | 22.59 (1.79) | 20.27 (1.57) |
| **0.05 Mix** | 267.33 (20.07) | 23.64 (3.45) | 17.42 (1.41) |
| **2.0 Hg** | 46894.12 (8142) | 3447.54 (587.9) | 1402.7 (315.5) |
| **5.0 Mix** | 30757.00 (8249) | 2976.07 (708.3) | 1402.4 (392.7) |

toxicological effects of the chemical mixture that mimics Arctic maternal blood profiles are associated with specific components of the chemical mixture and whether concurrent exposure to all components of the mixture can modify the toxicity of major components of the mixture. This study compared the effects of the complete mixture with the effects of three major components of the mixture (the PCB component, the organochlorine pesticide component, and the methyl mercury component).

## Activities

## In 2003-2004

The animal phase of the study has been completed and all tissues collected for subsequent analysis. Rats were dosed throughout gestation and lactation with corn oil vehicle, the complete mixture (0.05 or 5 mg/kg) or equivalent doses of its three major components: methyl mercury (MeHg- 0.02 or 2 mg/kg), PCBs (0.011 or 1.1 mg/kg) or organochlorine pesticides (OC - 0.019 or 1.9 mg/kg). Offspring were dosed *in utero* and via lactation and were never directly exposed to the chemicals. Subsets of animals within each litter were sacrificed at post-natal day (PND) 4, 22, 30, 100 and 175 and blood, brain and liver collected for residue analysis, neurochemistry, and liver enzyme analysis. Dams were sacrificed immediately after weaning and blood, brain and liver were collected for residue analysis, cholinesterase activity and liver enzyme analysis. Behavioural tests were conducted on subsets of offspring starting at PND 10 and with the final test at PND 160. Behavioural tests included: grip strength (PND 12 and 15), motor activity (PND 16 and 51), rotarod testing (PND 29), acoustic startle with prepulse inhibition (PND 21 and 49), visual discrimination learning (PND 100-130) and Morris Water Maze spatial learning (PND 70-100). Only a limited set of the behavioural data is available and presented here.

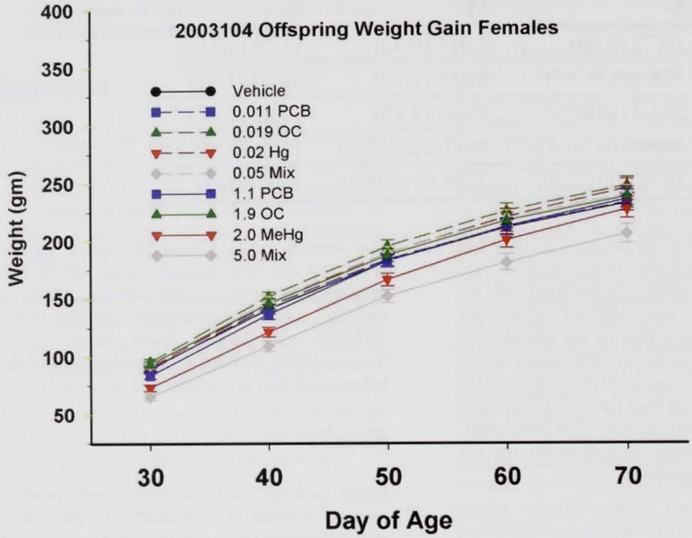
## Results

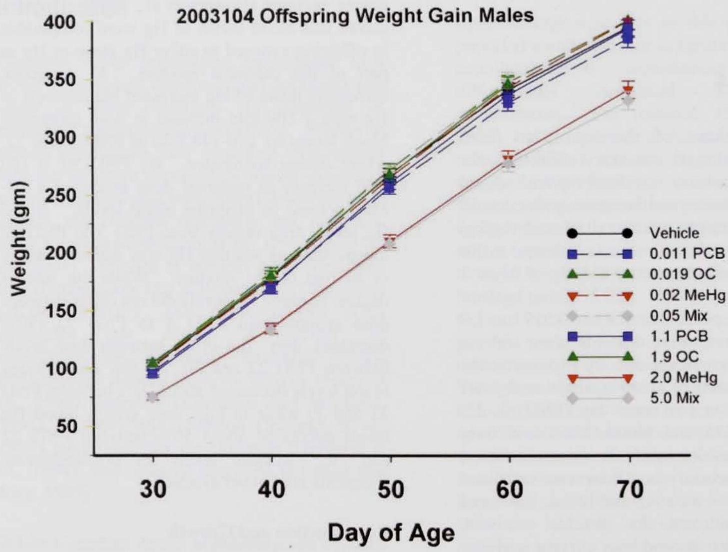
Blood mercury levels in control and low-dose mixture animals is comparable to previously reported results using this chemical mixture and dosing regimen (Bowers et al., 2003). Table 1 shows that blood levels of Hg were comparable in offspring exposed to either Hg alone or Hg as part of the chemical mixture. As expected, increasing doses of Hg increased blood levels of Hg with a 100-fold increase in dose increasing blood levels by 120-140 fold at PND 5 and 22, where dosing terminated. By PND 30, a 100 fold increase in maternal dose produced a 70-fold increase in offspring blood levels. Blood Hg levels drop rapidly from PND 5 to PND 22 independent of whether Hg was delivered alone or as part of the mixture. While the rate of decline in blood Hg levels did not differ between dose groups from PND 4 to PND 22 ~(90% decrease), they did differ between dose levels between PND 22 and 30. In low dose groups blood levels decreased about 10% between PND 22 and 30 while in high dose groups blood Hg levels decreased about 50% between PND 22 and 30. Residue levels for organochlorine chemicals are not yet available.

### Reproduction and Growth

No treatment altered maternal weight gains during gestation, though there was a small non-

**Figure1.** Body weight gain in female (top) and male (bottom) offspring from weaning to maturity. (Mean weight ± s.e.m).



significant decrease in maternal weight gain near parturition. Both the high mixture dose and the high MeHg dose decreased maternal body weight during lactation and these losses persisted until dams were sacrificed. Similar to dams, offspring weight gain was reduced in animals exposed to the high doses of the mixture and MeHg (see Figure 1). The reduced body weight persisted into adulthood in mixture-exposed offspring. Exposure to MeHg produced comparable reductions in body weight; however, while reduced body weights persisted into adulthood in male offspring, female offspring had recovered by PND 40-50. No other dose was associated with altered body weight. The high mixture and MeHg doses also produced small increases in offspring mortality rates (15-18%) in the early post-natal period (up to PND 5). Post-weaning mortalities are very unusual in our laboratory and we observed no mortalities in any dose group except offspring exposed to the high dose of MeHg (9% mortality rate). Moreover, these mortalities occurred primarily in male offspring, and occurred even after animals reached maturity.

Testing of neuromuscular strength (grip strength) revealed that the high dose of the mixture decreased grip strength at PND 12 and 15

**Figure 2.** Grip strength at PND 12 and 15 (Mean ($log_{10}$ transformed) grip time (± s.e.m).

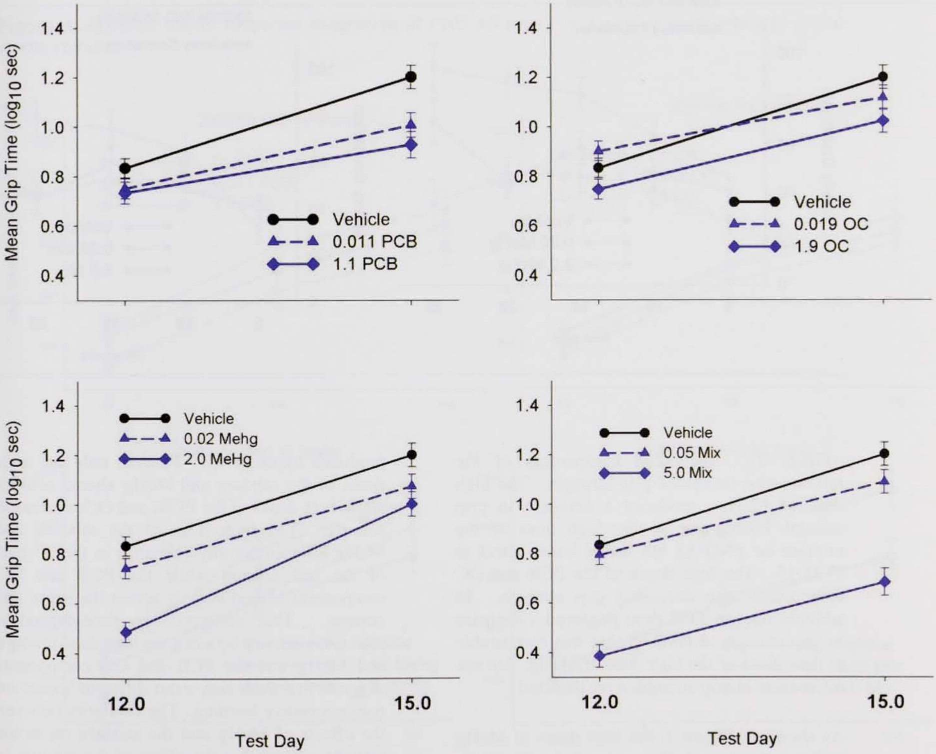
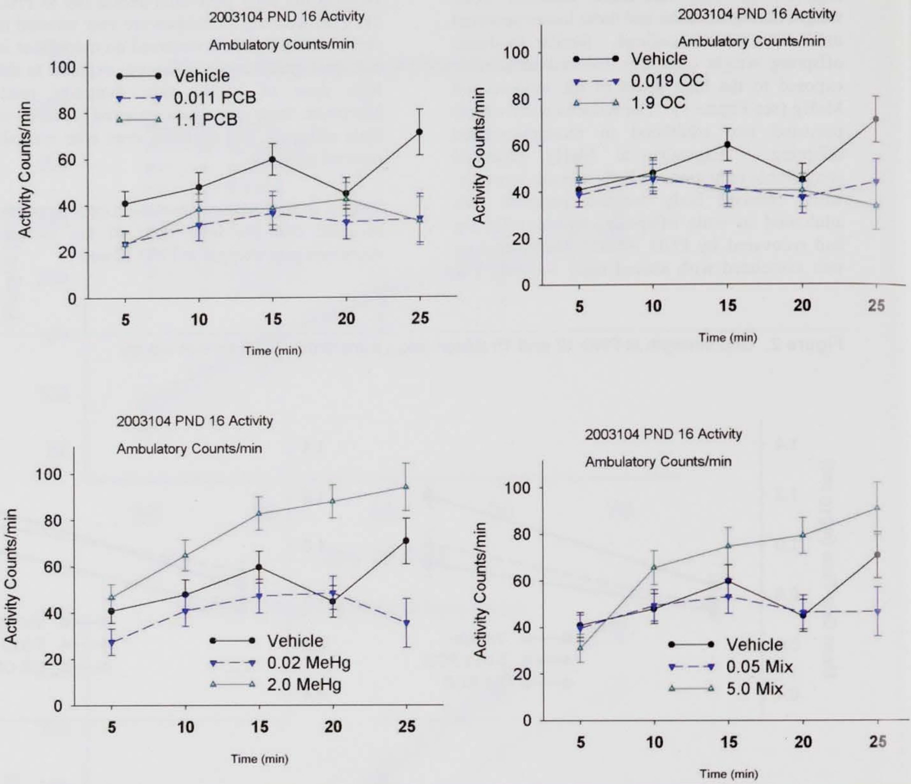


**Figure 3.** Motor activity counts (mean ± s.e.m) in animals at PND 16.



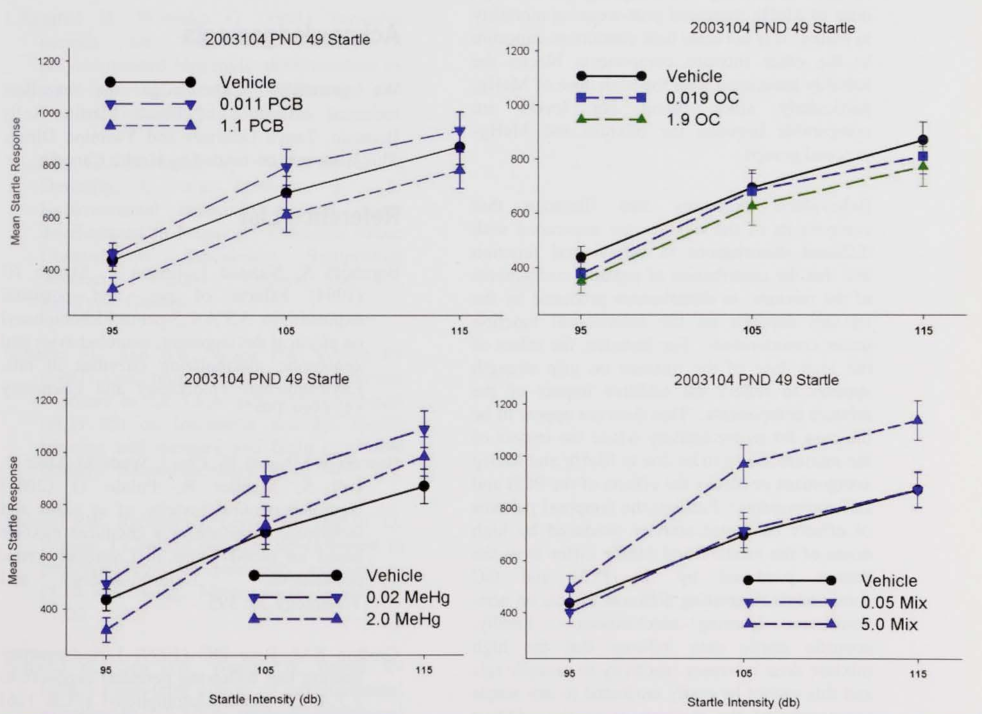

(Figure 2). Individual components of the mixture also decreased grip strength. The high dose of MeHg produced a decrease in grip strength comparable to the high dose of the mixture on PND 12 but had a lesser effect at PND 15. The high doses of the PCB and OC components also decreased grip strength. In addition the low PCB dose produced a decrease in grip strength at PND 15 that was comparable to the effects of the high dose of MeHg. No sex differences in grip strength were detected

As shown in Figure 3, the high doses of MeHg and the mixture both produced hyperactivity while the PCBs and OCs components both produced hypoactivity. Further, only the high doses of the mixture and MeHg altered activity while both doses of the PCBs and OCs decreased activity. The high dose of the mixture and MeHg affected activity primarily in the 2$^{nd}$ half of the test session while the PCB and OC components altered activity across the entire test session. This difference in time-dependent effects on activity between the high dose mixture and MeHg and the PCB and OC components suggests that these may exert different impact on non-associative learning. The similarity between the effects of MeHg and the mixture on motor activity suggest that the effect of the mixture is associated primarily with MeHg and MeHg appears to completely mask the effects of the PCB or OC components of the mixture on motor activity. It is unlikely that these effects are primarily related to disturbances in motoric capacity since a separate test of motor function (rotarod testing) did not detect any treatment-related effects.

Acoustic startle testing provides a measure of sensory reactivity to sound and prepulse inhibition of startle provides a measure of brain processing involved in the integration of multiple sensory inputs. Figure 4 shows that the high dose of the mixture increased startle responding at the two highest startle intensities while the low dose of the mixture had no impact. In contrast, the low dose of MeHg increased startle responding at the two highest startle intensities while the high dose of MeHg had no effects. The high doses of the PCBs and OCs produced small, marginally significant reductions in startle responding. Prepulse inhibition was not affected by any dose.

Analysis of plasma butylcholinesterase activity from PND 4 offspring revealed only a small decrease in enzyme activity in the low-dose MeHg-exposed animals. Similarly brain acetylcholinesterase was not affected by any treatment. These results are not surprising as the cholinergic system has not completely developed at PND 4. Because cholinergic systems appear early in brain development and are thought to play an important role in the developing nervous system, these data suggest that none of the treatments produce any signs of overt alterations in the development of cholinergic neural tissues.

**Figure 4.** Acoustic startle response magnitude at PND 49 (mean ± s.e.m) at each intensity of the startle stimulus.



## Discussion and Conclusions

One of our objectives was to determine if specific toxicological effects of the chemical mixture could be attributed to specific components of the chemical mixture. The preliminary data reported here indicate that different components of the mixture appear to be associated with separate toxicological outcomes while some outcomes cannot be easily attributed to any single component. For instance, the decreases in maternal body weight and body weight in young offspring after exposure to the chemical mixture can be attributed to the MeHg component of the mixture. However, there was no indication that mixture-exposed offspring recovered body weight losses as they approached maturity while MeHg-exposed females did recover from body weight losses. Thus, at least for females, the MeHg component of the mixture cannot account for the persistent decreased body weight in females after exposure to the mixture. Similarly, there was no post-weaning mortality in any mixture exposed offspring yet the high dose of MeHg increased post-weaning mortality in males. It is not clear how concurrent exposure to the other mixture components blocks the lethality associated with the high dose of MeHg, particularly since blood Hg levels are comparable between the mixture and MeHg-exposed groups.

Behavioural measures also illustrate that components of the mixture are associated with different disturbances in behavioural function and that the contribution of separate components of the mixture to disturbances produced by the mixture depends on the behavioural function under consideration. For instance, the effect of the high dose of the mixture on grip strength appears to reflect the additive impact of the mixture components. This does not appear to be the case for motor activity where the impact of the mixture seems to be due to MeHg and MeHg antagonizes or blocks the effects of the PCB and OC components. Further, the temporal patterns of effects on motor activity produced by high doses of the mixture and MeHg differ from the pattern produced by the PCB and OC components suggesting different effects on non-associative learning mechanisms. Finally, acoustic startle data indicate that the high mixture dose increases reactivity in juvenile rats and this cannot be easily attributed to any single component of the mixture or to the additive effect of the mixture components. Indeed, it appears that concurrent exposure to all components of the mixture at the low dose blocks the ability of the low dose of MeHg to increase startle responses.

Taken together, these data suggest that developmental and neurotoxicological effects of a chemical mixture that was based on blood contaminant profiles in Arctic populations may not be adequately predicted from the effects of components of the mixture. Indeed, for some measures the relationship between specific components (e.g., MeHg and mortality) is altered when exposure occurs as part of the complete mixture while for other measures (e.g., startle) the effects of the mixture would not be expected based on results for any of the components tested.

## Expected Project Completion Date

March 2005

## Acknowledgements

We gratefully acknowledge the excellent technical assistance of Bruce Martin, Kelly Brennan, Tanya Odorizzi and Yasmine Dirieh. This work was co-funded by Health Canada.

## Reference List

Bernhoft A, Nafstad I, Engen P, Skaare JU (1994) Effects of pre- and postnatal exposure to 3,3',4,4',5-pentachlorobiphenyl on physical development, neurobehavior and xenobiotic metabolizing enzymes in rats. Environmental Toxicology and Chemistry 13: 1589-1597

Bowers WJ, Nakai JS, Chu I, Wade M, Moir D, Gill S, Mueller R, Pulido O (2003) Neurobehavioural toxicity of *in utero* and lactational exposure to a chemical mixture based on blood levels in Canadian Arctic populations. Neurotoxicology and Teratology 25: 395

Crofton KM, Rice DC (1999) Low-frequency hearing loss following perinatal exposure to 3,3',4,4',5- pentachlorobiphenyl (PCB 126) in rats. Neurotoxicology and Teratology 21: 299-301

Hany J, Lilienthal H, Roth-Harer A, Ostendorp G, Heinzow B, Winneke G (1999) Behavioral effects following single and combined maternal exposure to PCB 77 (3,4,3',4'-tetrachlorobiphenyl) and PCB 47 (2,4,2',4'- tetrachlorobiphenyl) in rats. Neurotoxicology and Teratology 21: 147-156

Jacobson JL, Jacobson SW (1997) Evidence for PCBs as neurodevelopmental toxicants in humans. Neurotoxicology 18: 415-424

Koopman-Esseboom C, Weisglas-Kuperus N, de Ridder MA, van der Paauw GC, Tuinstra LG, Sauer PJ (1996) Effects of polychlorinated biphenyl/dioxin exposure and feeding type on infants' mental and psychomotor development. Pediatrics 97: 700-706

Lilienthal H, Winneke G (1991) Sensitive periods for behavioral toxicity of polychlorinated biphenyls: determination by cross-fostering in rats. Fundamental and Applied Toxicology 17: 368-375

Muckle, G., Jacobson, S. W., Ayotte, P., Dewailly, E., and Jacobson, J. L. Environmental contaminants and infant development in Nunavik. Canadian Arctic Contaminants Assessment Symposium Abstracts . 2003. Ottawa, Mar 4-7. Ref Type: Generic

Schantz SL, Seo BW, Wong PW, Pessah IN (1997) Long-term effects of developmental exposure to 2,2',3,5',6- pentachlorobiphenyl (PCB 95) on locomotor activity, spatial learning and memory and brain ryanodine binding. Neurotoxicology 18: 457-467

Stewart PW, Reihman J, Lonky EI, Darvill TJ, Pagano J (2003) Cognitive development in preschool children prenatally exposed to PCBs and MeHg. Neurotoxicol Teratol 25: 11-22

Schantz SL, Seo BW, Wong PW, Pessah IN (1997) Long-term effects of developmental exposure to 2,2',3,5',6- pentachlorobiphenyl (PCB 95) on locomotor activity, spatial learning and memory and brain ryanodine binding. Neurotoxicology 18: 457-467

Stewart PW, Reihman J, Lonky EI, Darvill TJ, Pagano J (2003) Cognitive development in preschool children prenatally exposed to PCBs and MeHg. Neurotoxicol Teratol 25: 11-22

# Health Effects of Chlordane-Related Food Contaminants: Characterization of Altered Target Organ Gene Expression Using Oligonucleotide Microarrays


## Project leader(s)

Dr. Ivan Curran, Health Canada Contact information: Toxicology Research Division, Postal Locator 2204D2, Bureau of Chemical Safety, Food Directorate, HPFB, Health Canada, Ottawa, ON K1A 0L2; phone: (613) 957-3052; fax: (613) 941-6959; e-mail: ivan_curran@hc-sc.gc.ca

## Project members

Ms. Andrée Hierlihy, MSc., Toxicology Research Division, Bureau of Chemical Safety, HPFB (Biologist, Microarray technologist); Dr. Genevieve Bondy, Toxicology Research Division, Bureau of Chemical Safety, Food Directorate, Health Canada (Toxicologist); Mrs. Susan Gurofsky, Toxicology Research Division (Molecular toxicology technical support with I. Curran)



## Abstract

Ongoing studies at Health Canada have provided toxicological data for chlordane-related food contaminants found in traditional foods. Based on these rodent studies the health effects of trans-nonachlor, cis-nonachlor and oxychlordane have been characterized in relation to the levels in fat and other tissues. The proposed research will address the question of how these contaminants cause changes in tissues that lead to adverse health effects. DNA Microarray technology used to examine multiple transcription events is a recent innovation that allows toxicologists to examine many cellular events simultaneously in a single tissue and has been termed "toxicogenomics". Using this technology, archived tissues from rats treated with chlordane, trans-nonachlor, cis-nonachlor and oxychlordane will be surveyed for relative changes in gene expression. The project will lead to a better understanding of the action of chlordane and some of its major constituents *in vivo* and will consequently contribute to an understanding of how health effects in rodent studies may relate to effects on humans ingesting these contaminants in foods.


## Key Project Messages

Although microarray experiments and data analysis are in progress, the study will address the following questions in the future:

1. What differences in gene expression are observed in rodent livers treated with a dose of 2,5mg/kg BW of chlordane, trans-nonachlor, cis – nonachlor chlordane, oxychlordane versus control samples?
2. Are there changes in expression for unique genes which would explain the higher toxicity of trans-nonachlor observed in female rats than in male rats.
3. Do observed changes in gene expression correlate to the relative toxicity of chlordane and its components?
4. Are there changes in expression for in groups of genes or unique genes for each compound or metabolite which would aid in profiling and identifying potential biomarkers of chlordane effects for possible applications in biomonitoring of Northern populations?
5. Is gene expression affected at a levels lower than NOEL's previously reported for these compounds?

## Objectives

- Short-term: To assess changes in gene expression in archived liver tissues caused by the exposure of male and female rats to 2.5 mg/kg/day chlordane, trans-nonachlor, cis-nonachlor or oxychlordane by gavage for 28 consecutive days.
- Long-term: To provide data that will clarify the mechanisms by which chlordane-related food contaminants cause adverse health effects. The data could also provide a fingerprint of effects on tissue leading to characterization of molecular changes typical of exposure to chlordane and chlordane contaminants for future identification. This information will be used to interpret the results of rodent toxicology studies, ensuring that regulatory decisions regarding safe levels of chlordane contaminants in human foods are based on an understanding of how these chemicals act on mammalian cells

## Introduction

In Canada, current concerns about chlordane focus on human exposure to chlordane-related contaminants in foods derived from the Arctic marine food chain (Andersen et al. 2001, Kuhnlein et al. 1995, Muir et al., 1988). Most chlordane toxicity studies (U.S. DHHS, 1994) utilize the parent mixture regardless of the possibility that a specific residue may be substantially more or less toxic than related residues. Studies done at Health Canada for the Northern Contaminants Program have focused on the relative toxicity of the most abundant chlordane-related residues found in foods, specifically cis- and trans-nonachlor and oxychlordane, in comparison to the technical chlordane mixture (Bondy et al.2000, Bondy et al. 2003, Bondy et al. 2004) . These studies identified physiological and histo-pathological changes in the liver, thyroid and immune systems of treated rats and confirmed that the nonachlors and chlordanes were metabolized to the more toxic and bioaccumulative oxychlordane. Female rats were more sensitive to these contaminants than males and accumulated higher residue levels in their adipose tissues (Bondy et al. 2003). The cellular effects of cis-nonachlor, trans-nonachlor or oxychlordane on liver tissues from male and female treated rats will be followed by monitoring changes in gene expression using oligonucleotide microarrays.

In previous studies male and female rats received purified trans-nonachlor, oxychlordane or trans-chlordane by gavage for 28 consecutive days (Bondy et al.2000, Bondy et al. 2003) . Preliminary studies using archived liver tissue from female rats dosed with 25 mg/kg/day trans-nonachlor or cis-nonachlor indicate that oligonucleotide microarrays can identify cellular changes in tissues from rats treated with these contaminants (I. Curran unpublished data). The results showed a greater than 2-fold increase in mRNA expression in selected genes involved in cellular transport, cellular metabolism, signal transduction, cell cycle and xenobiotic metabolism. Based on this work, the practical aspects of applying oligonucleotide microarray technology to tissues from toxicological studies have been addressed producing encouraging results.

Proposed work involves isolation of total RNA from archived liver tissues from male and female Sprague-Dawley rats treated with 2.5 mg/kg trans-nonachlor, cis-nonachlor or oxychlordane for 28 consecutive days. Purified cDNA will be prepared from total RNA samples and converted into cRNA by in vitro transcription. Biotin-labelled cRNA probes will be hybridized to rat oligo microarrays (1152 genes and EST's) from Mergen Ltd. Data from male and female rats and from trans-nonachlor, cis-nonachlor and oxychlordane treatment groups will be compared for differences in the expression 1,152 rat genes covering all aspects of cellular function. For selected genes showing a minimum 2-fold increase/decrease in gene expression in treated liver samples relative to control liver samples, microarray results will be verified using RT-PCR. Changes in protein expression for selected gene products will be analyzed using western blots of protein extracts from liver tissues. Data from these analyses will provide insight into the

Table 1. Complete list of genes that show a >2-fold increase in mRNA expression in oxychlordane treated liver vs. control liver as determined by Micro-array analysis rat chip (Mergen RO1).

| | Genebank | Unigene | Description |
|---|---|---|---|
| # | X56661 | Rn.10316 | gastrin-releasing peptide receptor |
| | X72341 | Rn.22609 | potassium inwardly-rectifying channel, subfamily J |
| | D14839 | Rn.25174 | fibroblast growth factor 9 |
| # | M22412 | Rn.9734 | potassium (K+) channel protein, slowly activating (Isk) |
| | U29881 | Rn.5887 | low affinity Na-dependent glucose transporter (SGLT2) mRNA, complete cds |
| # | J02701 | Rn.8925 | ATPase Na+/K+ transporting beta 1 polypeptide |
| | Z30663 | Rn.10339 | chloride channel (putative) 2313bp |
| # | D83044 | Rn.10555 | organic cation transporter OCT2r |
| | M37828 | Rn.10034 | cytochrome P450 mRNA, complete cds |
| | M77345 | Rn.11196 | solute carrier family 3, member 1 |
| | L13257 | Rn.37519 | solute carrier family 17 (sodium/hydrogen exchanger), member 2 |
| & | AB010467 | Rn.29977 | multidrug resistance-associated protein (MRP)-like protein-2 (MLP-2), complete cds |
| | X70497 | Rn.9808 | amiloride sensitive Na+ channel protein |
| & | AF001898 | Rn.6132 | aldehyde dehydrogenase 1 (phenobarbitol inducible) |
| # | X66494 | Rn.10336 | choline transporter |
| # | X67948 | Rn.1618 | aquaporin 1 (aquaporin channel forming integral protein 28 (CHIP)) |
| # | D63149 | Rn.2593 | proton-coupled peptide transporter PEPT2, complete cds |
| # | AJ010750 | Rn.21667 | Castration Induced Prostatic Apoptosis Related protein-1 (CIPAR-1) |
| | D00680 | Rn.1491 | plasma glutathione peroxidase precursor, complete cds |
| & | M34452 | Rn.2287 | cytochrome P450, 2b19 |
| | M23995 | Rn.6132 | aldehyde dehydrogenase 1 (phenobarbitol inducible) |
| # | D13906 | Rn.44378 | aquaporin 2 |
| # | D63772 | Rn.6384 | solute carrier family 1 A1 (brain glutamate transporter) |
| | X77932 | Rn.9807 | sodium channel, nonvoltage-gated 1, beta (epithelial) |
| | U22424 | Rn.10186 | hydroxysteroid dehydrogenase, 11 beta type 2 |
| # | AF058714 | Rn.10821 | sodium-dicarboxylate cotransporter SDCT1 mRNA, complete cds |
| | L35108 | Rn.11109 | water channel protein (AQP3) gene, complete cds |
| | AF022247 | Rn.3236 | intrinsic factor-B12 receptor precursor (CUBILIN) mRNA, complete cds |
| # | AF022819 | Rn.42895 | putative potassium channel TWIK mRNA, complete cds |
| # | X70062 | Rn.6700 | gamma subunit of sodium potassium ATPase |

# Total liver RNA analyzed via RT-PCR for gene expression changes using gene specific primer pairs

& Previous micro-array experiments with chlordane, trans-nonachlor or cis –nonachlor (25mg/kg BW) have detected changes in mRNA expression of these targets.

relationship between clinical toxicity and cellular responses. These data will be used to elucidate the structure-function differences observed between related chlordane contaminants and to more closely examine pathways associated with sex-related differences in response to the nonachlors and oxychlordane.

## Activities

### In 2003-2004

The project began in October of 2003 with the isolation of RNA from archived tissues. Briefly, total RNA was isolated from archived liver tissues from male and female Sprague-Dawley rats (n=6) treated with 2.5 mg/kg trans-nonachlor, cis-nonachlor, or oxychlordane for 28 consecutive days. Total RNA samples were pooled for analysis (n=6). RNA from each pool (20 ug) was converted to double-stranded cDNA using an oligo-dT primer containing a T7 promoter. Following phenol/chloroform extraction, purified cDNA was converted into cRNA. Biotin-labelled CTP was used to label the cRNA samples/probes. Labelled probes were chemically sheared into fragments of <100bp and hybridized to Mergen ExpressChip TM (Mergen LTD) overnight in a 30°C hybridization chamber (one sample per slide). Experiments were repeated in triplicate and pairwise comparisons were made between treated and control slides on the basis of median normalized signals. Verification of microarray gene expression results was accomplished by reverse transcriptase-polymerase chain reaction (RT-PCR). Primers were designed for a subset of genes that exhibited a minimum 2-fold increase in the treatment vs. control groups. Using pooled samples of total RNA which had been DNaseI treated to remove possible DNA contamination, RT was performed followed by PCR amplification of target sequences using Taq polymerase. Optimal conditions for each primer set were determined by cycle and temperature. Semi-quantitative analysis of gene expression was obtained by comparing relative amounts of cDNA produced by gene specific primers to the cDNA produced for the housekeeping gene, G3PDH.

Preliminary data analysis on gene expression has been completed for microarray experiments on oxychlordane treated samples vs control samples. Analysis of data from Mergen microarray chips for chlordane, trans-nonachlor, and cis-nonachlor are continuing.

## Results

Microarray analysis of pooled RNA from oxychlordane treated male and female rat livers found 2.6% (30/1152) of genes screened had a >2-fold change in gene expression (Table 1).

Analysis using RT-PCR for relative gene expression of 16 of the 30 detected genes by micro-array, found 4 genes to be changed in males and 3 genes in females. PEPT2 and SDCT-1 were elevated in male rats livers while, gamma ATPase and TWIK levels were depressed (Fig.1). Female livers expressed higher levels of SDCT-1 and gamma ATPase, while PEPT2 expression was repressed significantly versus control levels. The affected genes were primarily involved in ion and solute transport, and xenobiotic metabolism (Table 1, Fig 1).

Fig. 1 Changes in gene expression from genes indicated in Table 1. Film negative images of EthBr stained 2.5% agarose gel of RT-PCR products to specific primer pairs.

Previous microarray studies with chlordane, trans-nonachlor or cis-nonachlor dosed at 25mg/kg BW (10 fold higher dose) had found gene expression affected in the 12 genes listed in Table 2. RT-PCR analysis with gene specific primers for these previously affected genes found only 3 genes to be affected in oxychlordane treated male rat livers and 5 genes were changed in oxychlordane treated female rat livers (Fig.2). The genes effected were all involved in xenobiotic metabolism with the exception of IGF-BP1.

Fig. 2 Representitive negative images of RT-PCR products generated using gene specific primer pairs. These targeted genes were observed to change in chlordane, trans-nonachlor or cis – nonachlor treated rat livers (high dose, 25mg/kg

**Table 2.** Rat liver transcript levels monitored via microarrays previously observed to be affected by treatment with chlordane, trans-nonachlor or cis-nonachlor which are precursors to oxychlordane.

| | |
|---|---|
| p450MD | p450MD cytochrome P-450 |
| Glucagon R | glucagon receptor mRNA, complete cds |
| HIP | heat shock related protein |
| 17beta HSDII | 17-beta hydroxysteroid dehydrogenase type 2 |
| BrainDigCP | brain digoxin carrier protein mRNA, complete cds |
| ALDH | aldehyde dehydrogenase 1 (phenobarbitol inducible) |
| IGF-BP1 | insulin-like growth factor binding protein 1 |
| Thioredoxin | thioredoxin reductase (TrxR2) mRNA, nuclear gene encoding mitochondrial protein |
| MLP-2 | multidrug resistance-associated protein (MRP)-like protein-2 (MLP-2), complete cds |
| CYP3A | CYP3 mRNA |
| DNA topoII | DNA topoisomerase II |
| CYP2B19 | cytochrome P450, 2b19 |

BW) and were used here to assess effects of oxychlordane.

The induced metabolic genes ALDH, CYP3A and CYP2B19 were observed to be primarily microsomal and respond in what has typically been classified as a phenobarbitol-type response.

## Discussion and Conclusions

Several genes were observed to be gender specific in their response to the chlordane metabolite, oxychlordane. The transcription of P450MD and IGF-BP1 were observed to be repressed in female rat livers, while no change in expression was observed in male rat livers. Conversely, gamma ATPase was elevated in female rats and repressed in males. The opposite effect is observed in PEPT-2 expression as female transcripts decreased and male levels of transcript increased. The gene TWIK was also depressed in male rat livers while no change was seen in female rats. Previous observations indicate that there are differences in enzyme induction profiles and residue levels found in livers of male and female rats, probably as a result of sex-related metabolic differences (Bondy et al.(2000) , Bondy et al. (2003), Bondy etal. (2004)) . The differences in transcript induction/repression observed in liver genes of male and female rats to the metabolite oxychlordane give a insight into potential mechanisms of action of these compounds. Further investigation is required to assess whether the changes in transcription observed with gamma ATPase, PEPT-2, P450MD, IGF-BP1 and TWIK for both males and females translate into similar changes in protein levels.

Microarray methods can be used to survey and screen thousands of genes to determine changes in gene transcript levels as a result of treatment with persistent organic pollutant (POP) such as chlordane and its metabolite oxychlordane. These changes may potentially be used to form a fingerprint for identifying and classifying various toxins and POPs. Further conclusions based on this study await completion of the microarray data analysis of chlordane, trans-nonachlor, and cis-nonachlor samples.

## Expected Project Completion Date

Microarray analysis: September 2004.

RT-PCR verification of targeted genes: November 2004.

Data summary and statistical analysis: January 2005.

## Acknowledgements

The following individuals have made valuable contributions to this study: Judy Kwan, Karlene Smith and James Green.

## Reference List

Andersen, G., K.M. Kovacs, C. Lydersen, J.U. Skaare, I. Gjertz and B.M. Jessen. 2001. Concentration and patterns of organochlorine contaminants in white whales (Delphinaterus leucas) from Svalbard, Norway. Sci. Total Enviorn. 264:267-281.

Kuhnlien H.V., O. Receveur, D.C.G. Muir, H.M. Chan, amd R. Soueida. 1995. Arctic indigenous women consume greater than acceptable amounts of organochlorines. J Nutr. 125:2501-2510.

Muir, D. C. G., R. J. Norstrum, M. Simon. 1988. Organochlorine contaminants in Arctic marine food chains: Accumulations of specific poly-chlorinated biphenyls and chlordane-related compounds. Environ. Sci. Technol. 22: 1071-1079.

U.S. Department of Health and Human Services. 1994. Toxicological profile for chlordane (update). Agency for Toxic Substances and Disease Registry. TP-93/03.

Bondy, G. S., W. H Newsome, C. L. Armstrong, C. A. M. Suzuki, J. Doucet, S. Fernie, S. L. Hierlihy, M. M. Feeley and M.G. Barker. 2000. Trans-nonachlor, cis-nonchlor toxicity in Sprague Dawley rats: comparison with technical chlordane. Toxicol. Sci., 58: 386-398.

Bondy, G.S., C. Armstrong, L. Coady, J. Doucet, P. Robertson, M. Feeley and M.G. Barker.2003. Toxicity of the chlordane metabolite in female rats: clinical and histopathological changes. Food Chem. Toxicol. 41:291-301.

Bondy, G.S., I. Curran, J. Doucet, C. Armstrong, L. Coady, S.L. Hierlihy, S. Fernie, P. Robertson and M. Barker. Toxicity of trans-nonachlor to Sprague-Dawley rats in a 90-day feeding study. 42:1015-1027.

# Effects of Exposure to Organochlorines on the Infectious Diseases Incidence of Inuit Preschool Children


## Project leader(s)

Éric Dewailly Public Health Research Unit-CHUQ (CHUL) 945, Wolfe, 2nd floor Sainte-Foy, QC G1V 5B3; Phone: (418) 650-5115 ext 5240; Fax: (418) 654-3132; E-mail: eric.dewailly@inspq.qc.ca

## Project members

Frédéric Dallaire, Carole Vézina, Gina Muckle, Suzanne Bruneau, and Pierre Ayotte; All from the Public Health Research Unit-CHUQ (CHUL) and Laval University, Québec



## Abstract

The aim of this study was to identify an association between prenatal exposure to OCs and acute respiratory infections during the first five years of life. We reviewed the medical chart of 343 inuit children from Nunavik to evaluate the incidence rate of acute respiratory infections during the first 5 years of life. Using Poisson regression, we computed the association between prenatal exposure to PCBs (PCB congener 153 concentration in cord blood) and the rate of respiratory infections. We observed that children in the higher quartiles of exposure had a significantly higher incidence rate of outpatient visits for acute otitis media (AOM) and lower respiratory infections (LRTIs), but not for upper respiratory infections (URTIs). The association between AOM and exposure to PCB adopted a dose-response pattern. If the association observed in this population is causal, exposure to OCs during development would be responsible for a significant proportion of respiratory infectious episodes in these children.


## Key Project Messages

1. This study investigates possible detrimental effects on the immune system of Inuit preschool children that may be induced by prenatal exposure to persistent environmental contaminants such as organochlorine compounds.
2. Children exposed to higher level of PCBs during their development had more episodes of otitis and lower respiratory tract infections, such as bronchitis and pneumonia, compared to children exposed to lower level.
3. High exposure to PCB during pregnancy could be responsible for a significant number of acute childhood infections in this population.

## Objectives

### Main objective

The main objective of this project is to evaluate the effect of exposure to organochlorines on the infectious diseases incidence of Inuit preschool children.

### Specific objectives

1. To determine the incidence of infectious diseases during the first 5 years of life.
2. To assess the impact of prenatal exposure to OCs on the incidence of infections.

## Introduction

It is well known that Inuit children from Canada, United States and Greenland suffer from a high incidence of respiratory infections, and many authors have identified higher rates of ear infections and lower respiratory tract infections (LRTIs) in Inuit, compared to control Caucasian populations (Banerji et al. 2001; Bluestone 1998; Butler et al. 1999; Curns et al. 2002; Davidson et al. 1994; Holman et al. 2001; Karron et al. 1999; Koch et al. 2002; Ling et al. 1969; Lowther et al. 2000; Wainwright 1996). Among the factors suspected to be involved in this phenomenon, perinatal exposure to persistent organic pollutants has been incriminated (Dallaire et al. 2004b; Dewailly et al. 2000). Indeed, some organochlorine compounds (OCs), such as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and polychlorinated biphenyls (PCBs), produce a well known immunotoxic effect in animals and humans (Belles-Isles et al. 2002; Chang et al. 1982; Esser and Welzel 1993; Hoffman et al. 1986; Holsapple et al. 1984; Lu and Wu 1985; Neubert et al. 1992; Safe 1994; Thomas and Hinsdill 1979; Tryphonas et al. 1991a; Tryphonas et al. 1991b; White et al. 1986).

In 2000, we published a first study showing an association between perinatal exposure to OCs and acute otitis media in Nunavik Inuit infant (Dewailly et al. 2000). To confirm this association, we then investigated the relation between maternal OCs concentrations and acute respiratory and gastro-intestinal infections in a cohort of 199 infants of the same population (see the other paper on infections and OCs in this synopsis). We found that OCs concentration in maternal plasma were positively associated with the incidence of acute infections during the first 6 months of life, but not afterwards. The number of subjects was however small, and the associations were not always statistically significant. In order to clarify the possible link between prenatal exposure to OCs and infections in this population, we report here the association between PCB concentration in umbilical cord blood and incidence rate of acute respiratory tract infections in a third cohort of preschool Nunavik children.

## Activities

## In 2003-2004

We first finished the gathering and review of the medical charts. We then proceeded to data entry and programming to extract the incidence rates, as well as other statistical analyses. We then interpreted the results, and wrote the first draft of a scientific article. This project will be completed in June 2004. Most results are now ready to be presented.

## Results

### Participants

Four hundred ninety-one women were included in the initial cord blood monitoring program. Fifty children were initially excluded because contaminants concentrations in plasma were not available, or because there was not enough information in our database to trace the charts. Of the 441 remaining participants, it was impossible to get the chart of 43 (9.8%) children for various logistical reasons. Among the 398 available charts, 28 (7.0%) were incomplete, 17 (4.3%) families moved out of Nunavik during follow-up, 7 (1.8%) children died and 3 (0.8%) children were excluded because they suffered from a serious chronic disease. The final analyses included the 343 remaining children.

To be eligible for the 5-year follow-up interview, children had to be aged 5 years, and had to be under the care of their biological mother. We excluded 47 children because they were out of the age limit when our team traveled to their village, and 84 children because they were adopted. Out of the 212 eligible children for the 5-year interview, we were unable to contact 68 mothers, and 7 children/mothers were out of town at the time of the visit. We thus contacted 137 mothers. Only one mother refused to participate to the interview, but 10 did not show up to the appointment. Finally, it was impossible to interview 32 mothers, mainly because of travel problems between the communities. We were thus able to interview 94 mothers. Table 1 shows the characteristics for all participants, and

Table 1. Characteristics of participants

| Characteristics | Mean value (STD) or percentage | |
|---|---|---|
| | All infants (n = 343) | 5-year interview subgroup (n = 94) |
| Children | | |
| Sex (male) | 49.0% | 45.7% |
| Given to adoption | 24.6% | 0% [a] |
| Year of birth | | |
| 1994 | 37.3% | 26.6% |
| 1995 | 32.1% | 42.6% |
| 1996 | 30.6% | 30.8% |
| Hospital of delivery | | |
| Puvirnituq | 48.7% | 54.3% |
| Kuujjuaq | 51.3% | 45.7% |
| Gestational age | | |
| Mean gestational age | 39.1 weeks | 39.1 weeks |
| Preterm (< 37 weeks) | 5.3% | 4.3% |
| Village of residence | | |
| Kuujjuaraapik | 4.1% | 0% |
| Umiujak | 1.2% | 2.1% |
| Inukjuaq | 11.8% | 24.5% |
| Puvirnituq | 15.6% | 18.1% |
| Akulivik | 5.6% | 4.3% |
| Ivujivik | 2.9% | 4.3% |
| Salluit | 7.7% | 1.1% |
| Kangiqsujuaq | 5.9% | 3.2% |
| Quaqtaq | 6.7% | 5.3% |
| Kangirsuk | 5.6% | 2.1% |
| Tasiujaq | 0% | 0% |
| Kuujjuaq | 21.5% | 24.5% |
| Kangiqsualujjuaq | 10.6% | 10.6% |
| Birthweight (g) | 3494 g | 3526 g |
| Length (cm) | 51.5 cm | 51.1 cm |
| Mothers | | |
| Age | 23.7 years | 24.5 years |
| Parity | 2.1 | 2.2 |

[a] Adoption was a exclusion criterion during the selection of the 5-year interview subgroup.

for those included in the 5-year interview subgroup.

## Contaminants concentrations

Detailed contaminants concentrations in cord blood for these children have been published elsewhere (Dewailly et al. 1998). On a lipid basis, the geometric mean of the concentration of sum of the 14 PCB congeners (ΣPCBs) in cord blood was 323.5 µg/kg. The geometric mean of DDE concentration was 379,2 µg/kg. The PCB congener 153, the most abundant, had a mean concentration of 93.6 µg/kg. Based on the quartiles limits of PCB 153 in cord blood, the mean concentrations for the four quartiles of OCs prenatal exposure were 147.8 µg/kg, 261.8 µg/kg, 395.4 µg/kg, and 708.9 µg/kg for ΣPCBs, 163.0 µg/kg, 314.9 µg/kg, 473.5 µg/kg, and 841.9 µg/kg for DDE, and 38.5 µg/kg, 77.7

Table 2. Incidence rate of acute otitis media and respiratory infections during the first 5 years of life

| Infection | Incidence rate (events per 1000 children-year) | | |
|---|---|---|---|
| | < 1 year old | 1 to 2 years old | 2 to 5 years old |
| All respiratory infections | 5434 (5066 – 5803) | 4466 (4119 – 4814) | 1908 (1732 – 2083) |
| Acute otitis media | 2128 (1932 – 2324) | 2087 (1885 – 2290) | 697 (614 – 779) |
| Upper respiratory tract infections | 1974 (1799 – 2149) | 1487 (1338 – 1636) | 888 (786 – 991) |
| Lower respiratory tract infections | 1332 (1171 – 1493) | 892 (769 – 1015) | 323 (276 – 369) |

µg/kg, 120.8 µg/kg, and 229.2 µg/kg for PCB 153.

**Infection incidence rates**

The medical chart review of the 343 participants allowed us to identify 5 354 outpatient visits that lead to a diagnosis of respiratory infections before the age of five years. Annualized incidence rates of acute otitis media (AOM), upper respiratory tract infections (URTIs), and lower respiratory tract infection (LRTIs) are shown in Table 2. In children aged < 2 years, acute otitis media was the most frequently diagnosed infection, followed by URTIs and LRTIs. In children aged 2 years or more, URTIs were more frequent than AOM. Hospitalizations were frequent as 17.4% of outpatient visits for LRTIs led to an admission. The rate of hospitalizations for LRTIs was 303.2, 145.8, and 36.0 hospitalizations per 1000 children-years for children aged 0-11 months, 12-23 months, and 2-5 years, respectively. See chapter 4 for a complete portrait of outpatient visits and hospitalization rates for these infants.

**Prenatal exposure and incidence of respiratory infections**

Table 3 shows the association between prenatal exposure to OCs and respiratory infections (incidence of URTIs, LRTIs and ear infections combined). In the unadjusted model, the association reached statistical significance for the second (RR = 1.10) and forth quartiles (RR = 1.16). The continuous model yielded a positive, but non-significant association (2.3% increase of the incidence rate for each log increase of the concentration of PCB 153, $p = 0.24$). In the adjusted model A, the associations were significant for the three highest quartiles of exposure (RRs = 1.12, 1.11, and 1.26). In the continuous model A, the association was also significant (6.4 % increase for each log increase of PCB 153, $p = 0.005$). In the adjusted model B, the association was significant for the second and fourth quartiles (RRs = 1.38 and 1.37, respectively).

**Prenatal exposure and AOM**

Table 4 presents the association between OCs exposure and AOM, URTIs, and LRTIs. In the unadjusted model, prenatal exposure to OCs was associated with AOM incidence rates in a dose-response fashion (RRs = 1.13, 1.18, 1.25 for Q2, Q3 and Q4, respectively). In the unadjusted continuous model, we observed a 6.5 % increase of AOM rates for each log increase of PCB 153 concentration. When adjusted according to model A, we observed stronger and more significant associations, compared to that of the unadjusted model. In model B, the association was significant only for the fourth quartile (RR = 1.35, $p = 0,04$).

**Prenatal exposure and URTIs**

For URTIs, we did not observe significant associations in neither model (Table 4). We observed a slight negative association between URTIs and prenatal exposure to OCs, especially for children in the 3rd quartile of exposure. In the unadjusted continuous model, the association was negative. However, this trend became weaker when adjustment for confounding was performed (RR = 0.98 in model A, and RR = 1.01 in model B).

Table 3. Incidence rate ratio of respiratory infection according to prenatal exposure to organochlorines

| Prenatal exposure model | Rate ratio (95 % CI) |
|---|---|
| Unadjusted model (*n* = 343) | |
| Continuous (for each log increase) | 1.023 (0.985 - 1.064) |
| Categories | |
| Q1 (less exposed) | 1.00 (referent) |
| Q2 | 1.10 (1.02 - 1.19)* |
| Q3 | 1.06 (0.98 - 1.15) |
| Q4 (most exposed) | 1.16 (1.08 - 1.26)* |
| **Adjusted model A** (*n* = 330) | |
| Continuous (for each log increase) | 1.064 (1.019 - 1.110)* |
| Categories | |
| Q1 (less exposed) | 1.00 (referent) |
| Q2 | 1.12 (1.03 - 1.21)* |
| Q3 | 1.11 (1.02 - 1.20)* |
| Q4 (most exposed) | 1.26 (1.16 - 1.37)* |
| **Adjusted model B** (*n* = 90) | |
| Continuous (for each log increase) | 1.048 (0.955 - 1.150) |
| Categories | |
| Q1 (less exposed) | 1.00 (referent) |
| Q2 | 1.38 (1.15 - 1.65)* |
| Q3 | 1.04 (0.86 - 1.26) |
| Q4 (most exposed) | 1.37 (1.15 - 1.64)* |

**Prenatal exposure and LRTIs**

The strongest associations were seen with LRTIs (Table 4). Rate ratios ranges between 1.21 and 1.40 in the unadjusted model, and between 1.61 and 2.71 in adjusted model B. All associations were significant, except in the continuous model B (16.2 % rate increase for each log increase in PCB concentration, $p = 0.13$). Although the continuous models were strongly positive, a dose-response pattern was not obvious in the categorical models.

**Prenatal exposure and hospitalization for LRTIs**

Association between prenatal exposure to OCs and hospitalization rates for LRTI is shown in Table 5. We found no statistically significant association. Rate ratios were above 1.0 for the second and third quartile, but not for the fourth quartile. We observed a negative association in the continuous model, but it did not reached statistical significance. As stated in the methods section, when analyses with model B were performed, there were not enough episodes in each categories and the model was unstable. Therefore, only the results from model A are shown.

## Discussion

The aim of this study was to identify an association between prenatal exposure to OCs and acute respiratory infections during the first five years of life. We observed that children in the higher quartiles of exposure had a significantly higher incidence rate of outpatient visits for otitis media and LRTIs, but not for URTIs. This is the third study in which a positive association is observed between OCs and respiratory infections incidence or prevalence in this population. In a cohort of 98 breast-fed infants aged < 1 years recruited in 1989-90, we first observed that infants with higher exposure to OCs through breastfeeding had a higher prevalence of recurrent otitis media compared to that of infants in the lowest exposure group (Dewailly et al. 2000). In a second cohort of 199 infants aged < 1 year, we found that the incidence rates of ear infections and LRTIs were positively associated with PCB 153 and DDE concentration in maternal blood (see the other paper on infections and OCs in this synopsis). In the later study, the association was present only

**Table 4.** Incidence rate ratio of otitis media, upper respiratory tract, and lower respiratory tract infections according to prenatal exposure to organochlorines

| Prenatal exposure model | Rate ratio (95 % CI) | | |
|---|---|---|---|
| | AOM | URTIs | LRTIs |
| Unadjusted model (*n* = 343) | | | |
| Continuous (for each log increase) | 1.065 (1.002 - 1.131)* | 0.943 (0.887 - 1.002) | 1.109 (1.019 - 1.208)* |
| Categories | | | |
| Q1 (less exposed) | 1.00 (referent) | 1.00 (referent) | 1.00 (referent) |
| Q2 | 1.13 (1.00 - 1.28)* | 0.96 (0.86 - 1.08) | 1.37 (1.15 - 1.63)* |
| Q3 | 1.18 (1.04 - 1.33)* | 0.90 (0.80 - 1.02) | 1.21 (1.01 - 1.44)* |
| Q4 (most exposed) | 1.25 (1.10 - 1.41)* | 1.00 (0.89 - 1.12) | 1.40 (1.18 - 1.67)* |
| **Adjusted model A** (*n* = 330) | | | |
| Continuous (for each log increase) | 1.103 (1.031 - 1.180)* | 0.984 (0.920 - 1.053) | 1.148 (1.045 - 1.262)* |
| Categories | | | |
| Q1 (less exposed) | 1.00 (referent) | 1.00 (referent) | 1.00 (referent) |
| Q2 | 1.16 (1.02 - 1.32)* | 0.98 (0.87 - 1.11) | 1.37 (1.15 - 1.64)* |
| Q3 | 1.23 (1.08 - 1.40)* | 0.94 (0.83 - 1.06) | 1.26 (1.05 - 1.52)* |
| Q4 (most exposed) | 1.36 (1.20 - 1.56)* | 1.09 (0.96 - 1.24) | 1.47 (1.22 - 1.77)* |
| **Adjusted model B** (*n* = 90) | | | |
| Continuous (for each log increase) | 1.052 (0.904 - 1.225) | 1.005 (0.866 - 1.166) | 1.162 (0.958 - 1.411) |
| Categories | | | |
| Q1 (less exposed) | 1.00 (referent) | 1.00 (referent) | 1.00 (referent) |
| Q2 | 1.09 (0.81 - 1.47) | 1.24 (0.94 - 1.64) | 2.71 (1.77 - 4.14)* |
| Q3 | 0.95 (0.70 - 1.29) | 0.92 (0.69 - 1.22) | 1.61 (1.03 - 2.52)* |
| Q4 (most exposed) | 1.35 (1.01 - 1.81)* | 1.23 (0.94 - 1.63) | 1.83 (1.20 - 2.79)* |

during the first 6 months of life. The present study confirms the associations previously observed. Furthermore, it shows that the relation between OCs and respiratory infection seems to persist passed the first months of life.

In the scientific literature, higher rates of respiratory and ear infections have been reported in children born to mother accidentally or occupationally exposed to PCBs, compared to controls (Chao et al. 1997, Hara 1985, Rogan et al. 1988). For environmental exposure, the evidences of an harmful effect of OCs on infections incidence in children is not yet clear, as both an association (Karmaus et al. 2001, Smith 1984, Weisglas-Kuperus et al. 2000) and an absence of association (Rogan et al. 1987, Weisglas-Kuperus et al. 1995) have been reported.

Infection incidence rate in children can be affected by many factors, which make the control for confounding difficult. In this study, some important potential confounding factors were available for only a subgroup of subjects. Because of the small number of participants involved in this subgroup, the regression models were less stable and the RRs were a little more erratic between the exposure groups. However, in general, we observed that adjustment for confounding slightly increased the magnitude of the associations, both in model A and B. This was also true in our previous study, in which many factors were available for most subjects. We thus can conclude that in this population, the potential factors that have been considered so far did indeed confound the association by pulling the RRs towards 1.0. Therefore, unadjusted associations between OCs and infection rates for this population were likely to be slightly underestimated.

Table 5. Incidence rate ratio of hospitalization for lower respiratory tract infections according to prenatal exposure to organochlorines

| Prenatal exposure model | Rate ratio (95 % CI) | |
|---|---|---|
| | *Unadjusted model* ($n$ = 343) | *Adjusted model A* ($n$ = 290) |
| Continuous (for each log increase) | 0.920 (0.752 - 1.127) | 0.976 (0.768 - 1.240) |
| Categories | | |
| Q1 (less exposed) | 1.00 (referent) | 1.00 (referent) |
| Q2 | 1.32 (0.88 - 1.97) | 1.30 (0.80 - 2.11) |
| Q3 | 1.25 (0.83 - 1.87) | 1.45 (0.91 - 2.33) |
| Q4 (most exposed) | 0.94 (0.61 – 1.45) | 1.00 (0.59 - 1.70) |

In this study, we used a review of the medical charts to evaluate incidence rates. There is only one health center in each community included in this study. Participants almost always go to that health center when they seek medical attention, and copies of consultations done elsewhere are routinely requested to complete medical charts. We are, therefore, confident that we have reviewed a majority of outpatient visits sought by the participants. Nevertheless, we did not attempt to verify every diagnosis, nor did we try to inquire about infections for which medical attention was not sought by the parents. It is therefore important to keep in mind that the incidence rates reported here is an underestimation of the true incidence. Although the magnitude of this underestimation is difficult to evaluate, we can assume that it will be related to both the severity of the symptoms and the parent's perception of the disease (Saunders et al. 2003). We cannot exclude the possibility that the propensity to seek medical attention when respiratory symptoms are present was associated with traditional lifestyle, which in turn is known to be associated with OCs concentration in maternal blood (Muckle et al. 2001a). Should this happen with our participants, the direction of the bias that would be introduced would be unknown. We find it improbable, however, that Inuit families with traditional life-style would increase their frequency of medical contacts in such a way that the full extent of the observed association would be solely due to this bias, if any.

The environmental exposure to OCs for most populations, including that of Inuit from Nunavik, consists in a complex mixture of persistent lipophilic chlorinated substances. Because plasma concentrations for most of them are closely correlated with each other (Muckle et al. 2001b), it is impossible to determine which of these compounds – or which combination of them – is responsible for the association. In a previous study, DDE concentration in maternal plasma was found to be more closely associated with infection incidence rates, compared to PCB 153 concentration (Dallaire et al. 2004b). In the present study, results for DDE exposure are not shown, but were in general similar to that of PCB 153. Although our analyses were done using the congener PCB 153 as a proxy of OCs exposure, the potential harmful effect on the immune system could be due to any of the correlated compounds.

Our initial hypothesis stated that exposure to OCs could influence the severity of respiratory infections, thus leading to an increase of hospitalization rates for LRTIs in groups of higher exposure. Similarly to what was previously observed in the same population (Dallaire et al. 2004b), we did not find an association between OCs and hospitalization rate for LRTIs. The statistical power was limited, but the RRs close to 1.0 observed in the continuous models seem to indicate that no clear link was present. If this interpretation is right, it would mean that the increase incidence rate for LRTIs outpatient visits did not translate into an increase number of admissions, meaning that the episodes of LRTIs that could be explained by OCs exposure were fortunately not severe. Had it been the case, we would have observed equivalent RRs for LRTIs outpatient and inpatient events. Further studies are needed to clarify this important issue.

Inuit children from Nunavik are burdened by a high rate of respiratory infectious diseases. The medical charts review performed in this study allowed us to show that LRTIs infections were far more frequent in Nunavik compared to other Canadian populations, and that hospitalizations rate for LRTIs in Nunavik was one of the highest ever reported in recent scientific literature (Dallaire et al. 2004a). If the association between respiratory infection and prenatal exposure to OCs observed in this population is causal, exposure to OCs during development would be responsible for a significant proportion of respiratory infectious episodes in these children. The biologic mechanism underlying this effect in humans environmentally exposed is still obscure. Other studies are needed to identify which immune pathways are affected in exposed children. Risk-benefits assessments regarding the consumption of contaminated food items in the perinatal period should also be initiated.

## References

Banerji A, Bell A, Mills EL, McDonald J, Subbarao K, Stark G, et al. 2001. Lower respiratory tract infections in Inuit infants on Baffin Island. *Cmaj* 164(13):1847-1850.

Belles-Isles M, Ayotte P, Dewailly E, Weber JP, Roy R. 2002. Cord blood lymphocyte functions in newborns from a remote maritime population exposed to organochlorines and methylmercury. *J Toxicol Environ Health A* 65(2):165-182.

Bluestone CD. 1998. Epidemiology and pathogenesis of chronic suppurative otitis media: implications for prevention and treatment. *Int J Pediatr Otorhinolaryngol* 42(3):207-223.

Butler JC, Parkinson AJ, Funk E, Beller M, Hayes G, Hughes JM. 1999. Emerging infectious diseases in Alaska and the Arctic: a review and a strategy for the 21st century. *Alaska Med* 41(2):35-43.

Chang KJ, Hsieh KH, Tang SY, Tung TC, Lee TP. 1982. Immunologic evaluation of patients with polychlorinated biphenyl poisoning: evaluation of delayed-type skin hypersensitive response and its relation to clinical studies. *J Toxicol Environ Health* 9(2):217-223.

Chao WY, Hsu CC, Guo YL. 1997. Middle-ear disease in children exposed prenatally to polychlorinated biphenyls and polychlorinated dibenzofurans. *Arch Environ Health* 52(4):257-262.

Curns AT, Holman RC, Shay DK, Cheek JE, Kaufman SF, Singleton RJ, et al. 2002. Outpatient and hospital visits associated with otitis media among American Indian and Alaska native children younger than 5 years. *Pediatrics* 109(3):E41-41.

Dallaire F, Dewailly E, Vezina C, Muckle G, Bruneau S, Ayotte P. 2004a. Portrait of outpatient visits and hospitalizations for acute infections in Nunavik preschool children. *In preparation.*

Dallaire F, Muckle G, Ayotte P, Vézina C, Jacobson SW, Jacobson J, et al. 2004b. Acute infections in Inuit infants in relation to environmental exposure to organochlorines. *In preparation.*

Davidson M, Parkinson AJ, Bulkow LR, Fitzgerald MA, Peters HV, Parks DJ. 1994. The epidemiology of invasive pneumococcal disease in Alaska, 1986-1990--ethnic differences and opportunities for prevention. *J Infect Dis* 170(2):368-376.

Dewailly E, Ayotte P, Bruneau S, Gingras S, Belles-Isles M, Roy R. 2000. Susceptibility to infections and immune status in inuit infants exposed to organochlorines. *Environ Health Perspect* 108(3):205-211.

Dewailly E, Bruneau S, Ayotte P, Lebel G, Muckle G, Rhainds M. 1998. *Évaluation de l'exposition prénatale aux organochlorés et aux métaux lourds chez les nouveau-nés du Nunavik, 1993-1996.* Beauport: Centre de santé publique de Québec, Université Laval, 74 pp.

Esser C, Welzel M. 1993. Ontogenic development of murine fetal thymocytes is accelerated by 3,3',4,4'-tetrachlorobiphenyl. *Int J Immunopharmacol* 15(8):841-852.

Hara I. 1985. Health status and PCBs in blood of workers exposed to PCBs and of their children. *Environ Health Perspect* 59:85-90.

Hoffman RE, Stehr-Green PA, Webb KB, Evans RG, Knutsen AP, Schramm WF, et al. 1986. Health effects of long-term exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Jama* 255(15):2031-2038.

Holman RC, Curns AT, Kaufman SF, Cheek JE, Pinner RW, Schonberger LB. 2001. Trends in infectious disease hospitalizations among American Indians and Alaska Natives. *Am J Public Health* 91(3):425-431.

Holsapple MP, McNerney PJ, Barnes DW, White KL, Jr. 1984. Suppression of humoral antibody production by exposure to 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin. *J Pharmacol Exp Ther* 231(3):518-526.

Karmaus W, Kuehr J, Kruse H. 2001. Infections and atopic disorders in childhood and organochlorine exposure. *Arch Environ Health* 56(6):485-492.

Karron RA, Singleton RJ, Bulkow L, Parkinson A, Kruse D, DeSmet I, et al. 1999. Severe respiratory syncytial virus disease in Alaska native children. RSV Alaska Study Group. *J Infect Dis* 180(1):41-49.

Koch A, P S, Homoe P, K M, Pedersen FK, Mortensen T, et al. 2002. Population-based study of acute respiratory infections in children, greenland. *Emerg Infect Dis* 8(6):586-593.

Ling D, McCoy RH, Levinson ED. 1969. The incidence of middle ear disease and its educational implications among Baffin Island Eskimo children. *Can J Public Health* 60(10):385-390.

Lowther SA, Shay DK, Holman RC, Clarke MJ, Kaufman SF, Anderson LJ. 2000. Bronchiolitis-associated hospitalizations among American Indian and Alaska Native children. *Pediatr Infect Dis J* 19(1):11-17.

Lu YC, Wu YC. 1985. Clinical findings and immunological abnormalities in Yu-Cheng patients. *Environ Health Perspect* 59:17-29.

Muckle G, Ayotte P, Dewailly E, Jacobson SW, Jacobson JL. 2001a. Determinants of polychlorinated biphenyls and methylmercury exposure in inuit women of childbearing age. *Environ Health Perspect* 109(9):957-963.

Muckle G, Ayotte P, Dewailly EE, Jacobson SW, Jacobson JL. 2001b. Prenatal exposure of the northern Quebec Inuit infants to environmental contaminants. *Environ Health Perspect* 109(12):1291-1299.

Neubert R, Golor G, Stahlmann R, Helge H, Neubert D. 1992. Polyhalogenated dibenzo-p-dioxins and dibenzofurans and the immune system. 4. Effects of multiple-dose treatment with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) on peripheral lymphocyte subpopulations of a non-human primate (*Callithrix jacchus*). *Arch Toxicol* 66(4):250-259.

Rogan WJ, Gladen BC, Hung KL, Koong SL, Shih LY, Taylor JS, et al. 1988. Congenital poisoning by polychlorinated biphenyls and their contaminants in Taiwan. *Science* 241(4863):334-336.

Rogan WJ, Gladen BC, McKinney JD, Carreras N, Hardy P, Thullen J, et al. 1987. Polychlorinated biphenyls (PCBs) and dichlorodiphenyl dichloroethene (DDE) in human milk: effects on growth, morbidity, and duration of lactation. *Am J Public Health* 77(10):1294-1297.

Safe SH. 1994. Polychlorinated biphenyls (PCBs): environmental impact, biochemical and toxic responses, and implications for risk assessment. *Crit Rev Toxicol* 24(2):87-149.

Saunders NR, Tennis O, Jacobson S, Gans M, Dick PT. 2003. Parents' responses to symptoms of respiratory tract infection in their children. *Cmaj* 168(1):25-30.

Smith BJ. 1984. *PCB levels in human fluids: Sheboygan cas study. Technical report WIS-SG-83-240.* Madison, Winsconsin: University of Winsconsin Sea Grant Institutepp.

Thomas PT, Hinsdill RD. 1979. The effect of perinatal exposure to tetrachlorodibenzo-p-dioxin on the immune response of young mice. *Drug Chem Toxicol* 2(1-2):77-98.

Tryphonas H, Luster MI, Schiffman G, Dawson LL, Hodgen M, Germolec D, et al. 1991a. Effect of chronic exposure of PCB (Aroclor 1254) on specific and nonspecific immune parameters in the rhesus (*Macaca mulatta*) monkey. *Fundam Appl Toxicol* 16(4):773-786.

Tryphonas H, Luster MI, White KL, Jr., Naylor PH, Erdos MR, Burleson GR, et al. 1991b. Effects of PCB (Aroclor 1254) on non-specific immune parameters in rhesus (*Macaca mulatta*) monkeys. *Int J Immunopharmacol* 13(6):639-648.

Wainwright RB. 1996. The US Arctic Investigations Program: infectious disease prevention and control research in Alaska. *Lancet* 347(9000):517-520.

Weisglas-Kuperus N, Patandin S, Berbers GA, Sas TC, Mulder PG, Sauer PJ, et al. 2000. Immunologic effects of background exposure to polychlorinated biphenyls and dioxins in Dutch preschool children. *Environ Health Perspect* 108(12):1203-1207.

Weisglas-Kuperus N, Sas TCJ, Koopman-Esseboom C, Van Der Zwan CW, De Ridder MAJ, Beishuizen A, et al. 1995. Immunologic effects of background prenatal and posnatal exposure to dioxins and polychlorinated biphenyls in Dutch infants. *Ped Res* 38(3):404-410.

White KL, Jr., Lysy HH, McCay JA, Anderson AC. 1986. Modulation of serum complement levels following exposure to polychlorinated dibenzo-p-dioxins. *Toxicol Appl Pharmacol* 84(2):209-219.

# Effects of Prenatal Exposure to Organochlorines and Mercury on the Immune System of Inuit Infants


## Project leader(s)

Éric Dewailly Public Health Research Unit-CHUQ (CHUL) 945, Wolfe, 2nd floor Sainte-Foy, QC G1V 5B3; Phone: (418) 650-5115 ext 5240; Fax: (418) 654-3132; E-mail: Eric.Dewailly@crchul.ulaval.ca

## Project members

Frédéric Dallaire, Carole Vézina, Gina Muckle, Pierre Ayotte, and Gaston de Serres Public Health Research Unit-CHUQ (CHUL) and Laval University, QC; Houda Bilrha, Raynald Roy and Marthe Belles-Iles Rhumatology-Immunology Research Unit -CHUQ (CHUL), Ste-Foy, QC; Jean Philippe WeberDirection et laboratoire de toxicologie humaine, Institut national de santé publique du Québec–Ste-Foy, QC; Claire Infante-Rivard McGill University, Montréal, QC; Joseph Jacobson Wayne State University, Detroit, MI



## Abstract

The Inuit population of Nunavik is exposed to immunotoxic organochlorines (OCs) mainly through the consumption of fish and marine mammal fat. The effect of prenatal exposure to selected OCs on the incidence of acute infections in Inuit infants was investigated. The medical charts of a cohort of 199 Inuit infants were reviewed during the first 12 months of life. Incidence rates of upper and lower respiratory tract infections, otitis media, and gastrointestinal infections were evaluated. Maternal plasma during delivery and infant plasma at 7 months were sampled and assayed for polychlorinated biphenyls (PCBs), dichlorodiphenyl dichloroethylene (DDE) and other persistent chlorinated pesticides. Prenatal exposure (maternal blood concentrations) to PCBs and DDE was positively associated with incidence of acute infections during the first 6 months of life, but not afterwards. The association was strongest for DDE exposure. The association was no longer present with postnatal exposure (infant blood). These results support the hypothesis of an adverse effect of prenatal exposure to OCs on susceptibility to infection in Inuit infants, particularly during the first 6 months of life.


## Key Project Messages

1. This study investigates possible detrimental effects on the immune system of Inuit infants that may be induced by prenatal and postnatal exposure to persistent environmental contaminants such as organochlorine compounds and heavy metals.
2. A total of 199 infants' medical charts were reviewed to assess infectious disease incidence rate during the first 12 months of life.
3. It was shown that environmental prenatal exposure to OCs is associated with a higher incidence of infections, mainly during the first 6 months. Although the associations were not always statistically significant, infants in the higher quartiles of exposure to PCBs and DDE had systematically more episodes of infections than their counterparts in the first quartile of exposure.

## Objectives

The main objective of this project is to examine the effects of prenatal and postnatal exposure to organochlorines (OCs) and mercury on the immune system of Inuit infants from birth to 12 months of age. The specific objectives include:

1. Assessment of the prenatal and postnatal exposure to OCs and mercury.

2. Measurement of some immunological parameters (humoral and cellular immunity).

3. Determination of the incidence of infections.

## Introduction

Exposure to most OCs produces a wide variety of immunotoxic effects in animals and humans. OCs that have a chemical structure similar to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, such as dioxin congeners and coplanar PCBs, are especially immunotoxic. Alterations of T-cell subsets, of serum IgA and IgM concentrations, of delayed-type hypersensibility, and of complement function, have all been documented in rodents, primates and human (Belles-Isles et al. 2002, Chang et al. 1982, Esser and Welzel 1993, Hoffman et al. 1986, Holsapple et al. 1984, Lu and Wu 1985, Neubert et al. 1992, Thomas and Hinsdill 1979, Tryphonas et al. 1991a, Tryphonas et al. 1991b, White et al. 1986). The development of the immune system *in utero* and during infancy is particularly sensitive to immunotoxic agents. High exposure during early life could lead to permanent defects in the immune system and thus decrease resistance to infectious agents (Badesha et al. 1995).

The high incidence of acute infectious diseases in infants and children from Nunavik has been known for many years (Bruneau et al. 2001; Dufour 1988; Proulx 1988; Thérien 1988). In this context, we hypothesized that the incidence of infections among Inuit infants was related in part to the high maternal body burden of immunotoxic food-chain contaminants during pregnancy. In 2000, we published a first study on susceptibility to infection in Inuit infants recruited between 1989 and 1990 (Dewailly et al. 2000). We found that the risk of acute otitis media and recurrent otitis media was positively associated with prenatal exposure to OCs. However, postnatal exposure was not considered, and some potential confounding factors could not be evaluated. In order to confirm the association observed, we investigated the association between exposure to OCs and the incidence rate of acute infections during the first year of life in a second cohort of 199 Inuit infants recruited between 1995 and 2001.

## Activities

### In 2003/2004

In 2003-2004, we performed the final statistical analysis. We also double-checked the statistical models used. We then wrote the final draft of a scientific paper. The project is now completed.

## Results

**Recruitment and participation**

During the study period, 417 pregnancies were identified in the targeted communities. Of them, we excluded 47 pregnant women (11.3%) who had already been enrolled in the study during a previous pregnancy and three women (0.7%) due to miscarriage. We were unable to contact nine women (2.2%). Three hundred and fifty eight eligible women were thus asked to participate and 110 refused (30.7%). Of the 248 women willing to participate, we were unable to review the medical charts of 43 infants. Finally, we excluded six (2.4%) participants because no biological samples were available for exposure analysis. A total of 199 participants were included in the final analyses.

**Population characteristics**

Mothers included in the analysis were mostly from Puvirnituq (45.4%) and Inukjuaq (39.3%). The mean age at delivery was 25.2 years, and most of the them smoked during pregnancy (91.4% reported smoking at least one cigarette a day, mean = 10.6 cigarettes/day). Only 2.6% of the infants were not exposed to second-hand smoke during their first year of life. The mean parity was 2.1. There were more males than females (57.6%) and the mean birthweight and length were 3454 g and 50.3 cm, respectively. Breastfeeding was very common and only 12.2%

were not breastfed. Adoption was the main reason for exclusive bottle-feeding (83.3%).

### Incidence of infections

Incidence proportions and rates of various infections are detailed in Table 1. Otitis media was the most frequent infection diagnosed with a mean of 2.8 episodes per infant-year, followed by URTIs with 2.4 episodes per infant-year. Almost all infants had at least one episode of otitis (96.0%), and 17.1% had 5 episodes or more. LRTIs and urinary tract infections required hospitalization in 31.4% and 26.3% of cases, respectively. More than half of the infants (56.8%) were hospitalized at least once during their first year of life. Only infection categories with a mean incidence rate higher than 1.0 episode per infant-year yielded sufficient statistical power to be included in further analyses.

### Contaminant burden in plasma

Table 2 shows the concentration of contaminants in maternal and infant plasma. The geometric mean concentration of the sum of the 14 PCB congeners in maternal plasma was 308 μg/kg ranging from 60 μg/kg to 1951 μg/kg. The concentration of the sum of the PCB congeners was highly correlated with that of PCB congener 153 in maternal plasma ($r = 0.99$). The correlation between cord plasma and maternal plasma was also very high both for the sum the PCB congeners and for PCB congener 153 ($r = 0.95$ and 0.94, respectively). The geometric mean concentration for DDE in maternal plasma was 294 μg/kg ranging from 54 μg/kg to 2269 μg/kg. The correlation between cord and maternal plasma samples for DDE was also very strong ($r = 0.94$). PCB congener 153 and DDE were detected in all samples analyzed. Mean concentrations of PCBs and DDE were slightly lower in infant plasma than in maternal plasma. Means concentration in infant plasma was 259 μg/kg and 256 μg/kg for the sum of PCBs and DDE, respectively.

### Prenatal exposure to PCBs and infections

The relations between prenatal exposure to PCBs and incidence of infections are shown in Table 3. In preliminary analyses, we found that the associations between OCs and incidence rates were somewhat stronger during the first 6 months of life. Although this study was designed for a 12-month follow-up, we also present the results for the first 6 months of life. Regarding infections during the first 6 months of life and prenatal exposure to PCBs, we observed statistically significant associations only for LRTIs (3$^{rd}$ quartile; RR = 1.54 and 1.68 for the unadjusted and adjusted models, respectively). Although not statistically significant, almost all other RRs were above the unity. When the four types of infections were combined (labeled "all infections" in the tables), the relative rates ranged from 1.19 to 1.20 in the unadjusted model, and from 1.17 to 1.27 in the adjusted model. The trend was statistically significant in the adjusted model ($p = 0.04$).

Compared to the first 6 months of life, most associations were weaker when the first 12 months of life were considered, and only GI infections still pointed towards a positive association. The association was significant for the 3$^{rd}$ quartile in the adjusted model only (RR = 1.59). Globally, the relations were similar in the unadjusted and adjusted models, and for oth the 6-month and 12-month follow-ups.

### Prenatal exposure to DDE and infections

The relation between incidence of infections and prenatal exposure to DDE (Table 4) were stronger than that observed for exposure to PCBs. For the first 6 months of life, we detected significant associations with otitis (RR = 1.63, 3$^{rd}$ quartile) and LRTIs (RR = 1.52, 2$^{nd}$ quartile) in the unadjusted model, and with URTIs (RR = 1.56, 2$^{nd}$ quartile) and otitis (RR = 1.83, 3$^{rd}$ quartile) in the adjusted model. The trend was significant for otitis in the unadjusted model ($p = 0.04$) and borderline significant in the adjusted model ($p = 0.07$). When the four types of infections were combined, we observed significant associations for the 2$^{nd}$ quartile (RR = 1.49) in the unadjusted model, and for the 2$^{nd}$ (RR = 1.38) and 3$^{rd}$ (RR = 1.33) quartiles in the adjusted model. As observed for PCB exposure, almost all RRs were above the unity.

When the first 12 months of life are considered, we observed significant associations for GI infections (RR = 1.49, 2$^{nd}$ quartile) in the unadjusted model, and for URTIs (RR = 1.34, 2$^{nd}$ quartile) and GI infections (RR = 1.59, 2$^{nd}$ quartile) in the adjusted model. For all infections combined, the association reached statistical significance only for the 2nd quartile in the unadjusted model (RR = 1.17).

**Postnatal exposure to OCs and infections**

We used OCs concentrations in infant plasma to evaluate the effect of postnatal exposure on incidence of infections (sampling done at a median age of 7.0 months). Table 5 shows the incidence rate ratios for all four types of infections combined according to postnatal exposure to PCBs and DDE. Results are shown for the three different time periods (first 6 months of life, from 7 to 12 months, and for the entire 12-month period). We observed no obvious association between postnatal exposure and the incidence of infections. The only significant association was for PCBs in the unadjusted model (12-month follow-up, 2nd quartile, RR = 1.19), but the statistical significance was lost when we adjusted for confounding. No association was found for postnatal exposure to other OCs.

**Parameters of immune system function**

Parameters of immune system function were assayed using interleukine(IL)-10, tumor necrosis factor (TNF), and complement components (C3 and C4) in cord blood and infant blood (Table 6). Unfortunately, we were not able to evaluate these markers in a great proportion of the samples because the volume of blood collected was insufficient. Pearson correlation analysis yielded statistically significant results for IL-10 and HCB in cord blood and for C4 and HCB in infant blood. However, correlations with IL-10 and C4 were not constant across the different contaminants. These results are hard to interpret because of the small number of sample involved and further studies are needed to identify the effect of contaminants on immune biomarkers in this population.

## Discussion

Evidence of an effect of environmental exposure to OCs on susceptibility to infection in children is scarce and inconsistent. To our knowledge, the first study addressing this question was conducted in the Great Lakes area. The Wisconsin Maternal/Infant Cohort was designed to evaluate the effect of PCB dietary exposure on infant health status. The authors observed that fish consumption during pregnancy (a proxy of PCB exposure) was positively associated with colds, earaches, and flu symptoms in infants (Smith 1984). Between 1978 and 1982, Rogan et al. (1987) followed 900 families in North Carolina (USA). They reviewed the medical charts of the children and did not find any evidence of harmful effects of PCBs or DDE during the first year of life. In the Netherlands, Weisglas-Kuperus et al. (1995) observed no association between PCBs and the number of episodes of rhinitis, bronchitis, tonsillitis, and otitis during the first 18 months of life. However, the same group of children was seen at 42 months and current PCB burden was associated with a higher prevalence of recurrent middle-ear infections and of chicken pox (Weisglas-Kuperus et al. 2000). Karmaus et al. (2001) also observed a higher risk of otitis media, but the relation was only present with the combined exposure to DDE and PCBs. Finally, our group previously reported that exposed Inuit infants had a higher risk of acute otitis media during the first year of life (3rd tertile of exposure compared to the first). The relation was significant with exposure to DDE and HCB but remained above the unity for PCBs, dieldrin and mirex (Dewailly et al. 2000).

In this study, we showed that prenatal exposure to some environmental OC contaminants was associated with a higher incidence rate of infections during the first 6 months of life. Although the associations were not always statistically significant because of limited statistical power, infants in the highest quartiles of PCBs and DDE exposure had systematically more episodes of infections than their counterparts in the first quartile of exposure. This was mostly observed during the first 6 months of life, and the association was much weaker when infections during the first 12 months of life were considered. Postnatal exposure to OCs was no longer associated with infection incidence.

Because methods of evaluation of both exposure and frequency of infectious episodes varied among studies, it is difficult to directly compare previously published results with ours. Nevertheless, our results support the hypothesis that immunotoxic properties of OCs could affect the health status of prenatally exposed children, as did some of the above-mentioned studies involving accidental (Chao et al. 1997; Rogan et al. 1988), occupational (Hara 1985), and environmental (Karmaus et al. 2001; Smith 1984; Weisglas-Kuperus et al. 2000) exposure. In the literature, middle-ear infections are the most consistently reported infections associated with prenatal exposure to OCs. In our study, the strongest dose-response relationship was seen with ear infections. However, it is likely that OCs' insults on the developing immune system would result in the increase of incidence of many different types of acute infections, and not only ear infections. Consistent with that assumption, our results showed a higher incidence rate for the four most frequent infections in infants in the higher exposure groups, and the rate ratios were similar to that observed for otitis. Furthermore, when these four types of infections were combined, the association was more stable and the magnitude of the dose-response relationship was increased, compared to that of the four types of infection taken separately.

We also observed that the effect of prenatal exposure was mostly present during the first few months of life and that this effect seemed to vanish after 6 months of life. Furthermore, we found no effect of postnatal exposure to OCs with infections. It has already been suggested that the immune system is vulnerable to immunotoxic compounds during its development, and that high maternal burden during pregnancy and lactation could lead to permanent defects on the infant's immune system (Badesha et al. 1995; Barnett et al. 1987). Our results support the hypothesis of a stronger effect during early infancy, but we were unable to clearly identify any harmful effect persisting after the age of 6 months. After a few months of life, cumulative environmental influences on the immune system may begin to play a larger role, thus increasing the variability of responses to infections. Furthermore, contributions of the OCs exposure via breast milk, entangled with the beneficial effect of breast-feeding on infections, might have masked the effect. This could explain in part the discrepancies in results of other studies on OCs and infections because the age of children during disease and exposure assessment varied considerably between studies. Further studies are needed to clarify the time period during which environmental exposure to OCs has a detrimental effect on children health.

In this population, plasma concentrations of most of the OCs included in this analysis are strongly correlated. Muckle et al. (2001) already published correlation analyses for a subgroup of infants included in this cohort. They showed that PCB congeners and chlorinated pesticides are highly correlated with each other, and that concentrations in cord plasma, maternal plasma, and breast milk samples are also strongly correlated. It is, therefore, not possible to attribute the effect observed to one specific OC compound, nor are we able to unravel the specific contribution of each substance studied.

We used a review of the medical charts to evaluate disease frequency. There is only one health center in each of the three Inuit communities included in this study. Participants almost always go to that health center when they seek medical attention, and copies of consultations done elsewhere are routinely requested to complete medical charts. We are, therefore, confident that we have reviewed a majority of the medical consultations sought by the participants. Nevertheless, we did not attempt to verify every diagnosis, nor did we try to inquire about infections for which medical attention was not sought by the parents. Furthermore, we did not find a suitable proxy for the propensity to go to the clinic when symptoms were present. Our results are, therefore, likely to be an underestimation of the true incidence, especially for benign infections. It is possible that this underestimation was associated with traditional lifestyle, and thus with OC exposure, but the direction of the bias is unknown. However, if such a bias was present, we could assume that it would have persisted beyond 6 months of age. Since RRs for the 12-month follow-up are close to unity, it seemed to have little effect on our results.

Because of the relatively small number of subjects involved ($n = 199$), our results must be regarded with caution. Many factors can greatly influence the rate of acute infections. We have assessed many potential confounding factors, but unknown factors might still be present. Specifically, we cannot rule out the possibility that the infants in the lowest exposure group (first quartile) had better general health due to an unknown cause or simply due to chance. This would have resulted in RRs above the unity for the three highest quartiles of exposure without any dose-response relation, which is similar to what we observed. This needs to be kept in mind in the interpretation of our results.

The high rate of infectious episodes in young Inuit children has been observed in Northern Canada, the United States (Alaska), and Greenland (Banerji et al. 2001; Holman et al. 2001; Koch et al. 2002; Proulx 1988; Wainwright 1996). Many cultural, environmental, and economical factors contribute to this situation. Our study population is no exception, with a mean of almost nine infection-related medical consultations per infant during the first 12 months of life. In the context of such a high rate of infections, rate ratios of around 1.25, like the ones observed in this study, could have a tremendous impact on public health in this population. This is the second study identifying an increased susceptibility to infections associated with prenatal exposure to OCs in Nunavik. However, the relatively small number of subjects raises the possibility of an association that could be due to chance. To further clarify the potential contribution of persisting contaminants in the high infection rate of these children, we are currently conducting another study in which a third cohort of Inuit children from the same population is followed during the first five years of life. In the meantime, awareness and precautions regarding the selection of marine food items before and during pregnancies, such as the ones of Environnement Québec (Environnement Québec 2003), are warranted.

## References


Badesha JS, Maliji G, Flaks B. 1995. Immunotoxic effects of exposure of rats to xenobiotics via maternal lactation. Part I 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Int J Exp Pathol* 76(6):425-439.

Banerji A, Bell A, Mills EL, McDonald J, Subbarao K, Stark G, et al. 2001. Lower respiratory tract infections in Inuit infants on Baffin Island. *Cmaj* 164(13):1847-1850.

Barnett JB, Barfield L, Walls R, Joyner R, Owens R, Soderberg LS. 1987. The effect of in utero exposure to hexachlorobenzene on the developing immune response of BALB/c mice. *Toxicol Lett* 39(2-3):263-274.

Belles-Isles M, Ayotte P, Dewailly E, Weber JP, Roy R. 2002. Cord blood lymphocyte functions in newborns from a remote maritime population exposed to organochlorines and methylmercury. *J Toxicol Environ Health A* 65(2):165-182.

Bruneau S, Ayukawa H, Proulx JF, Baxter JD, Kost K. 2001. Longitudinal observations (1987-1997) on the prevalence of middle ear disease and associated risk factors among Inuit children of Inukjuak, Nunavik, Quebec, Canada. *Int J Circumpolar Health* 60(4):632-639.

Chang KJ, Hsieh KH, Tang SY, Tung TC, Lee TP. 1982. Immunologic evaluation of patients with polychlorinated biphenyl poisoning: evaluation of delayed-type skin hypersensitive response and its relation to clinical studies. *J Toxicol Environ Health* 9(2):217-223.

Chao WY, Hsu CC, Guo YL. 1997. Middle-ear disease in children exposed prenatally to polychlorinated biphenyls and polychlorinated dibenzofurans. *Arch Environ Health* 52(4):257-262.

Dewailly E, Ayotte P, Bruneau S, Gingras S, Belles-Isles M, Roy R. 2000. Susceptibility to infections and immune status in inuit infants exposed to organochlorines. *Environ Health Perspect* 108(3):205-211.

Dufour R. 1988. The otitis media among Inuit children. *Arctic Medical Research* 47(1):659-665.

Environnement Québec 2003. Guide de consommation du poisson de pêche sportive en eau douce. 2004

Esser C, Welzel M. 1993. Ontogenic development of murine fetal thymocytes is accelerated by 3,3',4,4'-tetrachlorobiphenyl. *Int J Immunopharmacol* 15(8):841-852.

Hara I. 1985. Health status and PCBs in blood of workers exposed to PCBs and of their children. *Environ Health Perspect* 59:85-90.

Hoffman RE, Stehr-Green PA, Webb KB, Evans RG, Knutsen AP, Schramm WF, et al. 1986. Health effects of long-term exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Jama* 255(15):2031-2038.

Holman RC, Curns AT, Kaufman SF, Cheek JE, Pinner RW, Schonberger LB. 2001. Trends in infectious disease hospitalizations among American Indians and Alaska Natives. *Am J Public Health* 91(3):425-431.

Holsapple MP, McNerney PJ, Barnes DW, White KL, Jr. 1984. Suppression of humoral antibody production by exposure to 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin. *J Pharmacol Exp Ther* 231(3):518-526.

Karmaus W, Kuehr J, Kruse H. 2001. Infections and atopic disorders in childhood and organochlorine exposure. *Arch Environ Health* 56(6):485-492.

Koch A, P S, Homoe P, K M, Pedersen FK, Mortensen T, et al. 2002. Population-based study of acute respiratory infections in children, greenland. *Emerg Infect Dis* 8(6):586-593.

Lu YC, Wu YC. 1985. Clinical findings and immunological abnormalities in Yu-Cheng patients. *Environ Health Perspect* 59:17-29.

Muckle G, Ayotte P, Dewailly EE, Jacobson SW, Jacobson JL. 2001. Prenatal exposure of the northern Quebec Inuit infants to environmental contaminants. *Environ Health Perspect* 109(12):1291-1299.

Neubert R, Golor G, Stahlmann R, Helge H, Neubert D. 1992. Polyhalogenated dibenzo-p-dioxins and dibenzofurans and the immune system. 4. Effects of multiple-dose treatment with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) on peripheral lymphocyte subpopulations of a non-human primate (*Callithrix jacchus*). *Arch Toxicol* 66(4):250-259.

Proulx JF. 1988. Meningitis in Hudson's Bay, Northern Quebec, Canada. *Arctic Medical Research* 47(1):686-687.

Rogan WJ, Gladen BC, Hung KL, Koong SL, Shih LY, Taylor JS, et al. 1988. Congenital poisoning by polychlorinated biphenyls and their contaminants in Taiwan. *Science* 241(4863):334-336.

Rogan WJ, Gladen BC, McKinney JD, Carreras N, Hardy P, Thullen J, et al. 1987. Polychlorinated biphenyls (PCBs) and dichlorodiphenyl dichloroethene (DDE) in human milk: effects on growth, morbidity, and duration of lactation. *Am J Public Health* 77(10):1294-1297.

Smith BJ. 1984. *PCB levels in human fluids: Sheboygan cas study. Technical report WIS-SG-83-240.* Madison, Winsconsin: University of Winsconsin Sea Grant Institutepp.

Thérien F. 1988. Otitis and hearing loss among northern Quebec Inuit. *Arctic Med Res* 47(Suppl 1):657-658.

Thomas PT, Hinsdill RD. 1979. The effect of perinatal exposure to tetrachlorodibenzo-p-dioxin on the immune response of young mice. *Drug Chem Toxicol* 2(1-2):77-98.

Tryphonas H, Luster MI, Schiffman G, Dawson LL, Hodgen M, Germolec D, et al. 1991a. Effect of chronic exposure of PCB (Aroclor 1254) on specific and nonspecific immune parameters in the rhesus (*Macaca mulatta*) monkey. *Fundam Appl Toxicol* 16(4):773-786.

Tryphonas H, Luster MI, White KL, Jr., Naylor PH, Erdos MR, Burleson GR, et al. 1991b. Effects of PCB (Aroclor 1254) on non-specific immune parameters in rhesus (*Macaca mulatta*) monkeys. *Int J Immunopharmacol* 13(6):639-648.

Wainwright RB. 1996. The US Arctic Investigations Program: infectious disease prevention and control research in Alaska. *Lancet* 347(9000):517-520.

Weisglas-Kuperus N, Patandin S, Berbers GA, Sas TC, Mulder PG, Sauer PJ, et al. 2000. Immunologic effects of background exposure to polychlorinated biphenyls and dioxins in Dutch preschool children.

*Environ Health Perspect* 108(12):1203-1207.

Weisglas-Kuperus N, Sas TCJ, Koopman-Esseboom C, Van Der Zwan CW, De Ridder MAJ, Beishuizen A, et al. 1995. Immunologic effects of background prenatal and posnatal exposure to dioxins and polychlorinated biphenyls in Dutch infants. *Ped Res* 38(3):404-410.

White KL, Jr., Lysy HH, McCay JA, Anderson AC. 1986. Modulation of serum complement levels following exposure to polychlorinated dibenzo-p-dioxins. *Toxicol Appl Pharmacol* 84(2):209-219.

# The Nunavik Health Survey: Environmental and Dietary Component


## Project leader(s)

Éric Dewailly, M.D.,Ph.D. Public Health Research Unit, Centre Hospitalier Universitaire de Québec (CHUQ) and National Institute of Public Health of Québec, 945, rue Wolfe, Sainte-Foy, QC G1V 5B3; Phone: (418) 650-5115 ext 5240; Fax: (418) 654-3132; E-mail: eric.dewailly@inspq.qc.cq

## Project members

Serge Déry, Nunavik Regional Board of Health and Social Services, Kuujjuaq, QC; Carole Blanchet, Public Health Research Unit, Centre Hospitalier Universitaire de Québec (CHUQ), Sainte-Foy, QC; Kue Young, Medecine Faculty, University of Toronto, Toronto, ON



## Abstract

The first objective of the project was to add a more precise evaluation of the Inuit diet and contaminant exposure in the framework of the Nunavik Health Survey that will be conducted in late summer 2004. The second objective was to support the preparation and the elaboration of the pilot study in order to field test the survey methods and dietary assessment tools. Hence, activities in 2003-2004 consisted of the elaboration of dietary questionnaires and of the environmental sampling design (quantity of each tissue and fluids, storage methods) that will be used for laboratory analyses of contaminants. Dietary data will be obtained during the Nunavik Health Study using a food frequency questionnaire and a 24-hour dietary recall. The pilot study was conducted in April 2004, in Kuujjuaq among 30 Inuit. The pilot study permitted to verify the accuracy of dietary questionnaires and to improve them in order to maintain the validity of questions. The information that will be collected in the framework of the Nunavik Health Survey will help public health authorities in Nunavik to target and design effective food protection and promotion strategies for the consumption of traditional/country foods among the Nunavik population.


## Key Project Messages

1. A detailed evaluation of the Inuit diet will permit to assess precisely how dietary intakes and patterns are involved in contaminant exposure.
2. The extensive 2004 Health Survey will provide to the Inuit of Nunavik the information needed to update informed decisions on their traditional/country food use.

## Objectives

- To add a more precise evaluation of the Inuit diet and contaminant exposure in the framework of the Nunavik Health Survey that will be conducted in summer 2004.

- To support the preparation and the elaboration of a pilot study in Nunavik in order to field test the survey methods and dietary assessment tools.

## Introduction

Inuit populations are exposed to environmental contaminants by eating traditional/country foods. During the last decades, dietary patterns evolved during the lifetime with regard to the availability of game, the accessibility of traditional food for families, the use of different tissues and organs of the animals, the availability of store-bought food and the contaminant exposure have become increasingly important in the discussion about food safety in the Arctic. The Santé Québec Health Survey conducted in 1992 provided numerous data about the contaminant exposure through traditional/country food consumption (Santé Québec 1994, 1995). This information was used extensively by our team to determine exposure levels of the Inuit, to target sub-groups who were more exposed, to measure contaminant intakes, to define socio-demographic factors, dietary behaviours and perceptions influencing contaminant and nutrient intakes etc. (Dewailly et al. 1994, 1996, 1998, 2001a, 2001b, 2001c, 2003a, 2003b; Furgal et al. 2003; Blanchet et al. 2000, 2002; Ayotte et al. 1997; Sandau et al. 2000). Moreover, since the sample size of the Santé Québec Health Survey was sufficient, it was possible to verify exposure levels of contaminants and dietary intakes between age groups, thus providing information about generational trends.

The determination of adverse health effects caused by contaminants is difficult since other factors such as lifestyle (alcohol intake, smoking, drug use, etc) diet, socioeconomic status and genetic factors play an important role in the etiology of several diseases among the Inuit populations. In addition, changes in lifestyle and dietary patterns have been observed among Inuit populations during the last decades. Because of the rapid societal transition, a shift away from traditional lifestyle and diet was observed in these populations (Labbé 1987; Hodgins 1997; Bjerregaard and Curtis 2002; Kuhnlein and Receveur 1996; Pars et al. 2001; Nobmann et al. 1992). This suggests the need to establish health surveillance systems in Arctic area to examine the significance of the environment, diet and living conditions for the development of chronic diseases. Hence, an extensive health survey (The Nunavik Health Survey: Qanuippitaa?, How are we ?) will be conducted in Nunavik in summer 2004. The 2004 Nunavik Health Survey, which is funded by the Ministère de la Santé et des Services Sociaux du Québec, will permit to gather recent information regarding the health of the Inuit population. Moreover, this survey will be the starting point of an international Inuit cohort study which will permit to assess the impact of risk factor emergence and lifestyle changes on subsequent morbidity and mortality for the major chronic diseases among Inuit populations of Canada, Greenland and Alaska. The target population of the Nunavik Health Survey will comprise all permanent adult residents of Nunavik. The participants will constitute a stratified probability sample of the Nunavik population and will be selected in the 14 coastal villages. The sample size has been set at 600 households. In Canada, 3,880 Inuit are expected to participate in the cohort study. From this Canadian sample, about 1,000 Inuit (men and women) will be selected in Nunavik .

In the framework of the Nunavik Health Survey, our team proposed a detailed evaluation of the Inuit diet in order to evaluate precisely how dietary intakes and patterns are involved in contaminant exposure, providing clearer information for risk communication. The updated information on contaminant exposure will be also compared with those obtained in 1992 during the Santé Québec Health Survey and will permit to verify temporal trends. The monitoring of contaminant exposure and dietary habits in the course of the international Inuit cohort study will permit to collect information necessary for the study of the effects of contaminant on chronic diseases. In addition to verify whether similar effects may be occur in other arctic regions characterized by high exposures, the large sample size of the cohort study will permit to study the significance of the environmental contaminants, diet and living conditions for the development of chronic diseases among the Inuit.

## Activities

### In 2003/2004

Activities in 2003-2004 consisted of the elaboration of dietary questionnaires in order to assess in detail traditional/country food consumption and contaminant intake and exposure. Dietary data will be obtained using a food frequency questionnaire and a 24-hour dietary recall. The food frequency questionnaire will be administered to adult women and men and will measure their consumption of traditional/country food for all four seasons during the year before the survey. Traditional/country food will refer to food items derived from fishing and hunting (including several parts of marine mammals such as meat, fat, skin, liver). Additional questions regarding the consumption of specific foods will asked to the participants in order to document some Inuit prevalent nutritional deficiencies such as anaemia, or in contrast, elevated consumption of some less nutritive foods such as sweet and fatty foods. The 24-hour dietary recall will permit to calculate the mean and median intakes of energy and nutrients, the contribution of foods or food groups to nutrient intakes, the importance of traditional/country foods and store-bought foods will also be assessed and this, according to socio-demographic factors. Questions about food security, accessibility, personal values, dietary attitudes, perceptions and beliefs of traditional/country and store bought foods were elaborated in order to better understand Inuit dietary intakes. In particular, questions about perception and knowledge of food chain contamination, as well as changes in lifestyle associated with perception are also included in the questionnaires of the survey. The environmental sampling design (quantity of each tissue and fluids) and their long term storage methods that will be used for laboratory analyses of contaminants have been developed. The following contaminants were selected to be measured: PCBs, pesticides, heavy metals including total and inorganic mercury fraction, and new contaminants such as PFOs and PBDEs. Ten (10) ml of blood will be collected for contaminant analyses.

Consultations were made among Inuit people and representatives of Nunavik to verify the accuracy of food items listed in the food frequency questionnaire. Numerous discussions were also effected with researchers of the international Inuit cohort study in order to ascertain that environmental and dietary questionnaires will be comparable for future comparisons. Finally, activities in 2003-2004 comprised the preparation of the pilot study to pre-test the survey tools. The pilot study was conducted in early spring 2004, in Kuujjuaq. For the realization of the pilot study, our team made contacts with Inuit representatives of Kuujjuaq for the sampling of Inuit participants and of Inuit interviewers. The pilot study involved also the preparation of training documents for interviewers.

## Results and Discussion

### Questionnaires

The list of traditional/country foods that were selected for the food frequency questionnaire is shown at Table 1. As mentioned above, country food refers to food items derived from fishing and hunting (including several parts of marine mammals such as meat, fat, skin, liver). The list of traditional/country foods is more exhaustive than that used in 1992. Since the consumption of traditional/country foods varies according to season, the respondents will answer for each season. With help of the local interviewers, we will prepare for each community an "Events Calendar". This "Events Calendar" will list a few well-recognized events that have taken place in the community one year ago from the time the survey is being done in that community. This "Events Calendar" will be useful for helping respondents appreciate the period of time that they need to consider when recalling foods eaten over the last year (traditional/country foods). The quantities of foods eaten as usual serving will be asked to the participants. Models of standardized portions will be used to help the interpreter better define and describe amounts of food eaten by the respondents. These food models are based on day-to-day tableware (i.e. containers of various sizes).

Examples of questions about food security, accessibility, personal values, dietary attitudes, knowledge, perceptions and beliefs of food chain contamination, as well as changes in lifestyle associated with these perceptions were included in the questionnaires of the survey. Table 2 shows some examples of these questions that will permit to assess more accurately the impact of perception of health risk in eating habits.

**Table 1.** List of traditional/country foods selected for the Food Frequency Questionnaire.

| Marine mammals: | Fish: |
|---|---|
| Beluga meat | Arctic char |
| Beluga misirak/blubber | Cod |
| Beluga muktuk | Whitefish |
| Dried beluga | Lake trout |
| Seal meat | Salmon and other trout |
| Seal parts (liver, kidney, etc.) | Other fish |
| Seal misirak/blubber | Dried fish |
| Walrus meat, raw | Clams, mussels, scallops |
| Walrus meat, cooked | |
| Walrus misirak/blubber | |
| Igunak (seal) | |
| **Land mammals:** | **Birds and wildfowl:** |
| Caribou meat | Ptarmigan |
| Dried caribou meat | Goose |
| Caribou liver or kidney | Pintail |
| Arctic hare | Other birds (tern, duck, etc.) |
| Other land animals: | Wild bird eggs |
| *Wild berries* | |

**Pilot study**

As mentioned above, the pilot study was conducted in Kuujjuaq in early spring 2004. The pilot study began by a training session for Inuit and professional interviewers. The training session concerning dietary data collection comprised oral presentation focusing on the objectives of the dietary part of the survey, a detailed presentation of dietary questionnaires, the use of food models, etc. Oral presentation was followed by simulations and practical exercises. Procedures of interviewers were checked and adjusted.

Thirty (30) Inuits participated to the pilot study. Interviews were conducted at home or in the office of the Nunavik Regional Board of Health and Social Services. Results obtained from the pilot study revealed that Inuit participants perceived the food frequency questionnaire as being long to answer. After checking the questionnaire, we decided to shorten the list of store bought food items. Regarding the 24-hour dietary recall, Inuit participants perceived this questionnaire easier to fill out. Once data was collected and the questionnaires were checked, the lack of any incongruity in results was verified and corrections were applied in order to maintain the validity of questions.

## Conclusion

The 2004 Health Survey will provide to the Inuit

**Table 2.** Examples of questions elaborated in order to assess knowing of food contamination, perceptions and attitudes influencing contaminant intakes and the level of hunting/fishing practice.

| |
|---|
| 1. Have you ever heard of country food contamination, e.g., the presence of pollutants or chemicals in country foods? |
| 2. Can you tell me if any of the following items are contaminants or pollutants that could be found in country foods? (mercury, lead, PCBs, cadmium) |
| 3. Have you modified your eating habits since you heard about contamination in country foods? |
| 4. If yes, can you tell me some of the changes you have made? |
| 5. What is it you like about eating country food? |
| 6. In the past 12 months, on average, how often did you go hunting or fishing? |
| 7. Do you usually share your catch with your family or friends? |
| 8. Do you receive country foods from your friends or relatives outside your house? |
| 9. Do you get country foods from the community freezer? |
| 10. If no, why don't you get food from the community freezer? |

of Nunavik the information needed to update informed decisions on their food use. Furthermore, since numerous data on nutrient intakes and contaminant exposure will be collected and biological indicators of nutritional intakes will be measured (n-3 fatty acids, selenium), it will be possible to balance potential health risks related to contaminant exposure with nutritional benefits.

## Project Completion Date

Activities proposed for 2003-2004 have been completed. The Nunavik Health Survey will be conducted from August to October 2004. Laboratory analyses, codification and data entry questionnaires will be performed from November to August 2005, and will be followed by data analyses and reports.

## References

Ayotte, P. Dewailly, É. Ryan, J.J. Bruneau, S. and G. Lebel. 1997. PCBs and dioxin-like compounds in plasma of adult Inuit living in Nunavik (Arctic Quebec). *Chemosphere.*34(5-7):1459-1468.

Bjerregaard, P. Dewailly, E. Young, K. Blanchet, C. And R.A. Hegele. 2003. Blood pressure among the Inuit (Eskimo) populations in the Arctic. *Scand J Public Health..*31:92-99.

Bjerregaard, P. and T. Curtis. 2002. Cultural change and mental health in Greenland: the association of childhood conditions, language, and urbanization with mental health and suicidal thoughts among the Inuit of Greenland. *Social Sciences and Medecine.*54:33-48.

Bjerregaard, P. and T.K. Young. 1998. *The Circumpolar Inuit: Health of a Population in Transition.* Munksgaard ed. Copenhangen: Manticore.

Blanchet, C. Dewailly, E. Chaumette, P. Nobmann, E.D. and P. Bjerregaard. 2002. Diet Profile of Circumpolar Inuit. In: Duhaime G, ed. *Sustainable Food Security in the Arctic.* Vol 1. Québec: Canadian Circumpolar Institute Press. 242 pp.

Blanchet, C. Dewailly, E. Ayotte, P. Bruneau, S. Receveur, O. and B.J. Holub. Contribution of selected traditional and market food to Nunavik Inuit women diet. *Can J Diet Pract Res.* 2000;61(2):50-59.

Dewailly, E. Bruneau, S. Laliberté, C. Lebel, G.

Gingras, S., Grondin, J. et P. Levallois. 1994. *Report of the Santé Québec Health Survey among the Inuit of Nunavik: 1992: The contaminants.* Montréal: Santé Québec, Gouvernement du Québec, Ministère de la Santé et des Services Sociaux; Volume 1, chapter 3.

Dewailly, É. Ayotte, P. Blanchet, C. and J. Grondin. 1996. Weigthing contaminant risks and nutrient benefits of country food in Nunavik. *Arctic Med Res.* 55(Suppl 1):13-19.

Dewailly, E. Ayotte, P. Blanchet, C. Gingras, S. and G. Muckle. 1998. *Integration of 12 years of data in a risk and benefit assessment of traditional food in Nunavik.* Québec: Québec Public Health Center. 74 pp.

Dewailly, E. Blanchet, C. Lemieux, S. Gingras, S. Sauvé, L. Bergeron, J. and B.J.Holub. 2001a. N-3 fatty acids and cardiovascular disease risk factors among the Inuit of Nunavik. *Am J Clin Nutr.*74(4):464-473.

Dewailly, É. Blanchet, C. Furgal, C. and S. Gingras. 2001b. Socio-demographic factors influencing nutrition and contaminant exposure in Nunavik. *Report and Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program.* Ottawa: Department of Indian Affairs and Northern Development, Canada; 26-35.

Dewailly, É. Ayotte, P. Bruneau, S. Lebel, G. Levallois, P. and J.P. Weber. 2001c. Exposure of the Inuit population of Nunavik (Arctic Quebec) to lead and mercury. *Arch Environ Health.* 56(4):350-357.

Dewailly, E. Blanchet, C. Gingras, S. Lemieux, S. and B.J. Holub. 2003a. Fish Consumption and Blood Lipids in Three Ethnic Groups of Québec (Canada). *Lipids.* 38:359-365.

Dewailly, E. Bruneau, S. Ayotte, P. Mirault, M.E. et P. Julien. 2003b. *Effects of mercury exposure on the oxidative status and neuromotor functions of an Inuit population of Nunavik.* Québec: Public Health Research Unit, CHUL Research Center - CHUQ; 66 pp.

Furgal C, Blanchet C, Dewailly É, Muckle G, Gingras S. 2003. *Relationships between risk perception of food chain contaminants and country food use, contaminant exposure and determinants of social and mental health among Nunavimmiut.* Québec: Public Health Research Unit, CHUL. Ottawa, Canada.

Hodgins, S. *Health and what affect it in Nunavik: How is the situation changing?* 1997. Kuujjuaq: Bibliothèque Nationale du Canada.

Kuhnlein, H. and O. Receveur. 1996. Dietary change and traditional food systems of indigenous peoples. *Ann. Rev Nutr.* 16:417-442.

Labbé, J. *Les Inuits du Nord québécois et leur santé.* 1987. Projet Nord, CHUL et Ministère de la santé et des services sociaux, Gouvernement du Québec. 42pp.

Nobmann, E. Byers, T. Lanier, E.O. Hankin, J.H. and M.Y. Jackson. 1992. The diet of Alaska Native adults: 1987-1988. *American Journal of Clinical Nutrition.*.55(5):1024-1032.

Pars, T. Osler, M. and P. Bjerregaard. 2001. Contemporary use of traditional food among Greenlandic Inuit. *Arctic.* 54(1):22-31.

Sandau, C.D. Ayotte, P. Dewailly, E. Duffe, J. and R.J. Norstrom. 2000. Analysis of hydroxylated metabolites of PCBs (OH-PCBs) and other chlorinated phenolic compounds in whole blood from Canadian Inuit. *Environmental Health Perspectives.*108(7):611-616.

Santé Québec. *Report of the Santé Québec Health Survey among the Inuit of Nunavik: 1992.* 1994. Montréal: Ministère de la Santé et des Services Sociaux du Québec, Gouvernement du Québec.

Santé Québec. *Report of the Santé Québec Health Survey among the Inuit of Nunavik: Diet, a Health Determining Factor.* 1995. Montréal: Ministère de la Santé et des Services Sociaux, Gouvernement du Québec; Tome 3.

# Time Trends of Mother/Child Exposure to Contaminants in the Canadian Arctic: Nunavik Component


## Project leader(s)

Éric Dewailly, ACADRE Center on Inuit Health and Changing Environment. Public Health Research Unit, CHUL-CHUQ, 945, rue Wolfe, Sainte-Foy, QC G1V 5B3; Phone: (418) 650-5115 ext 5240; Fax: (418) 654-2148; E-mail: eric.dewailly@inspq.qc.ca

## Project members

Daria Pereg, Pierre Ayotte, Gina Muckle, Carole Vézina, Suzanne Bruneau Public Health Research Unit, CHUL-CHUQ, 945, rue Wolfe, Sainte-Foy, QC G1V 5B3; Phone: (418) 650-5115 ext 4647; Fax: (418) 654-2148; Jean-Philippe Weber, Institut National de Santé publique du Québec, division de Toxicologie Humaine, 945, rue Wolfe, Sainte-Foy, QC G1V 5B3


## 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. The main objective of this project is to set the bases to allow spatio-temporal trends assessments in contaminants exposure in Nunavik, including emerging contaminants for which increasing concentrations in wildlife and human samples have been reported. This is being achieved by 1) integrating data gathered in past studies; 2) determining the availability of archived samples for the analysis of emerging contaminants; 3) generating new data to obtain an update on current exposure levels, and 4) validate the use of a newly developed analytical methods allowing the measurement of several analytes in a small volume of plasma (including the former suite of POPs and emerging contaminants). A sample collection was set-up in the Ungava region and analyses of these samples are being carried-out using both methods used in past studies, and a newly developed procedure. As well, databases from earlier studies are being standardized and merged, and the availability of archived samples from earlier projects is also being assessed.. This pilot study will set the bases for a larger study on spatial and temporal trends of exposure to environmental contaminants in Nunavik.


## Key Project Messages

1. A pilot study on spatio-temporal trends of contaminants in maternal and umbilical cord blood has been set-up in the Ungava region of Nunavik, in collaboration with the Ungava Tulattavik Health Center. This study involves recruiting women at Tulattavik in order to collect maternal and umbilical cord blood for analyses. This sampling is ongoing and will be pursued during the next 5 years.

2. A new analytical method has been developed in the Toxicology Laboratory of INSPQ, which allows the measurement of a larger number of contaminants in a smaller volume of plasma. This method is currently being compared and validated against methods formerly used to measure POPs in plasma.

3. An inventory of archived samples is being done in order to determine the availability of archived cord and maternal plasma that may be analysed for emerging contaminants such as BDEs and PFOS.

4. Integration of contaminants data in cord and maternal blood from past projects is ongoing and a harmonized database will be available shortly for further spatio-temporal trend assessments.

## Objectives

1) To integrate data gathered in past studies regarding contaminants levels measured in umbilical cord plasma / blood and maternal plasma / blood;

2) To determine the availability of archived samples for the analysis of emerging contaminants;

3) To generate new data on contaminants exposure in order to obtain an update on current exposure levels to the traditional suite of contaminants measured in previous projects since the mid-80s (polychlorinated biphenyls (PCBs), organochlorine (OCs) pesticides, mercury (Hg) and lead (Pb)), as well as emerging contaminants such as perfluorooctanesulfonate (PFOS) and brominated diphenyl ethers (BDEs).

4) To validate the use of a newly developed analytical methods allowing the measurement of several analytes in a smaller volume of plasma (including the former suite of POPs and emerging contaminants).

## 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 organochorines (OCs) (Kinloch, Kuhnlein et al. 1992; Dewailly, Bruneau et al. 1993; Muckle, Ayotte et al. 2001). 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 heavy metals (Pb, Hg) and OC exposure (mainly PCBs) suggest that prenatal life is the most susceptible period for 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 (Rogan, Gladen et al. 1986; Taylor, Stelma et al. 1989; Dewailly, Bruneau et al. 1993; Guo, Chen et al. 1994; Koopman-Esseboom, Morse et al. 1994; Guo, Lambert et al. 1995; Jacobson and Jacobson 1997; Patandin, Koopman-Esseboom et al. 1998; Winneke, Bucholski et al. 1998; Gladen, Ragan et al. 2000).. As well, prenatal exposure to methylmercury (MeHg) has also been linked to developmental and cognitive deficits in infancy and childhood (Weihe, Hansen 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, Fisk et al. 2001; Muir, Köck et al. 2001). 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, Dewailly et al. 2002) and in Nunavik Inuit residing in the Hudson Bay area (Dallaire, Dewailly 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 (BFR) such as brominated diphenyl ethers (BDEs), commonly added in the composition of electronic equipments, plastics and textiles. BDEs share some physico-chemical and toxicological properties with OCs, but contrarily to the latter for which production, sale and use generally tends to decrease, BDEs use and environmental occurrence has dramatically increased since the 1980s (Meironyte, Noren et al. 1999; Noren and Meironyte 2000; Ikonomou, Rayne et al. 2002).. 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 (i.e. embryotoxicity, interference with thyroid hormone signalling, neurotoxic effects, etc.) (Darnerud, Eriksen et al. 2001; Zhou, Taylor et al. 2002).

The main objective of this project is to set the bases to allow assessments of spatio-temporal trends of contaminants exposure in Nunavik, including emerging contaminants for which increasing concentrations in wildlife and human samples have been reported. This is being achieved by integrating data gathered in past studies and comparing the latter to newly generated data that provide an update on current levels of exposure. As well, exposure levels to emerging contaminants are being assessed and in order to derive spatio-temporal trends for these contaminants as well, the availability of archived samples for the analysis of emerging contaminants is being determined. Additionally, the use a newly developed analytical methods allowing the measurement of several analytes in a small volume of plasma (including the former suite of POPs and emerging contaminants) is being validated.

## Activities

### In 2003-2004

A sample collection was set-up in the Ungava region and analyses of these samples is being carried-out using methods formerly used and the newly developed procedure. As well, databases from earlier studies are being integrated and the availability of archived samples from earlier projects is also being assessed. An inventory of archived samples is currently being conducted in order to determine the availability of samples for analyses of emerging contaminants in cord and/or maternal blood collected in earlier studies. This pilot study will set the bases for a larger study on spatial and temporal trends of exposure to environmental contaminants in Nunavik.

*Recruitment and sample collection*

Sampling of maternal blood and umbilical cord blood is currently ongoing at the Ungava Tulattavik Health Center, Kuujjuaq. Women are informed of the project during their prenatal visit to the Health Center at 36 weeks of pregnancy, and the nurse in charge of pregnancy follow-up solicits their participation to the study. If the woman accepts to be part of the study, the nurse in charge explains the consent form to the participant and obtains her signature. The consent form is then kept in her medical file and a note is made on the obstetrical list in order to inform the physician that the patient participates to the research project.

After delivery, blood is drawn from the cord before it is discarded. A blood sample from the mother is collected 24h after birth during a standard procedure consisting in collecting maternal blood after delivery for hematocrit analyses. At this time, a short questionnaire is administered to document parameters that may affect contaminants in maternal and/or cord blood. After collection, blood samples are transferred to the hospital laboratory to be aliquoted, and processed to collect plasma. All samples are then frozen and shipped to the Toxicology laboratory at INSPQ.

*Analytical methods*

Contaminants measured in maternal and cord blood or plasma include the traditional suite of organochlorines (OCs) and heavy metals measured in previous projects since the mid-80s (14 polychlorinated biphenyls (PCBs) congeners, 11 OCs pesticides, mercury (Hg) and lead (Pb)), as well as emerging contaminants such as perfluorooctanesulfonate (PFOS) and brominated diphenyl ethers (BDEs).

For organochlorine measurements, two different methods are being compared: the conventional method used in the framework of our past studies (extensively described in (Muckle, Ayotte et al. 2001a; Muckle, Ayotte et al. 2001b)) and the new SACEMF method (Semi-Automated Comprehensive Extraction Multiple Fraction), 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 SACEMF 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 on 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, 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 SACEMF method followed by MS procedures to measure at least 14 PCB congeners, 33 OC pesticides, and 8 PBDE congeners. Development and validation is ongoing for the detection of more analytes, including toxaphene congeners, hydroxylated PCBs, hydroxylated PBDEs, brominated/chlorinated phenols, methyl-sulfonyl-PCBs/DDE and polychlorinated naphtalenes congeners.

Analyses of PFOS are being 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.

Metals are 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.. Isotope speciation of lead will be also assessed to better determine the origin of exposure (natural sources or ammunitions) and this will contribute to the evaluation of the efficiency of the lead shot ban in Ungava for locations where no data currently exists.

*Databases and archived samples*

Before performing statistical analyses to derive temporal and geographical trends for exposure to environmental contaminants, an important step is to integrate all exposure assessment data available from past studies. The comparability of variables from questionnaires and analytical methods used for the determination of environmental contaminants in different matrices needs to be verified (semantic data integration). All comparable data need then to be merged into a unique, harmonized database, where each sample is identified with a unique identifier, a geographical position (village of residence) and a sampling time (date of baby's birth). When analytical data are available, they will be included in this integrated database.

In parallel, an inventory of archived samples is currently being done in order to determine the availability of samples for the analyses of emerging contaminants. As well, all archived samples can then be linked to they related data in the integrated database. Depending on availability, remaining archived samples will be analysed for emerging contaminants and this additional data will be included in the standardized database.

## Results/Discussion

In order to proceed with the sample collection, documents pertaining to this project were elaborated (questionnaire, consent form, information letter) and we submitted the project to the Laval University Ethics Committee. Approval was obtained in mid-February to begin the project. Contacts were made in February with the authorities of the Ungava Tulattavik Health Center in order to set up the sample collection.

Recruitment actively started in early March 2004 at the Ungava Tulattavik Health Center. To this date, five participants have been recruited and have given birth out of the ten participants for this pilot study (the aim is to gather a total of 20 samples, 10 maternal blood samples and 10 cord blood samples). This low number of participants is due mostly to the low number of patients that gave birth in Kuujjuaq since recruitment began.

However, according to the nurse in charge of informing women and soliciting their participation to the study, there seem to be a strong interest from the women solicited and given the fact that the sampling procedure is not cumbersome, it is plausible that sampling will not pose a major problem in this area.

Laboratory analyses are currently being carried out in the human toxicology laboratory of the "Institut National de Santé Publique du Québec" (INSPQ), which is accredited by the Canadian Association for Environmental Analytical Laboratories and accredited ISO 17025. Analyses are ongoing and results will be available shortly.

The archived sample inventory and database integration were started in early Fall and are currently ongoing. Database integration is being achieved with the help of a statistician as well as a specialist in Geographical 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 collided 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.

## Acknowledgements

From the Ungava Tulattavik Health Center, we thank Dr. René Leclerc, Erika Poirier, Carl Grondines, Johanne Hardy, Michelle Audy and all medical and para-medical personnel involved in this study. From the Institut national de Santé Publique du Québec (INSPQ), Toxicologie Humaine, we thank Alain Leblanc, Évelyne Pelletier, Pierre Dumas, Normand Fleury and Torkjel Sandanger for contaminants analyses in maternal and cord blood. We also thank Jean-Sébastien Maguire for help with sample archiving (CHUQ-CHUL, URSP).

## References

Dallaire, F., E. Dewailly, et al. (2002). "Temporal trends of organochlorine concentrations in umbilical cord blood of newborns from the Lower North Shore of the St.Lawrence River (Québec, Canada)." Environmental Health Perspectives 110(8): 835-838.

Dallaire, F., E. Dewailly, et al. (2003). "Time trends of persistent organic pollutants and heavy metals in umbilical cord blood of Inuit infants born in Nunavik (Québec, Canada) between 1994 and 2001." Environmental Health Perspectives 111(13): 1660-1664.

Darnerud, P. O., G. S. Eriksen, et al. (2001). "Polybrominated Diphenyl Ethers: Occurrence, Dietary Exposure, and Toxicology." Environ Health Perspect 109 Suppl 1: 49-68.

Dewailly, É., S. Bruneau, et al. (1993). "Health status at birth of Inuit newborns prenatally exposed to organochlorines." Chemosphere 27(1-3): 359-366.

Gladen, B. C., N. B. Ragan, et al. (2000). "Pubertal growth and development and prenatal and lactational exposure to polychlorinated biphenyls and dichlorodiphenyl dichloroethene." Journal of Pediatrics 136(4): 490-6.

Guo, Y. L., Y.-C. Chen, et al. (1994). "Early development of Yu-Cheng children born seven to twelve years after the Taiwan PCB outbreak." Chemosphere 29(9-11): 2395-2404.

Guo, Y. L., G. H. Lambert, et al. (1995). "Growth abnormalities in the population exposed in utero and early postnatally to polychlorinated biphenyls and dibenzofurans." Environmental Health Perspectives 103(Suppl.6): 117-122.

Ikonomou, M. G., S. Rayne, et al. (2002). "Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981 to 2000." Environ Sci Technol 36(9): 1886-92.

Jacobson, J. L. and S. W. Jacobson (1997). "Evidence for PCBs as neurodevelopmental toxicants in humans." Neurotoxicology 18(2): 415-424.

Kinloch, D., H. Kuhnlein, et al. (1992). "Inuit foods and diet: a preliminary assessment of benefits and risks." Sci. Tot. Environ. 122: 247-278.

Koopman-Esseboom, C., D. C. Morse, et al. (1994). "Effects of dioxins and polychlorinated biphenyls on thyroid hormone status of pregnant women and their infants." Pediatrics Research 36(4): 468-473.

Meironyte, D., K. Noren, et al. (1999). "Analysis of polybrominated diphenyl ethers in Swedish human milk. A time-related trend study, 1972-1997." J Toxicol Environ Health 58(6): 329-41.

Muckle, G., P. Ayotte, et al. (2001a). "Determinants of polychlorinated biphenyls and methylmercury exposure in Inuit women of childbearing age." Environmental Health Perspectives 9: 957-963.

Muckle, G., P. Ayotte, et al. (2001b). "Prenatal Exposure of the Northern Quebec Inuit Infants to environmental contaminants." Environmental Health Perspectives 12: 1291-1299.

Muir, D., A. Fisk, et al. (2001). Temporal trends of persistent organic pollutants and metals in ringed seals from the canadian arctic. Synopsis of Research. Ottawa, Northern Contaminants Program, Indian and Northern Affairs Canada: 208-214.

Muir, D., G. Köck, et al. (2001). Temporal trends of persistent organic pollutants and metals in landlocked char. Synopsis of Research. Ottawa, Northern Contaminants Program, Indian and Northern Affairs Canada: 202-207.

Noren, K. and D. Meironyte (2000). "Certain organochlorine and organobromine contaminants in Swedish human milk in perspective of past 20-30 years." Chemosphere 40(9-11): 1111-23.

Patandin, S., C. Koopman-Esseboom, et al. (1998). "Effects of environmental exposure to polychlorinated biphenyls and dioxins on birth size and growth in Dutch children." Pediatric Research 44(4): 538-45.

Rogan, W. J., B. C. Gladen, et al. (1986). "Neonatal effects of transplacental exposure to PCBs and DDE." Journal of Pediatrics 109(2): 335-341.

Taylor, P. R., J. M. Stelma, et al. (1989). "The relation of polychlorinated biphenyls to birth weight and gestational age in the offspring of occupationally exposed mothers." American Journal of Epidemiology 129(2): 395-406.

Weihe, P., J. C. Hansen, et al. (2002). "Neurobehavioral performance of Inuit children with increased prenatal exposure to methylmercury." International Journal of Circumpolar Health 61(1): 41-49.

Winneke, G., A. Bucholski, et al. (1998). "Developmental neurotoxicity of polychlorinated biphenyls (PCBS): cognitive and psychomotor functions in 7-month old children." Toxicology Letters 102-103: 423-8.

Zhou, T., M. M. Taylor, et al. (2002). "Developmental exposure to brominated diphenyl ethers results in thyroid hormone disruption." Toxicol Sci 66(1): 105-16.

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


## Project leader(s)

Mike Inskip, Environmental and Occupational Toxicology Division, Bureau of Environmental Health Science, Safe Environments Program, Healthy Environments and Consumer Safety Branch, Health Canada. *Address*: 0803B, Environmental Health Center, Rue de la Columbine, Tunney's Pasture, Ottawa, ON K1A 0L2; phone: (613) 957 1885; fax: (613) 957 8800; e-mail: mike_inskip@hc-sc.gc.ca

## Project members

Don Forsyth, Health Products and Foods Branch, Health Canada, Ih Chu and Al Yagminas, Environmental and Occupational Toxicology Division, Health Canada; Francois Doré, Department of Psychology, L'Université Laval, Québec, Tom Clarkson, Dept. of Environmental Medicine, University of Rochester School of Medicine and Dentistry, Rochester, NY


## Abstract


The mechanism by which prenatal neurological damage occurs through maternal methylmercury (MeHg) ingestion (without apparent injury to the maternal nervous system) is not well characterized but the relative higher tissue levels in fetal blood and brain may be an important contributory factor. The current study – incorporating a new stable isotope approach - uses an animal model to better understand the flux of MeHg moving from mother to fetus, especially to characterize potential changes in tissue levels and endpoints in the pups, from the mother consuming periodic ('pulse' doses) intake of MeHg. Selected commercially-available enriched isotopes of mercury have been purchased and selection of the optimal formulation (abundances of the different isotopes that make up 'common' or 'native' mercury) has occurred, prior to the planned test administration to mice via the diet. The enriched isotopes are non-radioactive and are: $^{198}$Hg, $^{200}$Hg and $^{202}$Hg. Speciation of mercury using traditional extraction and separation techniques is time consuming and costly, resulting in many studies relying on total mercury analysis when speciation would be more appropriate. An alternative to earlier methylmercury methods is *in situ* derivatization followed by headspace analysis. Our project focuses on the development of a rapid and environmentally friendly (low solvent consumption) analytical technique for methylmercury determination based on enzymatic hydrolysis of biological tissue, *in situ* phenylation of methylmercury to methylphenylmercury and preconcentration by a new microextraction technique (MET). Isotopic surrogate addition and high resolution mass spectrometry will allow accurate, sensitive (low picogram) detection. Testing of a unique solid state extraction procedure and sensitive High Resolution-Mass Spectroscopy approach for distinguishing between the different isotopes is under development. In addition, a physiologically-based pharmacokinetic model of methylmercury developed for the rat, has been adapted for use in a mouse model. Such adaptations include the ability -in the current study - to incorporate generated key physiologic and analytical measurements of methylmercury in fetal and maternal tissues and fluids. During the first year of this project, design of a suitable dosing regimen using enriched stable isotopes was established, methodological development for isotope preparation and analysis explored and a PBPK model for the pregnant rat was adapted and modified for use with the mouse.

## Key Project Messages

1. Use of enriched stable isotopes of mercury (non-radioactive) offers the opportunity to explore mechanisms behind the enhanced risks to the fetus compared to the dam during Hg exposure in pregnancy.
2. A practical alternative to liquid-liquid extraction of methylmercury is *in situ* phenylation to methylphenylmercury, resulting in a rapid, simple analytical procedure. The approach, combined with High Resolution GC-MS analysis, offers the ability to distinguish between inpact on the fetus of 'pulse' doses of mercury ingested by the mother, as compared to exposure from continuous 'lower-level' background doses (steady state).
3. Adaptation of an existing physiologically-based pharmacokinetic model of methylmercury in the pregnant rat, will be of much use for experimental development applicable to pregnancy in the mouse, which (for methylmercury) is a preferable animal model for comparison with human pregnancy.

## Objectives

To increase the speed and accuracy of methylmercury determinations in biological tissues and to synthesize and measure isotopic methylmercury compounds in a form for feeding to animals.

To develop a protocol and suitable methodology to understand the pharmacokinetics and mechanism associated with accumulation of methylmercury in the fetal mouse brain and to explore the toxicological significance to the fetus of pulse doses of MeHg administered to the mouse dams during pregnancy (neurobehavioural changes in offspring).

## Introduction

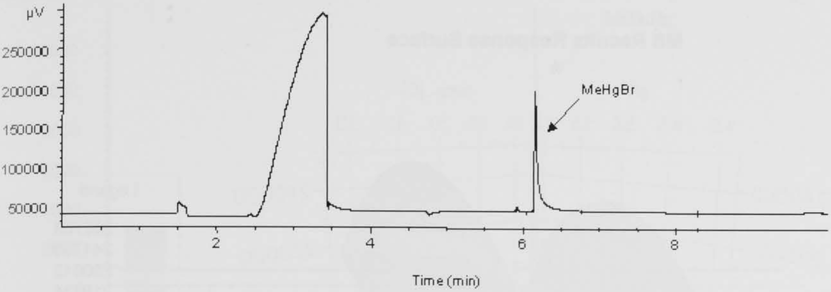
Methylmercury consumed in the diet and entering the maternal circulation, passes readily through the placenta and can accumulate in the developing fetal brain (WHO, 1991). The increased sensitivity of the developing fetal nervous system to methylmercury (MeHg) compared to the adult has been known for some time (Inskip and Piotrowski, 1986; W.H.O., 1991; Choi, 1989; and Lapham et al., 1995) but there are many questions which remain (Watanabe and Satoh, 1996; Zheng, Aschner, and Ghersi-Egea, 2003). Among these are how the magnitude and duration of exposure alter the toxicological impact of MeHg on the nervous system at different times in pregnancy (i.e., does a 'bolus' or 'pulse' exposure of the mother in early pregnancy or late pregnancy have an equivalent effect on brain development? (Inskip et al., 2003)).

This has 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.

In order to explore, in an appropriate small animal model, the kinetics of maternal:fetal transfer involving such 'pulse' or 'bolus' doses, a suitable strain of mouse (C57BL/6) has been selected and a supplier identified. As well as exhibiting closer physiological similarity to humans than the rat, this strain has also been shown in previous studies (Doré et al., 2001; Goulet et al., 2003) to demonstrate subtle neurobehavioural effects in the offspring and at concentrations of MeHg in the intended concentration ranges (physiologically relevant to human exposure regimes).

An experimental protocol has been developed utilizing a unique stable isotope dosing regimen which will be administered to the mice during pregnancy. The stable isotopes used are *non-radioactive* and data produced from application of this method allow interpretation in a similar manner to results from radioisotopic tracers (for example, in the case of lead isotopes, see:Inskip et al., 1996; Franklin et al., 1997; Hintelmann et al., 1997). In nature, 'common' (or 'native') Hg is made up of a combination of many separate isotopes each with a different atomic weight. Each isotope has its own particular atomic abundance (Hintelmann et al., 1997).

Figure 1. GC-ECD chromatogram of MeHgBr.




Using individually prepared mixes of isotopes in which a particular one is artificially enriched (so that its relative abundance to the others is increased) means that this mixture is now 'unique' and has a recognizable 'isotopic fingerprint'. Consequently, when mercury with this same 'isotopic fingerprint' is measured in analyzed tissues – it can be recognized, and quantified, thus making it possible to differentiate from other mercury doses having differently formulated isotopic fingerprints.

Many reported extraction methods for methylmercury from biological tissue are based on acid-solvent extraction (Lorenzo et al., 1993; Madson and Thompson, 1998; Quevauviller et al., 2000) or complexation to cysteine to assist in isolating the methylmercury from other organic coextractives (Newman 1971). One of the successful approaches using liquid-liquid extraction has been isolating the methylmercury as methylmercury chloride or bromide using GC-electron capture detection but some difficulties remain with the chromatography, even with modern capillary columns (Forsyth et al., 2004). Also, although effective, these methods are slow and use relatively large amounts of solvents. Quantitation is generally by gas chromatography with a variety of detectors reported, including: ICP-MS (Hintelmann et al., 1997), ECD (Caricchia et al. 1997, Quevauviller et al. 2000, AED (Madson and Thompson 1998), MS (Cai et al., 2000; Yang et al., 2003) or AFS (Cai et al., 1997).

A more recent approach is to derivative the methylmercury to a dialkyl mercury compound, using sodium tetraethyborate (Cai and Bayona 1995; Martin-Doimeadios et al. 2002), sodium tetrapropylborate (Chen et al. 2004), or sodium tetraphenylborate (Hu et al. 1997; Palmieri and Leonel 2000). Derivatization greatly improves the chromatography than can be achieved when chromatographing methylmercury halides. If the derivative is then collected from the headspace, a very clean extract is rapidly achieved, eliminating any further extract cleanup requirements.

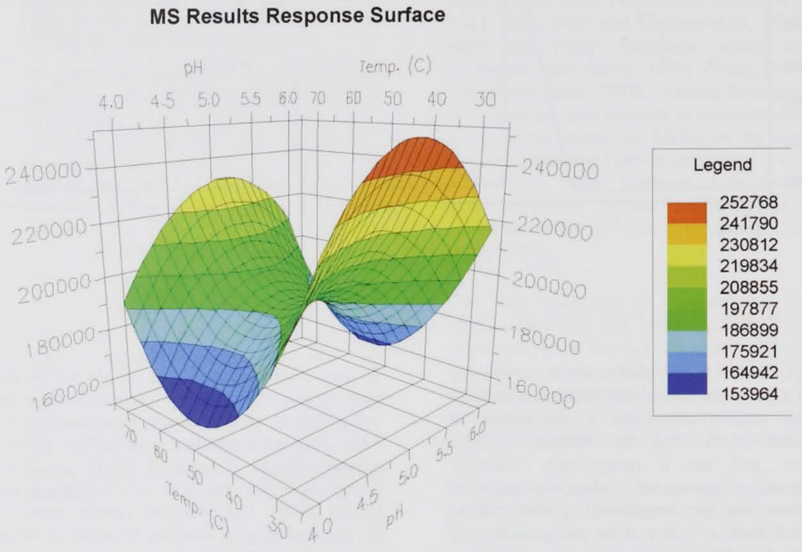
## Activities

### In 2003/2004

Appropriate quantities of three different enriched stable isotopes of mercury ($^{198}Hg$, $^{200}Hg$ and $^{202}Hg$ )have been purchased. Dr. Forsyth has completed several test syntheses of $Me^{200}HgBr$ from $^{200}HgO$ using methylcobalamin as the methylating agent (Hintelmann 1999). These studies have examined the effect of reaction time, temperature and methylcobalamin concentration on product yield.

Two candidate *in situ* derivatization procedures (ethylation, phenylation) for MeHgBr were examined in preliminary studies. Optimum

Figure 2. Surface response plot of effect of reaction pH and temperature (°C) on peak area response of MePhHg derivative.




reaction conditions (pH, temperature, time and [derivatizing reagent]) using sodium tetraethylborate and sodium tetraphenylborate in water were investigated using multivariate experimental design. The appearance of the reaction product (methylethylmercury or methylphenylmercury) was monitored by GC-MS (selective ion mode). Remaining starting material (MeHgBr) was measured by GC-ECD.

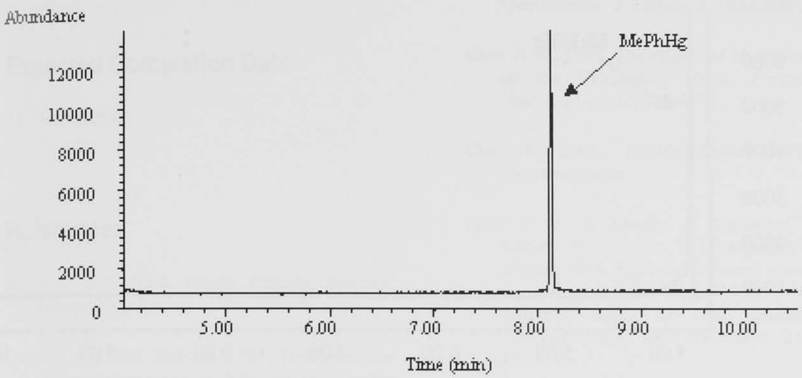
Test pathology material (brain tissue) containing methylmercury have been provided for the development of the extraction and GC-MS method, for developing expertise in micro-dissection and for calculations of requirements for pooling of harvested fetal brain tissues.

Collaborating scientists from sister establishments have been consulted on protocol design (Clarkson et al., University of Rochester) and neurobehavioural testing procedures (Dr F. Doré, Laval University), and given the uniqueness of the isotopic technique (as adapted to use with Hg stable isotopes rather than lead) experts in the field have been contacted for specific advice on enrichment and mathematical un-mixing procedures (Dr W Manton, University of Texas at Dallas and Dr E. Edwards, Toronto).

Preliminary assessments of the degree of enrichment of the selected stable isotope which will be required to label the doses administered in pregnancy, have been carried out (to be tested in a pilot dosing study).

Ensuring the integrity of the dosing strategy for the mice was considered very important given the need to estimate accurately the dose of

Figure 3. GC-MS chromatogram of MePhHg.




isotopes consumed. The choice of dose vehicle (inpregnation in supplementary diet (cookies)) has been made based on tests in the laboratory and on other work carried out at Health Canada (Chu, 2003, personnal communication).

An existing physiologically-based pharmacokinetic (PBPK) model originally developed for the rat (Farris et al., 1993; Gray, 1995) has been modified using specific data available in the literature for the mouse (Dr E Edwards, Toronto), and identified data gaps in physiological parameters which would be beneficial to improvement of the pregnancy model have been identified.

Test dissections of fetal mouse brains from pathology material have been conducted in late gestation and at term, as well as calculations of the minimum quantities of tissues available for the analytical extraction technique. Dietary content of methylmercury in standard commercially available mouse feed, have been investigated, given the propensity of some commercially available diets to contain background levels of methylmercury, presumably from the inclusion of fish produce in their formulation (Bowers, 2004, and Purina Inc., 2004, personal communication).

## Results

IN 2002-2003

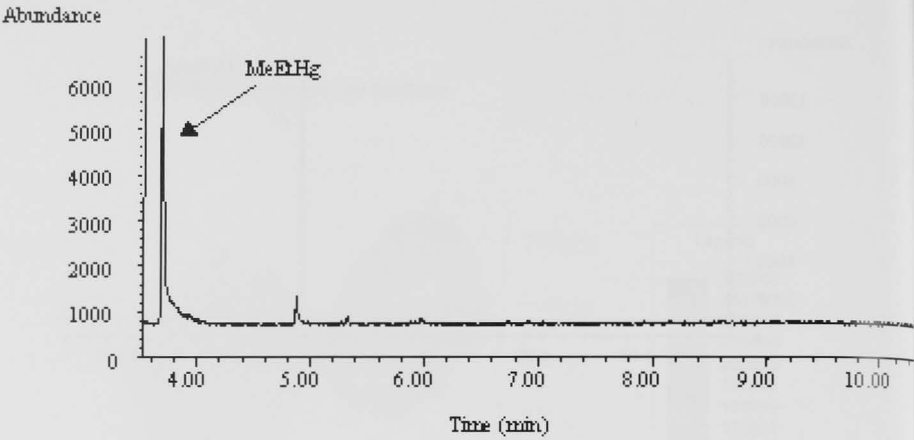
*$Me^{200}HgBr$ Synthesis*

The synthesized $Me^{200}HgBr$ (Figure 1) chromatogram showed few additional peaks. The reaction yield has reached 73% but further studies are underway with native mercury to assess other reaction pathways/conditions to achieve a higher yield prior to scaling the procedure up in anticipation of the amount of isotopic methylmercury required for the feeding study component of the study. Further testing by GC-MS and NMR will be used to examine the final product.

**In Situ Derivatization Studies**

Reaction conditions that maximized the formation of MeEtHg were 50ºC, pH 5.0, 30 min, 1.5% (w/v) sodium tetraethylborate whereas for MePhHg the best conditions were 45ºC, pH 5.0, 20 min, 2% (w/v) sodium tetraphenylborate (Figure2).

**Figure 4.** GC-MS chromatogram of MeEtHg.




These parameter values may change when forming the derivative in the presence of a tissue matrix and will be reassessed. Derivatization with sodium tetraphenylborate appears more promising than with sodium tetraethylborate, based on similar reactivity with MeHg, simplified handling requirements (no glove box required) and much lower reagent cost. Further, the MePhHg derivative chromatographs much better (Figure 3) than the more volatile MeEtHg compound (Figure 4).

*Class-100 cleanroom establishment and laboratory procedures.*

Due to the known potential for inter-isotope sample contamination in research involving stable isotopes (Inskip et al., 1996), and the ubiquity of gaseous Hg in laboratory environments, extensive efforts have been made in the area of contamination containment. A metal-free and Class-100 laminar air cabinet and preparation area have been dedicated to sample dissection and equipment treatment in the laboratory. In addition, according to the isotope mixtures to be used, separate sets of dedicated Teflon ware, dissection instruments and cleaning equipment have been assigned. Precautionary air-testing of occupied laboratory areas for historical metallic mercury spills was carried out.

## Discussion

The synthesis procedure, when finalized, will be used to produce three different isotopic methylmercury compounds ($Me^{198}HgCl$, $Me^{200}HgCl$ and $Me^{202}HgCl$). Two will be used in a feeding study to monitor chronic (low level) and bolus (high level) dosage contributions to the overall methylmercury burden in mouse brain tissue. The third isotopic methylmercury compound will be used for surrogate addition in the analyses. The methylcobalamin synthesis results are promising, but will need some further evaluation before synthesizing the remainder of the isotopic methylmercury compounds needed for the study. The ethylation and phenylation derivatization studies clearly demonstrated the feasibility of using the MePhHg derivative. Although the MeEtHg derivative has been reported extensively, it suffers from a number of drawbacks including cost and difficult handling of the sodium tetraethylborate reagent, and, at least in our studies to date, poorer chromatography. Additional changes to the derivatization procedure are anticipated when the phenylation reaction is tested in biological tissues The complexity of choosing the optimal isotopic dosing strategy (and the fact that the isotopes are very expensive) meant that a longer time than anticipated was required for the steps constituting this part of the study.

## Expected Completion Date

31st March 2005

## References


Bowers, W.J. 2004. Health Canada. Personal communication.

Cai, Y., and J.M. Bayona, 1995, Determination of methylmercury in fish and river water samples using *in situ* sodium tetraethylborate derivatization following by solid-phase microextraction and gas chromatography-mass spectrometry, *J. Chrom. A*, 696:113-122.

Cai, Y., Monsalud, S., Jaffe, R., and R.D. Jones, 2000, Gas chromatographic determination of organomercury following aqueous derivitization with sodium tetraethylborate and sodium tetraphenylborate- Comparative study of gas chromatography coupled with atomic fluorescence spectrometry, atomic emission spectrometry and mass spectrometry, *J. Chrom. A*, 876:147-155.

Cai, Y., Tang, G., Jaffe, R., and R. Jones, 1997, Evaluation of some isolation methods for organomercury determination in soil and fish samples by capillary gas chromatography-atomic fluorescence spectrometry, *Intern. J. Environ. Anal. Chem.*, 68:331-345.

Caricchia, A.M., Minervini, G., Soldati, P., Chiavarini, S., Ubaldi, C., and R. Morabito, 1997, GC-ECD determination of methylmercury in sediment samples using a SPB-608 capillary column after alkaline digestion. *Microchem. Journal*, 55:44-55.

Chen, S.-S., Chou, S.-S., Hwang, D.-F., 2004, Determination of methylmercury in fish using focused microwave digestion following by $Cu^{2+}$ addition, sodium tetrapropylborate derivatization, n-heptane extraction and gas chromatography-mass spectrometry. *J. Chrom. A*, 1024:209-215.

Choi, B. H. 1989. The effects of Methylmercury on the Developing Brain. *Progress in Neurobiology* 32, 447-470.

Chu, I. 2003. Health Canada. Personal communication.

Doré, F. Y., S. Goulet, A. Gallagher ,P. O. Harvey ,J. F. Cantin ,T. D' Aigle and M. E. Mirault.2001. Neurobehavioural changes in mice treated with methylmercury at two different stages of fetal development. *Neurotoxicology and Teratology* 23, 463-472.

Farris, F. F., R. L. Dedrick ,P. V. Allen and J. Smith. 1993. Physiological Model for the Pharmacokinetics of Methyl Mercury in the Growing Rat. *Toxicology and Applied Pharmacology* 119, 74- 90.

Forsyth, D.S., Casey, V., Dabeka, B., and A. McKenzie, 2004, Methylmercury levels in predatory fish species marketed in Canada. *Food Add. Contam.* In press.

Franklin, C.A., M.J. Inskip, C.L. Baccanale, C.M. Edwards, W.I. Manton, E. Edwards, and E.J. O=Flaherty. 1997. Use of sequentially administered stable lead isotopes to investigate changes in blod lead during pregnancy in a nonhuman primate. *Fundamental and Applied Toxicology* 39, 109-119.

Goulet, S., F.Y. Doré and M. E. Mirault. 2003. Neurobehavioural changes in mice chronically exposed to methylmercury during fetal and early post-natal development. *Neurotoxicology and Teratology* 25, 335- 347.

Gray, D. 1995. A Physiologically Based Pharmacokinetic Model for Methyl Mercury in the Pregnant Rat and Fetus. *Toxicology and Applied Pharmacology* 132, 91-102.

Hintelmann, H., 1999, Comparison of different extraction techniques used for methylmercury analysis with respect to accidental formation of methylmercury during sample preparation, *Chemosphere*, 39:1093-1105.

Hintelmann, H., Falter, R., Ilgen, G., and R.D. Evans, 1997, Determination of artifactual formation of monomethylmercury ($CH_3Hg^+$) in environmental samples using stable $Hg^{2+}$ isotopes with ICP-MS detection: Calculation of contents applying species specific isotope addition, *Fresenius J. Anal. Chem.*, 358:363-370.

Hu, G., Wang, X., Chen, X., and L. Jia, 1997, Determination of methylmercury in waters using sodium tetraphenylborate derivatization/solvent extraction and gas chromatography-ion trap mass spectrometry, *Anal. Letters*, 30:2579-2594.

Inskip, M. J. and Piotrowski, J. K. 1985 Review of the Health Effects of Methylmercury. *J. Appl. Toxicol.* 5,113-133.

Inskip, MJ., Franklin, CA., Baccanale, CL., Manton, WI., O'Flaherty, EJ., Edwards, CMH., Blenkinsop, JB and Edwards, EB. 1996, Measurement of the flux of lead from bone to blood in a nonhuman primate (*Macaca fascicularis*) by sequential administration of stable lead isotopes. *Fundam. Appl. Toxicol.* 33: 235- 245.

Inskip, MJ., Caiger-Watson,M., Donaldson, S., Chu, Ih, Yagminas, A. and Van Oostdam, J.2003 Consumption During Pregnancy of Fish and Marine Mammals Containing methylmercury: Approaches for Toxicological and Nutritional Studies to Aid Assessments of Benefits and Risks to the Developing Fetus. Presentation to annual Federal Food Safety and Nutrition Research Meeting, Health Canada, Oct.5-7, 2003, Saint-Hyacinthe, Quebec.

Lapham, L. W., E. Cernichiari, C. Cox, G. J. Myers, R. B. Baggs, R. Brewer, C. F. Shamlaye, P. W. Davidson, and T. W. Clarkson. 1995. An analysis of Autopsy Brain Tissue From Infants Prenatally Exposed to Methylmercury. *NeuroToxicology* 16(4), 689-704.

Lorenzo, R.A., Carro, A., Rubi, E., Casais, C. and R. Cela, 1993, Selective determination of methyl mercury in biological samples by means of programmed temperature gas chromatography, *J. AOAC International*, 76:608-614.

Madson, M.R., and R.D. Thompson, 1998, Determination of methylmercury in food commodities by gas-liquid chromatography with atomic emission detection, *J. AOAC International*, 81:808-816.

Martin-Doimeadios, R.C.R., Krupp, E., Amouroux, D. and O.F.X. Donard, 2002, Application of isotopically labelled methylmercury for isotope dilution analysis of biological samples using gas chromatography/ICPMS, *Anal. Chem.*, 74:2505-2512.

Newman, W.H., 1971, Determination of methylmercury if fish and in cereal grain products, *Agr. Food Chem.*, 19:567-569.

Palmieri, H.E.L., and L.V. Leonel, 2000, Determination of methymercury in fish tissue by gas chromatography with microwave-induced plasma atomic emission spectrometry after derivatization with sodium tetraphenylborate, *Fresenius J. Anal. Chem* ., 366:466-469.

Quevauviller, P., Fillippelli, M., and M. Horvat, 2000, Method performance evaluation for methylmercury determination in fish and sediment, *Trends in Anal. Chem.*19:157-166.

Watanabe, C. and H. Satoh. Evolution of our Understanding of Methylmercury as a Health Threat. 1996. *Environmental Health Perspectives* 104[Supplement 2], 367-379.

W.H.O. 1991 Methylmercury. Environmental Health Criteria, 101, International Programme on Chemical Safety, World Health Organization, Geneva, Switzerland.

Yang, L., Colombini, V., Maxwell, P., Mester, Z., and Sturgeon, R.E., 2003, Application of isotope dilution to the determination of methylmercury in fish tissue by solid-phase microextraction gas chromatography-mass spectrometry, *J. Chrom. (A)*, 1011:135-142.

Zheng, W. Aschner, M, and Ghersi-Egea, J-F. 2003, Brain-barrier systems:a new frontier in metal neurotoxicological research. *Toxicol. Appl. Pharmacol.* 192: 1-11.

# Interactions of MeHg, PCBs, Se and Omega-3 Fatty acids on Cardiovascular Markers of Oxidative Stress in Inuit of Nunavik


## Project leader(s)

Pierre Julien, Québec Lipid Research Center, CHUL Research Center, 2705 Boulevard Laurier, Room TR-93, Ste-Foy, QC G1V 4G2; phone: (418) 656-4141 ext 47802; fax: (418) 654-2145;
e-mail: piere.julien@crchul.ulaval.ca

## Project members

Marie-Claire Bélanger, Québec Lipid Research Center, CHUL Research Center, Ste-Foy, QC; Marc-Edouard Miraul, Health and Environment Research Unit, CHUL Research Center, Ste-Foy, QC; Eric Dewailly, Public Health Research Unit, CHUL Research Center, Ste-Foy, QC



## Abstract

The traditional Inuit diet, rich in n-3 polyunsaturated fatty acids and selenium, has been associated with lower mortality rate from ischemic heart disease. However, this diet is also contaminated by mercury, and polychlorinated biphenyls (PCBs), raising concerns about the potential harmful effects of these contaminants. Considering that mercury and PCBs could be sources of oxidative stress, and that selenium is an essential element of several antioxidant enzymes, we have measured two biomarkers of oxidative stress, plasma homocysteine and oxidized LDL, and three glutathione cycle indices of antioxidative processes. Despite the high levels of environmental contaminants, Inuit participants had normal lipoprotein profiles, low oxidized LDL levels (-43%) and elevated glutathione peroxidase (GPx) activity (+74%) as compared to reference populations. The elevated levels of selenium, the upregulated activities of GPx and glutathione reductase and the low concentrations of oxidized LDL suggest a decrease in the oxidative status as well as in the risk of cardiovascular disease in this Inuit population, despite high exposure to potentially pro-oxidant contaminants such as mercury and PCBs.


## Key Project Messages

1. This study investigates the possible detrimental effects of oxidative stress of the traditional Inuit diet is highly contaminated by mercury and polychlorinated biphenyls (PCBs), although rich in omega-3 fatty acids and selenium.

2. This study revealed that plasma level of oxidative stress markers were low in Inuit despite very high exposure to potentially prooxidant contaminants such as PCBs and mercury.

3. Other markers of oxidative stress are currently being assessed.

4. This ongoing research project suggests that beneficial effects of omega-3 fatty acids and selenium from the traditional diet counterbalanced the negative effects of PCBs and mercury.

## Objectives

The aim of the present report was to evaluate, in Inuit of Nunavik exposed to high levels of MeHg and PCBs, two physiologic markers of oxidative stress, the plasma levels of oxidized LDL (ox LDL) and homocysteine, and the status of three antioxidants, the activities of glutathione peroxidase (GPx) and glutathione reductase (GR) and the plasma levels of cellular glutathione (GSH).

## Introduction

Whether or not contamination by mercury could contribute to cardiovascular disease (CVD) has recently been the center of vigorous debates following recent publications showing that high intake of methyl mercury (MeHg) could be associated with higher risk of CVD in the European populations[1, 2]. Furthermore, Finnish studies have suggested that high intakes of mercury from non-fatty freshwater fish and its subsequent tissue accumulation could be associated with an increased risk of acute myocardial infarction as well as death from coronary heart disease[3, 4]. These studies have also suggested that such accumulation of mercury could be associated with the induction of lipid peroxidation. The traditional Inuit diet consisted primarily of marine mammals (white whale and seals), fish and caribou[5] which are known to be highly contaminated by MeHg[6] and PCBs[7, 8], two potentially pro-oxidant contaminants, as well as by selenium, an antioxidant[6]. This traditional diet has also been found to be enriched in n-3 polyunsaturated fatty acids (PUFAs) and associated with lower mortality rate from ischemic heart disease (IHD)[9].

Oxidative stress is involved in the pathology of numerous diseases including CVD and is tightly related to the production of reactive oxygen species (ROS), lipid peroxidation[10] and oxLDL, and, consequently, to the expression of atherosclerosis[11, 12]. It has been shown that mercury can stimulate the production of oxygen radicals and promote lipid peroxidation[13] by interfering with the mitochondrial electron transport chain, oxidizing the sulfhydryl groups of many proteins and depleting GSH[14].

## Activities

### In 2003/2004

The present report presents the research activities carried out during the 2003-2004 period. Furthermore, the present research project has also been presented at scientific meetings:

1- Bélanger MC, Julien P, Mirault ME, Dewailly E. Le mercure dans la diète des inuits du Nunavik et le risque de maladies cardiovasculaires. Journée de la recherche, Faculté de médecine, Université Laval, Ste-Foy (2003).

2- Bélanger MC, Julien P, Berthiaume L, Noël M, Mirault ME, Dewailly E. Mercury, fish consumption and the risk of cardiovascular diseases in Inuit of Nun. The 56th Annual Meeting of the Canadian Cardiovascular Society and Canadian Society of Atheroclerosis, Thrombosis and Vascular Biology, Toronto (2003); Can J Cardiol 19 (Suppl A): 133-134 (2003).

3- Bélanger M-C, Julien P, Berthiaume L, Mirault ME, Dewailly E. Effets de l'exposition aux contaminants environnementaux sur des marqueurs physiologiques d'oxydation chez des Inuits du Nunavik. Société québécoise de lipidologie, de nutrition et de métabolisme, Québec, 2004; Médecine/Sciences 20(3): IV (2004).

## Results

This study has been carried out in the Northern Inuit village of Salluit, Nunavik, on the Hudson Strait. Inuit participants not taking medication affecting the metabolism of lipids, glucose, insulin or blood pressure have been randomly selected (n=99). Data related to their health status, current health problems and use of medication have been collected. Participants were then asked to come back the next morning after an overnight fast for blood collection.

Among these participants, five percent had type II diabetes, nineteen percent had hypertension whereas the majority of them (72.3%) were smokers. The level of n-3 PUFAs in red cell membranes was 11%, in agreement with previously reported levels of plasma n-3 PUFAs in Inuit[5]. These data also reveal that these participants had significantly higher concentrations of Se, Hg and PCBs, levels found to be 7 to 18-fold higher than reported in Caucasian reference populations[15, 16].

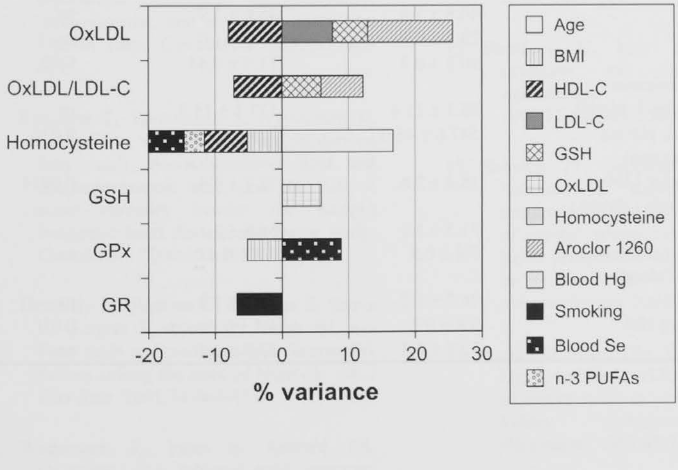
Multivariate logistic analyses (Figure 1) were then performed to determine whether environmental contaminants (PCBs and Hg) contributed to changes in the levels of oxidative stress markers (oxLDL, oxLDL/LDL-C and homocysteine) and antioxidants (GSH, GPx and GR). This figure shows the contribution of age, BMI, HDL-C and LDL-C on the variance of oxidative stress markers and antioxidants. These data reveals that LDL-C, GSH and Aroclor 1260 contributed to 26% of the increase in plasma oxLDL whereas the HDL-C contributed to its reduction (-8%). Age was an independent variable contributing to 16% increase in plasma homocysteine, whereas selenium, n-3 PUFAs, HDL-C and BMI contributed to 20% decrease in plasma homocysteine. It is of interest to note that even though oxLDL and n-3 PUFAs had significant positive effects on the levels of GSH and GPx, mercury, did not contribute to their variance. It is of interest to note that smoking negatively influenced GR (-7%).

Participants were then subdivided into low and high plasma levels of oxLDL, using the median value of the plasma oxLDL distribution (43.5 U/L) in the overall group. Table 1 reveals that even though age and BMI were not statistically different between groups, PCB and selenium were found to be increased in subjects with high concentrations of oxLDL. It is worth noting that the concentrations of n-3 PUFAs and GSH were also significantly increased in the high oxLDL group.

## Discussion and Conclusions

This study reveals that the concentrations of homocysteine in Inuit participants were similar to those reported in Caucasians whereas the levels of oxLDL in Inuit exposed to high levels of mercury and PCBs were remarkably lower than those previously reported in healthy controls[17, 18].

**Figure 1.** Multivariate analyses showing the contribution of various physiological markers on the expression of plasma oxidative stress markers (oxLDL and homocysteine) and blood antioxidants (GSH, GPx and GR). Percent contribution to the variance is indicated; the level of significance was $p<0.05$; Hg, mercury; Se, selenium.



The observations that higher levels of oxLDL were found in individuals with higher concentrations of PCBs, and that Aroclor 1260, a mixture of PCB congeners, contributed to 13% of the variance of plasma oxLDL (Figure 1), suggest that PCBs may have significantly contributed to the oxidation of LDL particles. However, it is worth noting that despite the potential effect of PCBs on LDL oxidation, the plasma concentrations of oxLDL remains lower in Inuit as compared to Caucasians. Furthermore, it is important to note that exposure to high concentrations of mercury did not affect the plasma levels of oxLDL.

Blood concentration of GSH, the required substrate for the activity of the seleno-GPx, was increased in Inuit carrying the highest concentration in oxLDL. GSH has been proposed as a protective factor against vascular endothelium dysfunction induced by reactive oxygen and nitrogen species generated during the atherosclerotic process[19].

In conclusion, these findings reveal that while the concentration of plasma homocysteine was within the normal range in the Inuit population, their plasma oxLDL was 43% lower than previously reported in normal non-obese Swedish individuals and 49% lower than reported in obese Swedish subjects[17]. This study thus suggests that oxidative stress is low in Inuit despite high exposure to PCBs and mercury. Furthermore, the higher GR and GPx activities combined with lower concentrations in GSH, probably resulting from increased GPx activity, is indicative of an elevated antioxidant status in this Inuit population. This ongoing research project suggests that beneficial effects of omega-3 fatty acids and selenium from the traditional diet counterbalanced the negative effects of PCBs and mercury.

## Expected Completion Date

Other biological parameters, oxidized and reduced vitamin E, ubiquinol-10 and ubiquinone-10 are being evaluated. This project will be completed in November 2004.

**Table 1:** Comparison of environmental contaminants, oxidative stress and antioxidants markers between subjects with low and high oxLDL (Mean ± SEM)

| | Low OxLDL | High OxLDL | P |
|---|---|---|---|
| N | 49 | 50 | |
| Age (years) | 40.8 ± 1.8 | 45.6 ± 1.9 | ns |
| BMI (kg/m$^2$) | 28.5 ± 0.9 | 29.5 ± 1.0 | ns |
| n-3 PUFAs (%) | 10.5 ± 0.3 | 11.9 ± 0.44 | 0.02 |
| Environmental contaminants | | | |
| Mercury (nmoles/L blood) | 88.1 ± 11.4 | 123.1 ± 15.9 | ns |
| Selenium (µg/L plasma) | 547.6 ± 46.0 | 718.2 ± 60.1 | 0.015 |
| PCBs (µg/L plasma) | | | |
| Aroclor 1260 | 18.4 ± 2.6 | 32.7 ± 3.4 | 0.0014 |
| Oxidative stress markers (plasma) | | | |
| OxLDL (U/L) | 31.5 ± 1.1 | 56.8 ± 2.1 | |
| homocysteine (µmoles/L) | 7.4 ± 0.5 | 7.3 ± 0.4 | ns |
| Antioxidant markers (blood) | | | |
| GPx (U/g Hb) | 76.7 ± 1.7 | 77.8 ± 1.8 | ns |
| GSH (µmoles/g Hb) | 3.8 ± 0.2 | 4.5 ± 0.2 | 0.01 |
| GR (U/g Hb) | 12.8 ± 0.4 | 12.7 ± 0.4 | ns |

## Acknowledgements

Supported by grants from the Northern Contaminant Program, Indian and Northern Affairs, Canada, the Toxic Substances Research Initiative, Environment and Health Canada and by a doctoral fellowship from the Cardiovascular Health Network of the Fonds de la recherche en Santé du Québec (FRSQ).

## References

1. Yoshizawa K, Rimm EB, Morris JS, Spate VL, Hsieh CC, Spiegelman D, Stampfer MJ, Willett WC. Mercury and the risk of coronary heart disease in men. *N Engl J Med.* 2002;347:1755-1760.

2. Guallar E, Sanz-Gallardo MI, van't Veer P, Bode P, Aro A, Gomez-Aracena J, Kark JD, Riemersma RA, Martin-Moreno JM, Kok FJ. Mercury, fish oils, and the risk of myocardial infarction. *N Engl J Med.* 2002;347:1747-1754.

3. Salonen JT, Seppanen K, Nyyssonen K, Korpela H, Kauhanen J, Kantola M, Tuomilehto J, Esterbauer H, Tatzber F, Salonen R. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in eastern Finnish men. *Circulation.* 1995;91:645-655.

4. Rissanen T, Voutilainen S, Nyyssonen K, Lakka TA, Salonen JT. Fish oil-derived fatty acids, docosahexaenoic acid and docosapentaenoic acid, and the risk of acute coronary events: the Kuopio ischaemic heart disease risk factor study. *Circulation.* 2000;102:2677-2679.

5. Dewailly E, Blanchet C, Lemieux S, Sauve L, Gingras S, Ayotte P, Holub BJ. n-3 Fatty acids and cardiovascular disease risk factors among the Inuit of Nunavik. *Am J Clin Nutr.* 2001;74:464-473.

6. Wagemann R, Innes S, Richard PR. Overview and regional and temporal differences of heavy metals in Arctic whales and ringed seals in the Canadian Arctic. *Sci Total Environ.* 1996;186:41-66.

7. Dewailly E, Ayotte P, Bruneau S, Laliberte C, Muir DC, Norstrom RJ. Inuit exposure to organochlorines through the aquatic food chain in arctic quebec. *Environ Health Perspect.* 1993;101:618-620.

8. Muckle G, Ayotte P, Dewailly E, Jacobson SW, Jacobson JL. Determinants of polychlorinated biphenyls and methylmercury exposure in inuit women of childbearing age. *Environ Health Perspect.* 2001;109:957-963.

9. Dewailly E, Blanchet C, Gingras S, Lemieux S, Sauve L, Bergeron J, Holub BJ. Relations between n-3 fatty acid status and cardiovascular disease risk factors among Quebecers. *Am J Clin Nutr.* 2001;74:603-611.

10. Nedeljkovic ZS, Gokce N, Loscalzo J. Mechanisms of oxidative stress and vascular dysfunction. *Postgrad Med J.* 2003;79:195-199; quiz 198-200.

11. Witztum JL, Berliner JA. Oxidized phospholipids and isoprostanes in atherosclerosis. *Curr Opin Lipidol.* 1998;9:441-448.

12. Steinberg D. Low density lipoprotein oxidation and its pathobiological significance. *J Biol Chem.* 1997;272:20963-20966.

13. Salonen JT, Seppanen K, Lakka TA, Salonen R, Kaplan GA. Mercury accumulation and accelerated progression of carotid atherosclerosis: a population-based prospective 4-year follow-up study in men in eastern Finland. *Atherosclerosis.* 2000;148:265-273.

14. Lund BO, Miller DM, Woods JS. Studies on Hg(II)-induced H2O2 formation and oxidative stress in vivo and in vitro in rat kidney mitochondria. *Biochem Pharmacol.* 1993;45:2017-2024.

15. Kingman A, Albertini T, Brown LJ. Mercury concentrations in urine and whole blood associated with amalgam exposure in a US military population. *J Dent Res*. 1998;77:461-471.

16. Butler Walker J, Seddon L, McMullen E, Houseman J, Tofflemire K, Corriveau A, Weber JP, Mills C, Smith S, Van Oostdam J. Organochlorine levels in maternal and umbilical cord blood plasma in Arctic Canada. *Sci Total Environ*. 2003;302:27-52.

17. Sigurdardottir V, Fagerberg B, Hulthe J. Circulating oxidized low-density lipoprotein (LDL) is associated with risk factors of the metabolic syndrome and LDL size in clinically healthy 58-year-old men (AIR study). *J Intern Med*. 2002;252:440-447.

18. Kopprasch S, Pietzsch J, Kuhlisch E, Fuecker K, Temelkova-Kurktschiev T, Hanefeld M, Kuhne H, Julius U, Graessler J. In vivo evidence for increased oxidation of circulating LDL in impaired glucose tolerance. *Diabetes*. 2002;51:3102-3106.

19. Rosenblat M, Aviram M. Macrophage glutathione content and glutathione peroxidase activity are inversely related to cell-mediated oxidation of LDL: in vitro and in vivo studies. *Free Radic Biol Med*. 1998;24:305-317.

# Determinants of Child Health and Development as Related To Contaminants: Feasibility of Nunavik Cohort Study Expanded To the Baffin Region


## Project leader(s)

Gina Muckle, Unité de recherche en santé publique, Centre Hospitalier Universitaire de Québec (CHUQ), Pavillon CHUL et École de psychologie de l'Université Laval. 945 rue Wolfe, Sainte-Foy (Québec) Canada G1V 5B3; phone (418) 650-5115 #5262 ; fax (418) 654-3132 ; e-mail address: Gina.Muckle@crchul.ulaval.ca

## Project members

Érica Myles, Erica Myles, AXYS Environmental Consulting Ltd; Eric Dewailly and Pierre Ayotte, Unité de recherche en santé publique, Centre Hospitalier Universitaire de Québec (CHUQ), Pavillon CHUL et Département de médecine préventive de l'Université Laval; Amy Caughey, Government of Nunavut; Jay van Oostdam, Health Canada



## Abstract

The proposed project was to evaluate the feasibility to expand the Nunavik infant development study to the Baffin region. This would substantially increase the power of the research design of the Nunavik study, as well as increase our ability to generalize and expand our conclusions to other Canadian Inuit. Baffin was the region selected since prenatal exposures to OCs and MeHg are the highest within the NWT and the Nunavut territories, and similar to those observed in Nunavik. The feasibility work was done jointly with Erica Myles, who conducted a feasibility study regarding the implementation of a monitoring program of human exposure to selected environmental contaminants. Health representatives and community groups consulted were supportive of the study. The results of the consultation process emphasize the need to develop research procedures that will minimize the solicitation of existing staff. The monitoring program of human exposure conducted during year 2004/2005 will provide the information missing to decide whether or not it is feasible to expand the Nunavik infant development study to the Baffin region.


## Key Project Messages

1. Health representatives and community groups consulted were supportive of the study.
2. The results of the consultation process emphasize the need to develop research procedures that will minimize the solicitation of existing staff.
3. The work accomplished this year provided significant information regarding the feasibility of conducting a prospective cohort study on infant development, but the feasibility analysis will be completed during year 2004/2005 with the implementation of the human monitoring program in the Baffin region.

## Objectives

The objective for this year was to evaluate the feasibility of conducting a prospective cohort study involving pregnant women and infants from the Baffin region. This cohort study is designed to study the effects of pre- and perinatal exposure to environmental contaminants. The long term objectives of the proposed project are to increase the power of the cohort study conducted in Nunavik, and to increase our ability to generalize and expand our conclusions to other Canadian Inuit. Moreover, the projected study represents an opportunity for public health authorities to get significant information regarding the effects of certain lifestyle factors on the development of infants from this region.

## Introduction

During the first and second phases of the Northern Contaminants Program, one longitudinal prospective cohort study in Nunavik aimed to look at determinants of child health and development, especially prenatal exposure to organochlorine (OCs) compounds and methylmercury (MeHg). Results from that study were presented to the Nunavik population during year 2002/2003, and to the Canadian Arctic Contaminants Assessment Symposium in March 2003. Scientific publications are in preparation. In order to substantially increase the power of the research design of the study conducted to date, as well as to increase our ability to generalize and expand our conclusions to the Nunavut Inuit, it would be interesting to expand the Nunavik cohort study to the Baffin region. This region is selected since prenatal exposures to OCs and MeHg are the highest within the Nunavut territory, and similar to those observed in Nunavik. The work planned for year 2003/2004 was to obtain all information required to assess the feasibility of expanding the Nunavik infant development study to the Baffin region during the third phase of the Northern Contaminants Program.

## Activities

### In 2003/2004

The feasibility study of conducting a prospective cohort study on Inuit infants from Baffin was conducted in conjunction with the feasibility study conducted by Erica Myles and collaborators, which focus on the monitoring of human exposure to environmental contaminants in the NWT and Nunavut. Work completed in 2003/2004 mainly focused on project planning and consultation. The following activities were conducted:

1. A meeting was held with the Niqitt Avatittinni Committee and several regional and territorial health representatives, including NTI and the Nunavut Research Institute on October 8, 2003. The proposed infant development study in Baffin was presented and discussed.
2. With the help of the NAC liaison, Mary Potyrala, the Chief Medical Health Officer, Medical Director of Nunavut, Hospital Lab Manager, Nurse in Charge of the In-Patient Ward and nurse in charge of the Prenatal Clinic were consulted on November 17, 2003. Presentations were made jointly with Erica Myles.
3. A meeting was scheduled on November 18th with various Nunavut health department staff and the regional directors for all health regions in Nunavut, QIA and NTI. Mary Bender, Clinical Nursing Supervisor for Baffin was the only invited participant who was able to attend, and she joined by phone.
4. On November 18, 2003, various Nunavut Health Department staff and the regional directors for all Health Regions in Nunavut, QIA and NTI were sent an introductory presentation to the planned infant development study. A follow up conference was held with the three regional Directors of the Baffin Region on December 10, 2003.
5. Several meetings were held with Erica Myles and Jocelyn Gagnon to discuss potential collaboration between the monitoring program and the infant development study. It was decided that for the Baffin region, both studies will be conducted in collaboration to ensure that protocols will serve both the purpose of the monitoring program and the expansion of the Nunavik infant development study.
6. Consent forms for the infant development study is currently under ethical review by the Nunavut Health and Social Research Review Committee.
7. Maternal interview to be used with pregnant women who will accept to participate to the infant development study has been drafted and discussed in a meeting held in Montreal. The participants to this meeting were Erica Myles, Olivier Receveur (University of

Montreal), Mary Potyrala (NAC liaison), Jocelyne Gagnon (CHUQ Medical Research Centre) and Gina Muckle (CHUQ Medical Research Centre/Laval University) Discussions on recruitment strategies, instruments/questionnaires, data entry, training on interviewing skills and plans for next year were performed.

## Results and Discussion

During these consultation and working meetings, discussions were related to the goals and scope of the proposed research, the research procedures to be developed regarding recruitment, selection of study participants and data collection. Each professional consulted was supportive of the study, but some expressed reservations regarding the impact of the study on their workload or the workload of their staff. The results of this consultation process emphasize the need to develop research procedures that will minimize the solicitation of existing staff and will be conducted with separate staff for recruitment, maternal interviews and infant testing. This corresponds to the approach that was previously adopted in Nunavik.

Following discussions with Erica Myles, it was decided that research to be conducted during 2004/2005 under the monitoring program of human exposure in the Baffin region would be coordinated to allow the participants to be involved in the 2005/2006 infant development study. Specifically, the maternal prenatal interview to be conducted during 2004/2005 within the human monitoring program would assess all variables required by the infant development study, and mothers who provided biological samples at delivery for the monitoring program would be recruited for the infant development study so that their infant would be tested at 6½ and 11 months of age in 2005/2006.

The first year of the human monitoring program will provide significant information to assess the feasibility of the infant development study. To be more specific, the number of women from Baffin to be recruited annually, the participation rate, and the success of blood and hair sampling are the key pieces of information that are needed for this proposed cohort expansion. Once these parameters are known, it can be assessed whether the needed sample size for the infant development study could be reached within 2-3 years.

## Conclusions

This project proposes collaboration between the human environmental contaminant trends monitoring program and the expansion of the infant development study conducted in Nunavik. Maternal blood, cord blood and hair samples collected in the Baffin region will provide needed data for both studies, as will the maternal prenatal interview. Recruitment and sampling protocols have been developed to serve the purposes of both studies and to ensure that follow up with infants remains possible for funding year 2005/2006. The monitoring program of human exposure conducted during year 2004/2005 will provide the information needed to decide whether or not it is feasible to expand the Nunavik infant development study to the Baffin region.

## Expected Completion Date

Feasibility study to be completed in December 2004.

was related to a delay of the visual evoked potentials. PCB plasma concentration at 5 year or age, which reflect the bioaccumulative effects from both pre- and perinatal exposures, is associated with non-optimal sensory process of visual information.Surprisingly, our results suggest that selenium intake during childhood may be high enough in this population to be associated with sub-clinical effects on the visual system. All the negative and beneficial effects reported here are very subtle and cannot explain why a particular child experienced learning difficulties, behavioural problems, or is delayed in his or her development.

## Objectives

The aim of this study was to document the effects at preschool aged of prenatal and postnatal exposures to PCBs, Hg and lead. 110 preschool aged children from Nunavik were assessed regarding their neurological, gross motor and fine neuromotor development. Electrophysiological testing was used to assess the integrity of the visual system as well as attentional functions. An evaluation of the child behavioural and emotional status during testing was also obtained.

## Introduction

Because fish and marine mammals represent an important part of the diet of the Inuit, elevated levels of OCs and Hg are found in Northern Quebec Inuit newborns. Prenatal exposure to OCs among Northern Quebec Inuit is two to three times higher than that observed in general populations in Southern Quebec and Massachusetts (USA) (Dewailly et al., 1996; Korrick et al., 2000; Muckle et al., 2001), while prenatal exposure to Hg is higher than that observed in general population samples in Canada and the United States (Rhainds et al., 1999; Smith et al., 1997).

The toxicity of PCBs and related compounds was first recognized in two industrial accidents - one in Japan in the late 1960's; the other in Taiwan in the late 1970's- when PCBs used as a heat transfer agent leaked into rice oil during its manufacture. Adults who ate the contaminated oil developed skin rashes and peripheral nervous system numbness and tingling (Hsu et al., 1985). Infants born to women who had eaten the contaminated oil also had skin rashes and exhibited poorer intellectual functioning during infancy and childhood (Chen, 1992). Prospective, longitudinal studies of U.S. (Michigan, North Carolina, Oswego) and Dutch children exposed prenatally to PCBs have linked this exposure to poorer intellectual function in children exposed at the upper end of general population levels (Jacobson & Jacobson, 1996; Patandin et al., 1999). The neurotoxicity of methylmercury was first recognized in the 1950's when residents of Southern Japan ate fish from Minamata Bay that were highly contaminated due to industrial pollution. This exposure led to mental retardation, motor damage, ataxia, and seizures in children born to women who ate the contaminated fish during pregnancy (Harada, 1995). The major neurobehavioral prospective studies of fish-eating populations exposed to methylmercury concentrations somewhat above general population levels were conducted in Seychelles Islands, New Zealand and Faroe Islands. While neurobehavioral effects during childhood were seen in the New Zealand and Faroe Islands cohorts, these effects were not seen in children from Seychelles Islands (Grandjean et al., 1999; NRC, 2000; Myers et al. 1995). In these studies, neurophysiological effects of PCB and Hg exposures were not fully studied even if, in view of the ease of administration, reliability, culture-free nature, event related potentials (ERPs) and visual evoked potentials (VEPs) are likely to be sensitive enough to detect sub-clinical effects of neurotoxicants in a pediatric population (Otto, 1981).

## Activities

### In 2003/2004

Data analyses on neurological, gross motor and fine motor functions, and on visual evoked potentials were completed. Analyses performed with emotional/behavioral endpoints underlined the need to re-examine these data with more sophisticated behavioural coding system, which will be perform and submit for publication during year 2004/2005. Results on neurological gros anf ine motor functions were submitted to a scientific journal for publication. Results involving visual evoked potentials were communicated to the Teratology Society conference in June 2004; the manuscript involving these results will be shortly submit for publication. All these results have been integrated and were presented to the Nunavik Nutrition and Health Committee (NNHC).

## Results and Discussion

Results could not be presented in detail here since they are under reviewed for publication in scientific journals. However, the main results are described in the two following abstracts.

**Impacts of Pre- and Postnatal Exposure of Mercury and Polychlorinated Biphenyls on Brain Development: A Visual Evoked Potentials Study.**

Since fish and marine mammal represent an important part of the diet of Inuit in Northern Quebec (Nunavik), elevated levels of mercury (Hg) and polychlorinated biphenyls (PCBs) has been reported in adults and newborns. Although behavioural studies have linked these contaminants to cognitive and sensory impairments, little electrological evidence of Hg and PCBs neurotoxicity is available. Pattern-reversal VEPs were recorded from Oz derivation. Visual stimulation consisted of vertical gratings (3 cycles/°) presented at 3 contrast levels (95%, 30%,12%). Blood concentrations of Hg and PCB 153 were measured at birth and at the time of testing (mean = 5.44 years old). The relationships between contaminants and VEP components were assessed by multivariate regression analyses taking into account several confounders such as selenium and n-3 fatty acids.

Our results somewhat corroborate a previous finding observed in an other fish eating population, since prenatal exposure to Hg was related to a delay of the visual evoked potentialsBlood Hg concentrations collected at testing time were associated with shorter latencies of the early VEP components (N75 and P100). This finding is somewhat surprising but has been previously observed in animals and humans. Two hypotheses could account for this result. First, normal sensory processing could be disrupted because of selective damages to inhibitory circuits by metallic toxicants. Second, since blood Hg concentrations are related to the nutrients assessed here (Se and n-3 fatty acids), child blood Hg concentrations may rather represent fish consumption and are likely to be a good proxy or surrogate for protein intake in this population. Cord plasma PCB concentrations were not associated with VEPs. However, plasma PCB concentrations at testing time were related to latency and amplitude impairments. Due to the long half-life of PCBs and since the majority of the tested children were breastfed for a long period of time, PCB plasma concentration at testing time is more likely to reflect bioaccumulative effects from both pre- and perinatal exposures.n-3 fatty acids appears to be beneficial for sensory processing either when absorbed during pregnancy or during childhood.

The expected beneficial effect of Se was not observed. Instead, Se concentrations were related to a delay of the VEPs. Se intake is very high in Inuit population and the hypothesis of Se toxicity should be considered.The high spatial resolution and contrasts of the stimuli used in the present study appears to be sensitive enough to detect sub-clinical effects in preschool aged children.

**Neuromotor function in Inuit preschool children exposed to Pb, PCBs and MeHg.**

The aim of this study was to examine the effects of prenatal and postnatal chronic exposure to methylmercury (MeHg), polychlorinated biphenyls (PCBs) and lead (Pb) on the neurological and motor development of preschool children. The study population consisted of 110 preschool Inuit children from Nunavik (Northern Quebec, Canada). MeHg, PCBs and Pb concentrations were measured at birth in umbilical cord blood and from a blood sample collected at the time of testing. Gross motor functions were evaluated and a neurological examination was performed. Fine neuromotor performance was assessed using computerized measures of postural hand tremor, reaction time, sway oscillations, alternating and pointing movements. Potential covariates were documented including demographic and familial factors, other prenatal neurotoxicants (alcohol, illicit drugs, tobacco), and nutrients (selenium, omega-3 polyunsaturated fatty acids (n-3 PUFA)). Hierarchical multivariate regression analyses were performed, controlling for significant covariates.

Neurological and gross motor functions were not linked to the contaminants assessed. However, significant associations were observed between postnatal Pb exposure and changes in reaction time, sway oscillations, alternating movements and action tremor. Negative effects of Hg and PCBs on neuromotor development were not clearly observed in this study. Beneficial effects of n-3 PUFA and selenium were not observed. These results suggest that Pb exposure during childhood (mean: 4.1 μg/dl) has sub-clinical effects on fine neuromotor function of Inuit children.

## Conclusions

The work projected for year 2003/2004 was accomplished successfully and the results of the study conducted under the Northern Contaminants Program will be available in scientific literature shortly. Moreover, these results were presented to the Nunavik Nutrition and Health Committee (NNHC).

## Expected Completion Date

March 31, 2005

## References

Chen Y-CJ, Guo Y-L, Hsy C-C, Rogan WJ. Cognitive development of Yu-Cheng ("Oil Disease") children prenatally exposed to heat-degraded PCBs. JAMA 268:3213-3218 (1992).

Dewailly, É, Ayotte P, Laliberté C, Weber J-P, Gingras S, Nantel A. Polychlorinated biphenyl (PCB) and dichlorodiphenyl dichloroethylene (DDE) concentrations in the breast milk of women in Quebec. Am J Public Health 86:1241-1246 (1996).

Grandjean P, Weihe P, White RF, Debes F, Araki S, Yokoyama K, Murata K, Sorensen N, Dahl R, Jorgensen PJ. Cognitive deficit in 7-year old children with prenatal exposure to methylmercury. Neurotoxicol Teratol 19:417-428. (1997).

Harada M. Minamata disease: methylmercury poisoning in Japan caused by environmental pollution. Crit Rev Toxicol 25:1-24 (1995).

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


## Project leader(s)

Erica Myles Kavik- AXYS Inc Suite 300, 805 Eighth Avenue, SW Calgary, Ab T2P 1H7; phone: (403) 269-5150; fax: (403) 269-5179; e-mail: emyles@axys.net

## Project members

Jack MacKinnon, GNWT Department of Health and Social Services (H&SS), Yellowknife, NWT; Janet Brewster, GN Department of Health and Social Services (H&SS), Iqaluit, NU; Mary Potyrala, GN Department of Health and Social Services (H&SS); Olivier Receveur, University of Montreal, Montreal, PQ; Laurie Chan, Centre of Indigenous Nutrition and Environment (CINE), Montreal, PQ; Eric Loring, Inuit Tapiriit Kanatami (ITK), Inuvik, NWT; Chris Paci, Dene Nation; Jay Van Oostdam, Health Canada; Gina Muckle, Centre Hospitalier Universitaire de Quebec (CHUQ); Russel Shearer, INAC; Jill Watkins, INAC; Mark Feeley, Health Canada; Jay Van Oostdam, Health Canada; Jack MacKinnon, GNWT H&SS; Janet Brewster, GN H&SS; Serge Dery, Nunavik Health Committee



## Abstract

In May 2003 the Human Health Steering Committee under the Northern Contaminants Program (NCP) met in Calgary and discussed the need to conduct a feasibility study to establish trends for human environmental contaminants in the NWT and Nunavut. The proposed study would act as follow up to the Human Environmental Contaminants Exposure Baseline conducted between 1995 and 2001 and would 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. In September of 2003, the feasibility study began with the goal of determining levels of capacity, interest and support to conduct repeat monitoring studies in the Inuvik and Baffin regions. Consultation was a key component of the feasibility study, and consultation activities included 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, communities and federal government.

Although there were some concerns expressed by stakeholders, related to capacity and communication, interest and support for the study was expressed by all those consulted. Based on the success of the feasibility study, a proposal was submitted to the NCP in January of 2004, for Year 2 of the program. Year 2 of the program will include participant recruitment, training of local health staff and community representatives, collection of hair and blood samples and lifestyle information, and ongoing communication with participants, stakeholders, and team members.


## Key Project Messages

1. A feasibility study for the temporal trends monitoring program began in September 2003

2. Work completed in 2003 mainly focused on project planning and consultation

3. Interest and support for the study was expressed by all stakeholders consulted. Key issues identified during consultation included issues related to capacity building and communication.

4. A proposal for Year 2 of the program was submitted to the NCP and funded. The project will be conducted in collaboration with Dr. Gina Muckle (for the Baffin region) and serve to collect preliminary information for the expansion of the Nunavik infant development cohort to that region.

## Objectives

Short Term Objectives:

- Assess the feasibility of establishing a temporal trend for maternal exposure to select organochlorine and metal contaminants in NWT and Nunavut.
- To establish a communication network with territorial and regional health departments, communities and Aboriginal organizations
- To develop recruitment and sampling protocols that will be compatible/comparable to the Nunavik maternal sampling program and with the baseline sampling program in the Baffin and Inuvik Regions.

Long-term objectives:

- evaluate temporal trends of maternal exposure to selected organochlorines and metal contaminants in the NWT and Nunavut using blood and hair as biomarkers
- describe relationships between contaminant exposure and frequency of consumption of traditional/country foods and select lifestyle factors
- contribute to other international blood monitoring programs and to meet Canada's commitment to the Global Monitoring Plan under the Stockholm Convention
- 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 and discussed the need to conduct a feasibility study to establish temporal trend monitoring programs of human environmental contaminants in the NWT and Nunavut. The proposed study would act as follow up to the Human Environmental Contaminants Exposure Baseline conducted from 1995-2001. The main purpose of the proposed study would 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 proposed project would also collect information on dietary habits and describe relationships between contaminant exposure and frequency of consumption of traditional/country foods and select lifestyle factors.

The feasibility study was partly proposed in response to study 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. The monitoring program would be valuable in Canada's effort to meet its international obligation 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) Convention. The program would 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. The Baffin region was a priority as it had the highest maternal and cord blood levels of most contaminants in the 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 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 allow comparisons between ethnic groups, as it is home to Dene, Metis, Inuvialuit and Caucasian women.

A proposal for the feasibility study was submitted to the NCP and approved in July 2003. A workplan outlining activities for the feasibility study was prepared and approved by the NCP Human Health Steering Committee. Consultation activities formally began in September 2003.

## Activities

### In 2003/2004

The feasibility involved meetings with a variety of stakeholders to discuss project feasibility and planning. Meetings held in 2003/2004 are summarized in the list below:

1) Territorial and regional stakeholders were contacted in **September** and **October 2003** to set up project introductory meetings and presentations.
2) A presentation was made to the Niqitt Avatittinni Committee (NAC) on **October 8, 2003**. Plans for collaborative efforts with Dr. Gina Muckle at CHUL/CHUQ Research Centre were discussed. Territorial health department staff identified a more detailed list of stakeholders.
3) A project research team meeting was held in Montreal on **October 10, 2003** where the questionnaire needs for both Baffin and Inuvik regions were discussed. The need to test a questionnaire in the Baffin region was identified.
4) With the help of the NAC liaison, Mary Potyrala, presentations were made to the Chief Medical Health Officer, Medical Director of Nunavut, Hospital Lab Manager, Nurse in Charge, In-Patient Ward, and Nurse in Charge - Prenatal clinic on **November 17, 2003.** Presentations to Baffin stakeholders were made jointly with Gina Muckle from CHUL/CHUQ Research Center.
5) A presentation was made to the NWT ECC on **November 28, 2003**. Meetings were held with the Chief Medical Health Officer of the NWT and the Territorial Epidemiologist.
6) Presentations were made to the Inuvialuit Regional Corporation (IRC); the CEO, Environmental Health Officer and Manager of Community Health Centre operations of the Inuvik Regional Health and Social Services Authority; and the Gwich'in Tribal Council on **December 1 and 2, 2003.**
7) A meeting was held with the Aurora Research Institute to discuss consultation and licensing issues in the NWT on **December 2, 2003.**
8) A conference call was held with Regional Nursing Directors for the Baffin region, Nunavut, **December 10th, 2003**
9) Ongoing consultation and teleconference meetings were held with the NCP Health Steering Committee. Ongoing consultation updates were distributed, an in-person meeting was held in Calgary on **November 6, 2003,** and a Consultation Summary report submitted to the Committee on **December 18, 2003.**
10) Presentations were made to communities in the Inuvialuit Settlement Region from **January 19th–27th, 2004** during the *Inuvialuit Health and Environment Tour.*
11) A proposal for Year 2 of the study was prepared and submitted to the NCP on **January 26th, 2004.**
12) Applications for research licensing were prepared in **February 2004**.
13) A working group meeting was held in Montreal on **March 29th and 30th, 2004** to review project consent forms, maternal interview questions, and recruitment scripts.

Other Consultation/Planning Activities included:

- A sample size paper was developed by Health Canada outlining the statistical power of a variety of samples sizes for the study.
- Consultations with Dene Nation and Inuit Tapiriit Kanatami with regards to regional selection within the territories.
- Questions on study design and regional statistics were sent to both the Nunavut Health Department and Inuvik Regional Health and Social Services Authority.
- Several meetings were held with Dr. Gina Muckle and Jocelyn Gagnon of Laval University to discuss potential collaboration

between the monitoring program and infant development study for assessments of feasibility and for study design in the Baffin region.

- Permission for access to the baseline contaminants database was requested from GN Health and GNWT Health was confirmed on **December 10, 2003**.

## Results

All Nunavut stakeholders that participated in meetings, discussions and conference calls were 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 no organizations that were opposed to the study and really no significant concerns expressed about the feasibility of conducting a maternal blood monitoring study in the Baffin region over the next two years. There were several significant comments and concerns related to study design, the most significant of which were; minimizing any additional work to community health staff and building community capacity in the region.

All Inuvik region and NWT stakeholders that participated in meetings, discussions and conference calls were 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 no organizations that were opposed to the study and no significant concerns expressed about the feasibility of conducting a trend monitoring study in the Inuvik region. There were several significant comments and concerns related to study design. These included; the inclusion of other Dene communities in the program, administration of project coordinator, the communication of results and building community capacity in the region.

Other key issues identified during consultations included:

- 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.
- Lifestyle and dietary information collecting during the prenatal interview is of significant interest from a public health perspective.

## Discussion

Based on the success of the feasibility study, a proposal was submitted to the NCP in January of 2004, for Year 2 of the program. Key issues raised by stakeholders were incorporated into study design where possible. The study will involve the recruitment of pregnant women from the Inuvik region of the NWT and Baffin region of Nunavut. Consultations on project planning resulted in the establishment of a recruitment goal of 100 women from each region. Program Coordinators will be hired to manage the project in each region. Participants will be interviewed prior to pregnancy to assess diet and lifestyle during pregnancy, and be asked to sign a consent form agreeing to provide blood and hair samples for the study.

For the Baffin region, year 2 of the program proposes collaboration between the human environmental contaminant trends monitoring program and the expansion of the infant development study to Nunavut. Maternal blood, cord blood and hair samples collected in the Baffin region will provide needed data for both studies, as will the maternal interviews. Recruitment and sampling protocols will be collaboratively developed to serve the purposes of both studies and to ensure that follow up with infants remains possible for the next funding year. Specifically, maternal interviews to be conducted during 2004/2005 would comprehensively address all variables required by the infant development study, and mothers who provided biological samples at delivery for the monitoring program would be recruited for the infant development study so that their infant would be tested at 6½ and 11 months of age in 2005/2006.

## Expected Completion Date

March 2006

## Expected Completion Date

# *Environmental Trends Related to Human Health and International Controls*

# Contaminants in Arctic Seabird Eggs


## Project leader(s)

Birgit Braune, National Wildlife Research Centre Canadian Wildlife Service, Environment Canada Carleton University, Ottawa, ON; phone: (613) 998-6694; fax: (613) 998-0458; e-mail: birgit.braune@ec.gc.ca

## Project members

Tony Gaston, Environment Canada (CWS-HQ, NWRC), Ottawa, ON; Bryan Wakeford, Environment Canada (CWS-HQ, NWRC), Ottawa, ON; Jason Duffe, Environment Canada (CWS-HQ, NWRC), Ottawa, ON; Grant Gilchrist, Environment Canada (CWS-P&N, NWRC), Ottawa, ON; Mark Mallory, Environment Canada (CWS-P&N), Iqaluit, NU; Keith Hobson, Environment Canada (CWS-P&N), Saskatoon, SK; Indian and Northern Affairs; Polar Continental Shelf Project


## Abstract


As an indicator of contamination in the Canadian Arctic marine environment, seabird eggs have been used to monitor changes in concentrations of a number of contaminants since 1975. The most recent collection of eggs from three species of seabirds in 2003 from Prince Leopold Island in the Canadian High Arctic show that concentrations of most of the legacy organochlorines continue to decrease in the Canadian Arctic. Concentrations of total mercury, however, continue to increase suggesting that the Arctic marine environment continues to be a sink for global Hg. A collection of thick-billed murre eggs from Coats Island in northern Hudson Bay extends the contaminant data set started for that Low Arctic colony in 1993. Eggs of northern fulmars were collected from a second colony at Cape Vera on Devon Island allowing, for the first time, comparison of data for this species from two Canadian Arctic colonies.


## Key Project Messages

1. Concentrations of most of the legacy organochlorines continue to decrease in Canadian Arctic seabirds.
2. Concentrations of β-HCH continue to be the major fraction contributing to total HCHs and appear to be increasing in black-legged kittiwakes and northern fulmars.
3. Concentrations of total Hg continue to increase in three Canadian Arctic seabird species suggesting that the Arctic marine environment continues to be a sink for global Hg.

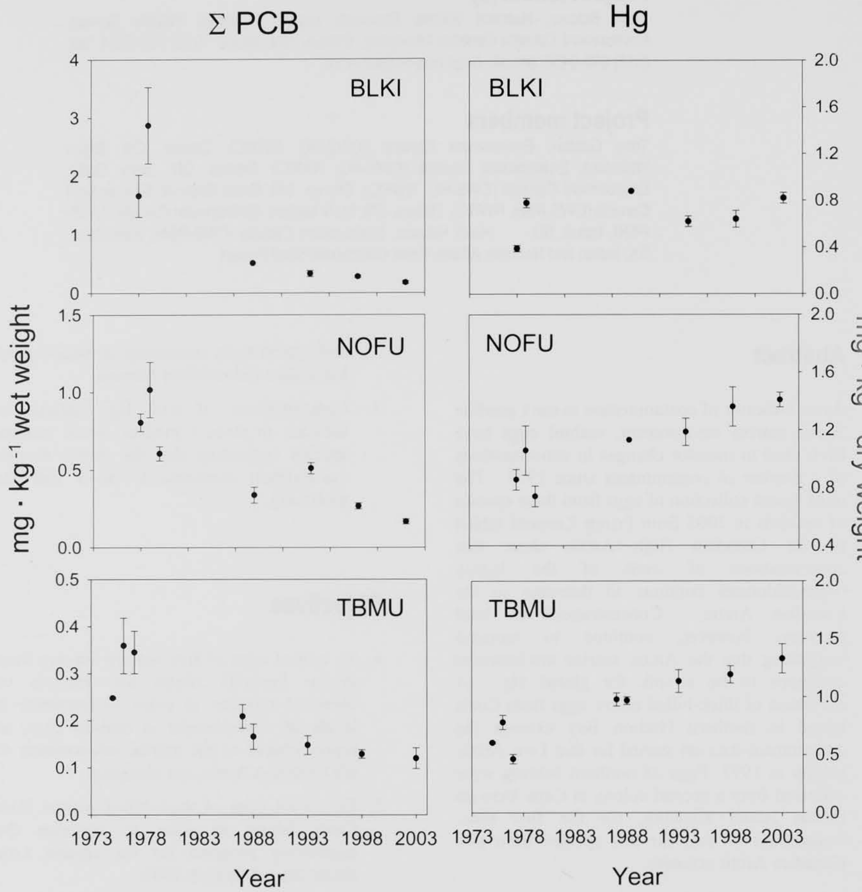
## Objectives

1. To collect eggs of five seabird species from Prince Leopold Island for analysis of chemical residues in order to determine if levels of contaminants in seabird eggs, as representative of the marine environment of the Canadian Arctic, are changing.
2. To collect eggs of thick-billed murres from Coats Island in order to continue the monitoring program for the eastern Low Arctic started there in 1993.
3. To collect eggs of northern fulmar from Cape Vera on Devon Island so that results for northern fulmars from Prince Leopold Island might be corroborated.

## Introduction

The Canadian Wildlife Service (CWS) has been monitoring contaminants in eggs of thick-billed

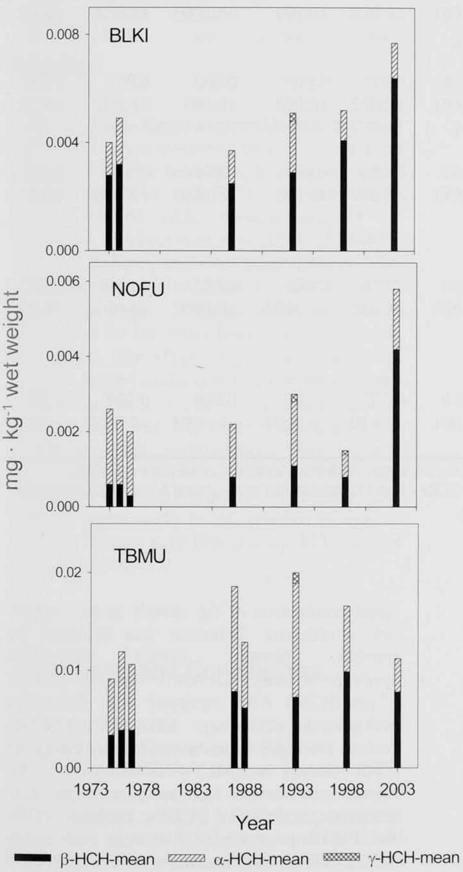
**Figure 1.** Mean concentrations (± standard error) of ΣPCB (mg·kg⁻¹ wet weight) and total Hg (mg·kg⁻¹ dry weight) in eggs of black-legged kittiwakes (BLKI), northern fulmars (NOFU) and thick-billed murres (TBMU) collected between 1975 and 2003.




murres (*Uria lomvia*), northern fulmars (*Fulmaris glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) from Prince Leopold Island (74°02'N, 90°05'W) in the Canadian High Arctic since 1975 (Braune *et al.*, 2001) to provide an index of contamination in the Arctic marine ecosystem and possible implications for seabird health. Seabirds breeding in the High Arctic are contaminated with a similar suite of organic contaminants as those breeding in temperate regions (Noble and Elliott 1986). Temporal trends for contaminants and stable isotopes in seabird eggs collected from Prince Leopold Island between 1975 and 1998 have been described in Braune *et al.* (2001, 2003).

Due to the high costs and logistical difficulties of accessing Arctic seabird colonies, collections of eggs for Arctic seabirds have been opportunistic in the past but, with the support of the Northern Contaminants Program, the collections have been standardized to every five years (i.e. ... 1993, 1998, 2003). Starting in 1993, black guillemots (*Cepphus grylle*) and glaucous gulls (*Larus hyperboreus*) were added as monitoring species to make the Canadian program more compatible with other monitoring activities under the international Arctic Monitoring and Assessment Program (AMAP). Thick-billed murre eggs have been collected from Coats Island (62°30'N, 83°00'W) in northern Hudson Bay since 1993, as well, establishing this location as a Low Arctic monitoring colony. Additionally, northern fulmar eggs were collected for the first time in 2003 from a colony at Cape Vera (76°18'N, 89°18'W) on Devon Island as part of a new initiative to study the biology of this species in the Canadian Arctic. Previous data have suggested increases in concentrations of mercury (Braune *et al.*, 2001) and polybrominated diphenyl ethers (PBDEs) (Braune *et al.*, 2003) in northern fulmars as well as high toxic equivalent (TEQ) values (Braune and Simon, 2003).

**Figure 2.** Contributions of α-HCH, β-HCH and γ-HCH to mean ΣHCH concentrations (mg·kg$^{-1}$ wet weight) in eggs of black-legged kittiwakes (BLKI), northern fulmars (NOFU) and thick-billed murres (TBMU) collected between 1975 and 2003.




## Activities

## In 2003-2004

*Sample collection/retrieval:* In 2003, collections of eggs were made for four species (northern fulmars (n=16), thick-billed murres (n=15), black-legged kittiwakes (n=13), and glaucous gulls (n=15)) from Prince Leopold Island, NU. Eggs were collected by hand on the basis of one egg per nest. Due to logistical problems, the planned collection of black guillemot eggs was not made from Prince Leopold Island in 2003 but a second attempt will be made in 2004. A collection of northern fulmar eggs (n=15) was made from Cape Vera on Devon Island and a collection of thick-billed murre eggs (n=18) was made from Coats Island. In addition to the northern fulmar and thick-billed murre egg samples collected from Prince Leopold Island in 2003, archived egg samples from thick-billed murres from 1976, 1977 and 1988 have been retrieved and issued to the lab for analyses of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), non-*ortho* PCBs and PBDEs to improve the temporal trend data series for those compounds in the murres.

*Chemical Analyses*: Eggs were analyzed for total mercury (Hg), selenium (Se) and

**Table 1.** Mean concentrations (± standard error) of organochlorines (mg·kg⁻¹ wet weight) and total Hg (mg·kg⁻¹ dry weight) in pooled egg samples (N) of black-legged kittiwakes (BLKI), northern fulmars (NOFU), thick-billed murres (TBMU) and glaucous gulls (GLGU) collected from Prince Leopold Island, Coats Island and Cape Vera in 2003. Trends for concentration data from 1975-2003 are indicated for black-legged kittiwakes, northern fulmars and thick-billed murres from Prince Leopold Island as follows: ↓ decreasing, ↑ increasing, ↔ no change.

| Species | N | % Lipid | ΣPCB[1] | ΣDDT | ΣCBz | ΣCHL | Dieldrin | ΣMirex | ΣHCH | Total Hg |
|---|---|---|---|---|---|---|---|---|---|---|
| Prince Leopold Island | | | | | | | | | | |
| BLKI | 4 | 9.1 ±0.2 | 0.177 ±0.026 | 0.043 ±0.007 | 0.018 ±0.001 | 0.045 ±0.004 | 0.005 ±0.0003 | 0.005 ±0.001 | 0.008 ±0.001 | 0.82 ±0.047 |
| Trend | | | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↑ | ↑ |
| NOFU | 5 | 10.5 ±0.4 | 0.167 ±0.016 | 0.124 ±0.013 | 0.014 ±0.001 | 0.112 ±0.008 | 0.007 ±0.001 | 0.007 ±0.0005 | 0.006 ±0.001 | 1.41 ±0.05 |
| Trend | | | ↓ | ↓ | ↓ | ↔ | ↔ | ↔ | ↔ | ↑ |
| TBMU | 5 | 12.8 ±0.5 | 0.120 ±0.022 | 0.103 ±0.008 | 0.032 ±0.001 | 0.031 ±0.002 | 0.009 ±0.001 | 0.003 ±0.001 | 0.011 ±0.001 | 1.33 ±0.13 |
| Trend | | | ↓ | ↓ | ↓ | ↔ | ↓ | ↔ | ↔ | ↑ |
| GLGU | 5 | 7.8 ±0.4 | 1.592 ±0.345 | 0.901 ±0.204 | 0.064 ±0.013 | 0.400 ±0.069 | 0.013 ±0.001 | 0.046 ±0.009 | 0.043 ±0.006 | 2.57 ±0.22 |
| Coats Island | | | | | | | | | | |
| TBMU | 5 | 12.1 ±0.6 | 0.114 ±0.008 | 0.116 ±0.006 | 0.029 ±0.002 | 0.031 ±0.002 | 0.005 ±0.0003 | 0.003 ±0.0001 | 0.009 ±0.001 | 0.56 ±0.03 |
| Cape Vera | | | | | | | | | | |
| NOFU | 5 | 10.6 ±0.3 | 0.145 ±0.014 | 0.112 ±0.010 | 0.014 ±0.001 | 0.105 ±0.010 | 0.007 ±0.0004 | 0.006 ±0.0004 | 0.004 ±0.0004 | 1.57 ±0.12 |

1 ΣPCB - Sum of 67 congeners; ΣCHL - Sum Chlordanes (oxychlordane, *cis*- & *trans*-nonachlor, *cis*- & *trans*-chlordane, heptachlor epoxide); ΣMirex - Sum Photo-mirex & Mirex; ΣCBz – Sum Chlorobenzenes (tetra-, penta- & hexachlorobenzene); ΣHCH - Sum Hexachlorocyclohexanes (α-, β- & γ-HCH).

organochlorines including PCBs as pooled (composite) samples of three eggs each. Chemical residue analyses were carried out at the CWS/NWRC laboratories at Carleton University in Ottawa, ON. Organochlorine analyses for the legacy POPs were carried out by gas chromatography using a mass selective detector (GC/MSD) operated in Selected Ion Monitoring (SIM) mode according to CWS Method No. MET-CHEM-OC-04D. Total Hg was analyzed using an Advanced Mercury Analyzer (AMA-254) equipped with an ASS-254 autosampler for solid samples according to CWS Method No. MET-CHEM-AA-03E. The method employs direct combustion of the sample in an oxygen-rich atmosphere. Selenium was analyzed by graphite furnace atomic absorption spectrophotometry (GFAAS) using a Perkin-Elmer 3030B AAS equipped with deuterium background corrector, HGA-500 graphite furnace and AS-40 autosampler according to CWS Method No. MET-CHEM-AA-02E. The fulmar and murre egg samples were also analyzed for PCDDs, PCDFs, coplanar PCBs and PBDEs as pools of five eggs each using HRGC/HRMS SIM according to CWS Method No. MET-CHEM-PCDD-01C. QA/QC was monitored by CWS Laboratory Services, NWRC, Ottawa, ON, which is an accredited laboratory through the CAEAL-SCC and has participated in the NCP's QA/QC Program. Stable-nitrogen isotope analyses were carried out through CWS in Saskatoon with isotopic measurements made at the Department of for 2003. Concentrations of total PCBs (□PCB), DDT metabolites (□DDT) and chlorobenzenes (□CBz) continued to decrease in eggs of thick-billed murres, northern fulmars and black-legged kittiwakes collected between 1975 and 2003 from Prince Leopold Island (Table 1, Figure 1). Soil Science, University of Saskatchewan, SK. All samples have been archived in the CWS Specimen Bank.

## Results

Analyses of the legacy organochlorines and total Hg for the eggs collected in 2003 have been completed but we have not yet received results for the PCDD/Fs and PBDEs in thick-billed murres, or the stable isotope data In the kittiwakes, concentrations of total chlordanes (ΣCHL), dieldrin, and total mirex(ΣMirex) also continued their declining trend as did dieldrin in the murre eggs. Concentrations of β-HCH continue to be the major fraction contributing to total HCHs (ΣHCH) and appear to be increasing in black-legged kittiwakes and northern fulmars (Figure 2). In 2003, concentrations of ΣHCH, dieldrin and total Hg in eggs of thick-billed murres differed significantly (t-tests,$p<0.05$) between Prince Leopold Island and Coats Island (Table 1). Concentrations of ΣHCH also differed significantly (t-test, $p<0.05$) in eggs of northern fulmars from Prince Leopold Island and Cape Vera (Table 1).

## Discussion and Conclusions

The pattern of organochlorine declines documented to date in these migratory seabird species most likely reflect overall lower contamination of the food chain in their oceanic wintering areas resulting from restrictions placed on the use of many of these compounds in the 1970s and 1980s (Braune *et al.*, 2001). The increasing concentrations of β-HCH in seabirds, however, are consistent with the recalcitrant nature of this isomer as reflected by the increasing proportions of β-HCH found in other marine animals such as ringed seals and polar bears (Fisk *et al.*, 2003). The lower concentrations of organochlorine contaminants such as dieldrin and ΣHCH in the Coats Island murre eggs compared with Prince Leopold Island in 2003 is consistent with results for these two colonies in 1998 but differs from the 1993 data suggesting a continuation of the differing rates of change between the two colonies as discussed by Braune *et al.*, (2002). The pattern of increase of total Hg in all three seabird species suggests that the Arctic marine environment continues to be a sink for global Hg. The lower concentrations of total Hg in the Coats Island murre eggs compared with Prince Leopold Island in 2003 parallels the pattern seen in 1998 and 1993 possibly suggesting a latitudinal pattern between the Low Arctic (Coats Island) and High Arctic (Prince Leopold Island) colonies (Braune *et al.*, 2002). Given the historical contaminants data available for Arctic seabirds, continuation of the seabird egg data sets will provide valuable information against which to compare the effectiveness of more recent international agreements such as the 1998 UN ECE LRTAP Protocols on Heavy Metals and POPs, and the 2001 Stockholm Convention on POPs, as well as contribute to the UNEP Global Mercury Assessment.

## Expected Project Completion Date

December 31, 2004

## References

Braune, B.M., G.M. Donaldson, and K.A. Hobson. 2001. Contaminant residues in seabird eggs from the Canadian Arctic. I. Temporal trends 1975 - 1998. *Environ. Pollut.* 114: 39-54.

Braune, B.M., G.M. Donaldson, and K.A. Hobson. 2002. Contaminant residues in seabird eggs from the Canadian Arctic. II. Spatial trends and evidence from stable isotopes for intercolony differences. *Environ. Pollut.* 117: 133-145.

Braune, B.M., G.M. Donaldson, and M. Simon. 2003. Contaminant trends in Arctic seabirds. Poster presented at Canadian Arctic Contaminants Assessment Symposium, Ottawa, 4-7 March 2003.

Braune, B.M., and M. Simon. 2003. Dioxins, furans and non-ortho PCBs in Canadian Arctic seabirds. *Environ. Sci. Technol.* 37: 3071-3077.

Fisk, A.T., K. Hobbs, and D.C.G. Muir. 2003. *Canadian Arctic Contaminants Assessment Report II: Contaminant Levels, Trends and Effects in the Biological Environment.* Ottawa: Indian and Northern Affairs Canada, 175 p.

Noble, D.G., and J.E. Elliott. 1986. Environmental contaminants in Canadian seabirds, 1968-1984: trends and effects. *Tech. Rep. Ser.* No. 13. Ottawa: Canadian Wildlife Service, 275 p.

# Northern Contaminants Air Monitoring and Interpretation


## Project leader(s)

Hayley Hung, Meteorological Service of Canada (MSC), 4905 Dufferin Street, Toronto, ON, M3H 5T4; phone: (416) 739-5944; fax: (416) 793-5708; e-mail: hayley.hung@ec.gc.ca

## Project members

Pierrette Blanchard and Terry Bidleman, MSC, Toronto, ON; Phil Fellin and Henrik Li, AirZone, Mississauga, ON; Ed Sverko, National Laboratory for Environmental Testing, Burlington; Gary Stern, Brian Billeck, Bruno Rosenberg, Freshwater Institute, Winnipeg, MB



## Abstract

An updated temporal analysis of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCs) measured in Arctic air at the Canadian High Arctic site of Alert, Nunavut (82°30'N, 62°20'W), is presented. Long-term trends developed using the digital filtration technique (DF) with 5 years of data (1993-1997) did not differ significantly from those determined with 7 years of data (1993-1999). This implies that with the DF technique, consistent long-term trends can be developed with less than 10 years of data. An acceleration in the decline of OC and PCB air concentrations was noted in 1999 for some compounds, although the reason for this is unknown.

Spatial comparisons of OC seasonality at Alert, Tagish, Dunai and Kinngait show elevated air concentrations of some compounds in spring. Elevated spring concentrations, however, were observed for different compounds at different sites. Potential causes are discussed. Further investigation of the atmospheric flow pattern in spring, which is responsible for the transport of POPs into the Arctic, is required.

Seasonally averaged air concentrations of γ-hexachlorocyclohexane (γ-HCH) and various polychlorinated biphenyl (PCB) congeners measured from 1993 to 1999 at Alert, were compared over the same time period to North American surface air temperatures and indices that reflect the strength of the Pacific North American (PNA) pattern. The PNA is an atmospheric circulation teleconnection pattern strongly associated with climate variations and air flow patterns in North America. The potential influence of climate variations occurring in temperate North America on the long-range transport of POPs to the Canadian Arctic is explored.


## Key Project Messages

1. Long-term time trends of OC and PCB concentrations in Arctic air developed by the digital filtration technique are consistent using 5 or 7 years of monitoring data.
2. The decline in air concentrations for some compounds was accelerated in 1999 for no apparent reason.
3. Spring OC concentration maxima in Arctic air may be the result of a combination of environmental factors. Further investigation in the atmospheric flow pattern, which controls the movement of pollutants into, through, and out of the Arctic in spring, is required.
4. Strong links between POP concentrations (γ-HCH and various PCB congeners) in Arctic air and springtime indices of the Pacific North American pattern (PNA) suggested that increased surface air temperatures enhanced re-volatilisation of historical residues in temperate North America, which

was followed by favourable atmospheric transport to the Arctic.

## Objectives

1. To measure and understand the occurrence and trends of selected OCs and polycyclic aromatic hydrocarbons (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), that will contribute to ongoing Northern Contaminants Program and Arctic Monitoring and Assessment Programme assessments, and provide advise to Canadian negotiators in preparing contaminant control strategies

## Introduction

Long-term trends were derived for the air concentrations of PCBs and OCs at Alert using a digital filtration method in previous Synopses of Research (2000/01, 2001/02). An update of these trends is given here with additional data up to the end of 1999.

Atmospheric measurements of POPs, 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. Kinngait and Alert in Nunavut, Tagish in Yukon and Dunai Island in Russia were operating simultaneously from March 1994 to April 1995. In the previous Synopsis of Research, elevated air concentrations of various PCBs and OCs measured in Arctic air during this co-sampling period was noted in spring. Factors which may lead to these "Spring Maximum Events" are discussed.

A preliminary investigation on the influence of the Pacific North American (PNA) Pattern on the air concentrations of $\gamma$-HCH measured at Alert was given in the previous Synopsis of Research. The relationship between PNA and the transport of POPs to the Arctic is further explored here, using air concentrations of 9 PCB congeners measured at Alert.

## Activities

## In 2003-2004

1. Regular weekly atmospheric measurements of OCs and PAHs continued at Alert. This involved the collection, extraction and analysis of air samples.
2. The site of Little Fox Lake,Yukon, which was activated in July 2002 to quantify trends in the western Canadian Arctic by comparison with observations made earlier at Tagish (December 1992– March 1995), was decommissioned in July 2003.
3. As part of a decision to integrate analytical activities within Environment Canada, chemical analyses have been moved from the 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. NLET is an active participant in major national and international interlaboratory performance-testing programs. A thorough comparison between FWI and NLET is currently underway to ensure that all quality assurance requirements are met and that data comparability is not compromised.
4. The chemical list has been revised to include 14 polybrominated diphenyl ethers (PBDEs), endosulfan II and 2 methyl-naphthalenes. These compounds are of growing international concern and are, or may be, impacting the Arctic environment. Seven chlordane related compounds, either components of technical chlordane or

Table 1. Halflives of selected PCBs and OCs at Alert

| PCBs | Alert (93-99) $t_{½}$ (y) | Alert (93-99) $r^2$ | Alert (93-97) $t_{½}$ (y) | Alert (93-97) $r^2$ | OC | Alert (93-99) $t_{½}$ (y) | Alert (93-99) $R^2$ | Alert (93-97) $t_{½}$ (y) | Alert (93-97) $r^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 28 | 10 | 0.55 | 12 | 0.58 | α-HCH | 9.1 | 0.80 | 17 | 0.79 |
| 31 | 6.9 | 0.86 | 6 | 0.87 | γ-HCH | 5.7 | 0.86 | 4.9 | 0.88 |
| 52 | 4.0 | 0.86 | 3 | 0.86 | Oxychlordane | 4.1 | 0.90 | 3.5 | 0.84 |
| 101 | 7.3 | 0.53 | 11 | 0.73 | *t*-chlordane | 5.5 | 0.67 | 8.3 | 0.48 |
| 105 | 11 | 0.21 | ND[a] | 0.021 | *c*-chlordane | 6.1 | 0.70 | 4.1 | 0.71 |
| 118 | ND[a] | 0.03 | ND[a] | 0.093 | *t*-nonachlor | 6.2 | 0.73 | 6.2 | 0.71 |
| 138 | ND[a] | 0.01 | ND[a] | <0.01 | *c*-nonachlor | 6.6 | 0.55 | 7.9 | 0.29 |
| 153 | 79 | 0.01 | 17 | 0.18 | Dieldrin | 13 | 0.21 | ND[a] | <0.10 |
| 180 | 4.2 | 0.76 | 4 | 0.78 | endosulfan I | 38 | 0.06 | ND[a] | 0.25 |
| | | | | | heptachlor epoxide | 8.3 | 0.70 | 6.3 | 0.72 |

[a] Compounds that do not show a consistent declining trend (i.e. greatly fluctuating or steady or slightly increasing trends) are indicated as ND = Not Determinable. In such cases, $r^2$ is the linear regression coefficient of the slope of ln P versus time.

Table 2. Spearman rank order correlations between spring mean air concentrations of selected compounds and PNA indices

| | HCHs | | PCBs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [a] | α-HCH | γ-HCH | 28 | 31 | 52 | 101 | 105 | 118 | 138 | 153 | 180 |
| $r_S$ | 0.43 | **0.86** | **0.68** | **0.79** | **0.75** | **0.68** | -0.11 | 0.11 | 0.64 | **0.82** | **0.82** |
| P | 0.34 | **0.01** | **0.09** | **0.04** | **0.05** | **0.09** | 0.82 | 0.82 | 0.12 | **0.02** | **0.02** |

[a] $r_S$ = Spearman correlation coefficient, p = Spearman p-values
Statistically significant correlations with p<0.10 are shown in bold types.

chlordane metabolites, as well as photoheptachlor and photomirex, which have always been found below detection limits have been removed from the chemical list.

5. Data analysis has been progressing well. Analysis of 1992-2000 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.

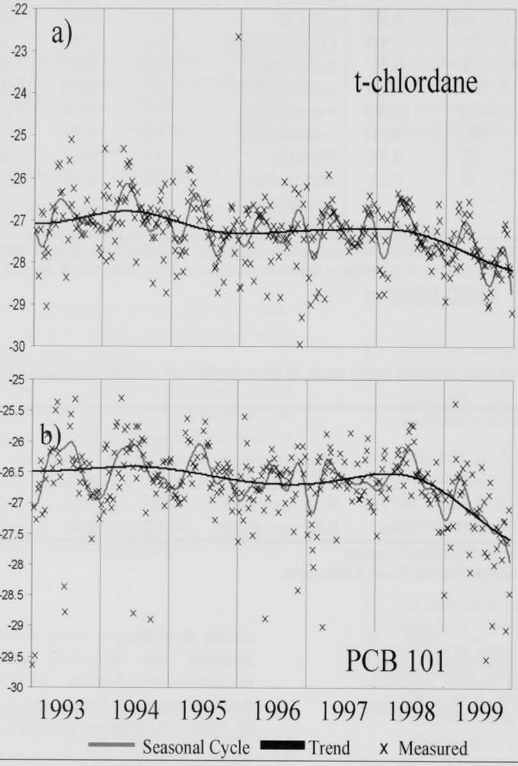
6. An article summarising findings under this project reported in the Canadian Arctic Contaminants Assessment Report II (CACARII) has been submitted to the Science of Total Environment for consideration of publication in the CACARII Special Issue.

7. In collaboration with Drs. Y. F. Li, J. M. Ma, S. Venkatesh and R. W. Macdonald, an article describing a mass balance model to estimate the historical budget of α-hexachlorocyclohexane (α-HCH) in the Arctic Ocean has been published in Science of Total Environment (Li *et al.*,, 2004).

8. An investigation on the influence of climate variation patterns, e.g. North Atlantic Oscillation (NAO) and the El Niño-Southern Oscillation (ENSO), on POP air concentrations measured under NCP and IADN (collaboration with Dr. Jianmin Ma at MSC) has resulted in an article published in the journal of Environmental Science and Technology (Ma *et al.*,, 2004).

9. Another article which investigates in detail the relationship between PNA and the air concentrations of the hexachlorocyclohexanes (HCHs) and PCBs in Alert air is currently under preparation.

**Figure 1.** Trends and seasonal cycles of (a) *t*-chlordane and (b) PCB 101




## Results and Discussion

### Update of PCB and OC Trends at Alert

The seasonal cycles and trends (1993-1997) of selected PCB and OC concentrations measured in Alert air were derived by the DF technique and reported in the Synopsis of Research in 2001.

Additional years of data are now available up to the end of 1999 and new trends are developed and presented here. Examples of the trends and seasonal cycles derived for *t*-chlordane and PCB 101 are shown in Figure 1. The gas phase air concentration is expressed as the natural log of partial pressure (P). Table 1 shows the estimated apparent first order halflives ($t_{½}$) determined from the regression slope (m) of the DF trend lines as follows:

$$t_{1/2} = \frac{\ln 2}{m} \quad (1)$$

The halflife of a compound is the time required for the concentration of the compound to decrease to half its original value. Halflives determined with data from 1993 to 1999 are similar to those found using data from 1993 to 1997. Except dieldrin and endosulfan I, which did not show a decline in trends when data from 1993 to 1997 were used, showed halflives of 13 and 38 years, respectively, with the two additional years of data. For dieldrin, this is the result of a downturn in air concentrations starting early in 1998 and continued until the end of 1999. Before then, dieldrin levels in Alert air had been fairly steady between 1994 and 1997. For endosulfan I, the level also declined from mid-1998 to end of 1999 but the extent was not as significant as that observed for dieldrin. The concentration of endosulfan I in the Arctic has been relatively steady throughout the sampling period. This may be because endosulfan is a current-use pesticide, but dieldrin and aldrin, which converts quickly to dieldrin in the environment, have been banned in most western industrialized countries. Similar to dieldrin, many PCBs and OCs showed accelerated decline in air concentrations in 1998/99 with no apparent reason. Further investigation is required to determine the cause of this accelerated decline.

## Spatial Variations of OC Seasonality in Arctic Air

It was noted that the air concentrations of many OCs measured at Alert showed elevated air concentrations in spring. Similar to that of *t*-chlordane shown in Figure 1a. To determine whether this is a unique phenomenon observed at Alert, OC gas phase air concentrations from Alert, Tagish, Dunai and Kinngait measured during the 1994-1995 co-sampling period are plotted against months of the year for comparisons. As an example, Figure 2 shows the box-and-whisker plots of *t*-chlordane air concentrations at Alert, Tagish and Dunai (left panel). For Alert, data from 8th March, 1993 to 24th April, 1995 (same as sampling period at Dunai) are used in the plots. Since there are very few data for Kinngait during this co-sampling period, as most samples were analyzed as four-week composites, a scatter plot of all data is given in Figure 2d. Also shown on Figure 2 are the box-and-whisker plots of the weekly averaged temperatures at the sites (right panel). For Kinngait, the temperatures are weekly averaged when 7-day samples were taken and four-weekly averaged when four-week composites were analyzed.

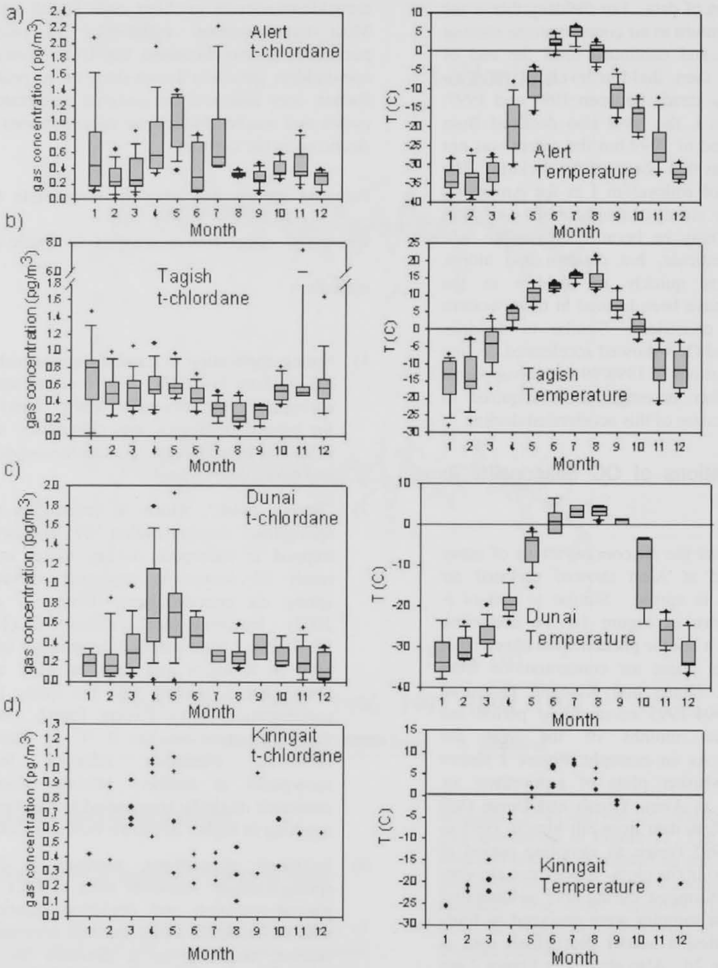
Spring peaks occurred for air concentrations of *c*-chlordane and endosulfan I at Alert, Kinngait and Dunai but not at Tagish; *t*-nonachlor at Kinngait and Dunai only; *o,p*'-DDE at Alert only; *o,p*'- and *p,p*'-DDT at Alert and Dunai only; octachlorostyrene at Dunai only; and tetrachloroveratrole at Alert and Tagish only. Most transformation/ metabolites of parent pesticides, i.e. oxychlordane, heptachlor epoxide and dieldrin, generally do not show spring peaks. Rather, they followed the seasonal temperature cycles and reached highest air concentrations in Arctic air in the summer.

Potential factors that may be responsible for spring OC concentration maxima in Arctic air include:

1) Spring application of current-use pesticides, e.g. lindane ($\gamma$-HCH). However, elevated spring air concentrations were also observed for banned pesticides, e.g. chlordanes, and industrial by-products e.g. octachlorostyrene and tetrachloroveratrole.
2) "Spring pulse", which is defined as the springtime revolatilization of chemicals trapped in snowpack during winter as a result of snowmelt, rendering elevated spring air concentrations (Gouin *et al.*, 2002). However, local ice/snowmelt ($T>0$ °C, Figure 2 right panel) did not occur until May in Kinngait and June in Alert and Dunai, not coinciding with the spring OC concentration peaks. Except Tagish where the temperature reaches 0 °C in March. However, chemicals released from snowpacks at southern latitudes during snowmelt might be transported to the Arctic resulting in higher Arctic air concentrations.
3) Increased atmospheric removal in late spring/summer. Removal rates of OCs by photodegradation and depletion reactions with OH radicals would increase after polar sunrise, resulting in a decrease in air concentrations during the summertime. Yet, if this was the only reason in effect, the 'spring maximum event' should occur at all sites.

Scavenging of OCs by forests along the transport pathway to the Arctic during the growing season.

**Figure 2.** t-chlordane seasonality and temperature at (a) Alert, (b) Tagish, (c) Dunaiand (d) Kinngait.Centre box of box-and –whisker plots, is bounded by the 25thand 75thpercentile with the horizontal line representing the median. Outliers ($^3$1.5´ interquartilerange) are represesntedby a □.Figure 2. t-chlordane seasonality and temperature at (a) Alert, (b) Tagish, (c) Dunaiand (d) Kinngait.Centre box of box-and –whisker plots, is bounded by the 25thand 75thpercentile with the horizontal line representing the median. Outliers ($^3$1.5´ interquartilerange) are represesntedby a •.




At leaf burst in late spring, the waxy cuticle on the new leaves would adsorb semivolatile organic compounds in air in the vicinity of forests. This process would reduce the amount of chemicals in air available for transport to the Arctic, resulting in a decrease in Arctic air concentrations in late spring/summer.It is currently not possible to explain why only certain OCs showed elevated concentrations in spring and only at some sites but not others. This is probably the result of a combination of the above factors. Spring is a sensitive time of the year when various activities resume in the Arctic as well as at southern latitudes. To determine the influence of each of the abovementioned factors on the 'spring maximum event' of different OCs at different locations, further investigation in the atmospheric flow pattern in spring, which controls the movement of pollutants into, through and out of the Arctic, is required.

## Influence of PNA on POP Air Concentrations at Alert

The PNA is characterized by atmospheric flow in which the west coast of North America is out of phase with the Eastern Pacific and Southeast United States. During its positive phase, wavy flow occurs over the continent with increased temperatures and decreased storminess in the Northwest and cold temperatures in the Southeast (NOAA-CIRES Climate Diagnostic Centre, http://www.cdc.noaa.gov/Teleconnections/pna.html). Roughly reversed conditions occur over the same geographical region during the negative phase. In the previous Synopsis of Research, it was reported that spring γ-HCH air concentrations at Alert showed a statistically significant positive correlation with the standardized Pacific North American (PNA) Index (Wallace and Gutzler, 1981). Further investigation has revealed similar correlations between the air concentrations of selected PCBs and the PNA Index (Table 2). The selected PCBs are 9 congeners which constitutes the AMAP (Arctic Monitoring and Assessment Program) subset (PCB 28, 31, 52, 101, 105, 118, 138, 153 and 180) (excluding PCB 156, since 96 % of all samples were below method detection limit for this congener).

Gamma-HCH, PCBs 28, 31, 52, 101, 153 and 180 showed statistically significant Spearman correlations with the PNA index at 90 % confidence level ($p<0.10$) (Table 2). For those compounds which showed statistically significant correlations with PNA, their air concentrations at Alert increased with increasing PNA index (indicated by positive values of $r_S$), i.e. towards the positive phase of the PNA.

During the positive PNA phase in spring, higher-than-normal surface air temperature (SAT) (or positive SAT anomalies) occurred across Canada, Alaska and the northern U.S.A. Enhanced re-volatilization of organic chemicals from reservoirs, accumulated due to past and present usage, may occur. At the same time, weaker than normal zonal flow at 700 hPa occurred throughout the U.S.A. and southern Canada during the positive PNA phase. This may enhance atmospheric mass exchange between polar and mid-latitude regions, favoring transport of pollutants from temperate North America to the Arctic during the positive PNA phase.

Statistically significant correlations between the PNA index and the springtime air concentrations of □-HCH and various PCB congeners measured at Alert implied that climate variations in temperate North America may result in enhanced pollutant transport to the Arctic region. In the coming year, air monitoring for POPs at Alert will continue to provide us with more information to determine temporal and seasonal variabilities of these compounds in Arctic air. Air concentration data obtained from Kinngait between 2000 and 2002 are now available and are currently under data analysis. This dataset will provide us with information on POP air concentrations in the eastern Canadian Arctic. Longer time series of POP air concentrations will enable the development of forecasting methods to predict chemical fate and how changes in the physical environment, e.g. climate variation, would affect their distribution.

## References

Gouin, T., G. O. Thomas, I. Cousins, J. Barber, D. Mackay and K. C. Jones. 2002. Air-surface exchange of polybrominated diphenyl ethers and polychlorinated biphenyls. *Environ Sci Technol* 36: 1426-1434.

Li, Y. F., R. W. Macdonald, J. Ma, H. Hung, and S. Venkatesh. 2004. Historical alpha-HCH budget in the Arctic Ocean: The Arctic Mass Balance Box Model (AMBBM). *Sci Total Environ* 324 (1-3): 115-139.

Ma, J., H. Hung, P. Blanchard. 2004. How Do Climate Fluctuations Affect Persistent Organic Pollutant Distribution in North America? Evidence from a Decade of Air Monitoring. *Environ Sci Technol*, ASAP publication.

Wallace, J. M., and D. S. Gutzler. 1981. Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Wea. Rev.* 109: 784-812.

# Passive Air Sampling for Persistent Organic Pollutants in Cold Environments


## Project leader(s)

Hayley Hung, Meteorological Service of Canada (MSC), 4905 Dufferin Street, Toronto, ON, M3H 5T4; phone: (416) 739-5944; fax: (416) 793-5708, e-mail: hayley.hung@ec.gc.ca

## Project members

Frank Wania, University of Toronto at Scarborough (UTSC) Tom Harner, Pierrette Blanchard (MSC)



## Abstract

Atmospheric transport is considered a major pathway for persistent organic pollutants (POPs) to enter the Arctic environment. Under NCP, air monitoring for 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. This approach, however, 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 cost prevents simultaneous sampling at multiple locations. Under this project, two types of passive air sampling devices for POPs that are suitable for use in cold, remote locations, such as the Arctic, have been developed. These passive air samplers require neither the use of a pump nor electricity, but rely on the devices' capability to directly take up contaminants from the atmosphere. Prototypes are currently being built and are to be tested in the field.


## Key Project Messages

1. A conceptual design of a flow-through passive air sampler has been developed which can potentially increase the sampling rates of passive air sampling by directing air through the sampling medium.
2. The existing design of polyurethane-foam-disk-based passive air sampler has been scaled up to increase sampling rate.
3. The scaled-up sampler is currently being tested in the field.

## 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 at Alert to test for sampling accuracy and to quantify POP uptake kinetics under arctic conditions.
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 persistent organic pollutant (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

Under the NCP, air concentrations of POPs have been measured in the Canadian and Russian Arctic since 1992. This is mainly because air is the major transport pathway for these pollutants to enter 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 peoples who consume a 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 cost 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.

Various designs of passive air samplers (PAS) are currently available. Various housing designs and sampling media have been explored in recent years. Common sampling media include semi-permeable membrane devices (SPMD) (Ockenden *et al.*, 1998; Ockenden *et al.*, 1998; Shoeib and Harner, 2002), polyurethane foam disks (PUF disks) (Shoeib and Harner, 2002), polymer-coated fibres (Khaled and Pawliszyn, 2000), organic-rich soil (Shoeib and Harner, 2002), polymer-coated glass (POG) (Wilcockson and Gobas, 2001; Harner *et al.*, 2003) and XAD-resin (Wania *et al.,*, 2003). While some samplers are clearly unsuitable for use under Arctic conditions, PAS based on XAD-resin (Wania *et al.*, 2003) and PUF disks (Shoeib and Harner, 2002) have been tested under Arctic conditions (these PAS were deployed at Alert in 2002-2003 for initial testing).

Passive samplers are promising to address the need for spatially resolved atmospheric concentrations of POPs in the arctic, because of:

- their capability of time-integrated sampling over extended periods of time. The deployment length is limited by the sampler uptake capacity, which for some samplers has been shown to be in the range of decades and longer. This makes it possible to use fewer samples to characterize long-term atmospheric contamination of a locale.
- their independence from power supplies and regular maintenance.
- their relatively low production and operating cost.
- their simplicity of construction and functionality that allows them to function under extreme weather conditions, such as extremely low temperature, and blowing wind and snow.

The capability of PAS to provide information on the large scale variability of atmospheric POP concentrations has been shown through the results of a network of 40 stations across North America (Shen *et al.*, 2004). However, in order to reach their full potential, 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, 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 (Wania *et al.,*, 2003), 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 passive air sampling techniques suitable for use under cold environments such as the Arctic.

## Activities

## In 2003-2004

1. Scaled up PUF-disk-based PAS to increase sampling rates. Field tests are currently underway (see Results and Discussion Section).
2. Developed a conceptual design of a flow-through PAS which increases the sampling rate by directing air through the sampling medium.
3. Conducted wind tunnel experiments to assess pressure drop over two types of sampling media to be used as sampling insert in (2): PUF disk and polymer-coated aluminium honeycomb.

## Results and Discussion

Two designs of PAS are under development:

(A) One design is a scaled-up version of the sampler using polyurethane foam disks (PUF disks) as the sampling medium (Shoeib and Harner, 2002). Owing to the low air concentrations typical of arctic locations, the existing PUF disk PAS (referred to as original PAS hereafter) which samples at a rate of approximately 3-4 $m^3$/day is being scaled-up to a unit that is capable of sampling 15-20 $m^3$/day (referred to as scaled-up PAS). This larger sampling rate would allow integrated samples at remote arctic locations to be collected on a seasonal basis (every 1 to 3 months) with effective sample air volumes on the order of 750-3000 $m^3$. Shorter integration times may also be possible. The sampling rate is enhanced by increasing the surface area of the sampling medium available for capturing chemicals. The larger sampling rate of the scaled-up PAS will alleviate some of the current detection difficulties.

Characterization of both the original and scaled-up PAS is currently underway:

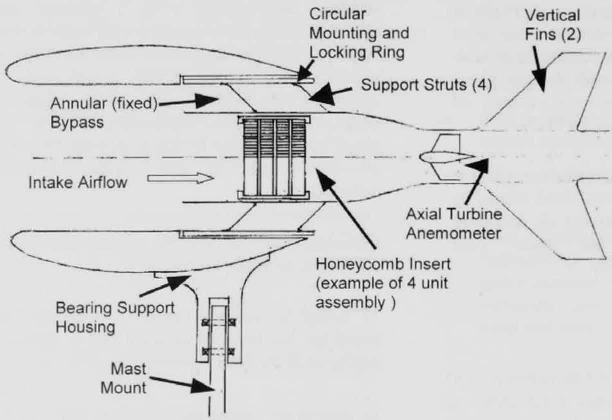
1) Sampling rate assessment: A scaled-up PAS prototype has been constructed and is currently deployed in the field to assess sampling rates.

2) Gas-phase versus particle-phase partitioning: It is important to understand what component of the air burden is being sampled by the PAS. Early results with the original PAS indicate that the gas-phase is predominantly sampled. These results are being confirmed in a winter-time field deployment study (Jan-Mar 2004) that will include separate conventional pumped HiVol air samples of the gas-phase and particle-phase components for PCBs (polychlorinated biphenyls) and PBDEs (polybrominated diphenyl ethers). The deployment will also test the scaled-up PAS as well as several stainless steel meshes used as wind barriers.

3) Depuration Compounds: The field study described above is employing depuration compounds to further confirm the PAS sampling rate. Depuration compounds are spiked to the PUF medium prior to deployment. These compounds do not exist in the atmosphere naturally. Since uptake and loss of chemical by the PAS is air-side controlled for our target chemicals, their loss during the sampling period (in relation to their physical-chemical properties, namely octanol-air partition coefficient, $K_{OA}$) can be used to assess and confirm the effective air sample volume.

4) Air Flow Characterization: A hot wire anemometer has been purchased and is being used to develop wind profiles inside the original and scaled-up PAS chambers. These results combined with an indoor, wind-field uptake

**Figure 1**. Conceptual design of a flow-through passive air sampler (PAS).




study using PUF disks will be used to better describe the uptake rates (mass transfer coefficients) under different wind scenarios.

(B) In addition to the scaled-up efforts, a conceptual design of a flow-through PAS, which directs air through the sampler by turning towards the direction of the wind, is being developed (Figure 1). The volume of airflow through the sampler is recorded by a small turbine-counter unit mounted at the exit. This enables accurate quantification of POP air concentrations sampled by the PAS.

To select a suitable material as the sampling medium, wind tunnel studies were conducted to determine the flow resistance of two types of sample insert, namely a ¼" PUF-disk (same as those used in PUF-disk-based PAS) and an aluminum honeycomb structure with 1/8" cell size. The latter configuration showed much lower resistance to air flow and was, therefore, selected. Multiple units of the aluminium honeycomb (length: 2 inches each) will be coated with a polymer, ethylene vinyl acetate (EVA), which is the material used to coat POG samplers, and will be mounted inside the housing as shown in Figure 1.

The sampling rate is improved by increasing the volume of air passing over the sampling medium. The fluid flow dynamics of this sampler is currently being analyzed by Prof. G. W. Johnston, a fluid flow specialist at the University of Toronto Institute for Aerospace Studies. A prototype of this sampler will be built and tested in a wind-tunnel. Sampling rates and efficiencies will be determined by co-sampling in the field with a conventional pumped HiVol sampler.

Different sampling media types and configurations will be explored and tested in order to improve the sampling efficiency of the two newly developed PAS designs and to minimize the possibility of contamination during sample change and shipment.

## References


Harner, T., N. J. Farrar, M. Shoeib, K. C. Jones, F. A. P. C. Gobas. 2003. Characterization of polymer-coated glass as a passive air sampler for persistent organic pollutants. *Environ Sci Technol* 37: 2486-2493.

Khaled, A., J. Pawliszyn, 2000. Time-weighted average sampling of volatile and semi-volatile airborne organic compounds by the solid-phase microextraction device. *J Chromatogr* A892: 455-467.

Ockenden, W.A., H. F. Prest, G. O. Thomas, A. Sweetman, K. C. Jones. 1998. Passive air sampling of PCBs: field calculation of atmospheric sampling rates by triolein-containing semipermeable membrane devices. *Environ Sci Technol* 32: 1538-1543.

Ockenden, W. A., A. J. Sweetman, H. F. Prest, E. Steinnes, K. C. Jones. 1998. Toward an understanding of the global atmospheric distribution of persistent organic pollutants: the use of semipermeable membrane devices as time-integrated passive samplers. *Environ Sci Technol* 32: 2795-2803.

Shen L., F. Wania, Y. Lei, C. Teixeira, D. Muir, T. Bidleman. 2004. Hexachlorocyclohexanes in the North American Atmosphere. *Environ Sci Technol* 38: 965-975.

Shoeib, M., T. Harner. 2002. Characterization and comparison of three passive air samplers for persistent organic pollutants. *Environ Sci Technol* 36: 4142-4151.

Wania, F., L. Shen, Y. D. Lei, C. Teixeira, D. C. G. Muir. 2003. Development and calibration of a resin-based passive sampling system for monitoring persistent organic pollutants in the atmosphere. *Environ Sci Technol* 37: 1352-1359.

Wilcockson, J. B., F. A. P. C. Gobas. 2001. Thin-film solid-phase extraction to measure fugacities of organic chemicals with low volatility in biological samples. *Environ Sci Technol* 35: 1425-1431.

# Digital Arctic for Environmental Study (DAFES)


## Project leader(s)

Yi-Fan Li, Meteorological Service of Canada, Environment Canada
4905 Dufferin Street, Downsview, ON. M3H 5T4; tel.: (416)739-4892;
fax: (416)739-4288; e-mail: yi-fan.li@ec.gc.ca

## Project members

Simon Wilson; AMAP Secretariat



## Abstract

The project "Digital Arctic for Environmental Study **(DAFES)**" is to integrate all arctic data produced from NCP and AMAP programs into one GIS (Geographic Information System) based and web based database. The AMAP grid system was created to be a platform to allocate all the data. The AMAP Grid is a polar stereographic projection grid system with the pole as the origin and cell size of around 25 km by 25 km. A database based on AMAP grid was developed, and some datasets were developed. These datasets include concentration data for some persistent organic pollutants (POPs) in various compartments along with population and landuse data. A GIS package was also developed for visualization of the data.


## Key Project Messages

- A GIS based database system, the Digital Arctic for Environmental Study **(DAFES),** was created to bring as much arctic data as possible into one place. This includes concentration data for contaminants in various compartments along with population and landuse data.
- The data in the system can be easily searched, queried, and downloaded. It can also be displayed using a GIS tool.

## Objectives

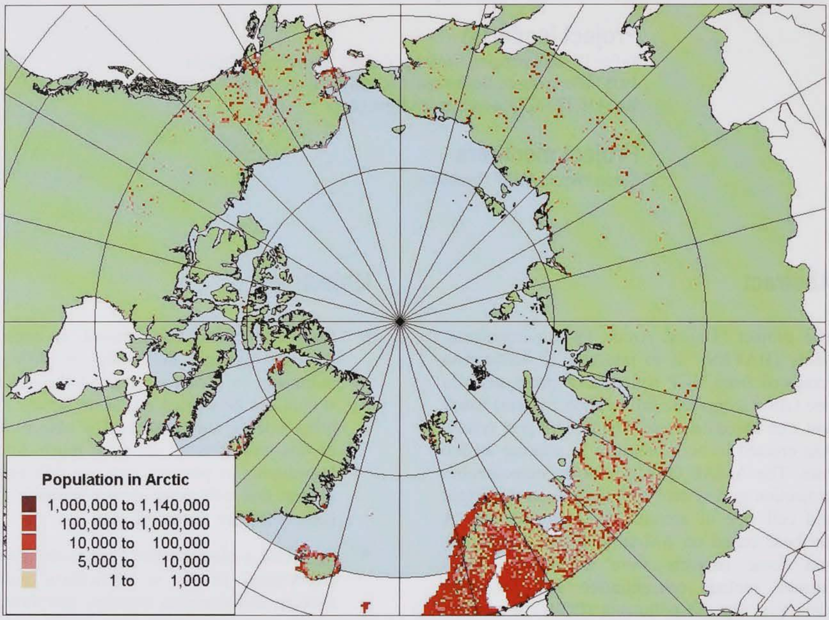
- Since the arctic environment is such a complex system, the study of different pollutants in different areas of the system should not be carried out in the absence of other existing information. The objective is of this project is to gather as much Arctic information as possible into one GIS based system that will assist with systematic and comprehensive Arctic research.
- To create a platform that brings the public (Aboriginal people in particular), policy makers, and scientists together, and through which communications may become more efficient and transparent.

## Introduction

Environmental contaminants are a global problem. Their presence and role in the Arctic reflects the environmental and social characteristics of the region, as well as the way the Arctic interacts with the rest of the world. Current concern about Arctic contaminants began with discoveries of high levels of persistent organic pollutants (POPs) in the arctic environment. Subsequent research confirmed that Arctic animals have elevated levels, posing a threat not only to the animals and their ecosystems, but also to the people who eat them.

The year 2002 was the last year of Phase II for both NCP and AMAP. As a result, a huge set of data arising from these programs is and will be made available to the scientific communitie and public. A new concept of **Digital Arctic For Environmental Study (DAFES)** is suggested to

**Figure 1.** Population for the Arctic region with the AMAP Grid system.




integrate all Arctic data produced from AMAP and NCP, and other programs under the Arctic Council. Data such as inhabitant population, vegetation, land use, ice cover, temperature, and contaminant levels in both biotic and abiotic media, will be combined into one GIS based database. To bring all this information into one place is the main purpose of the project. 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. Also, specific information (contamination level in wildlife, for example) for a given time period can be shown for the entire Arctic region. This database will be very useful for Arctic researchers, policy makers, and public interest groups.

## Activities

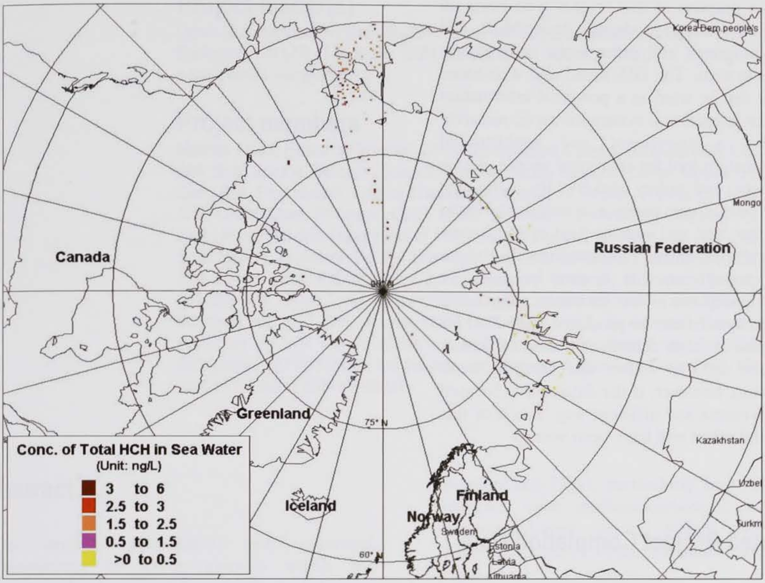
## In 2003-2004

The AMAP Grid System, was created specifically for the allocation of all arctic data. The AMAP Grid is a polar stereographic projection grid system with the pole as the origin, orientation of Greenwich meridian (LONG=0°) being the positive x-axis, and LONG = 90°E being the positive y-axis. The grid cell size is 25 by 25 km at 60° N.

The following non-concentration datasets have been created with the AMAP Grid system:

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

Figure 2. Concentration of ∑HCH in seawater with the AMAP Grid system.




- Concentrations (ng/L) of PCBs, CBs, α-HCH, β-HCH, γ-HCH, ∑HCH, CHLs, DDTs and HCBs in seawater (see Figure 2).
- Concentrations of PCBs, CBs, HCHs, CHLs, DDTs in suspended particulate matter (ug/g).
- Concentrations of HCBs, HCHs, DDTs, PCBs (ug/g dw) in sediments.
- Concentrations of CBs, HCHs, CHLs, DDTs, PCBs, Toxaphene, Dieldrin, Mirex in marine invertebrates. (ng/g ww)
- Concentrations in ng/g ww of CBs, HCHs, CHLs, DDTs, PCBs, Toxaphene, Dieldrin, Mirex in fishes.
- Concentrations of α- and γ-HCH (pg/m3) in Air.
- Concentrations of DDT, HCHs, PCB in human milk (mg/kg ppm, ug/kg ppb, mg/kg fat).
- Concentrations of DDT, HCHs, PCB, t-Chlordane and HCBs in deposition (ug/m2).
- Concentrations of DDTs, HCHs, PCB, t-Chlordane and HCBs in snow (ng/L).
- Concentrations of Endosulfan, Dieldrin, Mirex, Endrin, Toxaphene, DDTs, HCHs, t-Chlordane and CBs in Atmosphere (pg/m3).

A GIS package was developed for visualization of these data in the Arctic. This package does not include any commercial GIS software

## Discussion and Conclusions

The **DAFES** project was started last fiscal year. 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 can be used as a powerful information source for integral and systematic arctic research, and also a convenient and sophisticated communication tool for 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 will also be flexible enough so that it cam be used for different purposes. For example, an arctic education system can be produced from DAFES for the use in high school. Millions of dollars have been used to collect and compile arctic information, however, if the data cannot be used in a convenient and efficient way, much of this money and effort will have been wasted.

## Expected Project Completion Date

March 2005 - A PC-based software package including a powerful relational database management, a geographic information system (GIS) visualizing the data, and an interface linking the GIS AMAP grid system and the database together.

March 2006 - Web-based DAFES system available on the Internet

# New Contaminants in Arctic Biota


## Project leader(s)

Derek Muir, National Water Research Institute (NWRI), Environment Canada, Burlington, ON L7R 4A6; phone: (905) 319-6921; fax: (905) 336-6430; e-mail: derek.muir@ec.gc.ca

## Project members

Mehran Alaee, Research Scientist, NWRI, Environment Canada, Burlington ON L7R 4A6; Birgit Braune, Research Scientist, National Wildlife Research Centre, Ottawa ON Craig Butt, PhD student, Dept of Chemistry, University of Toronto, Toronto ON M5S 3H6; Laurie Chan, Professor, CINE, McGill University, Ste. Anne de Bellevue PQ; Paul Helm, Post-doc, Department of Fisheries and Oceans, Winnipeg, MB R3T 2N6 Scott Mabury, Professor, Dept of Chemistry, University of Toronto, Toronto ON M5S 3H6; Naomi Stock, PhD student, Dept of Chemistry, University of Toronto, Toronto ON M5S 3H6; Gregg Tomy, Research Scientist,Department of Fisheries and Oceans, Winnipeg, MB R3T 2N6; Xiaowa Wang, contractor, NWRI, Environment Canada, Burlington ON L7R 4A6; Arviat Hunters and Trappers Association, Arviat, NU XOA 0J0 (phone: 867-857-2636); Iviq Hunters and Trappers Association, Grise Fiord, NU XOC 0E0 (phone: 867-980-9063)



## Abstract

This project determined new chemical contaminants in Arctic animals which are important food sources for northern people, e.g. ringed seals, beluga whales, and seabird eggs. 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. Four major groups of chemicals were investigated, brominated flame retardants (BFRs), short and medium chain chlorinated paraffins (SCCPs), chlorinated naphthalenes (PCNs) and perfluorinated acids (PFAs). SCCPs were detected in almost all seal and beluga blubber samples. SCCP/MCCPs were not detectable in seabird (Northern fulmar) eggs and MCCPs were not detectable in any species. Two major BFRs, brominated diphenyl ethers (PBDEs) and hexabromocyclododecane, were present in all beluga and ringed seal blubber samples. Concentrations of PBDEs were highest in ringed seals from Hudson Bay and Hudson Strait compared to other locations. PFAs were detectable in liver of all species. Perfluorooctane sulfonic acid (PFOS) along with its possible precursor, perfluorooctane sulfonamide, were the predominant PFAs, particularly in beluga. Also detected were perfluorocarboxylic acids and perfluorotelomer acids. Future work will examine temporal trends of these chemicals in ringed seals and seabirds.


## Key Project Messages

1. A series of brominated, fluorinated and chlorinated chemicals which have not been measured extensively by NCP, were detected in Arctic biota.
2. Samples from Hudson Bay generally had higher concentrations of brominated flame retardants and perfluorinated acids.

## Objectives

1. Determine the geographic/spatial trends of new or emerging chemical contaminants (such as brominated flame retardants (BFRs), chlorinated naphthalenes (PCNs), short and medium chlorinated paraffins (SCCP/MCCPs), fluorinated sulfonic and carboxylic acids, as well as toxic metals in

Arctic biota which are important food sources for northern people, e.g. ringed seals, beluga.

2. Determine the temporal trends of these new contaminants in Arctic biota for which we already have good data for "legacy" POPs e.g. seabirds, ringed seals, and beluga. Do they differ regionally within the Canadian Arctic?
3. Identify and prioritize 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 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), short and medium chain chlorinated paraffins (SCCP/MCCPs), 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 however they are 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). PBDEs were determined in ringed seals at Holman (NT) and were found to be increasing during the 1980s and 1990s with a doubling time of 4 to 5 yrs (Ikonomou *et al.,* 2002). Levels of the total PBDEs were also found to have increased significantly in the beluga from Cumberland Sound over the period of 1982 to 1997 (Stern and Ikonomou 2000), in seabird eggs (Braune and Simon 2003a), burbot liver (Stern *et al.,* 2001) and landlocked Arctic char (Muir and Köch 2003). PCNs as well as SCCPs were detected in beluga and ringed seals from Cumberland Sound (Helm *et al.,* 2002; Tomy *et al.,* 2000). Fluorinated acids were detected in liver samples from ringed seals, polar bears, northern fulmars and mink (Martin *et al.,* 2003). On the other hand, other potential persistent, bioaccumulative and toxic (PB&T) Arctic contaminants, tributyl tin and synthetic musks, were near or at detection limits in ringed seals and Arctic char from Northern Québec (Muir *et al.,* 2000;Bidleman *et al.,* 2000).

While much was accomplished under NCP II there are numerous knowledge gaps. Good temporal trend data was developed only for PBDEs. Other BFRs such as hexabromocyclododecane (HBCD), a chemical that is replacing some PBDEs in Europe, were not determined. PCNs, SCCPs and perfluorinated acids were determined only in a very limited number of samples. Measurements of toxic heavy metals in most species (except in caribou, landlocked char and seabird eggs and liver) were limited to mercury, cadmium, lead, and sometimes zinc and arsenic. No information was found for thallium, nickel, vanadium and other toxic metals for marine mammals or most freshwater fishes. Information on geographic variation of all of these new contaminants was generally not available for any species.

Are these the only "new contaminants" likely to be found in the Arctic? This question was recently studied by Wania (2003) who examined the characteristics for "Arctic contamination potential" (ACP) using the Globo-POP model (Wania and Mackay 1999) and information on physical properties of selected chemicals. Wania noted that the chemical must reach the atmosphere in significant quantities, either by being directly emitted into air or by evaporating into the atmosphere. The chemical must be transported usually over a considerable distances through the atmosphere to the Arctic region and be sufficiently persistent in the atmosphere, with the actual level of persistence required depending on the distance to be traveled and the atmospheric travel time. The transported chemical must have the potential to be significantly deposited in the remote region in order to be detectable in the local ecosystem. Alternatively, the chemical can undertake the long distance migration with ocean currents or major rivers, which requires it to be sufficiently water soluble and very persistent in the aqueous phase. Chemicals resembling chlorobenzenes, HCH and lower chlorinated PCBs in their physical properties are shown to have highest ACP.

## Activities

## In 2003-2004

**Sample collection:** Ringed seals were used as the major bioindicator for spatial trends of new contaminants. Our reasoning was that there are lots of samples available (blubber and liver) and levels of new contaminants have been only barely explored in them – mainly the perfluoros (small number of samples; Martin *et al.,* 2004) and PBDEs (1 location; Ikonomou *et al.,* 2002). Ringed seal samples were obtained by Hunter and Trapper Organizations at Arviat and Resolute. The samples from Arviat arrived too late for use this year so archived samples were used instead.

Seabird (northern fulmar) liver, blood and egg samples were obtained from the CWS tissue bank. They were from Prince Leopold Island and Cape Vera on Devon Island. Beluga blubber and liver samples from Nunavik were obtained from Michael Kwan of the Nunavik Research Centre. Laurie Chan provided extracts from human dietary studies of Arctic communities for BFR analysis.

*Analytical methods:*

The analytical methods used for each chemical group are outlined in Table 1. Blubber and eggs were analysed for non-polar halogenated compounds and liver for perfluoro acids and metals. For the non-polar analytes (BFRs, SCCP/MCCPs) we used existing extracts for most seal samples and extracted beluga blubber and seabird eggs. 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 multi-element analysis and PFAs. In brief, blubber and eggs were Soxhlet extracted and lipid was removed by gel-permeation chromatography (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. SCCP-MCCP were quantified by GC-high resolution mass spectrometry (HRMS) 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 electrospray negative ionization mode. Hexabromocyclododecane was extracted along with other BFRs and quantified by LC-MS/MS and by GC-LRMS (Stuttaford *et al.,* 2004). Trace elements were extracted by acid digestion in a high-pressure microwave oven and analysed by inductively coupled plasma-HRMS (ICP-MS).

## Results

**Brominated flame retardants**: PBDEs ($Br_2$-$Br_7$BDEs) and HBCD were present at low ng/g (lipid weight) concentrations in ringed seal and beluga blubber (Table 2). Significantly higher (Students t-test of geomeans) concentrations were found in samples from Inukjuaq in eastern Hudson Bay and at Quaqtaq on Hudson Strait than in the central archipelago and western Arctic. As the results are all from females they are unlikely to be affected by differences in age of the seals. HBCD concentrations were similar or slightly higher than total PBDEs. HBCD consisted mainly of the α-isomer, although α- and γ- isomers were also present at low concentrations (Figure 1). PBDEs ($Br_2$-$Br_7$BDEs) and HBCD were present in beluga blubber from samples collected at Hudson Strait (Kangiqsujuaq) and East Hudson Bay (Nastapoka River) (Table 2). HBCD had not been previously reported in beluga whales.

**Table 1.** Analytical methodology for the new chemicals determined in samples for 2003-2004

| New chemical | Tissue | Extraction/isolation method | Quantification method |
|---|---|---|---|
| BFRs (Br2-Br8-PBDE, HBCD) | Blubber, egg | Soxhlet/ASE. GPC to remove lipids. | GC-LRMS and HPLC/MS/MS |
| SCCP/MCCP | blubber, egg | Soxhlet/ASE. GPC to remove lipids. | GC-HRMS (Negative ion mode) |
| PCN | blubber, egg | Soxhlet/ASE/Ball Mill. GPC to remove lipids. | GC-LRMS (Negative ion mode) |
| Perfluoro acids and neutral precursors | liver | Homogenization with ion pairing reagent | HPLC/MS/MS ESI |
| Metals | liver | Microwave Acid digestion | ICP- hi res MS |

**Table 2.** Average concentrations (±standard deviation) of brominated flame retardants in female ringed seal blubber (ng/g lipid weight)

| Species | Location | N | Sex | HBCD | | Total PBDEs[1] | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | SD | Mean | SD |
| Beluga whale | Kangiqsujuaq | 4 | F | 21 | ± 12 | 31 | ± 18 |
| | | 7 | M | 17 | ± 14 | 30 | ± 9.3 |
| | Nastapoka | 7 | F | 8.7 | ± 4.3 | 26 | ± 13 |
| | | 3 | M | 12 | ± 5.0 | 41 | ± 4.4 |
| Ringed seal | Sachs Harbour | 10 | F | 4.7 | ± 2.8 | 4.2 | ± 2.6 |
| | Grise Fiord | 7 | F | 3.1 | ± 1.4 | 5.3 | 1.3 |
| | Resolute | 5 | F | 1.3 | ± 0.7 | 2.9 | |
| | Pangnirtung | 12 | F | 2.8 | ± 1.0 | 5.2 | ± 3.9 |
| | Inukjuaq | 8 | F | | | 30 | ± 15.7 |
| | Hudson Strait[2] | 12 | F | | | 13 | ± 5.7 |

[1] Sum of $Br_2$-$Br_7$BDEs

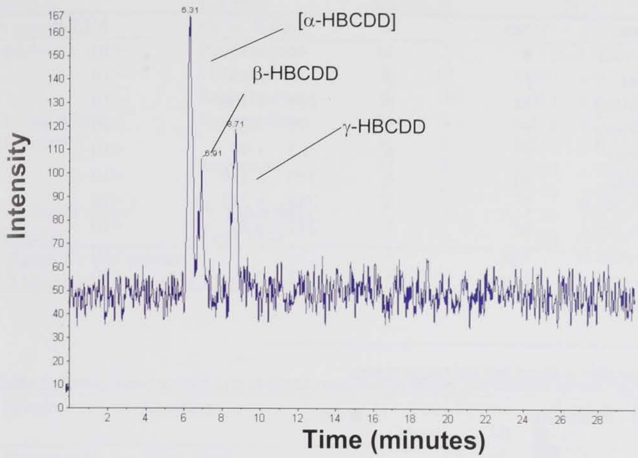
[2]Combined results for Kangiqsujuaq, Quaqtaq and Kangiqsualujjuaq

**Chlorinated paraffins**: SCCPs were present in ringed and beluga blubber but were undetectable (<1 ng/g) in fulmar eggs (Table 3). MCCPs were undetectable (<10 ng/g) in all samples. Concentrations of SCCPs in both ringed seals and beluga varied widely among individual animals. Higher concentrations were seen in males than in females for samples collected at Pangnirtung. Comparing females, ringed seals at Pangnirtung had higher concentrations than those from Grise Fiord or Resolute.

The profile of the C10-C13 chloroalkanes with 5 to 10 chlorines in ringed seal and beluga is shown in Figure 2. Hexachlorodecanes, undecanes and dodecanes predominated, especially in beluga blubber. Dodecanes ($Cl_6$-$Cl_8$) accounted for the highest proportion of SCCPs in both species.

**Polychlorinated naphthalenes (PCNs).** PCNs were determined in blubber from ringed seals and beluga whales and in northern fulmar eggs (Table 4). Concentrations of ΣPCN (tri- to octa-CN) ranged 0.03-0.60 ng/g lipid weight (lw) in ringed seal blubber, 0.07-0.89 ng/g lw in beluga blubber, and 1.02-1.92 ng/g lw in Northern fulmar eggs. The concentrations found in ringed seal were higher than the 0.035-0.071 ng/g lw found in 6 animals from Pangnirtung sampled in 1993 (Helm *et al.*, , 2002). Concentrations in beluga in this study compared well to the 0.036-0.383 ng/g lw determined in Kimmirut beluga from 1994 (Helm *et al.*, , 2002). PCNs were not detected in seabird eggs in a recent study in which detection limits were high (~2 ng/g ww) (Braune and Simon, 2004). Some geographical variations were apparent with ΣPCN concentrations lower in female ringed seal from Sachs Harbour than from the eastern arctic

Figure 1. LC-MS/MS chromatogram of hexabromocyclododecane isomers in ringed seal blubber from Pangnirtung (2002).




samples ($p < 0.01$; t-test). Male belugas from the Hudson Strait had significantly higher concentrations ($p < 0.05$; t-test) than males from Nastapoka in Hudson's Bay, although with a limited sample size. Dioxin toxic equivalents (TEQ) resulting from PCNs were calculated using relative potencies for several of the PCN congeners (Kannan *et al.,* 2003). The highest TEQ concentrations were found in the seabird eggs, followed by the beluga, then ringed seal (Table 4). Similar to previous findings, the ringed seals tend to have a PCN homolog distribution which favours the tri- and tetra-CNs compared to the beluga, which have more of the toxic penta- and hexa-CNs (Helm *et al.,* 2002). The latter is also true for the Northern fulmar eggs. The 0.5 ng/kg lw TEQ value for PCNs is considerably lower than the 936 ng/kg lw TEQ concentrations in northern fulmar eggs resulting from PCDD/Fs and dioxin-like PCBs using World Health Organization toxic equivalency factors (Braune and Simon, 2003b). In contrast, PCNs contributed 11% of the TEQ in beluga blubber relative to the dioxin-like PCBs (Helm *et al.,* 2002).

**Perfluorinated compounds.** Perfluorinated carboxylic acids (PFCAs), perfluorosulfonic acids, PFOSA and telomer acids were determined in liver samples from ringed seals, beluga whales and northern fulmar (Table 5). C7 to C14 PFCAs were detectable in all three species. In seals, C8-C11 PFCAs were the predominant components. Perfluorooctanoic acid (PFOA) was the major PFCA in seal liver from Grise Fiord and Sachs Harbour, while perfluorodecanoic and -undecanoic acid predominated in samples from Inukjuak (Eastern Hudson Bay). In beluga whales, perfluorodecanoic and -undecanoic acid were the predominant PFCAs while in northern fulmars perfluoro-nonanoic and decanoic acid were the major PFCAs. The fluorinated telomer acids, heptadecafluoro-2,3-decenoic acid or 8:2FTCA, heptadecafluoro-α,β-decenoic acid (8:2FTUCA), unadecafluoro-α,β-dodecenoic acid or 10:2FTUCA) were detectable in most samples and were particularly prominent in livers of northern fulmars. These chemicals are precursors in the microbial biodegradation and atmospheric breakdown of fluorinated telomer alcohols (Ellis *et al.,* 2004; Dinglasan *et al.,* 2004).

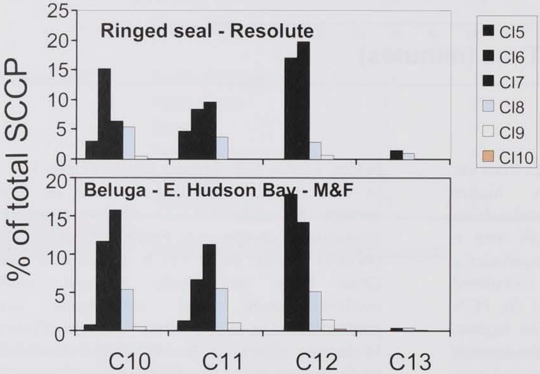
**Multi-element analysis:** Seal livers from 4 locations were analysed for 32 elements of which all except uranium, palladium and gallium were detectable in almost all samples (Table 6). With the exception of mercury, selenium, arsenic, cadmium, lead, and zinc, and the essential elements such as iron and copper, these elements

**Table 3.** Average concentrations (±standard deviation) of chlorinated paraffins in ringed seal and beluga blubber and seabird (Northern fulmar) eggs (ng/g lipid weight).

| Species | Location | Sex | N | SCCP | MCCP |
|---|---|---|---|---|---|
| Ringed seal | Grise Fiord | F | 7 | 46 ± 33 | <10 |
| Blubber | Resolute | F | 5 | 19 ± 15 | <10 |
| | Pangnirtung | M | 6 | 248 ± 166 | <10 |
| | Pangnirtung | F | 12 | 79 ± 24 | <10 |
| Beluga whale | Nastapoka | F | 6 | 62 ± 99 | <10 |
| Blubber | Nastapoka | M | 4 | 150 ± 190 | <10 |
| | Hudson Strait | F | 3 | 358 ± 281 | <10 |
| | Hudson Strait | M | 7 | 232 ± 89 | <10 |
| Fulmar eggs[1] | Pr. Leopold Is | Egg | 5 | <1 | <10 |
| | Cape Vera | Egg | 5 | <1 | <10 |

[1]2 locations x 5 pools of 3 individuals

**Figure 2.** Profile of chlorinated paraffins in ringed seal and beluga blubber.




have not been reported previously in ringed seal liver. The elements in addition to iron and copper, potassium, chromium, manganese, molybdenum, selenium, tin and zinc are all essential elements (Puls 1994). Among the 20 other elements the most prominent were rubidium which was present at concentrations ranging from 2.1 to 4.3 ug/g wet wt (Table 6). Rb is a naturally occurring alkali metal that is considered to be a biochemical analog for the essential element potassium (Peters *et al.*, 1999). At the sub-ug/g concentration range, silver (0.007-2.8 ug/g), vanadium (0.019-0.689 ug/g) and strontium (0.039-0.28) were relatively prominent Campbell et al (2004) have noted that silver, barium, lanthanum, lithium, antimony, uranium, palladium, and strontium were higher in marine zooplankton than in seals in their study of metal bioaccumulation in the arctic marine food web. Thus many elements are not accumulated by seals.

## Discussion and Conclusions

This study has identified several new 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

**Table 4.** Average concentrations (±standard deviation) of polychlorinated naphthalenes in ringed seal and beluga whale blubber and Northern fulmar seabird eggs and average (±standard deviation) PCN TEQ in each species (ng/g lipid weight).

| Species | Location | Sex | N | □PCN | | PCN TEQ | |
|---|---|---|---|---|---|---|---|
| Ringed seal | Grise Fiord | F | 7 | 0.277 | ± 0.149 | 0.023 | ± 0.012 |
| (Blubber) | Pangnirtung | M | 2 | 0.126-0.537[1] | | 0.0006-0.012[1] | |
| | Pangnirtung | F | 12 | 0.240 | ± 0.112 | 0.016 | ± 0.025 |
| | Sachs Harbour | F | 10 | 0.072 | ± 0.053 | 0.0002 | ± 0.0004 |
| Beluga whale | Hudson Strait | M | 8 | 0.421 | ± 0.258 | 0.288 | ± 0.121 |
| (Blubber) | | F | 3 | 0.248 | ± 0.275 | 0.187 | ± 0.133 |
| | Nastapoka | M | 4 | 0.160 | ± 0.043 | 0.184 | ± 0.032 |
| | | F | 6 | 0.156 | ± 0.094 | 0.109 | ± 0.074 |
| Northern Fulmar[2] | Pr. Leopold Is | | 5 | 1.33 | ± 0.38 | 0.524 | ± 0.143 |
| (Eggs) | Cape Vera | | 5 | 1.40 | ± 0.10 | 0.562 | ± 0.078 |

[1] Range for two animals
[2] 2 locations x 5 pools of 3 individuals

**Table 5.** Perfluorinated acids in liver of ringed seals, beluga whales and Northern fulmars (ng/g wet weight)

| Species | Location | N | Total PFCAs | | Total PFSAs | | PFOSA | | Telomer acids | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | ± SD | Mean | ± SD | Mean | ± SD | Mean | ± SD |
| Ringed seal | Grise Fiord | 11 | 65 | ± 28 | 48 | ± 33 | 1.4 | ± 0.5 | 9.1 | ± 8.9 |
| | Sachs Harbour | 11 | 61 | ± 41 | 48 | ± 33 | 2.8 | ± 1.4 | 6.2 | ± 7.3 |
| | Inukjuak | 11 | 97 | ± 52 | 126 | ± 67 | 3.0 | ± 2.2 | 2.1 | ± 3.5 |
| | Pangnirtung | 11 | 14 | ± 13 | 13 | ± 10 | 1.6 | ± 0.5 | 7.5 | ± 6.4 |
| Beluga whale | Eastern Hudson Bay | 19 | 64 | ± 17 | 17 | ± 12 | 145 | ± 53 | 14 | ± 10 |
| Fulmars | Cape Vera, Devon Is. | 10 | 13 | ± 11 | 1.9 | ± 1.5 | 0.7 | ± 0.9 | 15 | ± 12 |
| | Prince Leopold Is. | 5 | 8.2 | ±2.3 | 1.9 | ± 1.0 | 0.7 | ± 1.0 | 25 | ± 6.8 |

the environment but none previously in Arctic biota. While the C9-C15-PFCAs were reported for the first time in Arctic biota in a previous NCP report and in a paper by Martin *et al.* (2004), this study has added to the list with the detection of the fluorinated telomer (FT) acids. The FT acids are degradation products of the FT alcohols. These compounds have been detected in the North American atmosphere (Stock *et al.*, 2004) and were recently detected in air at Resolute NU (N. Stock, University of Toronto, Dept of Chemistry, unpublished data). The detection of the FT acids thus provides support for the hypothesis that the majority of PFCAs in arctic biota are derived from degradation of the fluorinated telomer alcohols. This study also reports about 20 elements in ringed seal liver that have not been measured previously. The most detailed previous multi-element study was by Braune and Simon (2004) who determined 24 elements in seabird eggs and livers using the same analytical methodology used here.

The lack of detection of MCCPs, which are C14-C17 chlorinated n-alkanes, in blubber of seals and beluga, and in fulmar eggs, was surprising considering that the C13- chlorinated n-alkanes are detectable albeit at low concentrations.

The study has also contributed the first information on spatial trends of several new chemicals including the PBDEs and SCCPs in seals, the PFAs and the PCNs. In general lower concentrations of several of these contaminants were found in western and high Arctic seals compared to Hudson Bay (Nunavik) animals.

Future work will focus on temporal trends of PBDEs, SCCPs, HBCD, PFAs and PCNs in ringed seals and seabirds.

**Table 6.** Concentrations of 32 elements (ug/g wet wt) in ringed seal liver from four locations

| | | Grise Fiord | | | Sachs Harbour | | | Pangnirtung | | | Inukjuaq | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Geomean | min | max | Geomean | min | max | Geomean | min | max | Geomean | min | max |
| Aluminium | Al | 0.059 | 0.030 | 0.110 | 0.687 | 0.020 | 42.3 | 0.131 | 0.070 | 0.450 | 0.360 | 0.080 | 42.3 |
| Antimony | Sb | 0.008 | 0.003 | 0.021 | 0.006 | 0.002 | 0.018 | 0.006 | 0.002 | 0.024 | 0.011 | 0.005 | 0.029 |
| Arsenic | As | 1.66 | 0.840 | 3.01 | 0.816 | 0.332 | 1.70 | 0.412 | 0.198 | 0.605 | 0.772 | 0.238 | 3.44 |
| Barium | Ba | 0.004 | 0.003 | 0.050 | 0.027 | 0.007 | 0.503 | 0.011 | 0.003 | 0.044 | 0.008 | 0.003 | 0.066 |
| Beryllium | Be | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 | 0.000 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 |
| Bismuth | Bi | 0.002 | <0.001 | 0.010 | 0.006 | <0.001 | 0.957 | 0.001 | <0.001 | 0.030 | 0.033 | 0.001 | 0.540 |
| Cadmium | Cd | 2.57 | 0.08 | 8.45 | 1.56 | 0.18 | 15.50 | 5.21 | 0.44 | 21.90 | 6.86 | 1.59 | 51.9 |
| Cesium | Cs | 0.028 | 0.019 | 0.039 | 0.023 | 0.019 | 0.037 | 0.021 | 0.016 | 0.040 | 0.035 | 0.020 | 0.059 |
| Chromium | Cr | 0.003 | 0.001 | 0.040 | 0.009 | 0.001 | 0.071 | 0.003 | 0.001 | 0.015 | 0.005 | 0.001 | 0.032 |
| Cobalt | Co | 0.014 | 0.009 | 0.029 | 0.027 | 0.011 | 0.199 | 0.015 | 0.010 | 0.022 | 0.022 | 0.009 | 0.034 |
| Copper | Cu | 5.35 | 2.74 | 15.3 | 11.2 | 4.47 | 37.4 | 12.1 | 5.49 | 27.7 | 8.34 | 4.11 | 19.1 |
| Gallium | Ga | <0.001 | <0.001 | 0.001 | 0.001 | <0.001 | 0.007 | 0.000 | <0.001 | 0.001 | 0.001 | <0.001 | 0.009 |
| Iron | Fe | 301 | 117 | 1468 | 931 | 246 | 3760 | 225 | 82.4 | 448 | 555 | 97.7 | 2330 |
| Lanthanum | La | 0.005 | 0.000 | 0.045 | 0.003 | 0.000 | 0.088 | 0.003 | 0.000 | 0.036 | 0.042 | 0.001 | 0.205 |
| Lead | Pb | 0.006 | 0.002 | 0.021 | 0.020 | 0.007 | 0.127 | 0.022 | 0.007 | 0.167 | 0.027 | 0.012 | 0.250 |
| Lithium | Li | 0.140 | 0.020 | 0.610 | 0.025 | 0.005 | 0.140 | 0.006 | 0.005 | 0.010 | 0.005 | 0.005 | 0.005 |
| Manganese | Mn | 3.69 | 2.31 | 5.38 | 3.96 | 2.70 | 5.55 | 4.99 | 3.50 | 6.54 | 4.21 | 2.79 | 5.81 |
| Mercury | Hg | 5.50 | 0.39 | 26.60 | 8.72 | 0.72 | 240 | 1.63 | 0.27 | 7.44 | 23.71 | 0.56 | 146.00 |
| Molybdenum | Mo | 0.783 | 0.531 | 1.050 | 0.773 | 0.335 | 1.18 | 0.819 | 0.657 | 0.984 | 0.744 | 0.517 | 1.020 |
| Nickel | Ni | 0.010 | 0.003 | 0.070 | 0.030 | 0.013 | 0.064 | 0.017 | 0.003 | 0.269 | 0.030 | 0.007 | 0.125 |
| Palladium | Pd | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Platinium | Pt | 0.006 | <0.005 | 0.050 | 0.050 | 0.050 | 0.050 | 0.006 | <0.005 | 0.050 | <0.005 | <0.005 | <0.005 |
| Potassium | K | 3594 | 3070 | 4410 | 3351 | 2700 | 4190 | 3632 | 2910 | 4320 | 3395 | 3020 | 3830 |
| Rubidium | Rb | 2.46 | 2.11 | 3.11 | 2.70 | 2.09 | 4.29 | 3.45 | 2.75 | 4.07 | 2.21 | 1.43 | 3.20 |
| Selenium | Se | 4.53 | 1.26 | 12.3 | 6.71 | 1.33 | 67.1 | 2.11 | 1.02 | 5.35 | 13.0 | 1.84 | 44.0 |
| Silver | Ag | 0.283 | 0.027 | 1.20 | 0.243 | 0.037 | 1.44 | 0.039 | 0.007 | 0.146 | 0.445 | 0.079 | 2.780 |
| Strontium | Sr | 0.076 | 0.039 | 0.123 | 0.143 | 0.088 | 0.277 | 0.137 | 0.073 | 0.257 | 0.132 | 0.057 | 0.254 |
| Thallium | Tl | 0.001 | <0.001 | 0.002 | 0.003 | 0.001 | 0.009 | 0.003 | 0.001 | 0.014 | 0.003 | 0.002 | 0.007 |
| Tin | Sn | 0.014 | 0.010 | 0.030 | 0.020 | 0.010 | 0.030 | 0.050 | 0.030 | 0.300 | 0.096 | 0.030 | 0.180 |
| Uranium | U | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.001 |
| Vanadium | V | 0.112 | 0.037 | 0.360 | 0.144 | 0.028 | 0.685 | 0.064 | 0.019 | 0.256 | 0.324 | 0.071 | 0.689 |
| Zinc | Zn | 46.8 | 37.4 | 56.0 | 46.6 | 29.5 | 63.4 | 50.0 | 38.9 | 59.3 | 47.3 | 34.3 | 65.1 |

## References

Alaee, M., D. Muir, C. Cannon, P. Helm, T. Harner and T. Bidleman. 2003. New persistent chemicals in Arctic air and water. In: *Sources, Occurrence, Trends and Pathways in the Physical environment. Canadian Arctic Contaminants Assessment Report II*. Indian and Northern Affairs Canada. Pp. 116-124.

Bidleman, T.F., D.C.G. Muir and G.A. Stern, 1999. New persistent chemicals in the Arctic environment. In: S. Kalhok (ed.), *Synopsis of Research Conducted under the 1998-99 Northern Contaminants Program*, pp.17-25. Indian and Northern Affairs Canada, Ottawa, ON, Canada.

Bidleman, T.F., M. Alaee and G.A. Stern, 2000. New persistent chemicals in the Arctic environment. In: S. Kalhok (ed.), *Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program*, pp. 93-104. Indian and Northern Affairs Canada, Ottawa, ON, Canada.

Braune, B. and M. Simon. 2003a. Retrospective survey of dioxins, furans, coplanar PCBs and polybrominated diphenyl ethers in arctic seabird eggs. pp. 251-254, In: Northern Science and Contaminants and Research Directorate (ed.), Synopsis of Research Conducted Under the 2001-2003 Northern Contaminants Program. Dept. of Indian Affairs and Northern Development, Ottawa.

Braune, B.M. and M. Simon. 2003b. Dioxins, furans, and non-ortho PCBs in Canadian arctic seabirds. Environ. Sci. Technol. 37: 3071-3077.

Braune, B.M.and M. Simon. 2004. Trace elements and halogenated organic compounds in Canadian Arctic seabirds. Marine Poll. Bull. 48: 986-1008.

Braune, B.M., Donaldson, G.M. and K.A. Hobson. 2001. Contaminant residues in seabird eggs from the Canadian Arctic. I. Temporal trends 1975 - 1998. Environ. Pollut. 114: 39-54.

Campbell, L.M., R J. Norstrom, K.A. Hobson, D.C.G. Muir, S. Backus, and A.T. Fisk. Mercury and other trace elements in a pelagic Arctic marine food web (Northwater Polynya, Baffin Bay). Sci. Total Environ. In press.

de Wit, C.A., A.T. Fisk, K. E. Hobbs, D.C.G. Muir, G.W. Gabrielsen, R. Kallenborn, M.M. Krahn, R. J. Norstrom, J.U. Skaare. AMAP, 2004. *AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic.* Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi +310 pp.

Ellis, D.A., J.W. Martin, A.O. De Silva, S.A. Mabury, M.D. Hurley, M.P. Sulbaek Andersen, and T.J. Wallington. 2004. Degradation of Fluorotelomer Alcohols: A Likely Atmospheric Source of Perfluorinated Carboxylic Acids. Environ. Sci. Technol.; 38(12); 3316-3321

Fisk, A.T., K.E. Hobbs and D.C.G. Muir. (eds) 2003. *Contaminant Levels and Trends in the Biological Environment, Canadian Arctic Contaminants Assessment Report II.* Indian and Northern Affairs Canada. 202 pp.

Hansen K.J., L.A.Clemen, M.E.Ellefson, and H.O.Johnson 2001. Compound-specific, quantitative characterization of organic fluorochemicals in biological matrices. Environ. Sci. Technol. 35:766-770.

Helm, P.A., T.F. Bidleman, G.A. Stern and K. Koczanski, 2002. Polychlorinated naphthalenes and coplanar polychlorinated biphenyls in beluga whale (*Delphinapterus leucas*) and ringed seal (*Phoca hispida*) from the eastern Canadian Arctic. Environ. Pollut.119:69-78.

Ikonomou, M.G., S. Rayne and R.F. Addison, 2002. Exponential increases of the brominated flame retardants, polybrominated diphenyl ethers, in the Canadian Arctic from 1981-2000. Environ. Sci. Technol. 36:1886-1892.

Dinglasan, M. A. J., Y. Ye, E.A.Edwards, S.A. Mabury. 2004. Fluorotelomer Alcohol Biodegradation Yields Poly- and

Perfluorinated Acids. Environ. Sci. Technol. 38, 2857-2864.

Kannan, K., K. Hilscherova, T. Imagawa, N. Yamashita, L.L. Williams and J.P. Giesy, 2001. Polychlorinated naphthalenes, -biphenyls, -dibenzo-p-dioxins, and –dibenzofurans in double-crested cormorants and herring gulls from Michigan waters of the Great Lakes. Environ. Sci. Technol. 35: 441-447.

Martin, J.A., S. Mabury and D. Muir. 2003. A Preliminary Assessment of Perfluorinated Compounds in the Canadian Arctic. In *Synopsis of research conducted under the 2001-2003 Northern Contaminants Program*, Indian and Northern Affairs Canada, Ottawa, ON pp. 301-310.

Muir, D., M. Kwan and J. Lampe, 2000. Spatial trends and pathways of persistent organic pollutants and metals in fish, shellfish and marine mammals of northern Labrador and Nunavik. In: S. Kalhok (ed.), *Synopsis of Research Conducted Under the 1999-2000 Northern Contaminants Program*, pp. 191-201. Indian and Northern Affairs Canada, Ottawa, ON.

Muir, D.C.G. and G. Köck 2003. Temporal Trends of Persistent Organic Pollutants and Metals in Landlocked Char. In. *Synopsis of research conducted under the 2001-2003 Northern Contaminants Program*, Indian and Northern Affairs Canada, Ottawa, ON pp. 311-317.

Peters E.L., I.R. Schultz, and M.C.Newman. 1999. Rubidium and cesium kinetics and tissue distributions in Channel catfish (Ictalurus punctatus). Ecotoxicology. 1999; 8: 287-300.

Puls, R., 1994. Mineral Levels in Animal Health. Diagnostic Data, 2nd Ed. Sherpa International Press, Clearbrook, BC. 356 p.

Stuttaford, K., G. Impey, D. Muir, M. Wilkliamson, C. Marvin, G. Macinnis and M. Alaee. 2004. Isomer Specific Determination of Hexabromocyclododecane (HBCDD) in Seal Blubber from the Arctic. Presented at the American Assoc Mass Spectrom., Montreal Qc.

Stern, G.A. and M. Ikonomou. 2000. Temporal trends of polybrominated biphenyls and polybrominated and polychlorinated diphenyl ethers in southeast Baffin beluga. In: S. Kalhok (ed.), *Synopsis of Research Conducted Under the 1999-2000 Northern Contaminants Program*, pp. 227-232. Indian and Northern Affairs Canada. Ottawa, ON.

Stern, G.A., W.L. Lockhart and M. Ikonomou, 2001. Temporal trends of organochlorine, organobromine and heavy metal contaminants in burbot from Fort Good Hope, Northwest Territories. In: S. Kalhok (ed.). Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program, Indian and Northern Affairs Canada. Ottawa, ON. pp. 230-236.

Tomy, G.T. and P.A. Helm 2003. In. *Synopsis of research conducted under the 2001-2003 Northern Contaminants Program*, Indian and Northern Affairs Canada, Ottawa, ON pp. 367-370.

Tomy, G.T., D.C.G. Muir, G.A. Stern and J.B. Westmore. 2000. Levels of C10-C113 polychloro-n-alkanes in marine mammals from the Arctic and the St.Lawrence river estuary. Environ. Sci. Technol. 34: 1615-1619.

Wania, F. and D. Mackay, 1999. Global chemical fate of□-hexachlorocyclohexane. 2. Use of a global distribution model for mass balancing, source apportionment, and trend predicition. Environmental Toxicology and Chemistry, 18:1400-1407.

Wania, F. 2003. Assessing the Potential of Persistent Organic Chemicals for Long-Range Transport and Accumulation in Polar Regions. Environ. Sci. Technol. 37; 1344-135.

# Temporal Trends of Mercury in Landlocked Char in the High Arctic: The Possible Influence of Climate Warming


## Project leader(s)

Derek Muir, National Water Research Institute (NWRI), Environment Canada, Burlington, ON L7R 4A6; phone: (905) 319-6921, fax: (905) 336-6430, e-mail: derek.muir@ec.gc.ca; Günter Köck, Institute of Zoology and Limnology, University of Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria; phone +43 512 507 6196; fax: +43 512 507 2930; e-mail: Guenter.Koeck@uibk.ac.at

## Project members

Jim Reist and John Babaluk, Freshwater Institute, Department of Fisheries and Oceans, Winnipeg, MB T3T 2N6; Doug Bright, UMA Engineering, Victoria BC; Lyle Lockhart, North-South Consulting, Winnipeg MB; Qausuittuq (Resolute Bay) Hunters and Trappers, Resolute, Nunavut (867-252-3800); Xiaowa Wang, Gino Sardella, (NWRI, Burlington ON



## Abstract

This study has examined temporal trends of mercury and other trace elements in landlocked Arctic char from lakes near the community of Qausuittuq (Resolute) by analysis of annual sample collections since 1997. In 2003, arctic char samples were collected from Amituk, Char, and Resolute Lakes as well as from Lake Hazen in northern Ellesmere Island. To assess temporal trends, results from 2003 were combined with previous data and, in the case of Lake Hazen, archived samples were analysed. Concentrations of mercury in the char in Resolute Lake were found to have increased slightly from 2002 to 2003 and overall have not declined significantly from 1993 to 2003. Higher concentrations continued to be observed in char from Char and Amituk Lakes in 2003 compared to samples from the early 1990s. For Char Lake, marginally significant higher concentrations ($P=0.097$) in samples from 2000 compared to 1993 using fish in the size range of 200-1000 g. For Amituk Lake, length adjusted mercury concentrations were higher in 2001-2003 than in 1989-1992, however, the differences were not statistically significant. At Lake Hazen, mercury concentrations were not significantly different in 2003 (0.106±0.018 ug/g wet wt) than in 1990 (0.118±0.056 ug/g wet wt) for fish in the size range of 290 to 375 mm. However, higher concentrations were found in this size class in archived samples from 1992 and 2001. This indicates that there may be considerable year to year variation in mercury which must be carefully accounted for when determining temporal trends.


## Key Project Messages

1. Mercury concentrations have not declined significantly in landlocked char from Resolute lake from 1993 to 2003.
2. Mercury concentrations have increased marginally in char from Char and Amituk Lakes over the same period.
3. At Hazen Lake in northern Ellesmere Island, mercury concentrations in char have also not changed overall but appear to show year to year variation which is probably related to diet.

## Objectives

1. Determine temporal trends of mercury (Hg)

and other metals in landlocked Arctic char in from lakes in the Canadian high arctic islands by analysis of annual sample collections.

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

## Introduction

The assessment of contaminants conducted by the NCP (Jensen *et al.*, 1997) found that there was limited information on temporal trends in fish especially in the eastern and High Arctic. This study was designed to help fill that knowledge gap. The Northern Contaminants Program's "Blueprint" for monitoring of health of arctic peoples and ecosystems" also recommended that freshwater fish be included in a comprehensive arctic contaminants biomonitoring program. Lakes in the high Arctic receive significant fractions of their water budgets in the form of snow melt runoff each year. Changes in deposition of contaminants to lake surfaces and watersheds , especially those scavenged from the atmosphere by snow, are reflected relatively quickly in changes to levels in water and top predator fishes, compared to the vast marine environment. We know this to be the case from the sedimentary record of POPs and mercury in small arctic lakes (Muir *et al.*, 1996; Lockhart *et al.*, 1998; Diamond *et al.*, 2003).

Small high arctic lakes also show major changes in water temperature during the short open water period of the Arctic summer. Because temperature affects contaminant uptake due to increased gill ventilation by fish, there may be seasonal differences in contaminant levels. Other factors such as increased lipids from higher productivity during summer may also influence levels of contaminants, especially POPs in fish. Köck *et al.*, (2001) have found increased accumulation of cadmium by char in Resolute Lake over the summer period. Köck *et al.* (1996) have previously shown that lake water temperature was a major factor in elevated cadmium and lead accumulation by landlocked char in high mountain lakes in Austria.

Results from our previous study on contaminants in char, which was funded from 1999-2003 in Phase II of the Northern Contaminants Program, have shown that mercury levels have increased in Arctic char from Char and Amituk Lakes and declined in Resolute Lake over a 9-10 year period (Muir *et al.*, 2001; 2004, Muir and Köck, 2003). 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. Additional lakes for which there is contaminant data from the early 1990s would help examine this question.

Data on contaminants are available for char from Lake Hazen (1990 for PCBs; 1992 for mercury) and cadmium in char livers (1992) and members of our research team have been responsible for most of the previous collections and analysis. Previous studies found average mercury concentration in char collected from Lake Hazen in 1990 of 0.18 ug/g ww, similar to lakes on Cornwallis Island (Muir and Lockhart, 1994). Köck et al (2004) measured cadmium in livers of 10 char from Lake Hazen and nearby small lakes (Lake A and Ekblaw Lake). Hazen Lake is of interest because it is fed by glacial melt waters and has a long water residence time. It could be particularly vulnerable to increased release of mercury from melting glaciers as well as to deposition. Sampling of char in Lake Hazen in 2003 was thus a priority for this project so that samples could be obtained and analysed for comparison with previous work.

Climate warming and the destruction of the ozone layer could be resulting in increased exposure of biota to mercury in high arctic lakes. Longer open water seasons and higher temperatures observed during the 1990s may be leading to increased phytoplankton productivity thereby increasing the rate of mercury scavenging via sedimenting particles from the water column into sediments (Macdonald *et al.*, 2003; Outridge *et al.*, 2004). There are suggestions that this release of mercury from terrestrial environments is already responsible for increasing concentrations in beluga feeding in the Mackenzie delta and Nelson River estuary (Lockhart *et al.*, 2001; Fisk *et al.*, 2003). A second factor is the reduction of the ozone layer which could be enhancing the oxidation of mercury ($Hg^{o}$ to $Hg^{2+}$) in the atmosphere. Inputs of $Hg^{2+}$ to lake surfaces and catchments are

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

| Lake | Year | Collected | Analysed |
|---|---|---|---|
| Amituk [1] | 1989 | 23 | 23 |
| Amituk[1] | 1992 | 15 | 15 |
| Amituk | 2001, 2002, 2003 | 5, 5, 6 | 5, 5, 6 |
| Char [1] | 1993 | 5 | 5 |
| Char | 1999, 2000, 2001 | 3, 3, 4 | 3, 3, 4 |
| Char | 2003 | 6 | 6 |
| Hazen [1] | 1990 | 35 | 35 |
| Hazen | 1992 | 20 | 20 |
| Hazen | 2001 | 20 | 20 |
| Hazen | 2003 | 20 | 20 |
| Resolute [1] | 1993 | 7 | 7 |
| Resolute | 1997 | 40 | 10 |
| Resolute | 1999-2003 | 25 each yr | 10+ each yr |

[1] Amituk 1989, 1992, Char 1993, Resolute 1993, and Hazen 1990 samples not available. Used results from W. L. Lockhart's database

occurring as a result of annual mercury depletion events (MDE) in spring time owing to interaction of sunlight and bromine oxide (BrO) formed from bromine emitted from the Arctic Ocean (Schroeder *et al.*, 1998; Lu *et al.*, 2001). This phenomenon has been shown to occur at high latitudes across the Arctic and as far south as Hudson Bay. The extent to which this deposition is contributing to mercury contaminant levels is unknown but fish in high arctic lakes would be good sentinels for studies of this process. The combination of sediment records for mercury which are now available for numerous arctic lakes, as well as other published information such as diatom records in sediments and changes in mean air temperatures, will allow us to examine the influence of climate warming effects on mercury trends in fish. The value of annual long-term sampling for measurement of temporal trends of contaminants has been recently confirmed in a study by Bignert *et al.*, (2004) which used datasets for mercury from various AMAP-related projects. The study demonstrated that only a few datasets such as those from Sweden had sufficient power to detect annual changes of 5% in mercury in fish. The authors concluded that annual sampling was critical to obtaining the desired statistical power.

This study, which began in 1999, was designed to continue annual sampling of char at Resolute Lake and other lakes on Cornwallis Island, as well as to study the trends of mercury and other metals in archived and newly collected samples from Lake Hazen for the first time since the early 1990s.

## Activities

## In 2003-2004

### Sample collection

Samples were successfully collected in August 2003 from Amituk, Char and Resolute Lakes, as well as from Lake Hazen. 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. The sample numbers collected in 2003 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). Data on mercury in char from Hazen Lake (1990) were provided by G. Stern of DFO Winnipeg from the original database created by L. Lockhart.

## Chemical analysis

### Mercury and other elements

Arctic char muscle 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 detemined by inductively coupled plasma high resolution Mass spectrometry mass spectrometry (ICP-HRMS). All analyses were performed by the National Laboratory for Environmental Testing (NLET) at NWRI, Burlington.

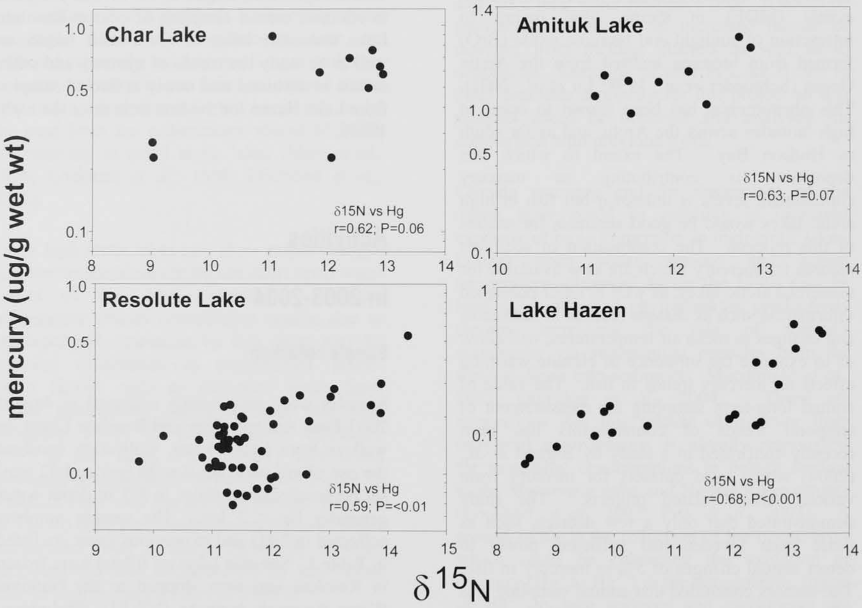
### Stable isotope analyses

Muscle from all fish analysed for mercury 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). The NLET metals labs is a participant in the NCP Quality Assurance Program and is accredited by the Standards Council of Canada through

**Figure 1.** Relationships between mercury concentrations and $\delta^{15}N$ in arctic char muscle in 4 Arctic lakes. Vertical axes are log scaled



Canadian Environmental Analytical Laboratory program to the standard CAN-P-4D (ISO/IEC 17025). Average deviations from certified values for the 12 certified elements in DORM-2 (dogfish muscle) and 9 elements in TORT-1 (lobster hepatopancreas) were 13% and 7.6%, respectively.

### Statistical analyses

All statistical analyses were conducted using the SYSTAT statistical package (SPSS Inc., Chicago, IL). Non-detect concentrations were replaced with half the detection limit for calculation of arithmetic and geometric means and standard deviations. Results for each collection year were first tested for normality using skewness and kurtosis tests. Results for all elements were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2. Analysis of covariance (ANCOVA) was used to examine the effect of collection year, length, and age and their interactions on concentrations of major elements as well as to examine differences in mean concentrations among lakes for samples collected over the period 1999-2003. The general model that was evaluated was: [element] = lake + P + P*Lake, where P = length, weight or age. Temporal and spatial trend comparisons were conducted with fish >200g and <1000 g to in order to reduce lake*P interactions. Temporal trends for mercury and other elements were examined using ANCOVA and Tukey's post-hoc multiple means test on least squared mean concentrations.

## Results

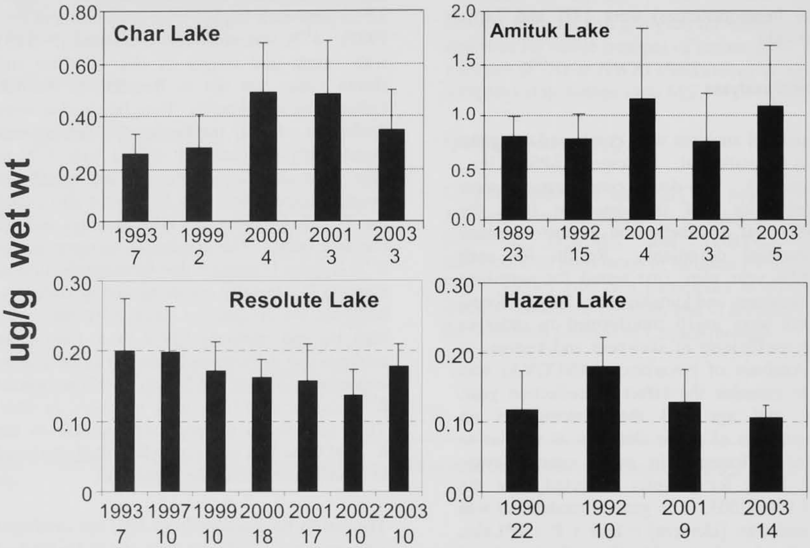
Mean concentrations of 16 elements in landlocked Arctic char muscle from Resolute, Amituk, Hazen and Char Lakes for 2003 are presented in Table 2. Of the 31 elements routinely determined, these 16 were detectable in most samples and 9 (Hg, Cu, Mn, Ni, Rb, Se, Sr, Tl, Zn) were above detection limits in all samples. Mercury (log transformed) was strongly correlated with fish length, weight and $\delta^{15}N$, as well as with thallium (Tl) ($P<0.05$) in all lakes, but not consistently with any of the other 9 elements. Mercury was also significantly correlated ($P<0.05$) with Rb in Hazen and Resolute lakes (data not shown).

The range of $\delta^{15}N$ in char muscle from the 2003 collections varied from 1.8% in Amituk to 5.1‰ in Lake Hazen. 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 ($P<0.05$) with length and weight of char in Char and Hazen Lakes but not in Resolute or Amituk Lakes (data not shown). Thus larger char were feeding at a higher trophic level. Mercury was significantly correlated ($P <0.05$) with $\delta^{15}N$ in char from all lakes (Figure 1) and significant positive correlations with $\delta^{15}N$ were also found for Tl (all 4 lakes), Rb (Hazen only) and Se (Amituk only). The results for mercury versus $\delta^{15}N$ (Figure 1) suggest that biomagnification of mercury is generally occurring due to piscivory, however, the presence of some individuals with high Hg and relatively low $\delta^{15}N$ in Char Lake suggests that differences in feeding could also be important. Hobson and Welch (1995) associated $\delta^{15}N$ values of 13.7% with piscivory in char. They also found a significant increase in the $\delta^{15}N$ of these fish with size which they attributed to cannibalism within the population.

The results for mercury from 2003 are combined with previous results for mercury in landlocked arctic char from Resolute, Char, Amituk and Hazen Lakes in Figure 2. Higher concentrations continued to be observed in char from Char and Amituk Lakes in 2003 compared to samples from the early 1990s. For Resolute Lake, Tukey's multiple means test was applied using geometric means concentrations of mercury in char from 1993-2003. Results indicated no significant trends over this period ($P>0.10$), although mean concentrations of mercury were about 20-25% lower in 2001 through to 2002 than those from 1993 and 1997 (Figure 2). For Char Lake, Tukey's test indicated a marginally significant higher concentrations ($P=0.097$) in samples from 2000 compared to 1993 using fish in the size range of 200-1000 g (Figure 2).

For Amituk Lake we calculated length-adjusted mean concentrations in char using ANCOVA. This was not possible for Char Lake and Resolute Lakes because of lack of data on the length of fish collected in 1993. Using samples limited to fish >200 and <1000 g, year-length interactions were not significant, thus a simple model of $[\log_{10}Hg]$ = Year + length was used and length-adjusted least square mean

**Figure 2.** Mercury concentrations (geometric means ± 95% confidence interval) in landlocked char from Char, Amituk, Resolute and Hazen Lakes (early 90s-2003). Sample numbers given below each date. Results for Amituk Lake are length adjusted using analysis of covariance (Muir *et al.*, 2004). Results from Lake Hazen are for char of size range of 280 to 375 mm.




concentrations were calculated. While length adjusted mercury concentrations were higher in 2001-2003 than in 1989-1992 (Figure 2), Tukey's test indicated that the differences were not statistically significant (P>0.10). This was due to small sample size for the period 2001-2003 after eliminating two larger fish. Without length adjustment and with these larger char (1000-1500 g) included, significantly higher mercury is observed for the period 2001-2003 as has been reported in a recent assessment report (Fisk *et al.,* 2003). However, given the strong correlation of mercury with length, and its significance as a covariate in the ANCOVA, the adjustment for length seems appropriate.

For Lake Hazen, two size classes of char were consistently sampled (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 $\delta^{15}N > 13$ ‰ in samples from 1992, 2001 and 2003. To compare among years we calculated arthimetic mean (± 95%Confidence interval) concentrations of mercury for the group of fish in the size range of 280 to 375 mm. Mean concentrations were not significantly different in 2003 (0.106±0.018 ug/g wet wt) than in 1990 (0.118±0.056 ug/g wet wt) (Figure 2). However, higher concentrations were found in this size class in 1992 and 2001. This indicates that there may be considerable year to year variation in mercury. The larger age class had much higher and more variable mercury concentrations, with means ranging from 0.24±0.08 ug/g wet wt in 1990 to 0.72 ±0.28 ug/g wet wt in 2001.

## Discussion and Conclusions

Considerable lake to lake variation is observed in the concentrations and temporal trends of mercury in the landlocked char. Mercury concentrations declined in Resolute Lake from 1993 to 2002 although overall trends from 1993 to 2003 were not significant. Mercury

**Table 2.** Geometric and arithmetic mean concentrations and ranges of length, weight, age, stable isotope ratios and major elements (ug/g wet wt) detected in muscle of landlocked Arctic char from Lakes in the Canadian Arctic archipelago collected in 2003

| Lake | Stat | Length (cm) | Weight (g) | Age (yr) | As | Ba | Cd | Co | Cr | Cu | Mn | Mo | Ni | Pb | Rb | Se | Sr | Tl | Zn | Hg | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amituk | GM | 46 | 696 | 19 | 0.01 | 0.01 | 0.0001 | 0.0090 | 0.02 | 0.3 | 0.09 | 0.0005 | 0.34 | 0.047 | 0.82 | 1.65 | 0.18 | 0.022 | 4.3 | 1.77 | -20.7 | 11.7 |
| N=5 | Mean | 46 | 728 | 19 | 0.01 | 0.01 | 0.0001 | 0.0094 | 0.03 | 0.3 | 0.09 | 0.0005 | 0.94 | 0.064 | 0.83 | 1.66 | 0.26 | 0.023 | 4.3 | 1.86 | -20.7 | 11.7 |
| | min | 40 | 398 | 18 | 0.01 | 0.00 | 0.0001 | 0.0070 | 0.01 | 0.2 | 0.05 | 0.0005 | 0.10 | 0.020 | 0.66 | 1.40 | 0.02 | 0.015 | 3.9 | 1.21 | -20.2 | 11.1 |
| | max | 50 | 926 | 20 | 0.02 | 0.02 | 0.0001 | 0.0150 | 0.08 | 0.5 | 0.15 | 0.0005 | 3.78 | 0.120 | 1.10 | 2.00 | 0.42 | 0.032 | 4.9 | 3.09 | -21.3 | 12.7 |
| | Detects (%)[1] | | | | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | |
| Char | GM | 50 | 1068 | 25 | 0.06 | 0.01 | 0.0001 | 0.0044 | 0.02 | 0.3 | 0.08 | 0.0008 | 0.09 | 0.011 | 0.71 | 0.50 | 0.05 | 0.007 | 3.7 | 0.48 | -24.0 | 11.4 |
| N=6 | Mean | 51 | 1286 | 26 | 0.06 | 0.01 | 0.0002 | 0.0048 | 0.03 | 0.4 | 0.08 | 0.0021 | 0.13 | 0.060 | 0.72 | 0.50 | 0.10 | 0.009 | 3.7 | 0.53 | -24.0 | 11.5 |
| | min | 40 | 399 | 21 | 0.05 | 0.00 | 0.0001 | 0.0020 | 0.01 | 0.2 | 0.06 | 0.0005 | 0.03 | 0.001 | 0.47 | 0.40 | 0.01 | 0.002 | 3.5 | 0.23 | -22.9 | 9.0 |
| | max | 62 | 2320 | 32 | 0.08 | 0.02 | 0.0010 | 0.0080 | 0.13 | 0.5 | 0.11 | 0.0100 | 0.29 | 0.210 | 0.85 | 0.60 | 0.37 | 0.013 | 4.0 | 0.76 | -25.1 | 13.0 |
| | Detects (%) | | | | 100 | 100 | 17 | 100 | 100 | 100 | 100 | 17 | 100 | 67 | 100 | 100 | 100 | 100 | 100 | 100 | | |
| Resolute | GM | 40 | 494 | 21 | 0.02 | 0.01 | 0.0001 | 0.0026 | 0.02 | 0.3 | 0.08 | 0.0007 | 0.06 | 0.018 | 0.64 | 0.60 | 0.04 | 0.006 | 4.0 | 0.17 | -22.0 | 11.6 |
| N=10 | Mean | 40 | 501 | 22 | 0.02 | 0.01 | 0.0010 | 0.0028 | 0.02 | 0.3 | 0.08 | 0.0015 | 0.07 | 0.023 | 0.65 | 0.60 | 0.08 | 0.007 | 4.0 | 0.18 | -22.0 | 11.7 |
| | min | 38 | 391 | 15 | 0.01 | 0.00 | 0.0001 | 0.0010 | 0.01 | 0.3 | 0.05 | 0.0005 | 0.03 | 0.010 | 0.54 | 0.50 | 0.01 | 0.003 | 3.5 | 0.11 | -21.2 | 11.1 |
| | max | 43 | 665 | 29 | 0.03 | 0.03 | 0.0100 | 0.0040 | 0.10 | 0.5 | 0.12 | 0.0100 | 0.13 | 0.070 | 0.76 | 0.70 | 0.25 | 0.015 | 4.4 | 0.28 | -22.9 | 13.1 |
| | Detects (%) | | | | 100 | 100 | 10 | 100 | 100 | 100 | 100 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | |
| Hazen | GM | 44 | 526 | 18 | 0.02 | 0.02 | 0.0001 | 0.0146 | 0.01 | 0.3 | 0.07 | 0.0005 | 0.06 | 0.002 | 0.97 | 1.20 | 0.16 | 0.009 | 4.2 | 0.16 | -21.0 | 11.1 |
| N=20 | Mean | 45 | 748 | 19 | 0.02 | 0.04 | 0.0002 | 0.0153 | 0.02 | 0.3 | 0.08 | 0.0005 | 0.07 | 0.005 | 1.04 | 1.23 | 0.23 | 0.010 | 4.3 | 0.21 | -21.1 | 11.3 |
| | min | 34 | 177 | 9 | 0.00 | 0.00 | 0.0001 | 0.0090 | 0.01 | 0.2 | 0.04 | 0.0005 | 0.03 | 0.001 | 0.47 | 0.90 | 0.04 | 0.003 | 3.4 | 0.06 | -17.7 | 8.5 |
| | max | 67 | 2560 | 29 | 0.04 | 0.25 | 0.0030 | 0.0330 | 0.04 | 0.5 | 0.18 | 0.0005 | 0.20 | 0.02 | 1.5 | 2.1 | 0.63 | 0.018 | 5.3 | 0.555 | -24.4 | 13.54 |
| | Detects (%) | | | | 100 | 100 | 10 | 100 | 100 | 100 | 100 | 0 | 100 | 40 | 100 | 100 | 100 | 100 | 100 | 100 | | |

[1]Frequency of detection based on sample numbers. Detection limit ranges from 0.001 - 0.0001 ug/g wet

concentrations have increased in Char Lake and Amituk Lakes over the same period and mean concentrations are above guidelines for subsistence consumption of 0.2 ug/g wet wt. The 2-3 fold increases in mercury in Arctic char from Char and Amituk lakes are within the range seen in seabirds and ringed seals in the Canadian Arctic archipelago during the 1990s (Fisk *et al.*, 2003). The slow declining trend in Resolute Lake suggests that these trends can vary widely among lakes. Resolute Lake has a much higher sedimentation rate than the two other lakes, and historical mercury inputs appear to have been greater in the 1960s than in more recent decades (Muir *et al.*, 2003). Of the four study lakes, Resolute Lake is the one most influenced by anthropogenic activity due to a road from the Hamlet of Resolute to the airport.

The elevated mercury in char from Amituk Lake relative to other lakes in the region cannot be readily explained by the available information on lake characteristics. Semkin et al (2004) developed a detailed mass balance of mercury in Amituk Lake and concluded that bedrock weathering was an important source of mercury due to the dolomite limestone bedrock in the watershed, although anthropogenic sources, e.g. from atmospherically deposited mercury, predominated by a factor of 2.6 in the early 1990s. This bedrock also underlies Char, North and Resolute lakes and is likely equally important as a source to those lakes because of very limited soils and large areas of exposed bedrock. Mercury concentrations in Amituk Lake surface sediments (0-1 cm) were 0.05 ug/g (dry wt), in a core collected in 2001, which was higher than surface slices in Resolute Lake (0.019 ug/g dw) but within the range for other small lakes in the Canadian arctic archipelago (Muir *et al.*, 2003). Additional study of the food web of Amituk Lake is needed to understand the reasons for elevated Hg in char from this lake.

The presence of small and large char morphotypes (distinctive forms of different size and feeding habits) has been previously reported for Lake Hazen (Guiguer *et al.*, 2002; Reist *et al.*, 1995). Guiguer et al (2002) showed that large Lake Hazen char (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.*, Further analysis of the data will be required to separate the "juvenile" and "small" morphotypes observed in Hazen, which have similar $\delta^{15}N$ but quite different diets based on the carbon isotope signatures (Guiguer *et al.*, 2002). Separating the two may help identify temporal trends in mercury and other contaminants.

The lack of significant change in mercury concentrations in Lake Hazen is consistent with the large size of this lake relative to the other study lakes. St. Louis (2003) found low concentrations of total mercury in snow at 23 sites on Ellesmere and Devon Islands and concluded that little of the spring-time oxidized mercury entered lakes via snowmelt due to volatilization and photochemical reduction. Thus even if atmospheric mercury deposition is increasing it is difficult to detect due to competing processes occurring in the snowpack. Small lakes such as those in the Resolute area that we have been studying since 1997 are best suited to detect changes in mercury inputs due to faster response than large systems such as Lake Hazen.

## Acknowledgements

We thank the Hamlet of Resolute Bay for permission to sample Char Lake and other lakes in the region, Parks Canada for their support of sampling at Lake Hazen and Polar Continental Shelf Project for accommodation and aircraft support.

## References

Bignert, A., F. Riget, B. Braune, P. Outridge and S. Wilson. 2004. Recent temporal trend monitoring of mercury in Arctic biota – how powerful are the existing data sets? J. Environ. Monit. 6: 351-355.

de March, B.G.E, C.A. de Wit, D.C.G. Muir, B.M. Braune, D.J. Gregor, R.J.Norstrom, M. Olsson, J.U. Skaare, K. Stange. 1998. Persistent Organic Pollutants. In: *Arctic Assessment Report*, Chapter 6. Arctic Monitoring and Assessment Programme. Oslo, Norway. pp. 183-372.

Diamond, M., P. Helm, R. Semkin, and S. Law. 2003. Mass balance and modelling of contaminants in lakes. In: Sources, Occurrence and Pathways in the Physical Environment. Canadian Arctic Contaminants Assessment Report II. Indian and Northern Affairs Canada. pp. 191-201.

Fisk, A.T., K. E. Hobbs and D.C.G. Muir. (Eds). 2003. Contaminant Levels and Trends in the Biological Environment, *Canadian Arctic Contaminants Assessment Report II*. Indian and Northern Affairs Canada. 202 pp.

Guiguer KRR, J.D. Reist, M. Power, J.A. Babaluk. 2002. Using stable isotopes to confirm the trophic ecology of Arctic charr morphotypes from Lake Hazen, Nunavut, Canada. J. Fish Biol. 60, 348–362

Hobson, K.A. and Welch, H.E. 1995. Cannibalism and trophic structure in a high arctic lake: Insights from stable-isotope analysis. *Can J Fish Aquat Sci* 52:1195-1201.

Jensen, J. K. Adare and R. Shearer (eds). 1997. *Canadian Arctic Contaminants Assessment Report*. Ottawa: Indian and Northern Affairs Canada, 460 pp.

Köck, G., Babaluk, J., Berger, B., *et al.* 2004. Fish from sensitive ecosystems as bioindicators of global climate change – "High-Arctic 1997-2003". G. Köck (ed.) ISBN: 3-901249-68-0, Veröffentlichungen der Universität Innsbruck, VUI 245. 114 pp.

Köck, G., Doblander, C., Wieser, W., Berger, B. Bright, D. 2001. Fish from sensitive ecosystems as bioindicators of global climate change: Metal accumulation and stress response in char from small lakes in the high Arctic. Zoology 104, Suppl. IV, 18.

Köck, G.,M. Triendle and R. Hofer. 1996. Season patterns of metal accumulation ) in Arctic char (*Salvelinus alpinus*) from oligotrophic alpine lakes related to temperature. Can. J. Fish. Aquat. Sci. 53: 780 786.

Lockhart, W. L., G.A. Stern, *et al.* 2001. Temporal trends of mercury in arctic beluga whale liver. Poster, 6th International Conference on Mercury as a Global Pollutant, Minamata, Japan.

Lockhart, W.L., P. Wilkinson, B. N. Billeck, R.A. Danell, R.V. Hunt, J. Delaronde and V. St. Louis. 1998. Fluxes of mercury to lake sediments in central and northern Canada inferred from dated lake sediment cores. *Biogeochemistry* 40:163-173.

Losetto, L., Siciliano, S. D. and Lean, D. 2004. Methyl mercury production in high arctic wetlands. *Environ Toxicol Chem.* 23: 17-23.

Lu J. Y., Schroeder W. H., Barrie L.A., *et al.* 2001. Magnification of atmospheric mercury deposition to polar regions in springtime: the link to tropospheric ozone depletion chemistry. Geophys. Res. Let. 28: 3219-3222.

Macdonald, R.W., T. Harner, J. Fyfe, H. Loeng and T. Weingartner. 2003. AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to, within, and from the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii+65 pp.

Muir, D., X. Wang, D. Bright, L. Lockhart and G. Köck. 2004. Spatial and temporal trends of mercury and other metals in landlocked char from lakes in the Canadian Arctic Archipelago. Sci. Total Environ. Submitted.

Muir, D.C.G. and G. Köch. 2003.Temporal trends of persistent organic pollutants and metals in landlocked char. In. *Synopsis of Research Conducted Under the 2001-2003 Northern Contaminants Program*, Indian and Northern Affairs, Ottawa, Canada. pp. 311-317.

Muir, D., Halliwell, D., Jackson, T. and Cheam, V. 2003. Spatial trends in loadings and historical inputs of mercury inferred from Arctic lake sediment cores. In. S. Smith (ed). *Synopsis of research conducted under the 2001-2003 Northern Contaminants Program*, Ottawa: Indian and Northern Affairs Canada, pp. 189-200.

Muir, D.C.G., G. Köch, J. Reist and D. Bright. 2001.Temporal trends of persistent organic pollutants and metals in landlocked char. In:

*Synopsis of Research Conducted Under the 2000/01 Northern Contaminants Program*, S. Kalhok (Ed). Ottawa: Indian and Northern Affairs Canada. pp. 202-207.

Muir, D.C.G., A. Omelchenko, N. P. Grift, D.A. Savoie, W. L. Lockhart, P. Wilkinson, and G. J. Brunskill. 1996. Spatial Trends and Historical Deposition of Polychlorinated Biphenyls in Canadian Mid-latitude and Arctic Lake Sediments. *Environ Sci Technol* 30: 3609-3617.

Muir, D.C.G. and W.L. Lockhart. 1996. Contaminant trends in freshwater and marine fish. In: J.L. Murray and R.G. Shearer (eds.). *Synopsis of research conducted under the 1994/95 Northern Contaminants Program, Environmental Studies Report, No. 73.* Ottawa: Indian and Northern Affairs Canada. pp. 189-194.

Muir, D. and L. Lockhart. 1994. Contaminant trends in freshwater and marine fish. In: *Synopsis of research conducted under the 1993/1994 Northern Contaminants Program. Indian and Northern Affairs Canada*, Environmental Studies Report, No. 72. pp. 264-271.

Outridge P., G.A. Stern, J.B. Percival, P.B. Hamilton and W.L. Lockhart. 2004. Effects of climate-warming and redox-dependant migration on mercury and other geochemical profiles in a varved Arctic lake sediment. Geochim. Cosmochim. Acta In press

Peterson, B.J. and B.Fry 1987. Stable isotopes in ecosystem studies. Ann. Rev. Ecol. Syst. 18:293-320.

Reist, J. D., E. Gyselman, J.A. Babaluk, J.D. Johnson, and R. Wissink. 1995. Evidence for two morphotypes of Arctic char (Salvelinus alpinus (L.)) from Lake Hazen, Ellesmere Island, Northwest Territories, Canada. Nordic J. Freshwater Res. 71, 396–410.

Schroeder W. H., Anlauf, K.G., Barrie L.A., *et al.* 1998. Arctic springtime depletion of mercury. Nature 394: 331-332.

Semkin, R.G. G. Mierle and R. J. Neureuther. 2004. .Hydrochemistry and mercury cycling in a high Arctic watershed. Sci. Total Environ. In press.

St. Louis, V. 2003. Deposition of mercury in snow and glacial runoff of mercury on Ellesmere Island in the high Arctic. In. *Synopsis of Research Conducted Under the 2001-2003 Northern Contaminants Program*, Indian and Northern Affairs, Ottawa, Canada. pp. 208-213.

# Mercury Measurements at Alert


## Project leader(s)

Alexandra Steffen Meteorological Service of Canada (MSC) 4905 Dufferin St, Toronto, ON M3H 5T4; phone: (416) 738-4116; fax: (416) 739-4318; e-mail: alexandra.steffen@ec.gc.ca

## Project members

Alexandra Steffen, Cathy Banic, Hayley HungMeteorological Service of Canada (MSC); Greg Lawson and Bill Strachan, National Water Research Institute, 867 Lakeshore Dr., Burlington, ON



## Abstract

Mercury is a toxic pollutant of great concern to the Arctic environment. Since 1995, atmospheric mercury concentration measurements have been made at Alert, Nunavut. Continuous measurements of gaseous elemental mercury (GEM) have shown a distinct repeatable seasonal/annual pattern. Between 1995 and 2002, there is no statistically significant trend (95% CI) in the annual median of GEM concentration at Alert. However, preliminary results suggest a change over the past 8 years in the amount of Hg returned to the atmosphere in the summertime relative to the springtime. Research continues into understanding the process and impact of atmospheric mercury depletion (MDEs) in the springtime. An international research campaign in Ny -Ålesund, Svalbard was undertaken in the spring of 2003 to address gaps of knowledge about measurement and chemical processes occurring during MDEs.


## Key Project Messages

1. Nine years of atmospheric mercury measurements have been made at Alert, Nunavut since 1995
2. Continued intensive studies of mercury depletion/deposition episodes and their impact on the Arctic environment were undertaken
3. Research into the measurement, formation and the fate of the various reactive mercury species has continued
4. Further insight into the cycling of mercury in the Arctic has been gained but a complete understanding of the cause, effects and implications of the depletion/deposition events are still pending.

## Objectives

The objectives of this project are to establish baseline atmospheric mercury concentrations and to study the behaviour of mercury in the Canadian high Arctic. By collecting information on ambient air concentrations of gaseous elemental mercury (GEM), temporal variability, transport events and long-term 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 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

Mercury is a toxic metal that has been identified as a priority pollutant of concern in the Arctic environment. 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) has a long atmospheric residence time, which allows it to be transported from emission sources to remote regions such as the Arctic. 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. Because of these measurements, significant advances in our knowledge of atmospheric mercury cycling in this environment have been made. 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 and 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 spatial variability and temporal trends of mercury in the Arctic environment 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 2003-2004

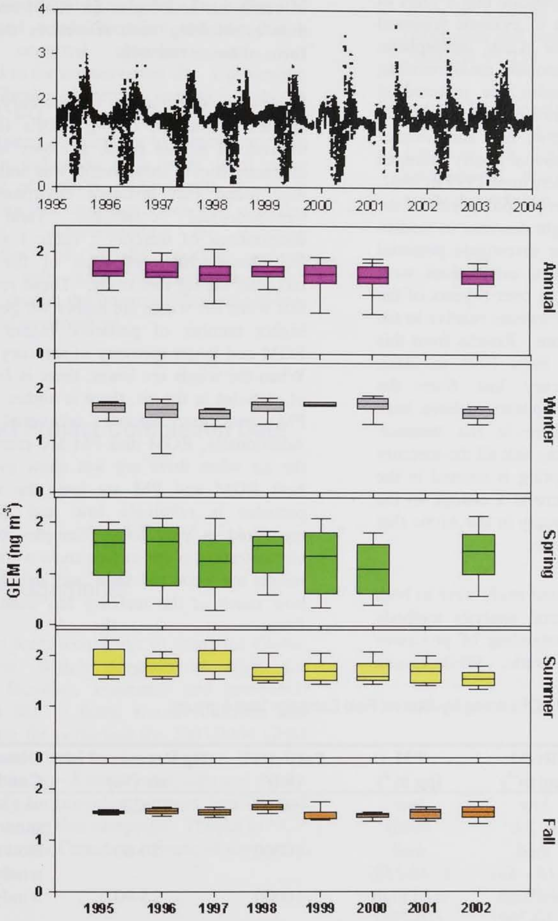
Ground-based atmospheric GEM measurements continued at Alert. Additionally, measurement of mercury species (RGM and PM) continued. During the spring of 2003, an international inter-comparative and processes field campaign was held in Ny- Ålesund, Svalbard where experts in the mercury community from 6 different countries combined knowledge and instrumentation to further understand mercury depletion events in the Arctic.

## Results

Ground-level concentration measurements were continued for GEM in ambient air at Alert. The data to the end of 2003 have been quality assured. There are currently 9 years of GEM concentration data from this site as shown in Figure 1. Recent analysis of the 1995-2002 data set show that there is no statistically significant trend (either increasing or decreasing) in the annual median mercury concentration. Although there is no annual trend there are distinct seasonal trends observed each year at Alert. In addition, it was found that between 1995 and 2002, progressively less mercury lost from the atmosphere in the spring appears to have been returned to the atmosphere in the summer.

Inter-comparative results from the Ny- Ålesund campaign indicate that while GEM measurements compare well, current reactive gaseous mercury (RGM) and particulate-phase (PM) methodologies compared poorly (Temme, personal communication). While we can differentiate between high and low concentrations (fractions) of these mercury species, further investigation into this result is warranted. Four different MDEs occurred during this field campaign. By combining the various data sets collected during this study each of these MDEs could be characterized. The distribution of different species of mercury during MDEs can aid in understanding the impact these events may have on the surrounding environment during varying meteorological conditions.

**Figure 1:** Gaseous elemental mercury (GEM) measurements at Alert from 1995 to 2002. Ongoing measurements of GEM from 1995 to 2003 [ng m-3] (top panel). Box and whisker plots of annual GEM concentrations 1995-2002 (second panel from top); winter GEM concentrations (third panel from top); spring GEM concentrations (forth panel from top); summer GEM concentrations (second panel from bottom) and fall GEM concentrations (bottom panel). The middle line in the box is the median concentration, the boundary of the box closest to zero indicates the 25th percentile and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles.



## Discussion and Conclusions

Overall, no statistically significant trend in the annual median GEM concentration can yet be established from the data from Alert from 1995-2002. These results are consistent with similar measurements undertaken in Svalbard (Berg *et al.*, 2004). These results indicate that 8 years of data is still not sufficient to evaluate temporal trends for mercury in the Arctic atmosphere. Hence, long term continuous measurements, potentially spanning decades, are required in order to evaluate the overall fate of mercury in the Arctic. Figure 1 shows box and whisker plots of the annual and seasonal hourly averaged GEM concentrations at Alert from 1995 to 2002. From this plot, the summer period appears as the only season to show a slight decrease in median concentration. To further investigate potential trends of mercury at Alert, calculations were made to assess any changes over 8 years of the high summer GEM concentrations relative to the low GEM in the springtime. Results from this calculation indicate that from 1995 to 2002, progressively less mercury lost from the atmosphere in the spring appears to have been returned to the atmosphere in the summer. While we are not suggesting that all the mercury that is deposited in the spring is emitted in the summer, we note that there is a change in the seasonal behaviour of mercury in the Arctic that warrants further investigation.

The goals of the Ny-Ålesund study were to both inter-compare sampling and analysis methods and to further our understanding of processes relating to MDEs in the Arctic. While results found that GEM measurements compared well, the RGM and PM measurements compared poorly. Currently, there is considerable research being undertaken on the speciation of mercury in the atmosphere and these results demonstrate that we should be prudent in reporting and interpreting this speciation data. At present, there is no standard reference material available to verify methodologies for RGM and PM and thus establishing such references should be a focus of future research.

Since the distribution of mercury, between species in the air, during MDEs is not well understood at this point, a closer look at the characteristics of these events was undertaken. It was found that different environmental and meteorological conditions yield varying distributions of mercury. Table 1 summarises the characteristics of each of the 4 events recorded during this study. These results show that when the winds are higher we generally see higher number of particles, higher PM than RGM and larger recovery of mercury in the air. When the winds are lower, there is less number of particles in the air, there is higher RGM than PM and the amount recovered is less. Additionally, RGM and PM are removed from the air when there are wet snow events since both RGM and PM are low, the number of particles is relatively low and the percent recovered is very low. Samples of mercury concentration in the surface snow were collected; results are expected soon and will help assess how much of the mercury has been deposited from the air.

**Table 1:** General Summary of MDEs during Ny-Ålesund Field Campaign from 4 groups.

| Event | Winds | RGM ($pg\ m^{-3}$) | PM ($pg\ m^{-3}$) | Particles* (#/l) | Hg Recovered in air (%) | Observed Conditions |
|---|---|---|---|---|---|---|
| **1** | med. | low *(<20)* | low *(<40)* | ~6000 | <20 | wet blowing snow |
| **2a** | high | med *(<10 – 80)* | med *(<10-150)* | ~10000 | 50-60 | blowing snow, windy |
| **2b** | high | med/high *(<10-200)* | med/high *(10-225)* | ~10000 | 25-90 | windy |
| **3** | low | med/high *(<20-300)* | med *(<20-80)* | ~5000 | 10-40 | sunny, low winds |
| **4** | low | high *(<10-225)* | low *(<50)* | ~6000 | 20-50 | |

Averaged particle count - only 0.3-0.5□m are reported

This characterization of events demonstrates that the distribution of mercury differs during various meteorological situations. Current speculation is that RGM produced during a MDE can easily associate to particles if they are present in the air. If the concentration of PM measures higher during a depletion event relative to RGM, this may indicate that the RGM produced during a MDE has associated to particles. The higher PM and elevated winds therefore indicate that a depletion occurred elsewhere and was transported to the measurement site. Conversely, if the distribution of mercury species is higher in RGM than PM, the oxidized mercury has had less opportunity to associate to particles and can thus be an indication of a more local event (Steffen *et al.*, 2003). The results shown in Table 1 from this campaign agree well with this speculation. Understanding the differing characteristics of MDEs during various conditions will help to understand and potentially predict the impact of depletion events to the Arctic environment.

## Expected Project Completion Date

ongoing

## Acknowledgements

The project team would like to thank the Global Atmospheric Watch program at Alert for supplying facilities, assistance and personnel. We would like to thank Kevin Anderson and Tim Christie for collecting the 2003/2004 GEM data at Alert. Many thanks to Torunn Berg for organising the Ny- Ålesund campaign and thanks to CNR-Italy for providing support, housing and assistance during this campaign. Thanks to NCP and Environment Canada for financial support of this program.

## References

Lu, JY, Schroeder, WH, Barrie, LA, Steffen, A, Welch, HE, Martin, K, Lockhart, WL, Hunt, RV, Boila, G, and Richter, A. Magnification of atmospheric mercury deposition to polar regions in springtime: the link to tropospheric ozone depletion chemistry, *Geophys. Res. Lett.* 2001; 28:3219-3222.

Macdonald RW, Barrie LA, Bidleman TF, Diamond ML, Gregor DJ, Semkin RG, *et al.*, Contaminants in the Canadian Arctic: 5 years of progress in understanding sources occurrence and pathways. Sci. Total Environ. 2000;254:93-234.

Schroeder, W.H., Steffen, A., Scott, K., Bender, T., Prestbo, E., Ebinghaus, R., Lu, J.Y. and Lindberg, S.E. 2003, Summary report: first international Arctic atmospheric mercury research workshop, *Atmos. Environ.*, 37(18).

# Persistent Metabolites of Polychlorinated Biphenyls (PCBs) and Polybrominated Diphenyl Ethers (PBDEs) In Marine Mammals from the Canadian Arctic


## Project leader(s)

Gregg Tomy, Department of Fisheries and Oceans (DFO), Winnipeg MB; phone: (204) 983-5167; fax: 204-984-2403; e-mail: tomyg@dfo-mpo.gc.ca; Robert Letcher, Great Lakes Institute for Environmental Research (GLIER), University of Windsor, Windsor ON N9B 3P4; phone: (519) 253-3000 (ext. 3753); fax: (519) 871-3616; e-mail: letcher@uwindsor.ca)

## Project members

Eric Braekevelt (DFO), Gary Stern (DFO), Thor Halldorson (DFO), Ole Nielsen (DFO)



## Abstract

Detecting and demonstrating bioaccumulation of current use or "new" chemicals in the Arctic environment is critical in the context of restricting such compounds under global agreements such as the Persistent Organic Pollutants protocol of the Convention on Long Range Transboundary Air Pollution and the Stockholm Convention on POPs. For this reason, and because of concerns about exposure of Arctic peoples to these chemicals through traditional diets, polybrominated diphenyl ethers (PBDEs) were studied in the livers of marine mammals from the Canadian Arctic. The highest levels of PBDEs were found in beluga 5.7 ng/g (sum of BDE-47, 99, 100, 153 and 154; lipid basis) from Baffin Island. PBDE levels in ringed seal from Baffin Island were 1.2 ng/g (sum of 47, 99, 100, 153; lipid basis. PBDEs were below detection limits in walrus (Foxe Basin) and narwhal (Baffin Island). No metabolites of PBDEs or PCBs were detecting in any of the mammals. This is perhaps due, in part, to the low levels of the parent compound in the animals.


## Key Project Messages

1. PBDEs were highest in beluga liver from south eastern Baffin Island;
2. Levels of ΣPBDEs (sum of at least 4 congeners) ranged from non detect in walrus (Foxe Basin) and Narwhal (Baffin Island) to low ng/g levels (lipid basis) in beluga and ringed seal (Baffin Island);
3. Metabolites of PBDE and PCBs were below detection limits in all animals.

## Objectives

1. Investigate levels of metabolites of PCBs and PBDEs in marine mammals from the eastern Arctic;
2. To estimate biotransformation rates from concentrations of parent chemicals and their identified metabolites.

## Introduction

Polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are industrial products that have become ubiquitous in the environment. PCBs were used primarily as dielectrics, but their manufacture has been banned since the early 1970s, and environmental concentrations are decreasing (Huestis *et al.* 1996). However, PBDEs continue to be used as flame retardants in a variety of consumer products, and concentrations in the environment, including humans and their food, are increasing (Luross *et al.* 2000; Norén & Meironyté 2000).

Elimination of halogenated organic contaminants from the body requires their conversion to more polar compounds. Phase I biotransformation occurs via the cytochrome P450 monooxygenases, and usually involves the addition of a hydroxyl (OH) group to the xenobiotic molecule. Further biotransformation by more sophisticated pathways (phase II reactions) can produce methyl sulfonyl ($SO_2CH_3$) substituted metabolites (Letcher *et al.* 2000). Methylated ($OCH_3$) metabolites may be formed in a two-step process: hydroxylation of the xenobiotic by phase I reactions followed by methylation by microorganisms in the intestine (Haglund *et al.* 1997).

Despite the addition of polar functional groups, some metabolites remain sufficiently hydrophobic to persist in tissues. Metabolite half-lives vary with chlorine number and position as well as the position of the polar functional group (Kannan *et al.* 1995).

Although PCBs and PBDEs are generally believed to influence endocrine systems indirectly through induction of enzyme systems, their metabolites interact directly with endocrine systems, and may exhibit higher toxicity than the parent chemicals themselves. The mechanism of action for some metabolites is not well known: they may bind to proteins (Klasson-Wehler *et al.* 1998), which prevents natural compounds that perform important signaling duties in the body from doing so. The accumulation of these protein-bound chemicals can disrupt normal organ functions. Hydroxylated metabolites structurally resemble the thyroid hormones T3 and T4 and have high affinity for transthyretin (TTR), a transport protein. They may therefore disrupt the thyroid transport system of exposed organisms (Brouwer & van den Berg 1986; Meerts *et al.* 1998; Marsh *et al.* 1998). Relationships between OH-PCBs and some indices of thyroid status have been found in polar bears (Sandau 2001). There is also some speculation that hydroxylated metabolites of PCBs decrease plasma retinol (vitamin A) levels (Brouwer *et al.* 1986). Vitamin A is an essential nutrient that plays a key role in embryo development and is a good indicator of exposure to xenobiotics.

The formation of OH-PBDEs has been demonstrated in rat liver (Meerts *et al.* 1998; Örn & Klasson-Wehler 1998), but little is known about the ability of different marine mammal species to biotransform PCBs and PBDEs and to eliminate metabolites. A variety of halogenated metabolites have been found in fish (Asplund *et al.* 1999), birds (Klasson-Wehler *et al.* 1998), marine mammals (Letcher *et al.* 2000; Sandau *et al.* 2000b) and humans (Klasson-Wehler *et al.* 1997; Sandau *et al.* 2000a). In the Canadian Arctic, $CH_3SO_2$-PCB have been identified in only a few marine mammals and terrestrial animals. $\Sigma CH_3SO_2$-PCB concentrations (µg/g, lipid weight) in ringed seals blubber ($n=11$) ranged from 0.007 to 0.02; in polar bear liver ($n=18$) and fat ($n>20$) concentrations ranged from 1.2 to 4.0 and 0.1 to 0.8, respectively (Letcher *et al.* 2000). Mean concentrations in male beluga blubber from the western Hudson Bay ranged from 121 to 185 ng/g (lipid weight).

There have been no reports of methoxylated PCBs or PBDEs in marine mammals from the Canadian Arctic. This study will be the first comprehensive investigation of a variety of metabolites in several marine mammal species in the Canadian Arctic. The increase in the number of available standards allows metabolites that were previously only detected to be identified and quantitatively determined. Examining relative concentrations of parent chemicals and metabolites will allow an assessment of metabolic capacity and identify areas of concern.

## Activities

### In 2003-2004

Archived liver samples from marine mammals were be analyzed for PCBs and PBDEs and their persistent metabolites (OH-, $OCH_3$- PCBs and PBDEs) in marine mammals from the Canadian Arctic. The animals analyzed include: beluga ($n=4$, Baffin Island), ringed seal ($n=3$, Baffin island), narwhal ($n=3$, Baffin island) and walrus ($n=2$, Foxe basin). Mammal samples were obtained through Fisheries and Oceans collection programs and sponsored by the NWMB.

## Results and Discussion

*PBDEs.* Total (Σ) PBDEs, reported here as the sum of 4 or more congeners, ranged from non detect (walrus and narwhal) to low ng/g levels [5.7 ng/g (sum of BDE-47, 99, 100, 153 and 154) lipid basis] in beluga. ΣPBDEs were also low in ringed seal liver [1.2 ng/g (sum of 47, 99, 100, 153) lipid basis] from Baffin Island.

*Metabolites.* Belugas, which contained the highest levels of PBDEs, were first screened for PBDEs metabolites. Non detectable levels of OH-PBDEs were found in these animals. No further attempts were made to quantify levels in the other animals. Similar observations were made for PCB ($OCH_3$) metabolites: non detectable levels were present in beluga.

When present, ΣPBDE levels in animals from the Canadian Arctic were in the low ng/g range. Considering the low levels of the parent compound in the animals (both PBDEs and PCBs), it is not surprising that their metabolites were undetected. Because of these results, no information could be gleaned on biotranformation rates in the animals.

The non-detect of the PBDE and PCB metabolites in the animals should be viewed with some caution. First, the recovery of our internal standards used for recovery correction (4'-OH-BDE-17 and 4'-OH-CB-72) were consistently low (<30%). Second, our method for PBDE metabolite analysis was limited to 15 congeners (MeO-BDEs) as this was all that was commercially available. Further work is warranted to address the current limitations in the analytical method for the analysis of polar PBDE metabolites.

## References

Asplund, L., M. Athanasiadou, A. Sjödin, Å. Bergman and H. Börjeson. 1999. Organohalogen substances in muscle, egg and blood from healthy Baltic salmon (*Salmo salar*) and Baltic salmon that produced offspring with the M74 syndrome. *Ambio* 28: 67-76.

Bergman, Å., E. Klasson-Wehler, H. Kuroki and A. Nilsson. 1995. Synthesis and mass spectrometry of some methoxylated PCB. *Chemosphere* 30: 1921-1938.

Brouwer, A. and K.J. van den Berg. 1986. Binding of a metabolite of 3,4,3',4'-tetrachlorobiphenyl to transthyretin reduces serum vitamin A transport by inhibiting the formation of the protein complex carrying both retinol and thyroxin. *Toxicol. Appl. Pharmacol.* 85: 301-312.

Haglund, P.S., D.R. Zook, H.-R. Buser and J. Hu. 1997. Identification and quantification of polybrominated diphenyl ethers and methoxy-polybrominated diphenyl ethers in Baltic biota. *Environ. Sci. Technol.* 31: 3281-3287.

Huestis, S.Y., M.R. Servos, D.M. Whittle and D.G. Dixon. 1996. Temporal and age-related trends in levels of polychlorinated biphenyl congeners and organochlorine contaminants in Lake Ontario lake trout (*Salvelinus namaycush*). *J. Great Lakes Res.* 22: 310-330.

Kannan, N., T.B.H. Reusch, D.E. Schulz-Bull, G. Petrick and J.C. Duinker. 1995. Chlorobiphenyls: model compounds for metabolism in food chain organisms and their potential use as ecotoxicological stress indicators by application of the metabolic slope concept. *Environ. Sci. Technol.* 29: 1851-1859.

# *Education and Communications*

# Communicating Appropriate CACAR II Information to the Inuvialuit Settlement Region


## Project leader(s)

Barbara Armstrong, Regional Health and Environment Coordinator, Box 1887, Inuvik NT X0E 0T0; phone: (867) 777-2072; fax: (867) 777-2135; e-mail: recycle@nt.sympatico.ca

## Project members

Nellie Cournoyea, Chair and Chief Executive Officer, Inuvialuit Regional Corporation, Inuvik NT; Eric Loring, Inuit Tapiriit Kanatami, Ottawa ON; Government of the Northwest Territories Health and Social Services, Northern Contaminants Program Secretariat Ottawa ON; Northwest Territories Environmental Contaminants Committee, Inuvik NT; Chairs: Aklavik, Holman, Inuvik, Paulatuk, Sachs Harbour and Tuktoyaktuk Community Corporations; Presidents: Aklavik, Holman, Inuvik, Paulatuk, Sachs Harbour and Tuktoyaktuk Hunters and Trappers Committees


## Abstract


The Inuvialuit Settlement Region (ISR) is concerned about the new information from the Canadian Arctic Contaminants Assessment Report II (CACAR II) report. Much of this information is good news for the people living in the ISR because it shows that levels of certain Persistent Organic Pollutants (POPs) and Heavy Metals are below some of the Health Canada guidelines. However, the report also shows some potentially disturbing results, especially concerning the people who eat a lot of marine mammals. In the ISR most communities are dependent on marine mammals as a nutritious source of food and require the information coming from CACAR II to make informed and educated decisions. In order for the ISR to be informed about wise food choices we needed to be coordinating our efforts between Northern Contaminants Program (NCP) researchers, Inuit Tapiriit Kanatami (ITK), the Northwest Territories Environmental Contaminants Committee (NWTECC) our communities. This years past proposal enabled the ISR to participate in a Pan Inuit Survey and to continue the communication, research and liaison activities necessary to effectively communicate information on contaminants in the food chain and the environment. This information was used to enable Inuit in the ISR to make informed decisions in regards to their diet. Through this network, stronger communication links among communities, schools, the NCP, and industry have been built. The Regional Coordinator organized the Inuvialuit Community Tour in January 2004, which visited all ISR communities offering successful and informative classroom presentations and community open houses/ workshops. In general, all communities had questions about contaminants in their food chain in our and other regions, global warming, climate change and the oil and gas industry/development. Apprehension, mistrust and alarm over contaminants information among community members have been somewhat mitigated, because someone from their region explained the NCP role and long-range contaminant issues in a plain language format.


## Key Project Messages

1. Participation with the initial Inuit Population Survey was very successful and the IRC looks forward to further participation as this study moves forward with the analysis and dissemination of these results.
2. Communities within the ISR have a broad range of concerns related to contaminants and their effects on wildlife and human health in the ISR. It is important that there be an ongoing, coordinated exchange of information and research results among

researchers, project managers and community members.

3. School curriculums have been requested from all our community educators as well as undated and organized nutritional food fact sheets and public information that relates to the consumption and benefits and safety of consuming our traditional diets.

## Objectives

1. Achieve an appropriate level of understanding among the Inuvialuit about the presence of contaminants within the ISR, how they enter the food chain and their effects on wildlife and the health of the Inuvialuit population.
2. Understand the questions and concerns Inuvialuit have in relation to contaminant issues within the ISR and beyond.
3. Facilitate interactions within and among Inuvialuit communities with regard to contaminant issues and, in turn, to facilitate interactions among communities, the NCP and research program managers.
4. Build capacity and partnership at the community level to effectively communicate community concerns and priorities, with regard to contaminants, to decision-making bodies at regional, national and international levels.

## Introduction

There is a history in Inuvialuit communities of miscommunication regarding contaminant issues, and such instances have led to unnecessary alarm, apprehension and mistrust. Language and cultural barriers have been major obstacles to effective communication. Promising communications strategies have now been developed at the community level and there has been increased communication at the regional and inter-regional levels.

Inuvialuit who consume large amounts of traditional/country foods are continually requesting information on the levels of contaminants present in their area and their potential impact on people and the environment. Many of these requests have led to workshops dedicated to contaminants information, which are able to summarize and communicate information from past and present contaminants-related research, such as the Centre for Indigenous Peoples' Nutrition and Environment (CINE) dietary benefits/risks study (Kuhnlein et al. 2000), the Inuvik Regional Human Contaminants Monitoring Program (Tofflemire 2000) and the status of contaminants in fish and marine mammals in the ISR (Macdonald 2000).

## Activities

## In 2003-2004

Barbara Armstrong filled the Regional Health and Environmental Coordinators position for the past two years. Activities included:

- Ongoing communications took place in all ISR communities through memos and quarterly reports, IRC Board presentations and submissions.
- Public meetings on contaminants with community corporations, hunters and trappers committees, and local schools were held during an all-community tour, which took place in January 2004.
- A series of Contaminates and Healthy Country Food Posters were distributed to all ISR communities;
- Working relationships were established with research institutions, government departments/agencies, and Inuvialuit co-management boards.
- Participation at regional and national workshops, and monthly Northwest Territories Environmental Contaminants Committee meetings.
- Ongoing consolations with Roger Connelly-IRC, Robin Fonger-IGC, DIAND Yellowknife-NWTECC, Eric Loring-ITK,

Simon Smith-NCP

- Recommendations and consultations to produce the 2003 Historical Land Use Mapping Project
- Prepared and revised several NCP proposals, budgets and work plans for 2003 Projects
- Several teleconference calls and pre survey tasks relating to the- Inuit Population Survey- Dr. Furgal and staff. Completed Survey in our region
- Worked on CACAR II communications, fact sheets
- Attended 'Risk Management Meeting in Iqaluit'
- Training for Annie Goose to be the Community Health Liaison
- Attended meetings in Iqaluit with Annie Goose
- Prepared IRC Board updates and the future workplan
- Completed mid-term, year end NCP reports and created 2004-2005 proposal for funding.
- Attended and gave a presentation regarding successful projects and capacity building to NEI (Northern Ecosystems Initiates), Environment Canada
- Completed second year of "Frontline Training Program' with the NWTECC.
- Consultations regarding the 2005 Blood Monitoring project-potential NCP project
- Completed the Health and Your Environment-Community Tour- January $19^{th}$-$28^{th}$ –04
- Continued giving High School classroom presentations after the tour
- Created a post-tour poster, several Country Food promotional items and distributed them to all communities in the ISR during and after the community tour
- Accompanied researches in region while presenting all research activates relating to long-range contaminants issues at the community level.

## Results and Discussion

The Regional Coordinator has been acting as a conduit for a two-way information exchange between communities and the NCP, and has brought contaminants issues to the attention of various individuals and agencies. Inuvialuit have been informed that contaminants are present in traditional/country foods but at low levels, and thus monitoring should continue but that the benefits of consuming their country foods outweigh the risks. A specific priority remains and should continue to be monitored regarding heavy metals (methylmercury) in marine mammals.

Inuvialuit communities expressed health-related comments and concerns during the Inuvialuit Community Tour. A variety of CBC and Newspaper interviews were given. In general, all communities had questions about contaminants that generally stayed focused on NCP related activities, which expressed the needed progress to educate our community members on NCP related information. Specific concerns of the communities are listed below.

**Health and Environment Community Tour**

From January $18^{th}$ to $27^{th}$, we had our ISR Community Tour, offering information on Health Monitoring Studies, the benefits of Country Foods and the NCP results from CACAR II (a summary of the past 5 years of research). We hosted open community meetings in the evenings, offering a plain language presentation of the CACAR II results, and gave presentations to the community schools during the day. The presentations remained informative, upbeat and not overly scientific, with a focus on the importance of healthy lifestyle choices that incorporated healthy country foods.

### School Visits/Presentations and Open House Worships

#### School Visits

Barbara Armstrong made the arrangements and then accompanied Simon Smith on a 20- 30 minute Power Point Presentations in each of the community schools. Annie Goose often attending the presentations, as well. These school visits were very successful and the students asked very good questions. Country Food, Contaminants and Health Canada Posters were put up during the presentations and selections of each were left for the schools and classrooms. Everyone was invited to attend the early evening workshops with their friends and families.

#### Open House/Workshops

All events started at 5 o'clock with a feast of Country Foods. Stew (Caribou or Muskox or both) and Bannock and or Eskimo Donuts, Quak (Arctic Char), Muktuk, Whitefish, Dry Caribou Meat, Fresh fruits, berries and vegetables were served. Coffee, tea and fruit juices were also provided, as well as a selection of dessert cups and cookies. Many adults and various children attended the meal and presentation while some people left after eating and taking home handouts and giveaways.

Each open house offered a table with give away and information handouts and had a variety of Health, Contaminant and Country Food Posters on the walls. The Joint Secretariat donated a few pens, organizer calendars and key chains for each community. ITK donated posters and fridge magnets with the Healthy Safe and Strong Country Food Message. The NWTECC sent Food and Species Fact Sheet sets and holders, Newsletters and CACAR II inserts. NCP offered Highlight books and summaries, pamphlets and summary booklets. Dene Nation sent posters from a previous poster contest.

When people were just about finished eating, we began the presentations and a community blessing. An elder from each community was asked to say a prayer either before dinner or before the presentation or Annie Goose volunteered this in both languages.

Annie Goose and Barbara Armstrong started the event with introductions and welcomes to the communities. Simon Smith presented first on the NCP, results from CACAR II and Country Food Messages. Erica Myles then offered her presentation on the past and potential future Blood Monitoring projects. The presentations evolved during the tour, making changes when needed and also to incorporate pictures from the previous community open houses. Simon Smith also created a slide show during the tour that played during the meal that had a very nice collection of pictures of people and activities from across the North. When required, Annie Goose offered translations and offered additional positive country food messages, in both languages. People asked questions during the presentations and then again after each presenter was finished.

Questions that were often repeated were:

- If you can't see or smell or taste contaminants, how do you really know about them?
- What effect did Chernobyl and Russian nuclear subs have on contaminants in Canada?
- What about contaminants and health warnings in other regions in the Arctic?
- Are foods from the south also contaminated?
- Can our people get sick from eating sick animals?
- What is going to happen to our Polar Bears?
- Will trimming fat away from our Marine Mammals really protect us from Contaminants?
- Do contaminants kill animals, and what effects do they have on them?
- What are the levels in Greenland? How does

Canada rate internationally with contaminants?

- Is international action working to reduce contaminants?

- Do we test men as well as women for contaminants levels, or older people as well as young mothers?

The event finished off with a Thank-you from Barbara Armstrong for attending and then door prises were offered. Everyone was offered a ceramic mug and cloth bags with the Country Food ('still healthy safe and strong' message), while supplies lasted. The tour also gave away a variety of Northern Food gift certificates, candles, boxes and or tins of chocolates, popcorn gift boxes, coffee and recycle bins and bags. Quak was always offered to the Elders to take home. A gift was left for our hosts and a set of posters put up at each accommodation that we stayed at.

## Conclusions

The important role of the Regional Coordinator in the ISR is to bridge the gap between community members and NCP scientists and management and all types of research activities relating to long-range contaminants in our region that has been successful in the past and needs to continue into the future. Over the years, we have also learned that many community concerns focus on local sources of contamination, but this does not fall within the NCP mandate. To build trust and respect, it is important to be able to address more of these non-specific NCP concerns. Moreover, it is felt that in order to communicate NCP information, we must also be aware of the big environmental picture in his region, in particular, knowing who is responsible for specific local issues of a variety of contaminant issues, including water or waste management problems and what is and or can being done about them. Therefore, in order to be effective, the Regional Coordinator must be aware of and work towards solutions that address issues both within and outside the NCP mandate. The Regional Coordinator and all the project partners urge the NCP to continue to keep up their monitoring efforts, especially for marine mammals and our wildlife species which are at risk or long range contaminant issues for both the species themselves as well as for all our community members who depend on the consumption of their country foods as an important self sustaining way of life.

## Expected Completion Date

The 2003-2004 projects have been completed.

## References

Kuhnlein, H.V., O. Receveur, H.M. Chan and E. Loring. 2000. Assessment of Dietary Benefit:Risk in Inuit Communities. Ste-Anne-de-Bellevue QC: Centre for Indigenous Peoples' Nutrition and Environment. ISBN# 0-7717-0558-1.

Tofflemire, K. 2000. Inuvik Regional Human Contaminants Monitoring Program: Regional Report. Inuvik Regional Health and Social Services Board. 38 pp.

Macdonald, C.R. 2000. The Status of Contaminants in Fish and Marine Mammals in the Inuvialuit Settlement Region. Prepared for The Fisheries Joint Management Committee, Inuvik, NWT. 52 pp.

# Risk Management Communications in Nunavut


## Project leader(s)

Amy Caughey Health Promotion Specialist, Nutrition Government of Nunavut PO Box 1000, Stn 1000 Iqaluit, NU X0A 0H0; phone: (867) 975-5729; fax: (867) 975-5705; e-mail: acaughey@gov.nu.ca

## Project members

Janet Bewster GN H&SS Iqaluit; Ainiak Korgak GN H&SS Iqaluit; Geraldine Osborne GN H&SS Iqaluit; Jim Talbot GN H&SS Iqaluit; Pitsiula Kilabuk GN H&SS Pangnirtung; Leanne Webb GN H&SS Pangnirtung; Rhonda Reid GN H&SS Cambridge Bay; Bob Phillips GN H&SS Cambridge Bay; Obed Anoee GN H&SS Arviat; Wendy Dolan GN H&SS Rankin Inlet; Laurie Chan CINE Montreal; Jamal Shirley NRI Iqaluit; Stephan Lopatka NTI Cambridge Bay; Neida Gonzalas NTI Iqaluit; BJ Barnes NTI Iqaluit; Eric Loring ITK Ottawa; Sylvia Cloutier INAC Iqaluit; Glen Stephens INAC Iqaluit; Mary Potyrala INAC Iqaluit



## Abstract

In response to Canadian Arctic Contaminants Assessment Report (CACAR) II, the Nunavut Environmental Contaminants Committee evolved to form the Niqiit Avatittinni Committee (NAC) to reflect the need to focus on human health related concerns in Inuit communities. The NAC set out to consider the research presented in CACAR II, and to "translate" this information into usable public health information and dietary recommendations for Nunavummiut. Following discussions with researchers, community members, and health care professionals, a public health message was created entitled "Country food: Nutrition & Safety". This message was shared throughout H&SS, as well as shared with communities during the Niqiit Avatittinni Tours, January to March 2004. As well as the public health message, significant community nutrition education was undertaken during the tours to put the contaminant information into an appropriate context, as well as facilitate understanding of the public health message.


## Key Project Messages

1. In relation to the Nunavut public health message, the key messages were:
   a. The benefits of country food for Nunavummiut out-weight the risks of contaminants. Country food provides excellent nutrition for energy and growth of children and adults.
   b. NAC and H&SS agree that, considering the best knowledge available, contaminants are not presently a concern for people of Nunavut, with one exception. Special care should be taken to protect our unborn children because these children are our future.
   c. To give unborn children the best future, mothers in Nunavut should stop smoking and drinking during pregnancy, and ensure their diet consists of a variety of nutritious foods. We recommend pregnant women should chose more country foods known to be high in nutrition and lower in contaminants, like caribou, char, seal meat & muskox. We recommend pregnant women choose less of those foods higher in contaminants, including fat from seal, whale and polar bear, and seal liver.
   d. Mother of newborns need to know that breastfeeding is the best choice for their babies, no matter what they eat. Breast milk is the safest, cleanest, most nutritious and healthiest choice for newborn children.
2. Following the communication of the community tour, the key messages were:
   a. There is evidence from the community tours and communications exercises that there remains uncertainty with the contaminant message. Efforts are needed to work

towards clarifying confusion that exists between "good" and "bad" fats, and the benefits and protective effects of country food.

b. Nunavummiut also want to know what the risks are to themselves from contaminants.

## Objectives

1. Acquire and maintain expertise for Nunavut to develop public health messages and communications strategies.

2. Evaluate CACAR II health & diet related results, in particular the Nunavik Cohort Study.

3. Provide Nunavummiut specific information about CACAR II diet & health related information in Nunavut.

## Introduction

In response to CACAR II, the Nunavut Environmental Contaminants Committee evolved to form the Niqiit Avatittinni Committee (NAC) to reflect the need to focus on human health related concerns in Inuit communities. The NAC set out to consider the research presented in CACAR II, and to "translate" this information into usable public health information and dietary recommendations for Nunavummiut.

To begin, the NAC invited researchers and committee member to attend a meeting October 2003 to discuss the CACAR II findings, discuss Nunavik Cohort Study results, and develop a plan to communicate the information to Nunavummiut. Following discussions with researchers, community members, and health care professionals, a public health message was created entitled "Country food: Nutrition & Safety".

Giving people in Nunavut this message in an appropriate context was essential, and was the desire of the NAC. This message was shared throughout H&SS, as well as shared with communities during the Niqiit Avatittinni Tours, January to March 2004. On top of the public health message, significant community nutrition education was undertaken during the tours to put the contaminant information into an appropriate context, as well as facilitate understanding of the public health message. Meetings with health center staff, CHRs and community health workers were also carried out before, during and after the community tours.

## Activities

### In 2003-2004

- Face-to-face NAC committee meeting October 2003, which included all project members
- Gina Muckle presented to committee the Nunavik Cohort Study
- Contracted Mary Potyrala for support and guided public health message development
- Developed public health message, "Country Food: Nutrition & Safety", including approximately 10 meetings of committee
- Participated in development and implementation in NAC lead Niqiit Avatittinni Tour, January to March 2004 to share information with Nunavummiut
- Disseminated the public health message throughout Nunavut to health professionals

## Results

- Overall, the presentation of the public health message highlighted the need to continue to evolve the communication of health and contaminant messages. In general, many people lacked the basic principles needed in order to understand health and contaminant messaging.
- It was observed throughout the communication of the results, and through the questions posed during the evaluation, that the majority of confusion and questions

centered on human health, nutrition and the effects of contaminants to the body.

- It was observed that people were not clear on the differences between environment contaminants found in their food and contaminated sites, such as DEW line sites, and how each of these impacts their health.
- Communication exercises are necessary to clarify confusion that exists between "good" and "bad" fats, and the benefits and protective effects of country food.
- Confusion exists around the specific recommendations around contaminants and prenatal health and breastfeeding.

## Discussion and Conclusions

Based on the above results, an obvious direction for further communication strategies has been established. It is necessary to work immediately to:

1) Clarify the confusion that exists, especially around specific recommendations for prenatal women

2) Clarify the confusion around breastfeeding, including education regarding the benefits and safety of breastfeeding for both mothers and babies

3) Focus on communication that puts the contaminant message into a context that allows Nunavummiut to make informed choices about country food, including education and messaging around the benefits of eating country foods, and clarification around the differences in country foods and store foods (i.e. clarify the 'good' fats, 'bad' fats situation)

## Expected Completion Date

This communication project is scheduled to continue through communications activities within GN H&SS, as well as within the context of the NCP. This work is ongoing.

## Acknowledgements

Thanks to the dedicated team work of the Niqiit Avatittinni Committee for tireless work in Nunavut. Also, thanks to Hamlets, CHRs and communities in Nunavut for their support.

## References

Potyrala, M. *Post tour summary report: Niqiit Avatittinni Tour, January 12-March 26, 2004.* Prepared for Niqiit Avatittinni Committee.

GN H&SS, *Public Health Message, Country Food: Nutrition & Safety*, January 2004

# Council of Yukon First Nations NCP Survey


## Project leader(s)

Cindy Dickson Council of Yukon First Nation (CYFN)

## Project members

Yukon First Nations; Yukon Contaminants Committee; Chris Furgal



## Abstract

Since the inception of the Northern Contaminants Program there have been numerous workshops and studies in the Yukon on environmental contaminants. People began asking questions about contaminants and their health effects. A Yukon-wide dietary study was conducted which included an analysis of the risks and benefits of traditional foods. While the results of this study showed that the benefits of consuming traditional foods far outweigh the risks, there continued to be concerns expressed. We continue to communicate the benefits of traditional food in the Yukon and to continue to support NCP research that show that our foods are safe to eat.

In order to better understand what people are hearing and retaining through our efforts to communicate, we organized an in-depth survey of Yukon communities. We want to know if the messages "Our Traditional Foods Are Safe to Eat" are getting out, and that the training and workshops that we have conducted over the years have been beneficial. It is important that as we enter NCP Phase III we have a clear understanding of what the communities are saying and what they know about the Northern Contaminants Program.


## Key Project Messages

1. What is known about the Northern Contaminants Program?
2. What does contaminants mean to a Yukon community member?
3. Are there any concerns about contaminants in Yukon communities

## Objectives

- To better understand Yukon community knowledge of the Northern Contaminants Program in order to plan for NCP phase III

- To enhance the confidence of Yukon First Nations (YFN) in making informed decisions about traditional food consumption and other health-related factors.

## Introduction

For several years, there has been substantial information on contaminants and related issues disseminated to the Yukon communities, and the First Nations peoples through workshops, conferences and training. Communications and education continues to be the top priority as questions and related concerns continue to surface. Also within the past 10 years the YFN peoples have witnessed an increase in cancer and other chronic diseases. This has created concerns that needed to be addressed. Many were wondering if the increase in cancer incidence were related to contaminants of a local or long range nature. In an attempt address these and other related concerns, a Yukon wide dietary study was conducted which included an analysis of the risks and benefits of traditional foods. While the results of this study showed that the benefits of consuming traditional foods far outweigh the risks, there continued to be concerns.

In the Yukon, long-range contaminant sources are low and traditional foods such as caribou and moose are safe to eat. Our communication efforts include workshops, radio shows, posters, presentations, poster contests, curriculum development and front-line training courses. As we enter NCP Phase III, a survey of Yukon communities on the NCP has been conducted to enhance and help shape Yukon priorities.

## Activities

### In 2003-2004

Surveyed 173 students and 5 teachers in 4 schools throughout the Yukon.

## Results

The reports received indicated that most communities are interested in hosting community based workshops on contaminants and other related issues. People involved in the NCP survey want answers and most participants want something to be done about the questions that were brought forward.

The surveys still need to be analyzed.

## Discussion and Conclusion

The survey was well received in the communities. Over 300 people responded. Most wanted community based workshops.

## Expected Completion Date

March 2005

## Acknowledgements

Yukon First Nations community members

# Nunavik Nutrition and Health Committee Communications Program: Follow-up Communications and Evaluation activities of the Nunavik Infant Cohort Study Results.


## Project leader(s)

Chris Furgal, Nasivvik – Centre for Inuit Health and Changing Environments - Public Health Research Unit, CHUL - CHUQ Research Center 945 Wolfe, Sainte-Foy, phone: (418) 650-5115 ext. 5260; e-mail: christopher.furgal@crchul.ulaval.ca; Suzanne Bruneau, Coordinator NNHC, Public Health Research Unit, CHUL - CHUQ Research Center 945 Wolfe, Sainte-Foy; phone: (418) 650-5115, ext. 5259; e-mail: suzanne.bruneau@crchul.ulaval.ca

## Project members

Minnie Grey, Chairperson, Nunavik Nutrition and Health Committee; minnie.grey@sympatico.ca; Serge Dery, Jean-François Proulx: Public Health Department, Nunavik Regional Board of Health and Social Services Kuujjuaq, J0M 1C0; phone: (819) 964-2222; fax: (819) 964-2888; e-mail: serge_dery@ssss.gouv.qc.ca and jean-francois.proulx@ssss.gouv.qc.ca; Michael Kwan, Manon Simard, Makivik Research Centre, Kuujuaq, J0M 1C0; phone: (819) 964-2951, e-mail: m_kwan@makivik.org and m_simard@makivik.org; Shirley White-Dupuis, Tullatavik Health Centre, Kuujuaq, J0M 1C0; phone: (819) 964-2905; e-mail: shirley.dupuis@ssss.gouv.qc.ca; Minnie Abraham, Kativik Regional Government (KRG), Kuujuaq, J0M 1C0; phone: (819) 964-2961; e-mail: mabraham@krg.ca; Eric Loring. Inuit Tapiriit Kanatami (ITK) 170 Laurier Ave, Suite 510 Ottawa, Ontario K1P 5V5; (613) 238-8181 ext. 234; e-mail: loring@itk.ca



## Abstract

In response to the initial results from the Inuit infant cohort study conducted in the Nunavik, which found some subtle effects on infant neurodevelopment from *in utero* exposure to environmental contaminants the Nunavik Nutrition and Health Committee conducted a series of communication activities in the spring of 2003. During the past year follow-up and evaluative activities took place to ensure that communications goals were met. Since the community visits, personal contact with participants, radio call-in programs and initial communications materials were distributed in the region, the NNHC has adapted and finalized the communication materials associated with the findings of this study, conducted a short survey with women in the three participating communities and incorporated findings into the Inuit Tapiriit Kanatami general newspaper on contaminants and Public Service Announcements that were aired on the radio in the region during the past year. As well, questions from the standard Inuit and Yukon survey on communications and information needs were adapted and worked into the upcoming Nunavik Inuit health Survey to be conducted in the fall of 2004. Initial results of the survey conducted in the three Nunavik communities shows a low level of recall of the messages released in spring 2003 and some basic conceptual misunderstandings with regards to contaminants information among women of child bearing age.


## Key Project Messages

1. Key messages on contaminants and infant development in Nunavik have been released in various formats (community visits, radio

call-in programs, fact sheet, radio PSAs, general Inuit newspaper);

2. It is important to place research messages in the proper public health and cultural context
3. It is essential to evaluate communication activities to ensure goals were met;
4. There is a need to continue to learn more about message reception, understanding and the factors that influence communications on these issues in Nunavik and other regions of the North.

## Objectives

The general objective of this project was to address the basic regional communication needs in relation to the February 2003 release of contaminants and health information related to infant development and the consumption of country foods. Specifically, the objectives of this study were:

1) To follow-up on communications activities conducted to present the results of the Nunavik infant cohort study on country foods and infant development released in the region in the spring of 2003;
2) To assess the reception and comprehension of key public health messages related to this project among the target group (women of child-bearing age) in three communities;
3) To assess comprehension and perception of contaminants issues among the general Nunavimmiut population in cooperation with a survey being conducted in other Inuit regions;
4) Inform future approaches to communications on contaminants in Nunavik with the general population and target audiences.

## Introduction

In late 2002 the Nunavik Nutrition and Health Committee (NNHC) received the first set of results from the Nunavik infant development study, a cohort study conducted on infants at 6 and 11 months of age in Nunavik investigating the impact of various pre and post-natal factors on infant development. The results at this time showed that there were some subtle effects on child development associated with *in utero* exposure to heavy metals and organochlorine contaminants, the major source of which were the mother's country food consumption. In consultation with the lead researcher on this study, Dr. Gina Muckle, the NNHC developed a series of basic findings and public health messages to help explain the results of this study in the proper cultural and public health context to Nunavimmiut (see Appendix 1). In the late winter of 2003, a series of communication activities were carried out to deliver this information to the Nunavik population, beginning with the study participants, their families, the population of the 3 engaged communities, and finally the general Nunavik population. In February of 2003 an initial community tour was conducted to return and discuss the results of this study with the population of three communities directly engaged in the study for the previous 7 years (Kuujjuarapik, Inukjuak and Puvurnituq). A variety of communication activities took place during and after this tour. The communication activities included the following:

- A tour to each of the three engaged communities by a team comprised of public health officials, NNHC members, researchers leading the study and Inuit organization representatives;
  - Delivery of personal letters to the study participants and families explaining the results;
  - Closed door community meetings to present and discuss findings and their meaning;
  - Special meetings with interested groups (e.g. health centre staff in the communities);
  - Local community radio call-in program;
- Region-wide radio call-in program (at the time of release and 2 weeks later);
- Distribution of a press release and information package (key findings, fact sheet, plain language newspaper);
- Development and airing of Public Service Announcements at the community and regional levels.

Due to the importance of the findings, and their sensitive nature, it was deemed important to assess the success of the communication activities to ensure that the target audiences received and understood the messages and that final communication materials took into consideration key information needs of the population in response to these complex and sensitive findings. It was for this reason that the NNHC conducted a series of follow-up activities to the communications events surrounding the Nunavik infant cohort study results in 2003-04.

## Activities

### In 2003/2004

In association with the community visits and communication activities surrounding the release of the initial results from the infant development study a report was prepared documenting the questions and concerns raised by community residents attending or participating to the communication events in their communities or during informal conversations with members of the visiting team of public health officials, Inuit organization representatives and researchers.

This documentation of questions and concerns was reviewed and incorporated into the development of a final fact sheet to communicate the basic results and public health context around the findings of this study. This fact sheet was then distributed to all health centres and hospitals in the region in spring 2004 and is being inserted in the Nunavik general contaminants package being developed in 2004-05 and being distributed via the Nunavik Inuit Health Survey in the fall of 2004. Similarly, this material will be included in a general contaminants information package being developed for Nunavik in preparation for the Nunavik Inuit Health Survey. As well, these messages were included in the ITK contaminants information newspaper and the Inuit general radio PSAs aired in this and other Inuit regions this winter. The newspaper was translated in Nunavik dialect Inuktitut and distributed throughout the region.

A short evaluative survey was developed to assess recognition, recall and comprehension of the basic public health messages that were given in association with the result findings in the three communities last spring (Inukjuak, Puvirnituq, Kuujjuarapik). The survey was conducted face to face in each community during the period March 21-31, 2004, with randomly selected women of child bearing age from the community population lists (as in Babbie, 1990) with the aid of a local research assistant / interpreter-translator in English or Inuktitut (Table 1).

In cooperation with the team developing the Inuit and Yukon communications survey, the NNHC adopted core questions from this larger survey for inclusion in the Nunavik Inuit Health Survey. These questions will be applied with a randomly selected sample of community residents in all Nunavik communities as part of the regional health survey to be conducted this fall (2004). The questions will represent the first group of comparable data of this nature from all Inuit regions and the Yukon and will be used in establishing regional communication priorities.

## Results and Discussion

The multi-stakeholder membership of the Nunavik Nutrition and Health Committee ensured that the initial messages developed for the release of the results from the infant cohort study were put in the appropriate cultural and public health context. Materials and messages used in the initial release and subsequently reviewed in light of the documented community questions and concerns did not significantly change in the development of their final versions. However, the 2-stage approach to material and message development with pre-testing and adaptation based on community feedback still proved to be a valuable process in that the reaction to the sensitive and as previously thought, alarming results, was quite balanced and not a strong negative response from the community, as thought potentially might happen. The preliminary analysis of the survey shows that the post-test or evaluation following communication activities is essential to ensure that communication goals are met and that assumptions of reception and comprehension should not be made. The preliminary analysis shows a relatively low recall of the public health messages that were delivered in the community nearly one year later and a number of challenges

**Table 1.** Number and age of community participants in evaluative survey.

| Community | No of participants | Mean age |
|---|---|---|
| Puvirnituq | 20 | 29.6 |
| Inukjuak | 23 | 26.3 |
| Kuujjuaraapik | 14 | 29.1 |
| **Total** | **57** | **28.3** |

related to the comprehension of basic contaminant concepts used in the delivery of these messages. It is for these reasons that survey work such as that being conducted here and studies such as that by Bruneau et al. (2001) aimed at understanding how this information is incorporated with Inuit knowledge on contaminants and food safety issues are critical in helping understand why these misconceptions remain despite significant communication efforts on these issues. Similarly, reasonable targets must be established after better understanding the role of this form of communication (research related results) in the general public's understanding of these issues related to food and health. Despite following lessons learned from studies in the region on these issues in the past (e.g., O'Neil et al., 1997; Poirier and Brooke, 1997; Grondin and Carron, 1999) and in other regions (Lampe et al., 1999) a lack of recall and understanding appears to persist regarding basic contaminant messages. Greater work needs to be conducted in evaluation of current and past communication efforts and gaining a better understanding of the factors that influence reception, comprehension and circulation of this information in Inuit communities.

## Expected Completion Date

The analysis of the three community survey will be completed in early summer 2004 and results will be returned to communities in fall of 2004. the Nunavik Inuit Health survey, which includes basic questions on contaminants perspectives and information needs similar to those conducted in other regions in 2003-04, will be conducted in fall 2004 and analysed in winter 2004-05. Results will be returned to communities in spring of 2005.

## Acknowledgements

We gratefully acknowledge the participation of all Nunavimmiut in the studies conducted on contaminants in the region to date. We acknowledge their willingness to participate and work with the researchers and NNHC and discuss these important results and help in guiding communications on these issues in the region. Thank you to the community assistants who aided in the conduct of the community visits. We would also like to thank the local and regional radio stations for their cooperation in airing the PSAs and organizing the radio call-in programs on these subjects. Special thanks go to Clara Amittu and Martha Aupaluk and the staff at the Puvirnituq CLSC, namely Marjorie Noel, as well as Anna Niviaxie and the cooperation of the CLSC staff in both Inukjuak and Kuujjuaraapik for their work on the evaluative survey. Finally, thanks go to Carrie Grable for all her work on the fact sheets and survey.

## References

Babbie ER. 1990. *Survey Research Methods.* Belmont, California: Wadsworth.

Bruneau, S., Furgal, C.M., and E. Dewailly. 2001. Incorporation of scientific knowledge into Inuit (traditional and lay) knowledge in Nunavik. In, Kalhok, S. (Ed.) Synopsis of Research Conducted under the 2000-2001 Northern Contaminants Program. Department of Indian Affairs and Northern Development, Canada. Ottawa, ON. ISBN: 0-662-30872-7.

Grondin, J. and H. Carron. 1999. Strategies and challenges for effective communication in Nunavik and Labrador. In, Avativut/Ilusivut

Final Report. CHUQ-Pavillon CHUL, Beauport, Qc. G1E 7G9. Dépôt légal, Bibliothèque Nationale du Québec, 1999. ISBN: 2-89496-095-6.

Lampe, J., Murphy, F., Furgal, C., and Craig, L. 2000. Country food, nutrition and health: Developing effective communication strategies in Labrador (Year 2). *In*, Kalhok, S. (Ed.) Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program. Department of Indian Affairs and Northern Development, Ottawa, ON. ISBN: 0-662-29320-7. pp: 271-280.

O'Neil, J. D., Elias, B., and A. Yassi. (1997). Poisoned food: culture resistance to the contaminants discourse in Nunavik. *Arctic Anthropology, Vol. 34*(No. 1), pp. 29-40.

Poirier, S., Brooke, L. 1997. Inuit perceptions of contaminants, environmental knowledge and land use in Nunavik: the case of Salluit . Avativut/Ilusivut - Eco research program report.

## Appendix 1

*Excerpt of text from NNHC Public Health Messages released in association with the Nunavik Infant Cohort study results*

### NUNAVIK INFANT DEVELOPMENT STUDY PUBLIC HEALTH SUMMARY

A recent study supported by the Public Health Department (PHD) of the Nunavik Regional Board of Health and Social Services and the Nunavik Nutrition and Health Committee (NNHC) investigated the role that nutrients from traditional food, life habits during pregnancy, environmental contaminants and other factors have on infant development in Nunavik. Almost 300 mothers and their infants from Puvirnituq, Inukjuak and Kuujjuaraapik participated in the study.

**Key findings of the research:**

- Fatty acids were found to be beneficial for infants' birth weight, vision, ability to communicate or solve problems, ability to sit, stand and walk.
- Prenatal exposure to PCBs had some negative effects on birth weight, duration of pregnancy and visual memory. This exposure did not result in an increased number of low birth weight babies or premature births. Prenatal fatty acid exposure partially reduced the adverse effects associated with PCBs.
- The only effect associated with prenatal exposure to mercury was a decrease in the infant's ability to maintain attention.
- Prenatal exposure to lead was associated with slower processing of information into memory.
- Smoking and alcohol consumption were both associated with some negative effects on infant's growth and/or development. Both alcohol and smoking have the same negative impact as PCBs were found to have on birth weight in this study.
- Maternal stimulation has a positive effect on infant's mental development.

**Public health perspectives:**

- Some exposure to contaminants has decreased substantially over the years in Nunavimmiut (PCBs, lead).
- The PHD suggests that women of childbearing age (13-45) must first ensure to eat a variety of nutritious foods in an adequate amount. Whenever possible, we suggest that women select country foods that are rich in fatty acids and less contaminated with PCBs (Arctic char, misiraq made from seal blubber instead of beluga).
- Reduction of smoking and alcohol use during pregnancy and improvement of the quality of maternal stimulation may rapidly have significant positive impacts on infant and child development.
- The NNHC and the PHD strongly believe that country food is generally the best food for Nunavimmiut. Country foods are nutritious, bind communities together and reduce the risk for several diseases such as heart disease and diabetes.
- It is not clear if adverse effects found at 11 months of age will significantly impact on future child development and day to day functions at school age. It is therefore important to continue to follow children from Nunavik to monitor their development and its influencing factors.

# Provision of Technical Survey Support for the Design, Development and Application of a Common Northern Communications Survey in Inuit Regions


## Project leader(s)

Chris Furgal, Nasivvik Centre for Inuit Health and Changing Environments; Public Health Research Unit, CHUQ-CHUL, Ste Foy, QC; phone: (418) 650-5115 ext 5260; fax: (418) 654-3132; e-mail: Christopher.Furgalcrchul.ulaval.ca

## Project members

Regional organizations in Labrador, Nunavik, Nunavut, the Inuvialuit Settlement Region, and ITK



## Abstract

The activities conducted under this project were aimed at providing technical support to the regional survey initiatives taking place in Labrador, Nunavik, Nunavut, the Inuvialuit Settlement Region and the Yukon in 2003-04. Surveys were lead by regional organizations to gain a better understanding of at what level residents in these regions were aware of contaminant issues and what their perception and understanding of these issues was in order to support the development of regional and national communication strategies for the future and address the identified need within the NCP (CACAR II, Knowledge in Action) for evaluation of communication activities and messages. Regional surveys were developed and conducted in each of the regions by regional and local staff with a random sample of the community populations. Surveys will be analysed and results will be reported to the regions and communities during 2004-05.


## Key Project Messages

1. Regional Inuit organizations and members of the Yukon Contaminants Committee developed evaluative surveys to assess contaminants awareness, perception and information needs among their populations;
2. These surveys were conducted with a representative sample of their populations in 2003-04 or are being conducted via their inclusion in the Nunavik Inuit Health Survey in 2004;
3. Surveys are being analysed and results will be used to help develop regional and national strategies for communications in 2004-05;
4. Technical assistance for the development of these surveys was provided by C Furgal.

## Objectives

The activities under this project:

- Provided technical assistance to each of the Inuit regional and Yukon communication survey initiatives;
- Advised these initiatives as to the design and methodological approaches used for regional surveys;
- Helped coordinate surveys to ensure inter-regional comparability for a core group of questions in each survey so that the resulting data has value both at the regional and national levels.

## Introduction

The Northern Contaminants Program has generated a significant amount of information in the past five years under Phase II. One of the objectives of the program is to provide information to northerners to support their informed decision making on contaminant and country food issues. Therefore, it has been important to disseminate the general messages resulting from the research conducted under the program in an appropriate, accessible and integrated manner. Although regional nuances have adapted some messages for delivery in specific locations, many general messages have been delivered throughout the North that are very much the same. However, little evaluation of the awareness of these messages, their reception or the understanding of them has been conducted previous to 2002. Recent work conducted by Furgal, Myers and Powell (2003) in Baffin and Labrador communities identified evidence indicative of potential misunderstandings or misinterpretations of basic contaminants messages previously released by NCP representatives.

As the Northern Contaminants Program begins another phase of research and action on contaminant issues in the North, and with recent research results showing some of the most critical results for northerners to date (i.e. subtle effects on infants from maternal PCB and Hg exposure) it is important to conduct evaluative work at this time to help identify communication priorities and needs at the regional and national scales. For the regions and national organizations and program committees to get the needed information from these activities, they must be conducted in a reliable, standardized and rigorous manner. Further, to ensure inter-regional comparability, survey design, core questions, and methods used for the application of the surveys and analysis of data must be standardized across regions. This project provided technical assistance to each of the regional survey initiatives to develop, implement and coordinate their surveys in 2003-04.

## Activities

### In 2003/2004

- The project lead met with each group individually to help develop regional surveys and develop survey methods applicable to their region, communities and objectives;
- Regional teams developed the surveys considering the advice of the project lead and included questions and issues of concern to their unique communities and context;
- Regional surveys were developed in which a core group of questions and the way they were applied was comparable across regions;
- Development was conducted in a way to support rather than lead regional survey development, so that regional teams gained experience in both question and survey preparation;
- All surveys were conducted by regional and local staff.

## Results

Surveys were conducted in the fall, winter and spring of 2003-04 under the authority of the regional organizations. Table 1 provides an overview of the numbers of participants to the surveys in each region.

Survey development and application went well in 2003-04 as is evidenced by the numbers achieved (see Table 1). Council of Yukon First Nations utilized a slightly different method of participant recruitment and was able to obtain a much larger sample size than originally identified. All compensation for participation was approved by the regional organizations and not used to recruit individuals. Surveys are being encoded, entered into a data spreadsheet and coded for qualitative and quantitative analysis this year (2004). Analysis is being conducted by the project lead in cooperation with the regional survey teams to provide experience in survey analysis and interpretation.

**Table 1**. Summary of responses to regional and community contaminant surveys in 2003-04 conducted by regional organizations.

| Region | Total Surveyed | # of Participating Communities / Schools |
|---|---|---|
| Labrador | 60 | 5 |
| Nunavik* | 58 | 3 |
| Nunavut | 201 | 17 |
| Inuvialuit | 70 | 6 |
| Yukon | 382 | 22 |
| Yukon Schools Survey | 173 – students<br>5 - teachers | 4 – schools<br>4 – schools |

* Two surveys are being conducted in Nunavik: 1. regional wide survey as part of the Nunavik Inuit Health Survey (being conducted in 2004 with over 700 participants in 13 communities); 2. Cohort evaluation survey with women in the 3 communities participating to the Inuit Child Cohort study (numbers reported here).

## Expected Completion Date

Surveys are being encoded and analyzed in summer / fall of 2004 and results are being communicated in fall / winter 2004. This project will be completed by March 2005.

# North Slave Métis Alliance Contaminants Communications and NWTECC Participation


## Project leader(s)

Kris Johnson Lands & Resource Coordinator North Slave Métis Alliance PO Box 340 Yellowknife, NT X1A 2N3; phone: (867) 873-9176; fax: 867-669-7442; e-mail: kris@nsma.net

## Project members

Robert Turner; Kris Johnson; Corinne Paul; NWT ECC; NSMA Board of Directors



## Abstract

Indigenous Métis of the North Slave Region depend on the land and waters of this region for food, medicine, and spiritual and cultural survival. As development in the North Slave region continues the North Slave Métis Alliance (NSMA) community has raised concerns about contaminants in their main food source, caribou and fish, and as a result many members have decreased consumption of these traditional foods. The NSMA are working diligently to dispel the myth that there are 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 maintained active in dispelling this myth and been able to provide accurate, up-to-date information about contaminants to our membership.

The North Slave Métis Alliance's Land & Resources Department received funding for 2003-4 via the Northern Contaminants Program (NCP) to participate in the NWT Environmental Contaminants Committee (NWTECC) and to communicate and receive feedback from the NSMA community regarding contaminants information discussed in NWTECC meetings and provided in Canadian Arctic Contaminants Assessment Report II (CACAR II). The following report, "The Myth of Contaminants in Country Foods," conducted by the Land & Resources Department of the NSMA outlines the participation of the NSMA in the NWTECC and describes the community consultation events.


## Key Project Messages

1. 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.
2. Traditional North Slave Métis foods are healthy, nutritious and contaminants levels are low enough not to pose a threat to Métis health.

## Objectives

1. To ensure the NSMA community has a liaison person available to answer questions and provide feedback to the NSMA community, NWTECC and NCP regarding contaminants impacting the NSMA community.
2. To ensure the North Slave Métis are continually consulted and informed on all relevant contaminant issues.
3. To increase the capacity of the NSMA to deal with contaminants issues.
4. To ensure participation on NWT Environmental Contaminants Committee (NWTECC) conference calls, frontline training, socio-economic proposal reviews, Local Contaminant Concern proposal review, discussions regarding contaminants in Northern ecosystems and in Traditional Aboriginal Foods.

5. Report to the NSMA Board and membership about the on-going work of the NWT ECC, researchers conducting contaminants research, and contaminants information as laid out in CACAR II and other relevant publications.
6. Conduct a NSMA Community Contaminants Information Session to educate the NSMA membership about the results detailed in CACAR II, re-enforce the importance of eating a diet high in Traditional Country foods and to dispel the myth there are significant levels of contaminants in NSMA Traditional foods.
7. To conduct community consultations to identify local contaminant concerns and research priorities.

## Introduction

The NSMA were active participants in the Northern Contaminants Program (NCP) over 2003-4. As such we have maintained an open communication between our membership, the NSMA Board and NCP/ NWTECC to ensure Métis in the region are provided with the sufficient information about contaminants to make informed decision-making in regards to the harvesting and consumption of traditional/country foods and that NSMA local contaminant concerns are communicated to responsible authorities.

The NSMA community has identified the following contaminant concerns:

- The Bathurst Caribou Herd that the NSMA relies on as a main food source has decreased in numbers and health. Concerns about contaminant levels, increased development and hunting pressures have been identified as significantly impacting the ability for caribou to thrive.
- NSMA people are concerned that consuming contaminants in traditional/country food is seriously impacting the overall health of the NSMA community. As a result, members have expressed their disinterest in eating traditional foods.
- 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 a 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 that 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, or lake sediments are churned during recreational boating and swimming.
- Increased diamond and other mineral exploration in the NSMA's traditional land use region is leaving cuttings from drilling operations on the land, possibility contaminating soils and vegetation. 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 discolorings 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.

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.

## Activities

The NSMA's participation in contaminants research and communication was very limited due to receiving insufficient funds to engage the NSMA community and conduct research on concerns identified by the community. As a result, the NSMA was only able to participate in NWTECC meetings, proposal reviews, frontline training and one community information session. Although the NSMA contaminants liaison provided the NSMA Board of Directors with regular updates on the work of the NWTECC and NCP, the NSMA lacked the capacity to provide much of this relevant information to the NSMA community on a regular basis as needed and requested by the NSMA. It is hoped in the coming year Métis' concerns about contaminants are addressed equally as those of our counterparts in the High Arctic and we will receive funding to properly consult within the NSMA community as those in the High Arctic receive.

## In 2003-2004

- Participated in 12 NWTECC meetings which required reviewing previous meeting material, consulting with NSMA Board or Directors and Executive about concerns and progress of the NWTECC,
- Participated in NWTECC Frontline training,
- Produced NWTECC participation proposal and final report,
- Conducted community contaminants information session, "The Myth of Contaminants in Country Foods." The information session was conducted March 24, 2004 to present relevant CACAR II information and to re-enforce that country foods eaten by the NSMA are safe and nutritious. The presentation was well received and many participants requested this type of information session happen on a regular basis to maintain open communications and provide updates.
- Kept NSMA Executive and Board up to speed on contaminants issues on the North and how this impacts the NSMA membership,
- Provided the NSMA community with a reliable point of contact to discuss and answer questions regarding contaminants in the North Slave Region.
- Assess and summarize the information in the Canadian Arctic Contaminants Assessment Report (CACAR) II and repackage it into a format easily digested by the NSMA Board, membership and Métis in the region.
- Coordinated and facilitated an information session for NSMA members who live in Yellowknife, Rae and Edzo. This information session provided a forum to communicate and gather information from Members about the CACAR II report and findings.
- Helped Métis people access contaminants information available to help them make healthy food choices for their families.
- Relayed contaminants information between Métis Peoples and Decision Makers in order for informed decisions to be made.

## Results

The NSMA's participation on the NWTECC is invaluable to the North Slave Métis. Although the NSMA have been limited due to funding as to the amount of time and effort we can provide to work on contaminants issues the work the NSMA has conducted has been very effective at providing information to our membership in hopes that NSMA people are better informed to make healthy food choices and identify local contaminant concerns.

## Discussion and Conclusions

During 2003-2004 the NSMA participated in the NWTECC and NCP initiatives with limited capacity. Although our involvement in the NWTECC meetings, NSMA Board of Directors updates and Contaminants Information Session were very effective we feel our role in the NWTECC has been diminished due to our increasing costs of participating in the program and our ever increasing concerns about the cumulative impacts of contaminants in the environment impacting the NSMA community. The feedback from the NSMA community about our role in the NWTECC and identifying and discussing contaminants issues has been positive however members feel more community consultations and information sharing is necessary.

## 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 Radio Talk Show & NWTECC Report


## Project leader(s)

George J. Lafferty, Liaison Person, Tlicho Logistics.

## Project members

Chris Paci, Environment Manger, Dene Nation; Chairman, NWTECC; Julie Ward, Contaminants Specialist, DIAND; Co-Chairperson, NWTECC; Brett Elkin, Contaminants Analyses, Rwed; Member, NWTECC; Jack Mackinnon, Human Health, Health; Member, NWTECC; Anne Gunn, Caribou Expert, Gnwt.


## Abstract


A 2003/2004 Proposal was presented to the Northwest Territories Environmental Contaminants Committee (NWTECC) regarding informed decision making about the harvesting and consumption of traditional food.

Tlicho Interpreter/Translator was hired to help in conducting the interview, compiling the data, translation into the Tlicho Language, and transferring it onto a cassette tape. Responsibility of ensuring appropriate language and understandable to the Tlicho public is the most important part of this communication process.

Several members of the NWTECC Committee were interviewed about various aspects of the Northern Contaminants Program (NCP). These interviews will be aired in both English and the Tlicho Language.


## Key Project Messages

To inform the Tlicho Public about the Northern Contaminants Program and let them know the Northwest Territories Environmental Contaminants Committee is working hard to deal with issues regarding contaminants in the Tlicho Region. Each member brings to the committee unique experiences, like the knowledge of caribou, capabilities of analyses, knowledge of human health issues, and specialist on transmission of contaminants to the Arctic Ecosystem from other parts of the world.

With the completion of the Talk Show we hope to receive some feedback from the Tlicho public on what their concerns or questions are. Plans could be formed from public opinion on what types of communications would be useful in the future.

The Project Leader, as member of the NWTECC, continues to be active in meetings through attendance of all meetings.

## Objectives

1. To introduce some members of the Northwest Territories Environmental Contaminants Committee to the Tlicho public.
2. 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.
3. To hire an interpreter/translator to ensure what is interviewed is efficiently communicated so the Tlicho public would understand the issues more clearly. We hope here any feedback would clear-up any misunderstanding or interpretations.
4. Complete cassette tapes and/or CD disk of translated interviews to be made available to Tlicho public through Band Offices.
5. To continue to participate in activities of the NWTECC, including monthly meetings and proposal reviews.

## Introduction

Efficient communication to the Tlicho communities can usually become costly, especially conducting interviews, completing presentations, or visiting with the public and organizations. Once the interviews are finished, the information will be aired on CKLB in both the English and Tlicho Language.

Three of the four Tlicho communities can only be access by air and winter road; we hope to reach more people with our contaminants information regarding traditional foods.

## Activities

## In 2003-2004

James Rabesca, interpreter/translator, was hired to work with the Project Leader and to make available completes tapes for airing. Other interpreter/translators will be used as necessary.

Interviews have been completed to-date with several NWT ECC members regarding different aspects of the Northern Contaminants Program.

Interviews will be aired on CKLB in Tlicho and English as airing time permits until all interviews are completed.

## Results

Interviews were designed to capture the strengths of several NWTECC members. George Lafferty, NWTECC member representing Tlicho, provided an introduction in the Tlicho language. Dene Nation provided some background information on the NCP and the NWTECC. DIAND described contaminants and how they arrive in the arctic and affect the environment. Representatives from GNWT Resources, Wildlife and Economic Development were asked questions about contaminants and their relationship to caribou, fish and other wildlife. GNWT Health and Social Services was asked questions regarding contaminants and human health.

Through continued participation on the NWTECC, projects such as these interviews can be completed with the help of other committee members. In addition, participation in the committee ensures a contact person is available to voice contaminants concerns from Tlicho communities and engage in discussion with scientists and NCP program coordinators to find answers.

## Discussion and Conclusions

It takes time to transfer the information from interviews onto to tape without first having the written information and it did not help when our interpreter's time was demanded elsewhere. Following the first interviews, others were asked to complete their interview by answering questions in written form that can be taped, to make it easier for translation.

The translation of these interviews provides a solid base of information on the Northern Contaminants Program in the Tlicho language. Through the use of radio, a very wide audience is reached. As the interviews are all stored on tape, rebroadcasts can be made several times to ensure as many people as possible are reached.

## Expected Project Completion Date

Interviews will be played during appropriate airing times on CKLB in the Northwest Territories. NWT ECC participation is ongoing.

# Development of an Inuit Communications Strategy on Contaminants Guiding Activities in Inuit Communities (2004-2008)


## Project leader(s)

Eric Loring Senior Environment Researcher Inuit Tapiriit Kanatami 170 Laurier Ave Ottawa, ON K1P5V5; phone: 613 238 8181 ext. 234; e-mail: loring@itk.ca

## Project members

Inuit Circumpolar Conference-Canada; Niqiit Avatittinni Committee; NWT Environment Contaminants Committee; Labrador Inuit Association Research Office; Nunavik Nutrition and Health Committee; GN Health and Social Service; Inuvialuit Regional Corporation; Nunavut Tunngavik Corporation; Makivik Corporation; Kativik Regional Government



## Abstract

The implications of poor communication, regarding the Arctic food chain contamination risk and the potential health impacts on Inuit, demonstrates the need to take an organized and rationale approach to work related to communicating these risks and benefits in Inuit regions. This strategy paper provides the background for the beginning of a long-term planning process for Inuit Tapiriit Kanatami and Regional Inuit Organizations in relation to their future communications and educations activities under the Northern Contaminants Program (NCP).


## Key Project Messages

1. Mercury concentrations have not declined significantly in landlocked char from Resolute lake from 1993 to 2003.
2. Mercury concentrations have increased marginally in char from Char and Amituk Lakes over the same period.
3. At Hazen Lake in northern Ellesmere Island, mercury concentrations in char have also not changed overall but appear to show year to year variation which is probably related to diet.

from Muir p. 149

## Objectives

- This project developed a general strategy process to help establish a path for the next 5 years of Inuit communications activities under the Northern Contaminants Program. It is proposed to develop such strategies such that they can be easily integrated with the Indian and Northern Affairs – NCP Blueprints.
- The development of a common organized and coordinated Inuit strategy for learning about, conducting and increasing the capacity to communicate and support informed decision making by Inuit.

## Introduction

The presence of contaminants in the Canadian Arctic environment has received increasing attention over the past few decades most notably due to the potential risks to human health from traditional/country food contamination (Canadian Arctic Contaminants Assessment Report (CACAR) I 1997; CACAR II, 2003). The management and communication of the risks posed by environmental contaminants in the food chain of northerners poses significant challenges in Inuit regions. Some changes over the past two decades in the consumption of country foods in Inuit regions may be attributed, in part, to the presence of industrial pollutants in the Arctic ecosystem. Some risk management and communication strategies in the past have been reported to have resulted in fear and confusion among community residents, and had significant direct and indirect social, economic, and health impacts in the involved communities.

The review of communications materials and activities conducted during Phase II of the NCP, as reported in Knowledge in Action (CACAR 2003) identified the need for an organized approach to communications activities and research. To date, various forms of evaluation (formal and informal) have documented various lessons at different times and in unique regions regarding methods of best practice or challenges faced in communicating about contaminants and health in Inuit regions. Further, as more is learned about the potential effects of contaminants on Inuit health (CACAR II Health Report) the messages are in fact becoming more complex, requiring greater levels of detail to be communicated and therefore understood by Inuit in order to support truly informed decision making. In 1995, in response to a review of the risks and benefits of contaminants in country foods consumed by Inuit the general message, following consultation with scientific and northern experts alike was as follows:

> "This statement is made with the support and agreement of the leaders from Nunavut, Nunavik, Labrador and Inuvialuit regions......So far as we are aware, the risks to public health from continuing to eat beluga and seal blubber are very small and are outweighed by the benefits to you of these foods. However, Inuit must judge for themselves what is an acceptable risk for themselves and their families..."

President, ITC – Rosemarie Kuptana, 1995

In 2003, in response to results from the Nunavik Inuit Child Cohort, the Public Health Director of that region released a public statement which including the following:

> "...the study results are interesting and very valuable to understanding the impact contaminants may be having on infant development in Nunavik, but more importantly, we must put these results in a greater public health context with the other things we know influence the health of young mothers and their babies".

> "The Public Health Department suggests that women of childbearing age (13-45) must first ensure to eat a variety of nutritious foods in an adequate amount. Whenever possible, we suggest that women select country foods that are rich in fatty acids and less contaminated with PCBs (Arctic char, misiraq made from seal blubber instead of beluga). "

> "The NNHC and the PHD strongly believe that country food is generally the best food for Nunavimmiut. Country foods are nutritious, bind communities together and reduce the risk for several diseases such as heart disease and diabetes. So yes, of course, they are still safe to eat. "

NNHC and Public Health Director, Nunavik, 2003

As the knowledge of the potential effects of these contaminants on Inuit health has increased the messages and activities required to increase awareness and understanding of these issues among Inuit has consequently become more complex as is seen in the differences in these two messages. At the same time, with the establishment of the Northern Contaminants Program as a permanent program within the Indian and Northern Affairs organizational and operational structure, the research program, in an attempt to gain a better understanding of these issues, is beginning to focus greater attention specifically on the issue of health effects of contaminant exposure among the most highly exposed group in the North: Inuit.

## Activities

### In 2003-2004

- Inuit Forum groups meets with all Territorial Contaminants Committees (TCCs) to develop a coordinated approach to funding in the Inuit Block

- Survey and tours conducted throughout the year to identify and understand knowledge gaps
- Presented first draft of strategy for review and comments to the NCP management committee in November
- Input from all Inuit regions from the ITK National Inuit Committee Environment (NICE) towards educating and communicating contaminant information to Inuit regions. At this meeting, participants recommended:
  - **Ongoing Dialogue**: the need for an ongoing regional and national dialogue on communicating about contaminants;
  - **Need for Learning** – need to document and have a strategy to learn in order to improve how communications are done;
  - **Coordination and regionalization** – the need for central messages to be developed with regionalized variations, the need to work together on materials and messages whenever possible to avoid duplication and ensure efficient use of resources;
  - **Develop Capacity** – the need to increase the chance of having regional representatives focussing on communication and coordination related to these issues via cooperative funding among research programs or other mechanisms;
  - **Make Best Use of Existing Materials**: the need to build on and use what has been done before and worked rather than have each region produce new materials year after year (e.g., update old material, translate good materials into regional dialects, etc.);
  - **Completion of all Initiatives** - Carry through on past initiatives, use good tools already developed, check to see if they have been used and have worked (e.g., PSA follow up survey and redistribution);
  - **Ensure Continuity** – Establish a long term vision with short and long term goals rather than reacting and changing directions from year to year.

## Discussion and Conclusions

In establishing the strategy, regions, ITK and ICC must first determine their specific priorities and objectives related to communicating about contaminants and health.

- What are your key issues and specific purposes of communicating?
- What do people and don't people know about this issue? How do you know this?
- What are perceptions and misconceptions about this issue in your region?
- What are the key things that people in your region should know?
- What do they want and need to know?
- What are you responsible to make them aware of / provide access to?
- How is this best done?
- What do you need to know to do this better?
- What needs to be done to increase this ability in the future?

Upon setting these priorities, it is recommended to develop a strategy that provides a balance in priority activities to support returning results and basic information, learning about how this can be improved and enhancing local capacity to conduct these activities. It is therefore recommended that priorities be organized under these three headings: 1. Communication Activities; 2. Communications Learning; 3. Communications Capacity.

Examples of activities that were conducted this past year under the NCP Inuit Block fund for communications (organized by category) include:

***Communication activities***

- Communications tours in Inuvialuit, Nunavut, Labrador
- Newspaper insert and fact sheets developed PSA dissemination
- Health workshop on Nunavut cohort
- Regional consultation and strategy processes

*Communications learning*

- Survey among Inuit regions on contaminants perspectives, knowledge, awareness
- Health workshop on Nunavut cohort

*Building capacity for communications at the regional or community levels*

- Regional representatives involvement and direction of communication activities and research
- Health workshop on Nunavut cohort (inter-regional exchange of experiences)

**Annual and Mid-Program Review**

As is expected that priorities and needs will change from year to year with results from new studies becoming available and adapting our understanding of the issues related to contaminants and health, it is recommended to conduct an annual review of the strategies. An Inuit Communications Working Group should be convened to review and adapt, as needed, regional, national and international communications priorities to ensure that long term goals are being met and short term goals remain relevant. It is recommended that this be the same committee involved in the development of regional, national and international long-term plans and that this group meet mid-fall of each year so that the most recent needs and priorities are reflected in the NCP annual call for proposals.

Further, in the development of the long term strategy it is recommended that the Inuit Communications Working Group incorporate a mid and end of strategy evaluation process at 2006 and 2008. Appropriate indicators and evaluation processes should be developed and utilized at this time to ensure goals and objectives are being met and to adapt future strategies for this work.

**Developing Priorities for 2004-2005:**

*Communication Activities (to include evaluative component where possible)*

- General National Inuit messages with regional variations
- General Inuit communications package with regional variations
- Messages tailored to specific groups (e.g. highly exposed WCBA in Baffin, etc.)
- Messages responding to misconceptions identified in survey

*Communications Learning*

- Complete analysis and return of results for survey
- Development of indicators of « effectiveness »
- Develop rationale and framework for communicating with WCBA on contaminant risks
- Understanding informal networks for communication in communities.

*Communications Capacity Building*

- Investigate feasibility of establishing regional communications / coordination positions for contaminant issues
- Review feasibility to re-print educational materials on contaminants for use in Inuit regions
- Review feasibility of delivering Contaminants Frontline Workers' Training Workshop in Inuit regions

**The Planning Process: A Way Ahead**

1. Initial Meeting to establish and introduce communications planning process and framework

2. Regional, National and International Planning Processes to set priorities and objectives

3. Finalize and Coordinate Regional, National and International Strategies

4. Translate Strategies into NCP Inuit Block Blueprint

5. Ensure Effective Review of Proposals

6. Revisit Blueprint Annually

# Developing the "Contaminants in the Deh Cho II" Booklet


## Project leader(s)

Kelly Pennycook Deh Cho First Nations, Box 89 Fort Simpson, NT X0E 0N0;
phone: (867) 695-2355/2610; fax: (867) 695-2038; e-mai:kellydcfn@Yahoo.ca

## Project members

Ria Letcher, Deh Cho First Nations; Kelly Pennycook, Deh Cho First Nations; Deh Cho First Nations Local elders; NWTECC



## Abstract

The Deh Cho First Nations communications and educations activities for 2003-2004 focused on the development of the *Contaminants in the Deh Cho II* booklet to provide accurate information to residents of the Deh Cho on the presence of contaminants in traditional foods. In addition, t-shirts were produced with the key message that traditional/country foods are safe to eat. All Deh Cho communities were visited this year and contaminants information and CACAR II were discussed.

The Deh Cho First Nations continued to participate in the NWT Environmental Contaminants Committee monthly meetings and in-person meeting. The Committee is responsible for providing information to Northerners on the presence and possible effects of contaminants in the environment.


## Key Project Messages

1. The Deh Cho First Nations Local Contaminants Coordinator provided information to communities about the results of CACAR II by community presentations (through the use of PowerPoint, pamphlets, questionnaires, t-shirts and the *Contaminants in the Deh Cho II* booklet).
2. The Local Contaminants Coordinator briefed and updated the Deh Cho First Nation's NWT Environmental Contaminants Committee representative for meetings to bring forward contaminants concerns in the Deh Cho and review Northern Contaminants Program proposals and other information.

## Objectives

The Deh Cho First Nation provides two-way transfer of contaminants information between communities and the Northern Contaminants Program (NCP).

1. To promote the results of CACAR II through the use of the *Contaminants in the Deh Cho II* booklet, pamphlets, tours, and key messages on t-shirts
2. To assist communities to identify concerns related to environmental contaminants
3. To inform and educate the public about contaminants in the Deh Cho.
4. To coordinate regional contaminant studies
5. To review NWT Proposals related to the NCP.

## Introduction

In this transition year following Phase II of the NCP, the focus of the Deh Cho First Nations was the production of the *Contaminants in the Deh Cho II* booklet to aid as a communication tool for CACAR II.

DCFN also actively participated in the NWT ECC through both monthly conference calls and an in-person meeting to review NCP proposals. DCFN has acted as a central contact for the Deh Cho for receiving and communicating information pertaining to the NCP, Stockholm convention, and CACAR II. This was accomplished through community tours, where contaminants information was presented discussed, as well as other environmental concerns.

## Activities

## In 2003-2004

- DCFN produced a booklet titled *Contaminants in the Deh Cho II* as a follow up to the *Contaminants in the Deh Cho* booklet produced after phase I of the NCP.
- DCFN conducted community tours of the Deh Cho communities where contaminants information was discussed and CACAR II reports and fact sheets distributed.
- T-shirts were produced with the key message from CACAR II that traditional foods are safe to eat.
- DCFN attended monthly meetings of the NWTECC by teleconference, and one in-person meeting to review NCP proposals.
- Participated in the NCP Frontline Training Session by Dene Nation.
- Prepared an NCP proposal for the 2004-2005 year.
- On-going communication of the results from the CACAR II and NWT Fact Sheets.
- Passed on community contaminants concerns to the NWTECC for discussion.

## Results

- Distributed the *Contaminants in the Deh Cho II* booklet and the DCFN t-shirt to Deh Cho communities, the NWTECC, the NCP Secretariat and any interested individuals.
- Acted as a point of contact for contaminants concerns in the Deh Cho.
- Learned about CACAR II through the NWT Fact sheets and CACAR II reports and helped provide this information to Deh Cho community members.
- Provided input to the NWTECC on Deh Cho contaminants concerns.
- Receive feedback from Deh Cho First Nation governments.
- Start compiling a contaminants resource data bank.

## Discussion and Conclusions

The Deh Cho First Nations 2003-2004 education and communication proposal provided a good solid base for the NCP through which to education and communicate to the Deh Cho Territory people on contaminant facts and concerns. This project could not have happened at a better time, as the Dene people, especially elders, expressed great concern about their traditional foods.

## Expected Project Completion Date

This proposal was completed in April 2004; audited financials will be forwarded as soon as cleared by leadership.

The Deh Cho First Nations will continue to be represented on the NWT-ECC, and address concerns and communicate information relating to contaminants in the Deh Cho.

# Deliver CACAR II information to Labrador Inuit and Participate to the Common Northern Survey on Contaminants Communications


## Project leader(s)

Jolyn Pijogge/Mary Denniston, Research Department, Labrador Inuit Association, P.O. Box 280, Nain, Labrador; A0P 1L0; phone: (709) 922-2847/864; fax: (709) 922-1040; e-mail: natsiq@nunatsiavut.com

## Project members

Eric Loring , Senior Environment Researcher, Inuit Tapiriit of Kanatami; Chris Furgal, PhD, Research Associate, CHUL Research Centre, Beauport QC; Labrador Inuit Heath Commission



## Abstract

The Northern Contaminants Program's (NCP) goal is to reduce and wherever possible eliminate contaminants in traditional foods. Supporting this goal are the NCP's priorities for providing people with the tools and information for making their own informed decisions, through education, communication, and community participation in the program. Having regional staff work on this agenda helps ensure that this goal is being met by having someone in place that is familiar with and sensitive to the culture and people.

In Labrador, the duties of the Labrador Inuit Association's (LIA) Researcher include acting as a liaison between five north coast communities and Upper Lake Melville, acting as a liaison between researchers and the community, communicating research results on risks and benefits of wild foods in plain language to the community residents in Labrador through various mediums, assisting in the delivery of workshops, open-houses, and information sessions, and carrying out projects funded by the NCP in the region.


## Key Project Messages

1. This project continues to enhance the ability of the LIA Research Office to better deal with the issues related to man-made chemicals entering the environment which are a concern among Labrador Inuit, and to provide information in a plain language, translated, and accurate form in order to support Labrador Inuit in making informed decisions about their health and the environment;
2. The LIA Research Office strives to continue its communication efforts, in a culturally relevant manner, on contaminants, research, and the environment; conduct research and promote mutually beneficial relationships between the communities of northern Labrador and outside scientists;
3. This project has enabled the Labrador Inuit Association Research Office to continue these communications, research and liaison activities, in order to effectively conduct research and communicate information on contaminants in the food chain and the environment, enabling Labrador Inuit to make informed decisions.
4. This work is a continuation of the Regional Contaminants Coordinator (RCC), Labrador Inuit Association, to enhance decision making capacity among Labrador Inuit, through the provision of information on risks and benefits relevant to the region in an accurate, timely and accessible manner.

## Objectives

One objective laid out by 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:
  - will continue to assist 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;
  - will continue to assist 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;
  - will act 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.

## 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 are of concern to the Inuit of Labrador because they sustain people in Labrador and may potentially affect the residents of the coastal communities. Evidence from Nunavik has showed subtle effects on unborn children due to the consumption of wild foods. Just this past year, LIA and LIHC, in cooperation with the Environmental Sciences group of Department of National Defense, released a health advisory for the consumption of wild foods in the Saglek area because of the potential for related health effects. Both of these issues are making it increasingly important to explain this information, the current state of knowledge on contaminants, and the related benefits and risks of wild foods to the population of Labrador. 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 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 (Laval University) and Lorraine Craig (University of Waterloo).

## Activities

## In 2003-2004

### *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 such things as 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 manner. Without this person, this newsletter would not be published. The main focus of the Avativut newsletter is on the benefits of wild foods to stress 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.

### *PCB Clean-up at Saglek, Labrador*

The LIA Research Office staff annually facilitates the communication of information about the presence of Polychlorinated Biphenyl (PCB) contamination in the Saglek Bay area. Information being communicated to date on this topic includes results on the marine and terrestrial plants and animals that have been contaminated by PCBs at the site. The messages on effects that PCBs have on humans through contamination were delivered this year, as well as up-to-date information about the clean–up activities of the contaminated soil at the site. This past year Bennett Environment Inc. held an open house in Nain, Labrador pertaining to the site clean up activities.

Jolyn Pijogge (LIA Researcher) worked with Dr. Chris Furgal of Laval University Hospital Centre (CHUL-CHUQ) and Zou Zou Kuzyk of the Environmental Sciences Group (ESG) on communicating about contamination issues at Saglek this past year. Jolyn, Chris, and Zou Zou worked together to develop key health and environment messages specific to the Saglek Bay area. This year, this included the joint LIA-LIHC release of a health advisory pertaining to consumption of wild foods in the Saglek Bay area.

The information compiled was disseminated through a workshop, an open house, and a call in radio show. A communications package of materials was developed and used during the various communication activities. The package included posters for general public release, an official press release, radio public service announcements, and fact sheets pertaining to the site's history, PCBs, the Saglek Remediation Project, marine system, marine wildlife effects, traditional foods and health.

### *Labrador Community Tour*

As part of the ongoing circumpolar effort to "work to reduce and, wherever possible, eliminate contaminants in traditionally harvested foods, while providing information that assists informed decision making by individuals and communities in their food use" (as per the mandate of the Northern Contaminants Program), a community tour was organized for the Labrador north coast communities this year. The tour started in the northernmost community (Nain) and was to include Hopedale, Makkovik, Postville and Rigolet. Due to the necessary postponement of several community visits, a second phase of the tour was to occur in the Spring of 2004, visiting the communities not reached in the initial trip. This second phase of the tour did not take place this year, due to circumstances beyond our control. Nain served as the base for all of the activities carried out in this phase of the tour, though every effort was made to include the other communities wherever possible (e.g. via regional radio broadcasts). An open house, school presentations, and call-in radio show were conducted by the team, which included representatives from LIA, ITK, DIAND (NCP), Laval University and Dalhousie University. The tour materials focused on delivering the state of the knowledge pertaining to contaminants in Labrador and other regions of the North as presented in the CACAR II reports.

## *LIAISING/CONTACT PARTICIPATION IN RESEARCH PROJECTS*

### *What do Labradorians Know about Their Environment and Health Survey?*

This survey was conducted in 5 north coast communities, Nain, Hopedale, Postville, Makkovik and Rigolet this year under the direction of C Furgal (Laval University). LIA field office staff filled the roll of community researchers to randomly choose participants in the community for the survey and help them complete the questionnaire. This survey was done to gather Inuit perspectives on what Inuit would like to know about the environment and how it influences their health, with special emphasis on contaminant related issues. After pre-testing the survey months before to ensure wording was accurate and understandable the survey was conducted with 60 participants among the 5 coastal communities.

### *Women's Perspectives on Climate Change and Health*

Sandra Owens, a Masters student at Laval University Public Health Research Unit conducted a research project entitled Women's Perspectives on Climate Change and Health. This project focused on women's perspectives on the effects that climate and environmental changes have had from a women's point of view. Sandra returned her results to the participants in Nain in April 2004 to verify the information gathered and analyzed was accurate and understandable to the participants of the project. Sandra will now compile this information in a report format, which will then be returned and sent to the Labrador Inuit Association.

### *Determinants of Food Choices in Labrador and Perspectives on Contaminants*

Susie Bernier and Chris Furgal of Laval University Public Health Research Unit returned the results of their research projects on the Determinants of Food Choices in Labrador and an earlier survey on Nain and Makkovik residents' perspectives on contaminants, respectively. These projects provided a better understanding of food preferences, attitudes and other factors influencing food choice behaviour as well as some concerns and misconceptions individuals have on contaminant issues in the region. The results of these studies were returned to the Nain population via an open house and radio interview at the OK society. The open house event was very well attended by the general public and school groups.

### *Participation in ACADRE – Nasivvik Centre by LIA Research Office Staff*

The purpose of this program is to develop a network of supportive research environments across Canada that will facilitate the development of capacity in Aboriginal health research.

Mary Denniston, LIA Researcher worked with the Susie Bernier, Coordinator of the Nasivvik Centre to find out the number of Inuit students from the Labrador region that are attending post secondary programs with respect to environment and health. The high school was also contacted to see what science courses are offered to students who are at the stage in their lives when they are considering what they would like to pursue as a career. This was done to help decide what actions the Nasivvik Centre would take and what circumstances needed to be considered when making decisions about what criteria/guidelines must be set in order to assist Inuit in building capacity in environment and health. It is expected that these activities and the initiatives of this centre will also help in future years of the NCP activities in helping enhance regional capacity in Labrador to conduct contaminant related research and communications.

### *Ongoing Daily Communications And Research Coordination*

In addition to these specific activities, the LIA Research Office staff fulfills a number of ongoing communication responsibilities. 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 daily interaction with various individuals and ongoing communications efforts.

## Results

The existence of this staff member has enabled and enhanced the abilities of the LIA to continue its mandate of providing information on environmental issues such as contaminants, research and the environment, acting as a liaison between communities and outside researchers, conducting research and acting as a co-facilitator in delivering workshops and training for community representatives. The financial support provided through the NCP continues to enable the LIA Research Office staff to improve the way information is being presented and delivered to Inuit communities of northern Labrador by utilizing the latest project results for the region in developing effective communication strategies. In addition to facilitating communications on contaminants information, this project enables the staff to anticipate and reduce the possibility of misunderstandings and mistrust among communities, organizations, researchers and scientists in communications activities in the region.

## Discussion and Conclusions

The LIA Research Office staff member continues to be a valuable addition to the LIA Office. 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 will determine, in consultation with community representatives who are responsible for communication of contaminants, health and environment information, which medium(s) best suit the information needs of the community, etc. Those utilized often include presentations and workshops delivered in a plain language format. 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.

## Expected Project Completion Date

This is an ongoing project in Labrador

## 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, for the translation of communication materials and Alice Pilgrim and Katie Harris and the Labrador Inuit Association's Fieldworkers for their assistance in activities related to the issues discussed in this report.

## References

Lampe, J., F. Murphy, and C. Furgal. 2000. Country Food Nutrition and Health: Developing Effective Communication Strategies in Labrador F9-14.

# Niqiit Avatittinni Community Tour

## Project leader(s)

Glen Stephens, Co-chair, Niqiit Avatittinni Committee, P.O. Box 2200, Iqaluit, NU X0A 0H0; phone: (867) 975-4549; fax: (867) 975-4560; e-mail: stephensg@inac-ainc.gc.ca; Niqiit Avatittinni Committee (NAC) members

## Project members

Inuit Tapiriit Kanatami (ITK), Government of Nunavut Health and Social Services, NCP Secretariat

## Abstract

The Nunavut-wide Niqiit Avatittinni Community Tour, funded by the NCP, commenced in January 2004. The initial purpose of the tour was simply to disseminate the findings of Canadian Arctic Contaminants Assessment Report II (CACAR II) and the public health message. However, at the last face-to-face meeting of the NAC in October 2003, the committee agreed that it would be important to provide the information in a balanced, context specific way. As a result, the committee decided the tour should also address nutritional and environmental health concerns to further help Nunavummiut to make balanced decisions about the consumption of their country foods for themselves and their families. The tour provided the initial steps to inform Nunavummiut regarding what is presently known about the benefits and risks associated with country foods. The NAC are required to remain vigilant in maintaining awareness and ensuring a consistent message to vulnerable groups and all Nunavummiut. The tour presentations were initially envisioned to be structured as a workshop. In the initial planning, there were to be four segments within the content of the presentation. Through a series of subgroup meetings of NAC members, the content of the Nutrition and Environmental Health presentations were developed. Nineteen communities were visited throughout Nunavut, allowing community members to be informed and ask questions of the tour presenters.

## Key Project Messages

1. It is important to meet Nunavummiut in person to discuss contaminant issues
2. Nunavut residents are concerned about contaminants in their traditional foods, and are appreciative of the efforts being made to communicate with them
3. Much was learned about how to improve further tours, from the content and logistics of the presentation, to the timing and advertising of them.
4. The presentation audience was encouraged to complete a written evaluation (in English or Inuktitut) of the presentation at the end of the session.
5. Twenty out of twenty-five communities were visited. The missed communities were Hall Beach, Arctic Bay, Chesterfield Inlet, Baker Lake, and Sanikiluaq.

## Objectives

To communicate the following information to the communities of Nunavut:

***Nutrition***

- Benefits of country food
- Iron (content, benefits, comparison of iron-rich CF with other foods)
- Protein (content, benefits, comparison of protein-rich CF with other foods)
- Healthy fats vs. unhealthy fats
- Sugar

- Fat and sugar presentation (hands on, very visual)

*CACAR II*

- Discussion of the basic concepts associated with environmental contaminants
- Environmental contaminants from a Nunavut perspective
- Health benefits of country food

***Keeping Country Food Safe (Environmental Health)***

- Animal farming practices and risks of contamination
- Naturally occurring contamination in animals
- Trichinella

***DHSS/NAC Public Health Message***

- Risk management focus on the prenatal and breastfeeding women
- Breastfeeding and its benefits
- Healthy Lifestyle during Pregnancy/Infant Development
- Promotion of adequate nutrition in Nunavut

## Introduction

The traditional workshop approach used to convey research results and program information has involved bringing selected community representatives to a central location, providing them with information regarding contaminants and the Northern Contaminants Program (NCP) and then sending them home. It had been the hope that these representatives would spread the information to the rest of the community. This, realistically, was an unfair burden to place on the community representatives as most of them were not in a position to talk to every interested person, nor was it usually their job to do so. Information overload and the potential for misinterpretation of the results and information was also a potential problem.

An alternative method for delivering the contaminant and NCP-related information is to send a small knowledgeable team to a community for a variety of meetings. This option was used in 1999-2001 and was found to be effective. The teams would generally consist of a program representative, an Aboriginal partner, a health specialist and a scientist. While the primary means of communication would be a public meeting, the team would also take advantage of the time in the community to talk with high school science classes, the Hunters and Trappers Association, the Hamlet Council and any other interested groups.

The advantages of going to a community rather than bringing a single representative to an outside meeting are numerous. Not only could more individuals be reached, but they would hear the message from the source rather than second hand, and the team would be able to answer most questions immediately. By having the team in the community and having more than just a public meeting, individuals have the opportunity to hear and comment about contaminants more than once. Also, a level of comfort would be afforded to the individuals since they would be with their families and neighbours, which could help people feel more comfortable to express opinions and concerns about the program.

Another benefit is the relationship-building that goes on while in the community. By going to the community, community members have an opportunity to meet some of the individuals (i.e. scientists, Aboriginal organization representatives) who are working in their region. This helps build relationships between community members and scientists conducting research.

A lesser benefit, but one that should be considered, is the economic benefit to the community. While in the community, the team inputs money into the local economy through accommodations and meals, logistical support (e.g. meeting organizer, translation services, hall rental) and souvenir shopping.

## Activities

### In 2003/2004

From January 12, 2004-March 26, 2004, the Niqiit Avatittinni Community Tour successfully visited and presented to 20 communities of the 25 identified communities in all three regions of Nunavut. The five communities that were not visited include: Hall Beach (cancelled due to a funeral), Arctic Bay (cancelled due to weather), Chesterfield Inlet (cancelled due to weather), Baker Lake (cancelled due to a public health concern) and Sanikiluaq (no time or human resources remaining within the fiscal year). It must also be noted that the two largest communities in Nunavut had the poorest turnouts per capita. Rankin Inlet had a presentation date, but no community members attended. The Iqaluit meeting was quite well represented by health and environment professionals, but otherwise very poorly attended by Inuit from the community.

Tour presenters and participants included representatives by DHSS, DIAND, ITK, NCP, NTI and/or a Regional Inuit Organization. Representation was not always complete on the entire tour due to challenging logistics. An interpreter/translator traveled with the group for convenience and to maintain the consistency of the Inuktitut or English translations. DHSS facilitated the health segments, while ITK or NCP communicated CACAR II.

Two evaluation forms were used on the tour. The *first* evaluation form was in use for the first 8 communities in the Qikiqtani Region (Cape Dorset, Kimmirut, Grise Fiord, Resolute Bay, Pangnirtung, Qikiqtarjuaq, Clyde River, Pond Inlet). Seventy-seven evaluations were collected these communities. This first evaluation form was designed with little input from those planning the tour and it was felt that more useful information could be collected.

A *second* evaluation form was then developed in collaboration with DIAND and DHSS over a very short time period. It was hoped the new form would help evaluate which details were being retained and what segments of the presentation were of greatest interest. This form was utilized for the rest of the tour. The total number of evaluations collected from the remaining 12 communities was 105.

A grand total of 182 evaluation forms were received from all visited communities. These forms are tabulated and transcribed as they were written in **Appendix A** (Evaluation Form #1) and **Appendix B** (Evaluation Form #2). Only a very few forms were not translated into English from Inuktitut, however any comments from these forms are not recorded.

## Results and Discussion

The evaluations and questions received during the tour clearly emphasize Nunavummiut are concerned about their health. They are interested in understanding what constitutes a healthy diet whether it be their country food or non-traditional. They are anxious to understand if there are risks to their health associated with their country food, and what can be done about this. While regional centers and decentralized communities are more likely to have available resources, access to information in Nunavut is variable, and most definitely not equitable. The Niqiit Avatittinni Community Tour was successful in reaching out to 20 of the 25 communities, providing an opportunity for Nunavummiut to be informed and ask questions.

The tour may perhaps have been ambitious in attempting to provide a large amount of information in a short presentation time. The necessity was (1) to take advantage of limited opportunities to visit the communities, as well as (2) the acknowledged need to ensure the tour was a well rounded approach to healthy choices in the context of the contaminant message. Many community members expressed their appreciation that the tour came to their community. They felt the issues are important and were very interested to come to upcoming NAC presentations.

## Conclusions and Future Considerations

### *Future Niqiit Avatittinni Community Tours*

It was recognized by all involved that preparation (content and logistics) for the Niqiit Avatittinni Community Tour was done over a very short time period. Allowing more time for planning and preparation of the tour prior to its commencement would likely have limited concerns about the length of the presentation as well as the variability in advertising and ensuring the targeted groups were present. More time would also have been made available to identify and discuss key messages to be presented and reinforced, to fine tune the overall presentation, arrange for translation, and discuss concerns and suggested revisions with NAC input. This was not really possible in the lead up to the tour. To complicate matters, a final consensus on the Public Health Message was agreed only several days before the beginning of the tour.

After observation and discussion with several tour participants regarding planning and logistics on the tour, the following suggestions may be considered in planning future events.

### *A. Content*

It would be useful to have expertise in environment, contaminants and health available for the entire tour, to answer specific questions put forth by the community. It would be recommended that the most knowledgeable presenter or tour participant act as a resource to decrease the risk of confusion and maintain accurate, Nunavut-specific responses.

Given the significant number of questions about the health of animals in the north, the inclusion of a participant/presenter with wildlife expertise would have been beneficial and could perhaps be a consideration for a subsequent tour.

### *B. Logistics*

Consider arranging the Community Liaison Officer (CLO) or another designate (i.e. Regional Inuit Organization Representative) involved in the planning of the presentation in their community. This person could be hired for 1-day prior, and the day of the meeting to:

- Arrange transportation in town other than taxi (which is often slow and usually expensive) to meet group at the airport and bring to the meeting venue.
- Ensure that equipment is available and ready to use.
- Ensure that coffee and tea with associated supplies are available for the meeting.
- Ensure adequate advertising.

### *C. Advertising*

Sustaining communication with communities to ensure message about meeting getting out was not always occurring. Arranging advertising from the Iqaluit office was not always feasible or successful. Community members complained in the evaluations about the limited advertising, or that the meeting was not at all what had been described on the radio (Pangnirtung). A more concerted effort could be made to improve the advertising of the event for several days before the arrival of the tour. These efforts would keep the tour in the forefront of peoples attention.

A generic, colourful poster that is laminated and sent to the communities would be a useful advertising tool.

- There would be space on these posters to enter the date and time of the event in each particular community.
- These posters can be sent to the communities well ahead of time and be put up by the Regional Inuit Representative/CLO/other designate in places like the HTO, Health Center, schools, Northern, Coop, and elders centers.

As part of their contract, the NTI rep/CLO/other designate could also be made responsible for arranging advertising by other media:

- Scripted radio PSA, CB announcement, messages on the Co-op TV Station and arranging for information handouts to be placed in all mailboxes the day before the event.

### *D. During the Presentation*

Allow scheduled time for a coffee break and inform the meeting participants that this will be occurring.

- To bring people back to the meeting have a draw after the break.
- In Arviat the coffee and bannock came out just as Jim began giving his health message. Most people headed for the coffee table and did not hear the information.

Perhaps reconsider the timing and format of the presentations. Evening presentations are likely a better option in the larger communities.

- The concern that an evening presentation would result in a poor turnout proved not to be the case in Coral Harbour.
- Inuvialuit had evening presentations, which apparently went well. It might be worthwhile speaking more with tour organizers from that region.
- Given the poor turnout of community presentations in Iqaluit and Rankin Inlet, and the relatively large turnout in Coral Harbour for an evening presentation it would be worth considering loosening the initial NAC plan for afternoon sessions. This experience supports other comments made during the tour that if the tours were in the evening there would be more people.
- Another suggestion would be a 'health fair' while waiting for the feast to begin. This could be a time to set up information tables or give an educational talk while people are waiting for the feast to begin.

***Drawbacks***

- Transitioning from the feast to presentation can be tricky.
- The presentation cannot be too long.
- Many children will be there which will cause distraction as well as dictate the length of the event.
- May not reach the targeted audience identified by the NAC.

***Advantages***

- Likely to have many more people attending the evening event than one in the afternoon.

Door prizes are useful for attracting more community members

- $200 per community; Gift certificates and donations from local business.
- Additional prizes for children (which focus on health or development) might want to be considered.
- Allow for breaks before each prize draw. This was also mentioned in the evaluations.

As much as possible have Inuit giving the presentations.

- This not only builds capacity, but also several evaluations specifically commented on the importance of Inuit speaking about country food.

***E. Evaluation Forms***

An evaluation form, which assesses community interest and information retention, could provide useful direction for planning further health promotion strategies. A better evaluation would have been developed given enough time and thought. It is suggested that the evaluation form be considered earlier in the planning of the tour.

- A possible suggestion for the next tour might be to have the registrations and evaluations on the same form. In this way the number of people who stayed for the entire presentation would be able to give the most valuable feedback, and it would give a true reflection of participation.
- Evaluation forms with the contributor's sex and age would be informative for directing future health promotion activities and direction for NAC and NCP activities.
- In the future it may be more beneficial to discuss with the NAC/NCP what the specific messages for the tour would be and have those reflected in the evaluation.
- Pre-testing of the evaluation would also be a beneficial step if using the evaluations for future planning.
- Building translating of the evaluation/registration forms into the contract terms for the interpreter accompanying the tour will limit the problems experienced in attempting to have them translated for review afterwards.

***F. Registration Forms***

These forms could be used to estimate the attendance of audience members that the tour is hoping to reach. The use of check boxes (for each of the target groups) that the individual can fill in would make it easier and take out the guesswork

## Expected Completion Date

This project was completed on March 26, 2004. However, several communities were missed from the tour this year, and it is planned to visit these communities in the near future

## Acknowledgements

Special thanks goes out to all of those who participated in the tour, especially Sylvia Cloutier, who kept things running smoothly. Mary Potyrala also deserves special mention for preparing the Post Tour Summary Report, on which this Synopsis Report is based.

## Appendix A: Evaluation Form #1

**(Total of 77 from 8 Communities)**

(Cape Dorset, Kimmirut, Grise Fiord, Resolute Bay, Pangnirtung, Qikiqtarjuaq, Clyde River, Pond Inlet)

**1. Did you find the presentation/workshop understandable?**

The overall majority of comments were very positive. The communities found the presentation understandable and they learned a lot. One person complained that the presentation was too long (Clyde River) another did not appreciate the presenters moving about so much (Pangnirtung), and a third commented the dialects were difficult to understand (Cape Dorset).

**2. Did you find the presentation/workshop helpful?**

Feedback was very positive as it was reiterated that their health is important to them. The nutrition and contaminants section were stated to be very useful information. One person felt 'more comparison between store bought food and country food should be dealt with especially with students around' (Grise Fiord) and another commented 'from now on I'll know what helps the baby grow' (Pond Inlet). Several others commented that the contaminants information was important since it was becoming more of a problem in the north (Cape Dorset, Grise Fiord).

**3. Do you have any questions concerning the topics discussed today?**

Most people seemed to understand the messages about country food consumption. One reported being confused as to what to eat now (Pond Inlet). Questions came from every area of the presentation: more information on Trichinella (Grise Fiord), where do POP concentrate (Resolute Bay) and what levels are considered tolerable by Health Canada (Pond Inlet)?

**4. Do you have any related concerns that were not addressed in this workshop?**

There were not too many answers stated here. Comments ranged from concern about nuclear fallout (Grise Fiord) and bombs (Pangnirtung), to political action (Resolute Bay) and compensation for past contamination of local sites (Cape Dorset).

**5. Would you feel comfortable contacting the Niqiit Avatittinni Committee in the future about the topics talked about today?**

In general people felt comfortable contacting the NAC. Several were not sure how to do this. Two comments from Pond Inlet identified concerns to be put forth to the NAC: (1) *More campaigns on poor habits, availability and quality of fresh produce-especially in winter seasons. Social awareness campaign –esp. on effects of poor nutrition. (2) I would like to know which foods are NO GOOD FOR YOU.* A Grise Fiord resident suggested that contact details for the NAC be provided to all major organizations, including the Hamlet and schools.

**6. Would you attend another NAC Tour in the future?**

There was an overwhelming interest in coming to another presentation. Requests were made for better advertising prior to the next visit.

**7. Is there anything else that you would like to tell us?**

Most respondents thanked the tour for coming to their communities, some wanted to know when the next visit would be. There were diverse opinions about the appropriate length of the presentation; 'It is important that the presenters keep their talk short and sweet and <u>have only Inuit people make presentations on country foods</u>' (Clyde River) was balanced with 'Do not rush the session which would be great' (Cape Dorset). There were suggestions that more be discussed about plants and berries (Cape Dorset & Qikiqtarjuaq), dry food (Kimmirut), and more elaboration about sugars and fats (Resolute Bay).

## Appendix B: Evaluation Form #2

**(Total of 105 from 12 Communities)**

(Igloolik, Iqaluit, Whale Cove, Arviat, Repulse Bay, Coral Harbour, Rankin Inlet (not attended), Kugaruk, Taloyoak, Gjoa Haven, Kugluktuk, Cambridge Bay)

**1. What made you come to this workshop?**

This question was not very specific, though respondents were telling us that they are concerned about their health and wanted to know more information about contaminants and country food. Nearly half (43) of the 105 evaluations stated they were invitees to the meeting.

**2. Which information of the workshop did you find useful?**

'Keeping country food safe' garnered the highest number of checkmarks. However that number should be evaluated with consideration of the progression of changes that occurred in the tour presentation. This part of the presentation originally was planned to discuss context-specific Environmental Health (EH) concerns. As the tour continued and changes were made, EH concerns were vastly shortened. The content was incorporated into the presentation, and not under a specific 'Keeping Country Food Safe' segment. Therefore it is unclear how the respondents perceived this particular heading. The information about environmental contaminants and nutrition are both highlighted as useful, and the health messages a little less so. The fat and sugar demonstration was an extremely effective and popular hands-on educational tool that garnered a high level of interest.

**3. How did the workshop benefit you?**

Most people provided an answer to this question. Many respondents felt they learned a great deal of new information about nutrition and environmental contaminants. They pointed out that they were more aware of making appropriate dietary choices, the nutritious value of their country food, and better understand the issues associated with environmental contaminants and country food. Several communities stressed the need to make more effort to teach youth to make better food choices (Repulse Bay, Iqaluit, Whale Cove). One respondent stated 'I learned that country foods help prevent diabetes, too' (Coral Harbour). It is difficult to know if this answer was given in understanding that diet is only one aspect of the diabetes puzzle.

**4. What can a pregnant woman do to help their unborn child become healthy, smart and strong?**

Respondents in Igloolik, Iqaluit, Whale Cove and Cambridge Bay were able to list the major prenatal activities that reduce risk to the unborn child (smoking, drinking, drugs, eat country food but reduce marine mammal fat consumption), however breastfeeding was not mentioned. Arviat gave very limited responses (eat char, smoking, good nutrition), though perhaps this can be attributed to most people being diverted to the coffee and bannock that were put out at the beginning of the discussion on the public health message. Repulse Bay, Taloyoak and Kugluktuk where the only communities to mention breastfeeding. A Taloyoak mother lamented the inability to breastfeed her adopted children, which was similar to an experience that occurred in Arviat after the presentation was over. People were VERY clear that arctic char, caribou and muskox were excellent choices as they were low in contaminants, but there were NO respondents who mentioned limiting seal liver during pregnancy.

**5. Do you have any other questions about the issues talked about today?**

Some respondents were not clear what environmental contaminants would do to their bodies (Coral Harbour, Iqaluit, Kugluktuk). Others were curious about environmental concerns such as toxin levels around garbage/dumps (Iqaluit, Repulse Bay), DEW line sites (Igloolik), and airline exhaust (Taloyoak). Another respondent wondered how mining would affect the water quality (Kugluktuk). Many respondents again stated their appreciation for the tour and stressed the need to further reach out to the youth (Taloyoak, Cambridge Bay) and prenatals (Iqaluit).

***Attendance/Registration Forms (Kivalliq and Qikiqtani)***

Since information was missing on a significant number of registration forms the 'identified' numbers do not equal the TOTAL. Registration forms and number of male/female participants may not necessarily add up. A fair number of forms had various particulars missing such as sex, age and/or employment status.

***Sex and Age Bracket of those who completed registration forms in Qikiqtani and Kivalliq Regions***

It was clear from personal observations that while many people registered for the presentation, they did not necessarily stay until the end. Registration numbers are therefore not necessarily a true representation of the number of people in the community who were present from start to finish. A more noteworthy example from early in the tour would be Pangnirtung, where 101 persons registered but by the end it was noted that no more than 30 people were present. Over the months, as the presentation was shortened and became more concise this was likely less of a concern. Apparently in comparison to previous NCP tours, community participation has apparently increased substantially.

***Attendance by Target Groups (Kivalliq and Qikiqtani)***

When planning for the tour, certain target audiences were identified by the NAC as important groups to disseminate the information to. While the presentations were open to everyone, specific invitation letters where sent out in hopes to raise the presence of HTO/Hunters, Hamlet workers, Elders, local representatives of Inuit organizations, health practitioners, store workers, youth and educators.

Because the registration forms did not include a section for elderly, it is difficult to know how many Inuit seniors attended the presentation. Elder in this case is a (40+) distinction based on determined age brackets on the registration forms.

Those who identified themselves on the registration forms as targeted audience members for the NAC Tour (Qikiqtani & Kivalliq regions only)

***Community Questions and Comments***

Not all communities had questions or comments. Qikiqtarjuaq shared a few comments. Kugluktuk, Gjoa Haven, Arviat and Clyde River had no questions. The queries from Repulse Bay and Coral Harbour were recalled after the presentations and it is likely not a complete list. Whale Cove, one of the smallest hamlets in Nunavut yielded many questions, possibly due to the small group and intimate atmosphere of the venue.

Most responses appear to focus primarily on further clarification about environmental contaminants. People also felt it was important to provide more education and information on nutrition to all Nunavummiut, most particularly the youth and prenatals. A woman in Taloyoak was concerned about the brevity of the presentation and stressed that an evening meeting would have drawn more of the community member. A review of the compiled queries and comments identified these main issues:

*Environmental Contaminants*

- Limitation of discussion on the safety of certain country foods (vegetation and birds): berries, plants, sculpin, ptarmigan, musk ox, other birds etc.
- More elaboration requested on the negative health impacts of environmental contaminants on humans.
- How to identify country food affected by environmental contamination. How to know if it is safe to eat?
- How does food preparation change the amount of contaminant intake, i.e. dry, cooked or raw? Also further distinction about the safety of the various kinds of marine mammal fats (misiraq, whale fats, aged fats).
- Human health risks from pollution of water sources and environmental contamination from DEW line sites, heavy-duty equipment, diamond mines, paints etc.
- Action by Canada to limit environmental contaminants locally and internationally.

- Interest in knowing whether southern food is also contaminated (animals, fruit and vegetables.

*Nutrition*

- Understanding the effects of sugar on the body and what is an acceptable level of intake (Likely asked in consideration of the increasing awareness of diabetes).
- Elaboration on healthy and unhealthy fat/oil choices, and measures to improve dietary intake.
- Stressing the need to ensure youth are informed about appropriate dietary choices.
- Increasing the number of youth (and prenatals) at any future presentation.
- Increasing the accessibility and affordability of country foods.
- Affirmation of the health benefits of country food.

# Sahtu Dene Council Participation with the Northwest Territories Environmental Contaminants Committee (NWT ECC) and Radio Talk Show on Contaminants


## Project leader(s)

Bella T'Seleie on behalf of the Sahtu Dene Council, P.O. Box 155 Deleine, N.T. X0E 0G0; phone: (867) 598-2148; fax: (867) 598-2148, e-mail: bedavidson@shaw.ca

## Project 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 Northwest Territories Environmental Contaminants Committee (NWTECC) - The communications network used for obtaining information concerned with contaminants and relaying community concerns to governing bodies, scientists committed to Northern research and the research institutes. The committee also is responsible for accepting or denying research carried out under the Northern Contaminants Program (NCP), as it relates to proper consultation and communications of results.

2. Radio talk show communications on contaminants related to the NCP. The goal of the radio talk shows were to development an open dialogue between community members and the Contaminant Coordinator and to provide an opportunity for people express their contaminant concerns. Also, the radio talk shows provided communication of NCP in both English and Slavey languages.


## 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 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 NCP and other contaminants related programs.

2. To establish a communications network that ensures communities are informed and involved in contaminants related activities which 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.

7. Radio Talk Show Objectives- to inform the public both young and old in all communities about contaminants in which to gather information regarding next steps, recommend, short and long term goals in order to enhance and develop what has already been implemented.

## Introduction

The NCP is now in a transition year from the second phase to the third phase with more than twelve years of research to date. The program has evolved to include NWT communities and regions extensively in research and communication efforts. This has increased the need to have a central body that can coordinate contaminants information and research initiatives.

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.

## Activities

## In 2003-2004

Participation in the NWTECC meeting

Included:

- Participation in monthly conference calls
- In-person meeting in Yellowknife (November 26-28, 2004)
- Participation in the NCP Frontline Training Session (March 2-3rd)
- Social/Cultural Review of NWT scientific proposals funded under the NCP (March 3-4th)
- Proposal preparation for next year
- Final reporting

Radio Talk Show

- Regular morning talk shows from community radio station.
- Information communicated in both English and Slavey language regarding contaminant research and scientific studies already conducted in the Sahtu.
- Invitations extended to community members to bring contaminant concerns to the attention of the Sahtu Contaminant Coordinator.
- The radio talk show will also make it known that people can approach the Sahtu Coordinator with any concerns regarding these type of issues.

## 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.

Radio Talk Show

Regular radio talk show information session conducted. A number of contaminant issues raised by community members as a result of these information sessions.

## Discussion and Conclusions

The Sahtu Contaminant Coordinated noted that there was evidence to suggest major communication gaps where scientists doing research in the north needed to take time to translate the research results back to the communities and the coordinators do not have the training to interpret scientific information.

Accordingly, there is a sense that more work is needed in the area of translating scientific information to community members, preferably both in English and Slavey languages.

# Gwich'in Tribal Council Communication & Education of the NCP-CACAR II


## Project leader(s)

Tom Williams, Chief Operating Officer, Gwich'in Tribal Council, P.O. Box 1509, Inuvik, NT X0E 0T0; phone: (867) 777-7900; fax: (867) 777-7919, e-mail: twilliams@gwichin.nt.ca

## Project members

John Edwards, Gwich'in Tribal Council; Designated Gwich'in Organizations, Gwich'in Renewable Resource Councils, NWTECC



## 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 and participate in research programs established by the Northern Contaminants Program (NCP).

The Gwich'in Community Liaison will continue to promote dialogue and information between the Gwich'in communities, Gwich'in Organizations, NCP representatives, and NCP scientists.

Gwich'in Tribal Council (GTC) GCL has participated in monthly Northwest Territories Environmental Contaminants Committee (NWTECC) meetings, liaison of relevant contaminant information materials, and joint Local Contaminants Concerns (LCC) with Julie Ward, DIAND, Environmental Specialist, Contaminants Division, Yellowknife, N.T., Chris Paci, Manager, Land & Environment, Dene Nation. Brett Elkin, Disease/Contaminant Specialist, Department of Resources, Wildlife and Economic Development. Barbara Armstrong: Inuvialuit Regional Contaminants Coordinator,

- Preliminary inventory of LCC mapping in the Gwich'in Settlement Area (GSA): Martin House 2004
- Monitoring the Health of Dene: A Preliminary assessment of Heavy Metal, Organochlorines, and Radionuclide levels in Boreal Woodland Caribou, Moose, and Dall's sheep 2003
- Bootlake Leachate Study 2002
- Member of the NWTECC Meetings.
- Community Liaison of Canadian Arctic Contaminants Assessment Report (CACAR) II and NWT Contaminants Fact Sheets


## Key Project Messages

1. The Gwich'in Community Liaison will continue to promote dialogue and information between the Gwich'in communities, Gwich'in Organizations, NCP representatives, NCP scientists.
2. The GCL has attended workshops and training courses to enhance his capacity to carry out the duties of the GCL position.

## Objectives

The GCL will facilitate the process of collaborative study, assessment and communication of information to residents of the GSA about the presence and possible effects of contaminants in the air, land, water and wildlife. The GCL's goals are to:

1. To promote the role of the GTC as a partner in the NCP
2. To assist the Gwich'in Communities to identify research & 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.
8. To review NWT Proposals for the NCP prior to full technical reviews.

## Introduction

This is the fifth year that the GTC has been actively involved in the NCP. Over the course of involvement with the NCP the Gwich'in representative for the GTC has established a very good track record. The GTC is confident that the GCL will continue this successful relationship in the future with NCP.

The following concerns have been identified:

- Persistent organic pollutant (POP) levels in caribou. Due to the importance of the Caribou to the Dene/ Gwich'in culture, continued long term monitoring of caribou health is essential. Caribou should be sampled every few years, at a minimum.
- Health – The relationship between contaminants in the food chain and the environment and elevated incidences of cancer and diabetes in local communities such as Fort McPherson and Aklavik.
- Local contaminants – The by-product of the oil and gas exploration in the past and with the recent activity for the future in the GSA.
- Water quality in Gwich'in communities. There is a concern of very poor water quality in Gwich'in communities.
- Uptake of contaminants in beaver and muskrat of the Mackenzie River Delta. Beaver and muskrat meat in the Gwich'in settlement area is safe to eat and can continue to form part of the traditional diet.
- Bootlake Leachate Study 2002 w/ Inuvialuit Contaminants Coordinator
- Monitoring the Health of Dene: A Preliminary assessment of Heavy Metal, Organochlorines, and Radionuclide levels in Boreal Woodland Caribou, Moose, and Dall's sheep 2003 w/ Dene Nation and DREWD
- Preliminary inventory of LCC mapping in the GSA: Martin House 2004 w/ DIAND and Dene Nation.

## Activities

## In 2003-2004

- The GTC-GCL attended monthly meeting with the NWTECC by phone and in-person meetings.
- Identified a LCC project from a concerned Gwich'in Beneficiary in August 2003. The area of concern was in the Martin House Area, which is located 65 km south of Tsiigehtchic, N.T. on the Arctic Red River. Went out in January 2004 to do Soil and Water sampling, Analysis for the final report will be due in April 2004 so a draft report will handed in by March 31, 2004.
- On-going communication of the results from the CACAR II as well as the NWT Fact Sheets, due to communication strategy breakdown, this will be on-going in 2004-2005.
- Continue to relay information to the Gwich'in communities through the GTC-GCL and Aboriginal partners to the NWTECC, which will relay major concerns to the NCP management committee and vice versa.

- Participated in a two day in-person meeting, which was held by the NWTECC in November 2003. This meeting was to discuss communications strategies and action plans for the communication of CACAR II. Discussions included the use of focus groups for key message testing for CACAR II, communications materials including fact sheets, newspaper inserts, public service announcements, and the NWT ECC newsletter. Also to review Social/Cultural review and Education and Communications proposal review March 2004.

## Results

The Gwich'in Community Liaison participated in the following projects:

- Contaminant Sampling at Martin House 2004 (Gwich'in Tribal Council) Will present the report results back to Gwich'in Tribal, the Local Renewable Resource Councils in the GSA, and Northwest Territories Environmental Contaminants Committee.
- A Preliminary assessment of Heavy Metal, Organochlorines, and Radionuclide levels in Boreal Woodland Caribou, Moose, and Dall's sheep 2003 (Dene Nation and DREWD) Will present the report results back to Gwich'in Tribal, the Local Renewable Resource Councils in the GSA, and Northwest Territories Environmental Contaminants Committee. Contaminants sampling at the Inuvik Landfill (Inuvialuit Regional Corporation) Will present the report results back to Gwich'in Tribal, the Local Renewable Resource Councils in the GSA, and Northwest Territories Environmental Contaminants Committee.

## Discussion and Conclusions

In 2003-2004, the GTC-GCL has addressed and continues to address concerns of the residents of the Gwich'in Settlement Area by gathering, organizing, and distributing information, and initiating research programs. The GTC-GCL has attended workshops, training courses, and meetings to enhance his capacity to carry out the duties of the GCL position.

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.

## Expected Project Completion Date

The GTC-GCL will continue to represent the Gwich'in Beneficiaries by continuing to be a part of the NWT-ECC, and addressing concerns relating to Contaminants in the Gwich'in Settlement Area, and the Northern Ecosystems.

# International Policy

# Effective Translation and Use of Inuit-Specific CACAR II Data in International Circumpolar, National, and Local Fora


## Project leader(s)

Stephanie Meakin M.Sc. Technical Advisor Inuit Circumpolar Conference (Canada) 170 Laurier Ave West, Suite 504 Ottawa Ontario K1P5V5; Phone: (613) 563-2642/direct (613) 258-9471 Fax: (613) 565-3089 direct (613) 258-7621email: smeakin@allstream.net

## Project members

Sheila Watt-Cloutier, Chair Inuit Circumpolar Conference P.O Box 2099 Iqaluit, NU X0A 0H0; Phone: (867) 979-4661; Fax: (867) 979-4662; E-mail: icccan@nunanet.com; Duane Smith President P.O. Box 2120 Inuvik, NT X0E 0T0; Phone: (867) 777-2828; Fax: (867) 777-2610; E-mail: igc-c@jointsec.nt.ca; Terry Fenge PhD Strategic Counsel to the Chair Inuit Circumpolar Conference 170 Laurier Ave West, Suite 504 Ottawa ON K1P5V5; Phone: (613) 563-2642/direct (613) 722-7006; Fax: (613) 565-3089; E-mail: tfenge7006@rogers.com; Eric Loring, Senior Environment Researcher Inuit Tapiriit Kanatami (ITK) 170 Laurier Ave. Suite 510 Ottawa, ON K1P 5V5; Phone: (613) 238-8181 x 234; Fax: (613) 233-2116; E-mail: loring@itk.ca



## Abstract

The NCP Priority Action Plan for 2003-2004 identified Inuit regions at the 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 Long-range Transboundary Air Pollution (LRTAP) and Stockholm agreements are achieving the reductions in human exposures in the Arctic" was identified as an area of interest. Inuit Circumpolar Conference (ICC) Canada undertook a number of activities 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. These activities and their products were to ensure that the Inuit specific results within Canadian Arctic Contaminants Assessment Report (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 Project Messages

1. 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.
2. Regional and international policy instruments and activities are reducing the amount of certain legacy contaminants to the Arctic.

## Objectives

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.

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 2003-2004

ICC Canada using CACAR II has contributed to the Arctic Contaminants Action Plan (ACAP) Mercury Program, the United Nations Environment Programme (UNEP) Global Mercury Progamme and North American Free Trade Agreement (NAFTA) Commission for Environment Cooperation (CEC) Mercury North American Regional Action Plan (NARAP).

An Inuit specific mercury case study is under preparation; related to Inuit exposure, diet and health concerns for use in international, circumpolar and regional initiatives.

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.

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 developed on Stockholm, and the CEC Lindane Taskforce process and were distributed at the National Inuit Environment Committee meeting, the CEC Lindane Taskforce meetings, INC 7 in Geneva in July 2003 and the Alaska Forum on the Environment in 2004.

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 LRTAP persistent organic pollutants (POPs) heavy metals protocols, Stockholm Convention, the UNEP Global Mercury Programme, the Arctic Council 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.

## Results/ Discussion and Conclusions

- **Stockholm Convention**

ICC has undertaken significant international advocacy through letters, speeches, presentations and personal communication with countries to encourage ratification. The Convention will enter into force May 17, 2004. ICC continues to prepare for the Conference of the Parties in Uruguay in 2005.

- **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 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.

- **Communications**

ICC Canada's web site has been improved and new material is being added regularly, including all speeches delivered by the Chair. Ms. Watt-Cloutier has given numerous interviews to both Canadian and international media, including BBC, CNN, CBC, and newspapers including the Washington Post, New York Times, Los Angeles Times, and The Independent, and she is now the acknowledged political spokesperson for Arctic perspectives on climate change and transboundary contaminants. Sheila Watt-Cloutier will receive the Canadian Aboriginal Achievement Award for the Environment in April 2004.

## Expected Completion Date

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 who are on the ground, and John Buccini who opened doors at the UN and held them open for Inuit.

# Program Management

# Public Management of Environmental Health Information: Nunavik Nutrition and Health Committee (NNHC)


## Project leader(s)

Suzanne Bruneau, Coordinator NNHC, Public Health Research Unit, CHUL - CHUQ Research Center 945 Wolfe, Sainte-Foy, QC; phone: (418) 650-5115 ext. 5259; e-mail: suzanne.bruneau@crchul.ulaval.ca; Chris Furgal, Nasivvik – Centre for Inuit Health and Changing Environments - Public Health Research Unit, CHUL - CHUQ Research Center 945 Wolfe, Sainte-Foy, QC; phone: (418) 650-5115 ext. 5260; e-mail: christopher.furgal@crchul.ulaval.ca

## Project members

Minnie Grey, Chairperson, Nunavik Nutrition and Health Committee; e-mail: minnie.grey@sympatico.ca.; Serge Dery, Jean-François Proulx: Public Health Department, Nunavik Regional Board of Health and Social Services Kuujjuaq, J0M 1C0; phone: (819) 964-2222; fax: (819) 964-2888; e-mail: serge_dery@ssss.gouv.qc.ca and jean-francois.proulx@ssss.gouv.qc.ca; Michael Kwan, Manon Simard, Makivik Research Centre, Kuujuaq, J0M 1C0; phone: (819) 964-2951; e-mail: m_kwan@makivik.org and m_simard@makivik.org; Shirley White-Dupuis, Tullatavik Health Centre, Kuujuaq, J0M 1C0; phone: (819) 964-2905; e-mail: shirley.dupuis@ssss.gouv.qc.ca; Minnie Abraham, Kativik Regional Government (KRG), Kuujuaq, J0M 1C0; phone: (819) 964-2961; e-mail: mabraham@krg.ca; Eric Loring. Inuit Tapiriit Kanatami (ITK) 170 Laurier Ave, Suite 510 Ottawa, Ontario K1P 5V5; phone: (613) 238-8181 ext. 234; e-mail: loring@itk.ca


## Abstract


The Nunavik Nutrition and Health Committee (originally named the PCB Resource Committee) was established in 1988 to deal with issues related to food, contaminants, the environment and health in Nunavik. Since its' inception, the committee has broadened its' perspective to take a more holistic approach to environment and health issues inclusive of both benefits and risks. Today, the committee acts as the authorized review and advisory body for health and nutrition issues in the region and includes representation from many of the organizations and agencies concerned with these issues, as well as those conducting research on them. The committee provides guidance and acts as a liaison for researchers and agencies, from both inside and outside the region, directs work on priority issues, communicates to and educates the public on health and environment topics and research projects, and represents Nunavik interests at the national and international levels. All activities are conducted with the goal to protect and promote public health in Nunavik, through more informed personal decision-making.


## Key Project Messages

1. The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik;
2. The committee originated in 1989 and supports the activities of the Public Health Director in advising and educating the public on food and health issues, including benefits and risks associated with contaminants and country foods
3. The committee continues to be active within the NCP, reviewing and supporting research in the region, liaising with researchers, and helping in the communication of research

results in a way that is appropriate and meaningful to Nunavimmiut.

## Objectives

- To provide the population and health workers with background information to help them understand and contextualize environmental health, nutrition and contaminants research, objectives and results;
- To compile elements of public concern that have not been addressed to date, and to steer and support research activities towards providing the data needed to address these concerns;
- To undertake public communication of environmental health data, including results of Northern Contaminants Research Projects, and help develop regional communications and evaluations strategies for this information;
- To prepare state of the knowledge summaries on these issues to assist in communication and intervention activities of local health and environment officials;
- To facilitate research on environmental communications and risk perception issues;
- To help researchers translate their data into meaningful information for the public;
- To support partnerships in various research and intervention activities related to country foods, nutrition and health.

## Introduction

In Nunavik, a group of individuals representing different organizations concerned with health, the environment, and nutrition issues formed to address these topics and communicate with / educate the public so that they may make more informed personal decisions. The group, the Nunavik Nutrition and Health Committee, evolved from the PCB Committee, created in 1989 and later renamed the Food, Contaminants and Health Committee. The name has changed over the years as the group has learned of the importance to not only focus on negative impacts of contaminants, but the need for a more holistic approach to nutrition, health and the environment including benefits as well. On an ongoing basis, the committee addresses a number of issues relating to food, contaminants, nutrition and health and the relationship to the environment.

This evolution and recognition of the NNHC places it in an important role in addressing issues related to contaminants, food, health and the environment in the region. The Committee is therefore well positioned, and has the necessary capacities to support research activities (through review, facilitation, and communication) related to these issues under the Northern Contaminants Program as a regional contaminants committee. This report represents a synopsis of the committee's activities for the 2003-2004 year.

## Activities

### In 2003/2004

**Committee meetings**

The committee meets regularly through the year with special meetings being held (if needed) to respond to immediate issues. This past year the committee held 3 general meetings (Kuujjuaq, Quebec, Montreal). At these meetings the committee addressed a number of issues: past and current business were discussed as well as research projects lead by the committee and dissemination of results from other research projects. Furthermore, the committee held two conference calls, the first to discuss research results coming from a study conducted by Dr. Dewailly and his collaborators and the other to evaluate projects submitted in 2004 to the NCP.

Finally, the committee held a 1 ½ day special meeting in March at Mont-Gabriel, north of Montreal to discuss the orientation and future of the NNHC. For this special occasion, regular membership was increased to include Nunavimmiut from different organisations (KRG, Innulitsivik maternity ward, Inukjuak CLSC, Municipal office of Kangirsuk, Northern Quebec Coop Federation), as well as nutritionists and a research nurse (CHUL Public Health research Unit and the Nunavik Regional Board of Health and Social Services.

Below, a summary of the issues discussed and addressed at meetings, and activities of the committee throughout the year is presented.

***Food safety and security***

The committee regularly reviewed updates of the botulism response and trichinella detection programs operated by Nunavik Public Health Department in partnership with the Kativik Regional Government (Hunters Support Program) and Makivik Research Centre (laboratory testing of samples), providing advice for communication of information and public education strategies during hunting seasons.

***Trichinella***

An information pamphlet on this issue is updated every year and distributed to all communities and organizations. Furthermore, hunters participate actively in the monitoring program by sending samples for analysis to the research lab at Makivik.

***Botulism***

Prevention of botulism is an important ongoing issue for the committee. A Public Health representative does a regular radio-show each year to remind people of the importance of aging food in a very cool place and storing it in containers (not plastic bags), to allow air to circulate around the meat. Additionally, a prevention message is broadcasted regularly on the regional radio.

***Toxoplasmosis***

Toxoplasmosis infection is quite rare; however, as we still do not know a great deal about vectors and cycles of this disease, it was recommended that antibodies continue to be screened at the beginning of pregnancies. The Nunavik Clinical Prevention Committee is assuring the update of information for toxoplasmosis.

***Research liaising***

NNHC members acted as liaisons between researchers and specific communities to gain the proper authorization and facilitate the conduct of appropriate consultation with community councils, health officials, and potential participants in the region. Similar support is provided by the committee for projects funded within the region and conducted by various organizations on priority environmental health issues including those related to contaminant exposure and human health. The committee also provided support in the form of reviewing results and recommendations for communication / dissemination activities on many projects.

In some cases, the committee also worked with researchers to suggest needed research projects in the future to address identified priority environmental health issues. A project monitoring the effectiveness of the ban on lead shot in the region was implemented as a result of these efforts. This intervention on the use of lead pellets was deemed successful in Nunavik in the past year. The public awareness campaign has changed the practices of hunting in Nunavik. Recent data shows that the average blood lead level of the residents of Nunavik is decreasing and will probably continue to decrease in the future. However, monitoring will be conducted to continue to make sure lead levels are still low.

***Contaminants in Nunavik***

Monitoring new contaminants is now an important issues fro the NNHC. Results from recent cord blood analysis shows that contaminants that come from the utilisation of products like Scotch Guard (protection of furniture tissues) and also flame retardants (PFO's and PBDE's, chlorophenols, Hydroxy PCB's and methylsulfone PCB's) found in all electronic devices are increasing in Nunavik. The committee is closely following results from cord blood monitoring studies to keep informed and to educate Nunavimmiut about these results, the possible health effects and potential solutions to decrease or minimize exposure from these contaminants.

***Research Projects***

The committee continues to review, provide advice and encourage valuable projects relating to environment and health issues in the region such as the Food Security and Sustainable Development project, the Climate Change and Health project (both of which were finalized this past year), and many of those conducted under NCP.

Furthermore, the committee had its own research project this year. The project entitled "*Nunavik Communications Survey on Return of Results from the Infant Development Study*" was conducted to learn more about what Nunavimmiut women have heard about the study done on country foods, mothers' and infants' health (Investigor: Dr. Gina Muckle). A consultant was hired and travelled to the three communities of Puvirnituq, Inukjuak, and Kuujjuaraapik in order to conduct the survey with women between the ages of 18-45. The survey was designed to document if and what women of childbearing age (WCBA) heard about the results which were returned in spring of 2003 from the 7 years of research done by the Public Health Research Unit at Laval University on Nunavik mothers' and infant development. In all, we conducted surveys with 58 Nunavimmiut women between the ages of 18 – 45: twenty (20) women from Puvirnituq, twenty-four (24) from Inukjuak, and fourteen (14) from Kuujjuaraapik.

Analysis of the survey is presently underway and will be available soon. Through analysis, some major trends will be identified, especially on the general status on awareness level of contaminants issues and on how few women have heard and/or remember the return of results on the infant development studies (as shown in preliminary review f the data). The results will also determine if the women who did hear the results or were engaged in the project have an increased awareness/knowledge of the study and contaminant issues in general.

***Communication Activities***

The committee is active in communicating information relating to health and nutrition issues as well as preparing, reviewing and supporting communication activities of researchers conducting work on these issues in the region. Last year a tour of 3 communities, set-up to communicate research results from the infant cohort study confirmed the importance of continuously updating information and disseminating basic information on contaminants, nutrition and health and research done in Nunavik. Additionally, last year's communication of CACAR II results inspired the committee to develop a series of communication tools for Nunavimmiut.

The following tools were developed and distributed in all Nunavik communities:

1- A CD-Rom containing a series of radio Public Service Announcements (PSA's) designed to educate and inform Nunavummiut about global contaminants and wildlife in their area were sent to all local and regional radio stations. These announcements were developed using findings from the Northern Contaminants Programs (NCP) Canadian Arctic Contaminants Assessment Report (CACAR 2) and the infant cohort study. The PSA's are in English and Nunavik Inuktitut. These PSAs address a variety of audiences such as pregnant women, youth and hunters and provide basic information on the results of research conducted in Nunavik and other Inuit regions on contaminants in the environment, wildlife and their relationship with human health.

   Recently, all radio stations were contacted in order to see if the PSA's were broadcast on a regular basis. Surprisingly, many radio stations respondents told us they never received the CD-Rom. We have decided to resend the CD-Rom to all local and regional radio stations and to ask the respondent to broadcast the PSA's regularly for 2 months. A follow-up of this activity will be conducted again in the near future. The documentation of key community questions and concerns done at the time of the community visits to return results about the Inuit infant cohort study was reviewed and incorporated into the development of a final fact sheet to communicate the basic results and public health context around the findings of the study. Entitled: *"Research in Nunavik: country foods, mother and infants health"* this fact sheet, developed in collaboration with ITK, was sent to the 14 communities' public offices , local Health Centres and Hospitals, Municipal Offices and Regional organizations. Furthermore, it will be inserted in the Nunavik general contaminants package that will be distributed via the Nunavik Inuit Health Survey in the fall of 2004. The fact sheet presents plain language information about types of research done on contaminants and health, what is known about contaminants and babies health, and what can mother's do to be healthy. It also clearly disseminates the following message: *"Eat country food and be healthy"*.

2- A contaminants information newspaper originally developed by Inuit Tapiriit Kanatami's (ITK) Guide to the *Canadian Arctic* Contaminants Assessment report II was adapted for Nunavimmiut and provides information specific for Inuit about Arctic animals, nutrition, and contaminants in the environment.

3- Results of a study carried-out by Dr. Éric Dewailly and his collaborators on subtle effects of mercury exposure on the oxidative status and neuromotor functions of Salummiut were discussed at a committee meeting. It was recommended that a personal letter informing participants about their results should be sent. Furthermore, since all results from participants were within "normal ranges" only a radio-show is being organised to inform the population about the overall findings of the study.

***Participation to Workshops***

The committee members are active in attending workshops to promote the activities of the committee, learn of other regional and international initiatives and communicate the results of regional research projects. This year, those conferences and workshops included:

- Northern Contaminants Science Managers Meetings - review of NCP priorities, feedback on proposal review, and provide regional perspectives on NCP research
- Participation to Educations and Communications Committee meetings for NCP process
- Participation to NCP CACAR II communication strategy development meeting
- Presentation by Minnie Grey at the12th International Congress on Circumpolar Health – Nuuk, September 2003
- Poster presentation by Suzanne Bruneau on the NNHC project entitle *"Evaluation of a risk management strategy to protect pregnant women from contaminant exposure in Nunavik"* at the12th International Congress on Circumpolar Health – Nuuk, September 2003
- *Participation to Qanuippitaa Health survey and the Inuit Diet and Health Study consultation meetings*

## Conclusions

The Nunavik Nutrition and Health Committee is an active body supporting and enhancing the region's research and decision-making capacity related to environmental health issues including exposure to environmental contaminants. This is done through a variety of activities in which they represent the interests of Nunavik residents. Through these activities they cooperatively manage and disseminate information to the public to support informed decision making on issues of health and nutrition.

## Expected Completion Date

This is an ongoing project as the committee is active on these issues in the region annually.


## Acknowledgements

The committee would like to thank the Nunavimmiut for their on-going participation and support. Furthermore, the NNHC is also grateful to the Northern Contaminants Program and the Nunavik Regional Board of Health and Social Services for ongoing support and funding of their activities related to health, contaminants and nutrition in the region.

# Northwest Territories Environmental Contaminants Committee (NWTECC)

## Project leader(s)

Northwest Territories Environment Contaminants Committee (NWTECC) Chair: 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) 669-2833, e-mail: phippens@inac.gc.ca

## Project members

Members of the NWTECC: Co-Chair NWTECC Lands and Environment, Dene Nation; Inuit Tapiriit Kanatami; Inuvialuit Game Council; Gwich'in Tribal Council; Sahtu Dene Council; Deh Cho First Nations; Tlicho Government (Dogrib Treaty 11 Council); 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

Northwest Territories Environmental Contaminants Committee (NWTECC) is one of four territorial contaminants committees in the service of the Northern Contaminants Program (NCP). The NWTECC is a multi-party committee that is supported by the NCP to provide regional coordination for the Northwest Territories; it contains more than 20 representatives from federal, territorial and aboriginal governments. As a representative technical committee, collectively the NWTECC brings an interdisciplinary perspective to questions related to the occurrence and effects of long-range contaminants in the north. The NWTECC meets monthly to discuss contaminants in traditional/country foods. In 2003-2004, ten conference calls and two meetings in-person were held. The second in-person meeting was a combination of Frontline training (see Dene Nation summary of the frontline training course) and social/cultural review of NCP proposals for 2004-2005. The new focus of the NCP is to understand the relationship of human health effects caused by exposure to long-range contaminants, and this has become the guiding focus for the NWTECC. Scientific research studies and assessments continue to form the basis of communication and education activities for NWTECC membership. NCP provides information to 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. Through the efforts of committee members, the NWTECC has attracted funding from Environment Canada, Northern Ecosystem Initiative, Contaminants Partner Issue Table, to fund Local Contaminant Concerns. This year NWTECC completed three LCC projects and were successful in securing NEI funding for 2004-2005.

## Key Project Messages

1. The NWTECC enabled 11 Aboriginal Governmental Organizations and 5 Government Departments to focus and coordinate their activities related to long range contaminants.
2. The NWTECC provided a forum for discussion and two-way transfer of contaminants-related information among Northerners (NWT), governments and researchers.

3. The NWTECC aided in proposal development and reporting for regional members in order for them to participate in NCP project competitions.
4. NWTECC assisted researchers and community members with information to meet funding requirements and address contaminant concern/questions.
5. The NWTECC advised the Management Committee of other funding sources or training opportunities.

## Objectives

1. To build capacity in NWT to work on the important issues related to long range contaminants in traditional/country food and their human health effects.
2. To coordinate all levels of government with the authority and responsibility for long range contaminants and human health effects.
3. To facilitate the efforts of northerners to address concerns arising from environmental contaminants in the NWT.
4. To provide a forum for the two-way transfer of contaminants information in the NWT between northerners and researchers.
5. To bridge the NCP with other contaminants related programs in the NWT, i.e. NEI, AMAP.
6. To act as a communications network to ensure Northerners are informed of, and involved in, contaminants related activities.
7. To identify priorities and information gaps related to environmental contaminants research in the NWT.
8. To act as a central repository for environmental contaminants information.
9. To provide advice on appropriate funding sources.
10. To review NWT proposals for the NCP for social/cultural content.

## Introduction

The NCP has completed transition from the second phase to a renewed third phase. With more than twelve years of research NCP provides northerners with a balanced approach of the risks and benefits of country/traditional foods. The NWTECC has taken a greater role in the communication and education of research and communication efforts in each of the eight regions. This focus has increased the need to have a central coordinating body to ensure the highest quality contaminants information is being conveyed. The NWTECC stimulates important research initiatives by drawing on the expertise of the members. The Chair and Vice-chair, who are responsible to organize meetings, activities and distribute information, are elected annually. However, the committee uses a consensus-style decision-making approach allowing all to speak. For 2002-2004, the Chairs have been Contaminants Division, Indian and Northern Affairs Canada (Yellowknife) and Lands and Environment, Dene Nation.

The NWTECC provides a forum for researchers and regions/communities to discuss contaminants issues and propose activities to better understand problems. NWTECC regularly invites speakers (i.e., NWT Chief Medical Officer) to discuss important issues of concern. Membership is composed of representatives from three departments of the federal government and two territorial government departments, as well as national Aboriginal partners, the seven regional Aboriginal governmental organizations, and one research institute. The committee is well suited to address research priorities and information gaps in the NWT.

## Activities

## In 2003-2004

The NWTECC met twelve times to discuss various contaminants related issues and education and communication priorities (Table 1). Frequent roundtable discussions and updates helped to keep contaminants workers in government (Federal and Territorial), regions and Aboriginal governmental organizations informed of study results, current activities, upcoming proposals, workshops, training opportunities, and conferences.

The NWTECC held a two day in-person meeting (November 2002) to discuss the renewal of the NCP and share communications information. Discussions included update on current education and communication projects; update on current NCP funded research projects in the regions, discussion of block-funding pros and cons, and brainstorming for a future strategy for education and communications. An action plan was developed for various communications approaches. In addition, the meeting provided an opportunity for committee members to learn from each other about their activities and future projects within the NWT.

An evaluation component was added to the list of tasks. At the end of the year the members were asked to evaluate the work of the NWTECC, designed by Contaminants Division. The evaluation will be refined in 2004 to better allow the chairs to understand the needs of the NWTECC. The level of participation of communities/ regions has been very high. NWTECC will need to revisit government participation to find ways to encourage all members to fully participate. In 2003 the ability of the chairs to process information flowing to the members was increased with better coordination.

## Results and Conclusions

The NWTECC secured resources under the national and regional coordination envelope of the NCP, which allowed the committee to meet. 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.

A significant change in NCP funding in 2003-2004 was the distribution of education and communication dollars to priority regions. The majority of funding is being allocated to high risk regions exposed to international/ transboundary contaminants. Denendeh regions are identified as low risk. In the Inuvialuit region communities are seen as medium to high risk. In the NWT, the 'block funding' approach to funding allocation for the education and communication envelope has taken two paths, Denendeh and the Inuit block. NWTECC has become the main forum for the allocation and management of the Denendeh block of funds. The Inuit block funding is managed through ITK and are not discussed in any detail at the NWTECC. Such changes were made relatively late in the year causing funding decisions for education and communications within NWT to be made directly by the territorial contaminant committees (TCCs). The delay in education and communication projects is reflected in the lag time it has taken to complete projects.

This year was significant in the NWT for the shift in priority funding, the reorientation from past investments (i.e., Regional Contaminants Coordinators) and a progression from Government- and Aboriginal Partner-led projects to region-led (i.e., Deh Cho First Nations) projects. Dene Nation and the two Metis organizations were responsible for the allocation of funds, which included secured participant funding for NWT Aboriginal membership. In this respect the NWTECC Chairs (Lands and Environment/Contaminants Division) acted as supports to regions conducting their own communications projects. Overall results will be summarized in the following paragraphs and specific projects will be reported by the regional participants separately.

Education and Communication Project Decisions for 2003-2004

In total NWT requested $678,000.00, which with Nunavut, Yukon and Nunavik, exceeded the funding limit of one million dollars. In order to facilitate funding distribution, NWTECC was earmarked $140,000.00 to block fund education

Table 1. Meetings held by the NWTECC during 2003-2004 fiscal year.

| Meeting # | Date | Key agenda items |
|---|---|---|
| 41 | May 8, 2003 | Call for nominations for chair and vice chair<br>Follow up on final reports (due March 31/03)<br>Review of NCP management committee meeting<br>Health advisories<br>Remaining tours - YK, Ndilo, Dettah, and Rae<br>Roundtable Discussions |
| 42 | May 22,2003 | Proposals<br>Roundtable Discussions |
| 43 | June 24, 2003 | Update on NWT proposals<br>Alternative funding for LCC's<br>Roundtable Discussions |
| 44 | July 22, 2003 | LCC funding review - From NEI (Carey Ogilvie)<br>Update on NWT proposal funding<br>NWTECC memberships - ITK, Inuvialuit seat (IRC or IGC)<br>UNEP Draft Global Mercury Assessment<br>Giant $AsO_3$ removal motion from Dene Nation and other environment related motions from Aklavik<br>Roundtable Discussions |
| 45 | August 27, 2003 | NWTECC memberships<br>LCC funding review<br>Education and communications funding<br>Roundtable Discussions |
| 46 | September 24, 2003 | Education and communication funding<br>LCC proposals<br>Roundtable Discussions |
| 47 | October 8, 2003 | In-person meeting - location, date, agenda<br>LCC proposals<br>Update on education and communication projects<br>Roundtable Discussions |
| 48 | November 3, 2003 | LCC proposals<br>Update on education and communication projects<br>Roundtable Discussions |
| 49 | November 27&28, 2003 (in-person) | Update on education and communication projects<br>Expected deliverables for each project - 2004<br>Funding method and adequacies<br>Taiga Lab tour<br>Contaminated sites database - Presentation (Regan Fielding)<br>LCC brainstorming and proposal development<br>Erica Myles presents health project proposal<br>Future and plans of NCP (Presented by Simon Smith - INAC-HQ)<br>Funding and projects for 2004-05<br>Education and communications proposal development for 2004-05<br>Roundtable Discussions |

| | | |
|---|---|---|
| 50 | January 7, 2004 | LCC's<br>NCP call for research proposals (Health, Monitoring and Communication and education)<br>Potential in-person review and training session<br>NEI funding update<br>Roundtable Discussions |
| 51 | February 13, 2004 | Dr. Corriveau addresses concerns regarding meningitis<br>ISA Tour update<br>LCC's (NEI update)<br>HAPs meeting<br>Edmonton POPs Consultation<br>LCCs (GTC update, Sahtu [Colville Lake], others)<br>In-person meeting and training (review, time and location)<br>Roundtable Discussions |
| 52 | March 2-5, 2004 (in-person) | Frontline training<br>Environmental Trends, Human Health, and Education and Communication Proposal Social/Cultural Review |

and communication activities. Members who submitted proposals under education and communications (Dene and Metis) requested that they decide on distributing funds in an equitable manner. The added time and resources needed to do this has subsequently impacted all members of the NWTECC.

The ability of project leaders to successfully carry out projects relied to various degrees on the support of Government (INAC)/Aboriginal Partner (Dene Nation). Regions formerly with 'regional contaminant coordinator' (RCC) positions found additional support mechanisms to complement the participant funds now provided to the regional representatives. Specific project funding supplements the activities of NWTECC representatives.

The question of funding support will continue to be a problem in regions that lack resources and capacity to work within the new NCP funding structures, which focus on high-risk areas. The ability of each region to communicate and educate their members will be an important consideration for the NWTECC, and for this reason we are developing a communications strategy. The goal of the NWTECC is to facilitate and network organizations that are responsible and authorized to communicate information about long range contaminants in traditional/country food.

The continued need to train and orient NWTECC members will be an important concern for NCP to consider. Finding innovative ways to build capacity, including on-going training (i.e. Front line training course), will be an important consideration in future years. The full cost to regions, governments, and all participants in the NWTECC should be accounted for, demonstrated and communicated.

Conference calls and November in-person meeting

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 advisories, new contaminant findings, environmental issues, and community concerns. Minutes of each meeting are produced summarizing the discussions, activities, and decisions of the Committee. Minutes are archived by the Contaminants Directorate, INAC (Yellowknife).

Representation by Aboriginal Partners, such as Inuit Tapiriit Kanatami (ITK), in the committee is essential to ensure effective communications.

Social/Cultural Review

The social/cultural review process took place on March 3 and 4. In previous years, the NWTECC reviewed all projects of relevance to the NWT and provided ratings that went forward to a separate Social/Cultural review table. These two levels of review then were forwarded to the Management Committee. The reorientation of social/cultural review to the NWTECC was well received by committee members. Because the added responsibility was not set-out in the project agreement, additional resources were invested by the Secretariat so that each TCC could be compensated. However, most members volunteered time for this review and INAC regions absorbed associated costs of travel, etc.

During the social/cultural review by the NWTECC, the committee went through each proposal in detail, ranking proposals 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 the community members (our 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 Chair and Aboriginal Partners participation in the review process and bringing these views forward to Management Committee.

At the TCC level, the social/cultural review was quite beneficial, despite the extra time commitment necessary from the regions. However, one observation by the NWTECC Chair is that comments of the NWTECC made little impression in Management Committee decision-making. NWTECC feels that the social/cultural review comments are being somewhat dismissed over technical review comments. For researchers who wish to continue to do work in the NWT and fulfill their obligations under Land Claim Agreements, and federal legislation is clear on this, a process must be put in place whereby the territorial committees social/cultural review comments will become more relevant and highly regarded.

Education and Communication Review for 2004-05 Proposals

The purpose of this review was to prioritize proposals in order to recommend which ones should go forward to the management committee under the block fund. A total of $472,931.50 in projects was requested. During the review it was decided that proposal by Dene Nation did not completely fit within the block fund. Two were pan-northern but matched the NCP blueprints. A third proposal on developing a communication strategy was in direct completion with proposals from individual regions. Dene Nation choose not compete with their membership for funds. Other members reduced their funding requests to fit within the block.

The review of project proposals by the NWTECC, before submission to the NCP Management Committee, creates better projects, sounder budgets, and strengthens the NCP structures in the NWT. It gave committee members a greater perspective on the amount of funds available, and the type of work/projects required. Such insights were essential for members in decreasing their funding requests.

The 'block fund' approach only partially worked for the NWT. We know this because the internally-ranked high priority proposals submitted to the NWTECC and Management Committee were rejected. The difference in proposal priority for the Management Committee when compared to the NWTECC is apparent. The differences are due to lack of communication, lack of a regional communications strategy, and/or differences in interpreting the education and communication blueprints. This issue is a concern for NWTECC and will be addressed by drafting a long term territorial education and communication strategy in 2004.

Evaluation Results

An evaluation survey was created by the NWTECC Chair (INAC-YK), circulated to all NWTECC representatives. The survey was to capture feedback and identify areas for improvement. From the 17 members, 13 provided comments. A summary of results of the review follow.

*Conference Call*:

All respondents rated high the time of day, day of week, organization of agenda, follow-up on action items, value of items discussed, and clarity of minutes. Some observed the need to improve clarity of the call (due to the problems with the phone system earlier in the year) and length of calls. Some calls went onto 2 ½ hours which produced informant fatigue in all. The length of meeting will be an issue for future meetings. One way to work on reducing the length of calls is to produce a side forum for issues requiring greater attention. Furthermore, co-chairs should consider ahead of time, agenda items being discussed and time requirements for each. Because the committee follows a consensus style decision making process it would be wrong to limit discussion.

*Regional Funding*:

Respondents noted that regional representation is well made in the NWTECC and that funding levels assigned for participation in conference calls, including preparation and reporting, was high to medium. In addition proposal development funding levels are satisfactory to members. Some reported disappointment and lack of funds for social/cultural review; some were disappointed with the level of education and communications project funding. Development of an NCP communications strategy and looking into funds outside the NCP will aid in these issues.

*In-Person meeting in November:*

Every respondent outside of Yellowknife was very happy with the meetings being hosted in Yellowknife. Most respondents from Yellowknife noted that the meeting should be conducted in other regions. Due to increased costs associated with having the in-person meeting outside Yellowknife it is not feasible, unless additional funds are found. One option is to meet elsewhere when members are at another event to find cost-sharing opportunity.

*Social/Cultural Review:*

Most respondents noted the time of year for the social/cultural review was a very busy time, other commitments and not knowing about the review ahead of time were major concerns. All respondents reported the review as valuable, but one member felt it was not of high value or well organized.

*Chair's Review:*

Most respondents felt the chairs were providing necessary support. The questionnaire asked participants to list high to low performance, but we will need to evaluate the ability of this question to answer what it is we are asking. There may be bias because informants are not confidential. Thus, no negative feedback was stated for the chair. There were however, some good comments regarding Dene Nation's work load and inability to fully participate.

*Committee's general activities:*

Most respondents rated the Terms of Reference (TOR) high and felt they were not hard to understand. A number of respondents did not rate the TOR or the time of review (May). Possible, the lack of results on this question is due to lack of understanding the questionnaire or the activity. When reviewing the TOR it seems more time is necessary in discussing its purpose.

Most people highly rated the last election when held (May) as fair. Others did not respond possible because they were not involved in the elections last year. Some noted that elections should be carried out a month or so before proposals are submitted to the management committee so that funding could be applied to build capacity in the Chair. INAC has been the chair for the past few years and the full costs of the Chairmanship are unreported. Under NCP funding limited capacity is provided to the Chair. NWTECC should look to ways of improving the fairness of elections and Contaminants Division/INAC-YK should find other ways to keep connected with the Management Committee.

All respondents agreed the overall purpose of the NWTECC was important. One respondent took the position that the NWTECC has not evolved with changes to the NCP and needed to refocus its priorities.

*Involvement in the committee:*

Respondents were quite critical in their self evaluation. Their involvement will be reported on in their individual final reports under committee participation.

*Main reason for being on the committee:*

The main reason respondents reported participation in the NWTECC varied from region to region. In general, the northern regions (Gwich'in and Inuvialuit) where less concerned with contaminants from mine sources and the regions in the south, Sahtu, Tlicho, Deh Cho and Akaitcho are more concerned with contaminants from mine sources, but are also concerned with long range contaminants. All regions were concerned with local contaminant concerns. Health officials were concerned mainly with contaminants in traditional foods. The research institute was concerned with providing an advisory role. All participants regardless of region or organization were concerned with contaminants in traditional foods.

Reasons for respondents being on the committee are an important consideration to assess future direction and identification of alternative funding sources. It would be important particularly in South Slave for the committee to approach other sources or programs for funds, for example industry or Contaminated Sites Program, which is particular to their main concerns.

## Expected Project Completion Date

The NWTECC will continue to meet through phase three of NCP. The role and terms of reference for the committee will continue to evolve. The orientation of the committee will be influenced on funding decisions made by Management Committee and based on NCP priority areas.

# Yukon Contaminants Committee Communications


## Project leader(s)

Pat Roach, Chair, Yukon Contaminants Committee, Department of Indian Affairs & Northern Development, Whitehorse, Yukon; phone: (867) 667-3283; fax: (867) 667-3341; e-mail: RoachP@inac.gc.ca

## Project members

Yukon Contaminants Committee: DIAND; Council of Yukon First Nations; Environment Canada; Yukon Renewable Resources; Yukon Health and Social Services; Yukon Conservation Society; Yukon College



## Abstract

The Yukon Contaminants Committee (YCC) was established in 1992 and continues to coordinate research projects operated under the Northern Contaminants Program (NCP). It responds to inquiries by individuals, communities, research scientists, and others with an interest in the NCP or other environmental issues in the Yukon. The YCC consists of representatives from government, the Council of Yukon First Nations, individual First Nations, non-governmental organizations, Yukon College, and private industry. Membership has always been "open" and the active members vary over time, with a core group that has been involved since the inception of the Committee. The YCC reviews project submissions under the NCP, for scientific and socio-cultural relevance to Yukon communities. It then makes recommendations to the NCP Managers, on the suitability of these project proposals. The Committee often takes a leadership role in communicating the results of research through directed publications, the provision of guest speakers, representation at professional workshops and conferences, and in the development of materials for use in education. This year the Committee concentrated on advertising the release of CACARII and the results of the last five years of Yukon NCP research. In this role the YCC provides a link between the scientific community and the Yukon public. The Committee continues to grow with the NCP and remains a diverse and active organization in the North.


## Key Project Messages

The Yukon Contaminants Committee has been active since 1992, provides representation for all stakeholders to the NCP, direction for research professionals, a Yukon perspective at the NCP Manager's meetings and an outlet for directed communications.

## Objectives

Ensure that the scientific research conducted in Yukon under the Northern Contaminants Program (NCP) meets the needs of the Yukon, while respecting the socio-cultural needs of it's people.

Communicate the results of NCP research to the Yukon people in a culturally appropriate manner.

## Introduction

The establishment of the YCC came about in 1992, as a development of the Committee studying the Lake Laberge toxaphene issue. It was created to provide the Yukon with an organization to review research projects planned for the Yukon, or which would effect the Yukon public. The Committee is composed of a diverse group of stakeholder representatives, who provide perspective from across the Yukon cultural and political landscape. While the principle role for the YCC is for project review, it has also taken a leadership role in communications designed to educate the Yukon public. It also provides an avenue for the public to express concerns regarding contaminants in the North.

## Activities

## In 2003-2004

The YCC continued to review project proposals for the 2003-2004 program year. Committee members travelled to the Manager's meetings, the NCP Symposium, contributed to CACAR II, AMAP II, and the Education and Communications strategic planning for the final year of the second phase of the NCP.

The Committee planned and initiated a number of directed communications strategies for the 2003-2004 operating year. An assortment of advertisements for CACAR II was completed. These included radio and television ads that ran as public service announcements. An insert in the Yukon News was produced to promote the Highlights Report and the work completed in Yukon during the past NCP terms. Brochures, posters, and fridge magnets were produced to communicate the safety of traditional foods and promote their consumption. A foldable "paper cruncher" was produced for school aged children to fold and then manipulate to read messages on traditional foods.

## Discussion and Conclusions

The Yukon Contaminants Committee continues to provide a Yukon perspective to the NCP Management Committee and will continue to develop, produce, and distribute directed communications on NCP research.

## Expected Project Completion Date

This project is on-going.

[illegible]

## Activities

### [illegible]

[illegible]

[illegible]

## Discussion and Conclusions

[illegible]

## Expected Project Completion Date

[illegible]

# Mercury Levels in Fish in Traditionally Harvested Lakes


## Project leader(s)

M. S. Evans, National Water Research Institute (NWRI), Environment Canada, 11 Innovation Boulevard, Saskatoon S7N 3H5; 306-975-5310 (W); 306-975-5143 (F); marlene.evans@ec.gc.ca

## Project members

George Low, Fisheries and Oceans (DFO); Ruby Jumbo, Sambaa K'e (Trout Lake), NT; Monica Krieger, Lutsel K'e Dene Band, Lutsel K'e; Sam Stephenson DFO, Inuvik; L. Lockhart, c/o DFO, Winnipeg, Manitoba; J. Keating, NWRI, Saskatoon; Lyndsay Doetzel, University of Saskatchewan, Saskatoon; Derek Muir, NWRI, Burlington, Ontario; G. A. Stern, DFO, Winnipeg, Manitoba



## Abstract

Since the mid 1990s, mercury levels have been investigated in fish in several lakes along the Mackenzie River. In many lakes, mercury levels in fish exceed the 0.2 $\mu$g/g (parts per million) guidelines for frequent consumers of fish and the 0.5 $\mu$g/g guideline for the commercial sale of fish. Consumption advisories have been issued for some lakes. Higher mercury levels are associated with fish-eating fish (lake trout, pike, and walleye) and seem to be more common in small lakes with old fish populations. Many lakes have yet to be studied. Here we looked at mercury levels in Stark and Trout lakes. These are medium size lakes. Mercury levels were low in Stark Lake although larger (>750 mm), older (>20 yr) lake trout had mercury levels >0.5 $\mu$g/g. Mercury levels generally were low in fish in Trout Lake although some large walleye (>500 mm) had mercury levels >0.5 $\mu$g/g. Mercury levels were lower in pike, possibly because they are less predaceous than walleye and lake trout. Whitefish, small lake trout and large walleye in Trout Lake appeared to have higher mercury levels in 2003 than 1990-1991. The study attempted to investigate skinny fish in Stark Lake and Trout Lake but too few were caught. Mercury levels were also looked at in sea running Dolly Varden char from the Rat River in the Mackenzie River delta and were very low although these char were predaceous; however, they were young (6 yr). Results of this study are being sent to Lutsel K'e, Sambaa K'e, and the NT Environmental Contaminants Committee. Limnological and related data have been integrated into larger data sets investigating causal factors for mercury levels in fish.


## Key Project Messages

1. Fish in Stark Lake have low mercury levels except for large and old lake trout
2. The two skinny lake trout examined from Stark Lake did not appear unusual in terms of their growth rate (length) with age. Mercury levels may have been a little high for their trophic feeding.
3. Mercury levels were low in fish in Trout Lake with the exception of larger walleye.
4. Small lake trout may be heavier in Trout Lake in 2003 than 1990-1991 and have higher mercury levels. Larger walleye may be lighter and have higher mercury levels in 2003 than 1990-1991. Whitefish have the same length weight relations between the two periods of study but mercury levels were higher in 2003.
5. Mercury levels were very low in sea running Dolly Varden char collected from the Rat River. These char are predaceous and young (6 years).

## Objectives

1. Determine mercury levels in lake trout in Stark Lake in "normal" and "skinny" fish. Determine whether higher mercury levels in skinny fish is associated with fish length, weight, age, and feeding relationships.
2. Determine mercury levels in lake trout, pike, walleye, and whitefish in Trout Lake and compare to data collected during 1990-1991 studies to see if there are differences between the two periods. Investigate "skinny" lake trout and walleye in Trout Lake and investigate whether these fish have higher mercury levels than "normal" fish.
3. Integrate the Trout Lake and Stark Lake data sets into the larger NCP funded studies of mercury levels in fish in the Mackenzie River Basin and a TSRI studying investigating lake trout in northern Canada.
4. Provide the communities of Sambaa K'e and Lutsel K'e with information on mercury levels in their fish and whether skinny fish have higher mercury levels. Provide these data to the NT Environmental Contaminants Committee.

## Introduction

For several years, the Northern Contaminant Program supported measurements of mercury levels in fish in lakes in the NT (Lockhart and Evans 1999; Lockhart et al. 2001; Stewart et al. 2003 a, b). Higher mercury levels were found in predaceous fish such as lake trout, walleye, and pike than in plankton and benthos feeding fish such as cisco and whitefish. In addition, mean mercury levels in fish in many of these lakes exceeded 0.5 $\mu$g/g, the guideline for the commercial sale of fish. Subsequently, consumption advisories were issued for many of these lakes. Research studies investigated potential causal factors for high mercury levels in some lakes and not others and determined that higher mercury levels appear to be associated with lakes which had relatively old fish populations (Evans and Lockhart 1999, 2001). Predatory fish begin to approach a 0.5 $\mu$g/g mercury concentration as they reach ca. 12 years in age.

Higher mercury levels in fish also appear to be associated with smaller lakes as opposed to larger lakes (Evans et al. 2003) although such comparisons were made by comparing levels in relatively small lakes along the Mackenzie River (<50 km$^2$) with the very large Great Slave Lake and Great Bear Lake (7,500-29,500 km$^2$). The influence of lake size in affecting mercury levels in fish weakens when these two lakes are removed from the analyses. The addition of moderate-size lakes into these statistical comparisons would allow for a more effective investigation of lake size as a variable affecting mercury levels in fish.

Despite the progress on the NCP studies, communities continue to be concerned about levels of mercury (and other chemicals) in their fish. Only a relatively small number of lakes used by communities in the Mackenzie Basin (and elsewhere in the Northwest Territories) have been sampled (Stewart et al. 2003 a, b). Our current understanding of the factors affecting mercury levels in fish do not allow for a precise prediction of which lakes are likely to have fish with elevated mercury levels (Evans et al. 2003). Thus, there is a continued community interest in having fish populations investigated for mercury (and other chemical) concentrations.

On occasion, community members note the presence of diseased, skinny, or otherwise unusual appearing fish in their harvest and are concerned that such incidences are related to contaminants, including mercury. Lutsel K'e, for example, has been concerned for many years about skinny lake trout in Stark Lake. More recently, Sambaa K'e (formerly known as Trout Lake) reported concerns with skinny fish to DFO. NCP funding in 2003-2004 provided an opportunity to fill in some of the gaps in our understanding of mercury levels in food fish in lakes in the Mackenzie River Basin and, in the process, investigate some of the issues related to skinny fish.

## Activities

## In 2003-2004

Following consultations with the Northwest Territories Environmental Contaminants Committee (Chris Paci), the Department of Fisheries and Oceans (George Low, Sam Stephenson) and various communities, two lakes were selected to fill in some of the gaps in mercury levels in traditional food fish in lakes in

the Mackenzie River Basin. These were Trout Lake and Stark Lake. In addition, sea running char were collected from the Rat River (south of Inuvik) and analyzed for mercury.
Stark Lake is a medium size lake (177 $km^2$) located east of Lutsel K'e on Great Slave Lake, and on the Canadian Shield. Baseline data was collected on this lake by Falk (1979). The lake has been of concern to community members because of the presence of skinny lake trout over many years. NCP has supported studies related to the uranium audit (Chair of the Lutsel K'e Environment Committee 1998) and, more recently, the community, with Fish Habitat Funds, has been conducting its own studies of lake trout habitat and parasite body burden. In collaboration with DFO and Lutsel K'e, Stark Lake fish were collected during the last week of August and early September 2003. Limited limnological sampling was conducted including collecting water, plankton, and forage fish for mercury and stable isotope analyses.
Trout Lake is a medium-size lake (520 $km^2$) located west of Great Slave Lake. Water and fish quality were assessed in Trout Lake in March 1990 and July 1991 (Swyripa et al. 1993), including mercury concentrations in lake trout, walleye, pike, and whitefish. In collaboration with DFO and Sambaa K'e, fish were collected from Trout Lake in the first week of September 2003. Limited limnological sampling was conducted including collecting water, plankton, and forage fish for mercury and stable isotope analyses.

Finally, mercury levels were investigated in sea-run populations of Dolly Varden char caught from the Rat River, Northwest Territories. Dolly Varden char (*Salvelinus malma*) is a member of the Salmonidae family. Scott and Crossman (1998) report it as a fresh and salt water species found in western North America and eastern Asia where it inhabits rivers and cold water lakes. In North America, it is reported as far north as the Bering Strait. Its range overlaps the western range of the Arctic char (*Salevlinus alpinus*). There are several sea run populations of char in the Mackenzie River Delta area, including the Rat River which flows into the main river channel and south of Inuvik. Rat River char were investigated for persistent organochlorine contaminants in the mid 1980s (Muir et al. 1990). It is now believed that the Rat River char are Dolly Varden.

## Results

**Stark Lake:** Sixty-six lake whitefish, one round whitefish, 34 lake trout, and 2 northern pike were collected during the August September 2003 sampling (Table 1). In 1971, Falk (1979) surveyed 10 lakes in the Northwest Territories, including Stark Lake. A total of 209 fish were caught during his gill net stock assessment. Whitefish (80) and lake cisco (83) dominated the catch followed by lake trout (22), longnose sucker (11), and round whitefish (7). Northern pike (2) and grayling (1) also were collected. Length and weight were determined on all fish but only whitefish were aged (mean age 9.5 yr). Falk used 5-panel gill nets with mesh size ranging from 38 to 140 mm while a 114 mm net was used in this study. Thus Falk would have collected smaller fish than in our study; whitefish in his study averaged 372 mm in length and lake trout 616 mm in length.

Fish were relatively old in Stark Lake with whitefish averaging 11.6 yr and lake trout 22.0 yr (Table1). Many lake trout otoliths could not be aged, including all fish over 800 mm in fork length. These fish are presumed to be old.

Of the 34 lake trout collected in Stark Lake in 2003, two were considered skinny by the field party and guide. Trout length and weight were strongly correlated ($r = +0.94$); "skinny" were slightly lighter than "normal" trout (Fig. 1). Trout length and age also were strongly correlated ($r = +0.81$) with a 780 mm trout having a predicted age of 30 years. Based on this regression, a 867 mm lake trout may have been as old as 32 years. The one "skinny" trout which was aged was not unusually old and had a growth rate similar to other trout in its length category.

Mercury levels (Table 1) were low in whitefish (mean 0.07 $\mu g/g$) and higher in pike (mean 0.33 $\mu g/g$). Pike were not aged but, based on studies in Great Slave Lake at Lutsel K'e, pike would have been at least 12 years old. In comparison, the mean mercury concentration in northern pike in Colville Lake, a relatively large lake (448 $km^2$), averaged 0.24 $\mu g/g$; pike in this lake had a mean length of 639 ± 70 mm and a mean age of 10.6 ± .3 yr (Evans et al. in press)

Mercury levels were moderately high in lake trout in Stark Lake (Fig. 1), increasing with fish

**Table 1**. Biological and chemical measurements of fish collected from Stark Lake and Dolly Varden char from the Rat River in late summer early autumn 2003.

| **Species** | **N** | **Fork length (mm)** | **Weight (g)** | **Age (yr)** | **Hg (ug/g)** | **δC[13] (‰)** | **δN[15] (‰)** |
|---|---|---|---|---|---|---|---|
| Stark Lake | | | | | | | |
| Whitefish | 66 | 472 ± 33 | 1503±346 | 11.6 ± 2.2 | 0.07 ± 0.03 | -22.6 ± 2.0 | 9.0 ± 0.4 |
| Round Whitefish | 1 | 404 | 620 | 6 | - | - | - |
| Lake trout | 34 | 700 ± 86 | 4062 ± 1936 | 22.0 ± 5.6 | 0.43 ± 0.37 | -26.3 ± 2.5 | 12.5 ± 0.7 |
| Pike | 2 | 846 ± 203 | 5450 ± 4229 | - | 0.33 ± 0.13 | -24.0 ± 1.1 | 11.1 ± 0.2 |
| | | | | | | | |
| Rat River | | | | | | | |
| Dolly Varden char | 20 | 452 ± 60 | 1927 ± 487 | 6.0 ± 0.9 | 0.05 ± 0.01 | -23.3 ± 0.5 | 13.7 ± 0.7 |

**Figure 1**. Length, weight, age, mercury, and δN relationships for lake trout (normal and skinny) collected from Stark Lake, August 30-September 1, 2003.

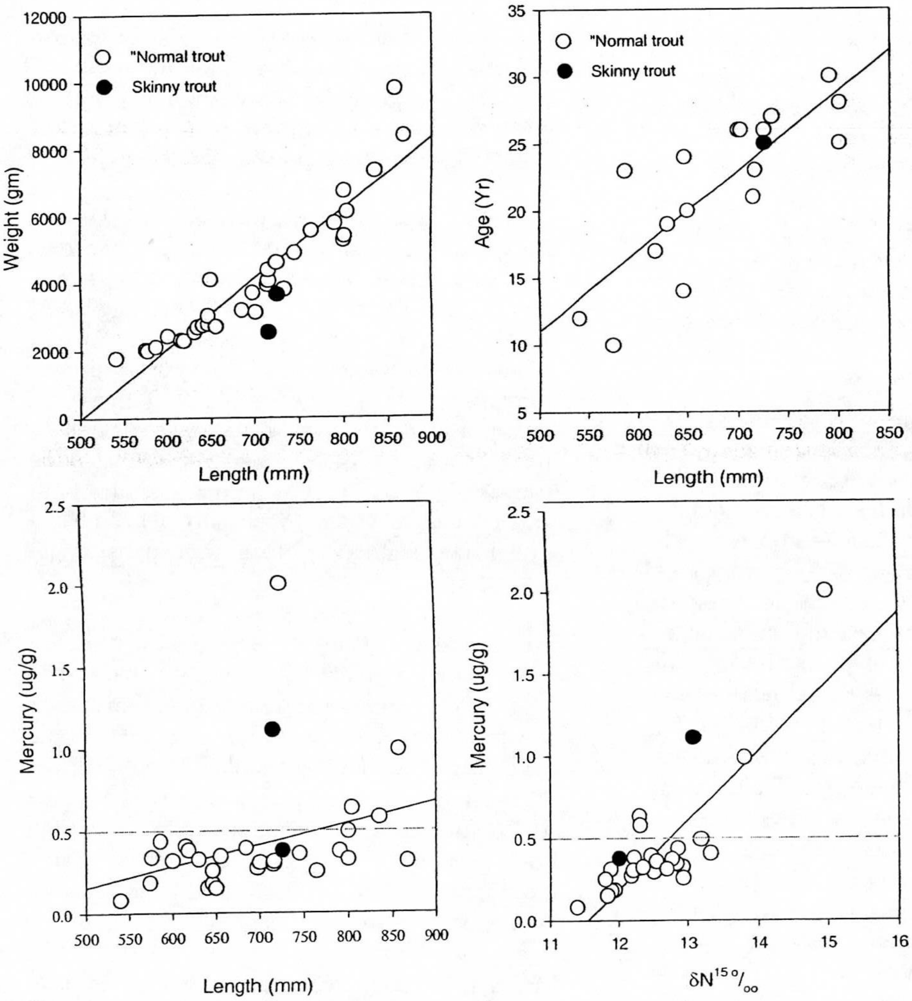


**Table 2.** Biological and chemical measurements of fish collected from Trout Lake in September 2003. Also shown are March 1990 and July 1991 data from Swyripa et al. (1993).

| Species | N | Fork length (mm) | Weight (g) | Age (yr) | Hg (ug/g) | $\delta C^{13}$ (‰) | $\delta N^{15}$ (‰) |
|---|---|---|---|---|---|---|---|
| 2003 | | | | | | | |
| Whitefish | 27 | 354 ± 20 | 568 ± 111 | 7.6 ± 1.6 | 0.05 ± 0.01 | -25.7 ± 08 | 8.8 ± 0.7 |
| Longnose sucker | 4 | 470 ± 35 | 1567 ± 378 | - | 0.09 ± 0.03 | -27.7 ± 0.7 | 9.0 ± 0.7 |
| Lake trout | 28 | 624 ± 78 | 2864 ± 743 | 17.2 ± 5.5 | 0.35 ± 0.08 | -27.1 ± 1.1 | 12.6 ± 0.8 |
| Pike | 7 | 744 ± 204 | 3330 ± 2382 | - | 0.27 ± 0.19 | -27.5 ± 1.8 | 10.5 ± 1.3 |
| Walleye | 11 | 502 ± 74 | 1140 ± 452 | - | 0.51± 0.38 | -27.8 ± 0.5 | 12.1± 0.8 |
| | | | | | | | |
| 1990/1991 | | | | | | | |
| Whitefish | 7 | 340 ± 66 | 574 ± 352 | 8.0 ± 2.8 | 0.03 ± 0.01 | - | - |
| Longnose sucker | 16 | 472 ± 17 | 1528 ± 198 | 16.1 ± 4.0 | 0.05 ± 0.02 | - | - |
| Lake trout | 12 | 535 ± 18 | 1810 ± 272 | 14.9 ± 2.6 | 0.22 ± 0.08 | - | - |
| Pike | 2 | 629 ± 9.2 | 2075 ± 2048 | 6 | 0.08 ± 0.12 | - | - |
| Walleye | 20 | 474 ± 67 | 1203 ± 439 | 9.4 ± 1.5 | 0.13 ± 0.05 | - | - |

length (and age). Given the extreme age of these fish, higher mercury levels are to be expected. In comparison, lake trout in Great Bear Lake (mean age 19.9 ±5.1yr) have mercury concentrations of 0.35± 0.31 (Evans et al. in press). Lake trout in Lac Ste. Therese, the only other lake investigated with similar old lake trout (mean age 24.9 yr), have mean mercury levels of 0.77 ±0.47 µg/g. There were two fish with very high mercury levels for their length - one skinny fish and one "normal: fish. Mercury levels in lake trout increased with $\delta N^{15}$; the highest mercury concentrations were associated with two highly predaceous fish (one 725 mm female 25 years old and a 725 mm male which could not be aged) and the one skinny lake trout which could not be aged.

Carbon isotope values suggest that whitefish are feeding in the nearshore on littoral zone carbon while lake trout are more pelagic. The two skinny lake trout had similar carbon isotope values as normal lake trout.

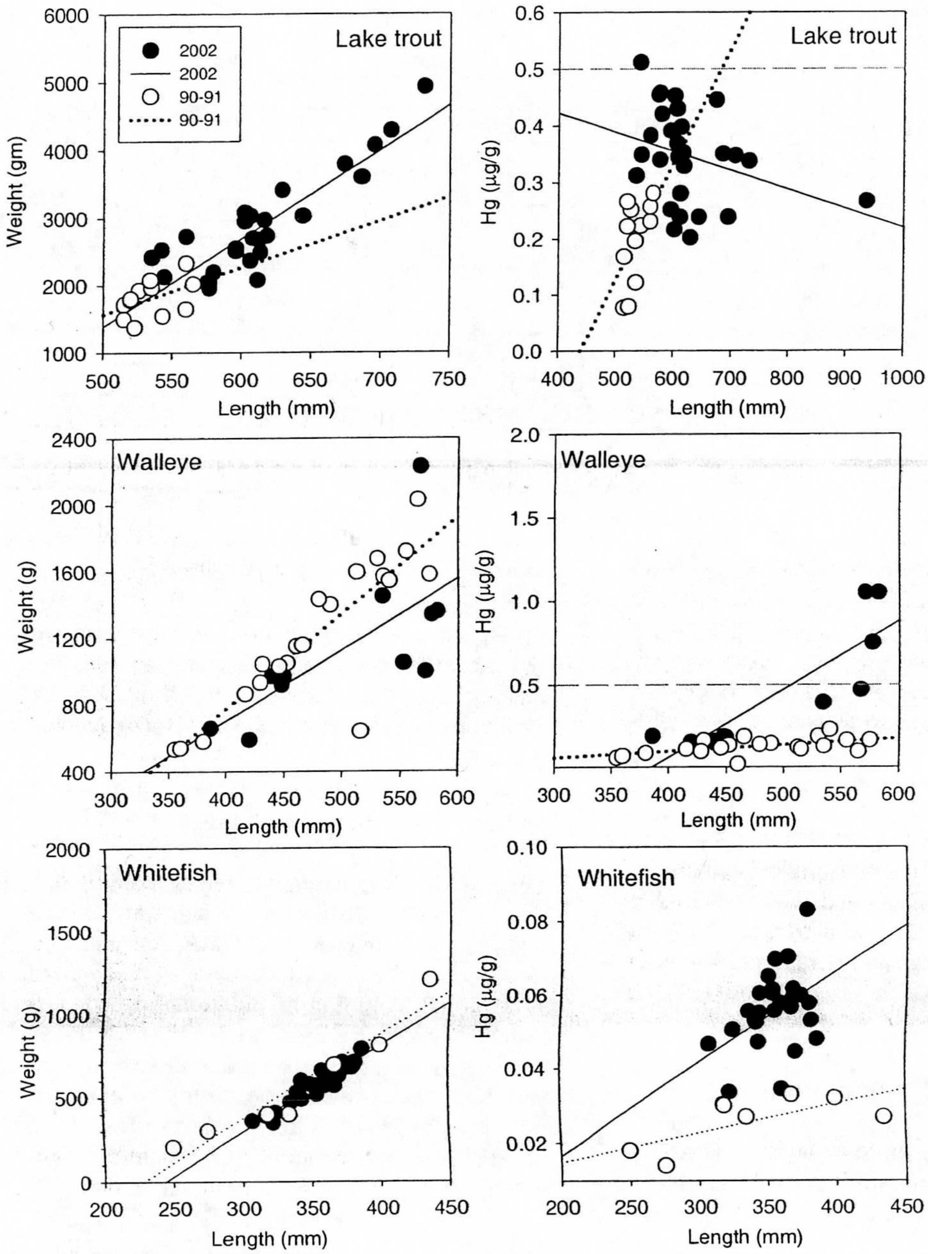
**Trout Lake:** Seventy fish were caught in late August and early September 2003 from Trout Lake. None of the fish were considered skinny by the field party. Only lake trout and whitefish were aged. Whitefish were relatively young (Table 2) but trout were old averaging 17.2 yr. This is similar to the situation observed in Stark Lake with whitefish substantially younger than lake trout. If pike have similar growth rates as on Great Slave Lake, they would have bean at least 9 years old. Walleye, based on studies conducted in Trout Lake in 1990-1991, also would have been at least 9 years old.

Mercury levels were low in whitefish and longnose sucker with higher levels observed in lake trout, pike, and walleye (Table 2) in 2003. Only in walleye did the mean level reach 0.5 µg/g, the commercial sale guideline. This higher value is probably associated in part with fish age and predatory feeding (higher $\delta N^{15}$).

In order to investigate possible differences in fish growth rates and mercury accumulation, we calculated length-weight and length-mercury regressions for lake trout, walleye, and whitefish for our 2003 sampling and sampling conducted in March 1990 and July 1991 (Fig. 2). A wider size range of lake trout were sampled over 2003 than 1990-1991 limiting the ability to compare differences in growth rates across the two study periods. However, trout 535-565 mm in length were heavier, on average, in 2003 than 1990-1991. In 2003, mercury levels in lake trout negatively correlated with fish length while a positive correlation was observed in 1990-1991. Lake trout 535-565 mm had a mean mercury concentration of 0.22 ± 0.06 µg/g for 2003 fish; lake trout 535-560 mm caught in 1990-1991 had a mean mercury concentration of 0.39 ± 0.09 µg/g or 77% higher.

Similar size ranges of walleye were sampled in 2003 and in 1990-1991. Larger walleye tended to be lighter in 2003 than 1990-1991. Walleye accumulated mercury with increasing length at a

**Figure 2.** Length, weight, and mercury relationships for lake trout, walleye, and whitefish collected from Trout Lake in September 2003 and in 1990 (March) and 1991 (July). 1990-1991 data are from Swyripa et al. (1993).




more rapid rate in 2003 than in 1990-1991. As a consequence, mercury levels were substantially higher in fish >500 mm in 2003 than 1990-1991.

Similar size ranges of whitefish were sampled in 2003 and 1990-1991. The length weight regressions were near identical. Nevertheless, whitefish accumulated mercury with increasing size at a faster rate in 2003 than 1990-1991 with the result that fish >300 mm in fork length had higher mercury levels in 2003.

**Dolly Varden Char:** Twenty Dolly Varden char were collected from the Rat River. They were smaller than the lake trout investigated in Stark Lake, Trout Lake, and young, averaging only 6 years. Based on their $\delta N^{15}$ they also were predaceous. However, mercury levels were exceedingly low and comparable to concentrations observed in whitefish at Stark and Trout lakes. Mercury levels were similar to concentrations observed in sea-run trout from northern Labrador and much lower than observed in landlocked populations in the Arctic Archipelago (Muir et al. 1999, 2000; Muir and Kock 2003).

## Discussion and Conclusions

This study provides new information on mercury levels in fish in moderate size lakes in the Mackenzie River Basin. Mercury levels in lake trout and pike from Stark Lake were moderately high (>0.2 $\mu$g/g but < 0.5 $\mu$g/g). However, some lake trout in Stark Lake had very high (>1 $\mu$g/g) mercury concentrations. These high values were associated with size (>700 mm), age (>20 yr), and trophic (predaceous) feeding. Only two "skinny" fish were caught during our study; there was no evidence that skinny fish were older or had different growth (length) rates than normal fish. With only two fish analyzed, it is difficult to infer much about the relationship between mercury level and fish length, age, and trophic feeding; one of the two fish could not be aged.

Mercury levels were low in whitefish and longnose sucker from Trout Lake in 2003. Higher values were observed in lake trout and pike with walleye mean mercury slightly exceeding (0.5 $\mu$g/g) the commercial sale guidelines. However, mercury values were high only in walleye > 525 mm in fork length. Lower values in pike than walleye may be associated with differences in trophic feeding; pike had lower $\delta N^{15}$ (10.5‰) than lake trout (12.6‰) and walleye (12.1‰).

Whitefish length weight regressions were identical in 1990-1991 and in 2003 while smaller lake trout and larger walleye appeared heavier in 1990-1991 than 2003. Mercury levels were higher in smaller lake trout and larger walleye in 2003 than 1990-1991. Mercury levels also were higher in whitefish in 1990-1991 than 2003. Overall, while these data are limited with only two years of comparison, they are strongly suggestive of higher mercury levels in fish in Trout Lake in 2003 than 1990-1991.

## References

Chair of the Lutsel K'e Environment Committee. 1998. Radiation exposure in Lutsel K'e. Pp. 147-154, In J. Jensen (Ed). Synopsis of research conducted under the 1997/98 Northern Contaminants Program.

Evans, M. S., and W. L. Lockhart. 1999. An investigation of factors affecting elevated mercury levels in predatory fish in the Mackenzie River Basin. Pp. 103-110, In S. Kalhok (Ed). Synopsis of research conducted under the 1998/99 Northern Contaminants Program.

Evans, M. S., and W. L. Lockhart. 2001. An investigation of factors affecting elevated mercury levels in predatory fish in the Mackenzie River Basin. Pp. 174-184, In S. Kalhok (Ed). Synopsis of research conducted under the 2000-2001 Northern Contaminants Program.

Evans, M. S., W. L. Lockhart, and G. Stern. 2003. An investigation of factors affecting elevated mercury levels in predatory fish in the Mackenzie River Basin. Pp. 259-268, In Synopsis of research conducted under the 2000-2001 Northern Contaminants Program.

Evans, M. S, W. L. Lockhart, L. Doetzel, G. Low, D. C. G. Muir, K. Kidd, J. Keating, J. Delaronde, and G. A. Stern. In press. Elevated mercury levels in fish in lakes in the Mackenzie River Basin: the role of fish age and lake size. Science of the Total Environment.

Falk, M. R. 1979. Biological and limnological data on ten lakes surveyed in the Northwest Territories, 1971-72. Fisheries and Marine Service Data Report 129. Winnipeg, Manitoba.

Lockhart, W. L., and M. S. Evans. 1999. Mercury in fish from surveys in lakes in the western Northwest Territories. Pp. 133-142, In, S. Kalhok (Ed). Synopsis of research conducted under the 1998/99 Northern Contaminants Program.

Lockhart, W. L., G. Stern, G. Low, and M. Evans. 2001. Mercury in fish from surveys in lakes in the western Northwest Territories: investigations into the factors affecting mercury levels. Pp. 194-201, In S. Kalhok (Ed). Synopsis of research conducted under the 2000-2001 Northern Contaminants Program.

Muir, D. C. G., N. P. Grift, C. A. Ford, A. W. Reiger, M. R. Hendzel, and W. L. Lockhart. 1990. Evidence for long-range transport of toxaphene to remote arctic and subarctic waters from monitoring of fish. In, Kurtz, D. (ed.). Lewis Publisher.

Muir, D., M. Kwan, and J. Lampe. 1999. Spatial trends and pathways of POPs and metals in fish, shellfish, and marine mammals of northern Labroador and Nunavik. Pp. 165-171. In S. Kalhok (Ed). Synopsis of research conducted under the 1998-1999 Northern Contaminants Program.

Muir, D., G. Köck, J. Resit, and D. Bright. 2000. Temporal trends of persistent orgnic pollutants and metals in landlocked char. Pp. 202-207, In S. Kalhok (Ed). Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program.

Muir, D., and G. Köck. 2003. Temporal trends of persistent organic pollutants and metals in landlocked char. Pp. 311-317. Synopsis of Research Conducted under the 2001-2003 Northern Contaminants Program.

Scott, W. B., and E. J. Crosmann. 1998. Freshwater Fishes of Canada. Galt House Publications, Oakville, Ont. 966 pp.

Stewart, D. B., W. E. F. Taptuna, W. L. Lockhart, and G. Low. 2003a. Biological data from experimental fisheries at special harvesting areas in the Sahtu Dene and Metis Settlement Area, NT: Volume 2. Lakes near the communities of Colville Lake, Fort Good Hope, Norman Wells, and Tulita. Canadian Data report of Fisheries and Aquatic Sciences 1126.

Stewart, D. B., P. L. Taylor, W. E. F. Taptuna, W. L. Lockhart, C. J. Read, and G. Low. 2003b. Biological data from experimental fisheries at lakes in the Deh Cho Region of the Northwest Territories, 1996-2000.

Swyripa, et al. 1993. Water and fish quality from Trout Lake, NWT 1990-1991. DIAND. Yellowknife, 108 pp.