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Re-thinking the Mercury Contamination Issue in Arctic Canada

By

Shawn Donaldson, B.Sc. (Honours)

**A thesis submitted to the Faculty of
Graduate Studies and Research in partial fulfillment
of the requirements for the degree of
Master of Arts**

Department of Geography and Environmental Studies

**Carleton University
Ottawa, Ontario**

2002

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acceptance of this thesis

Re-thinking the Mercury Contamination Issue in Arctic Canada

Submitted by Shawn Donaldson, B.Sc. (Honours)
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the degree of Master of Arts

Chair, Department of Geography and Environmental Studies

Thesis Supervisor

Carleton University

May, 2002

Abstract

The present study examines the problem of environmental mercury contamination in Arctic Canada. Mercury from distant anthropogenic and natural sources is transported to the Arctic primarily via the atmosphere. Mercury can be converted in the environment to methylmercury, which is a potent neurotoxin. Clearly, the first priority is to reduce the level of anthropogenic emissions and the amount of mercury transported to and deposited in the Arctic region. However, like mercury itself, the development of appropriate policy is complex. As a first step, this study designs an Integrated Policy and Science Conceptual Model (IPSCM) that takes into account: sources; biogeochemical processes; Arctic lifestyles; and exposure levels. This model is based on extensive literature reviews, a case study and interviews with stakeholders. The results demonstrate that the complex interplay of cultural, scientific, and political processes underscores the need for an integrated approach to effectively manage this issue.

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Acronyms Used in this Study and their Definitions

kg = kilogram
km = kilometer
g = gram
L = liter
m = meter
mg = milligram
ppb = parts per billion
ppm = parts per million
 μ g = microgram
wt = weight
ww = wet weight

AEPS = Arctic Environmental Protection Strategy
AMAP = Arctic Monitoring and Assessment Program
CACAR = Canadian Arctic Contaminants Assessment Report
CARC = Canadian Arctic Resources Committee
CEPA = Canadian Environmental Protection Act
DD = dry deposition
DDE = dichlorodiphenyldichloroethylene
DDT = dichlorodiphenyltrichloroethane
DFAIT = Department of Foreign Affairs and International Trade
DIAND = Department of Indian Affairs and Northern Development
DOC = dissolved organic carbon
GE = gaseous exchange
 Hg^0 = elemental mercury (also called metallic mercury)
 Hg_2^{2+} = mercurous ion (monovalent mercury)
 Hg^{2+} = mercuric ion (divalent mercury)
ICC = International Circumpolar Conference
IPSCM = Integrated Policy and Science Conceptual Model
ITC = Inuit Tapirisat of Canada
LOAEL = lowest observed adverse effects level
NCP = Northern Contaminants Program
NGO = non-governmental organization
NOAEL = no observed adverse effects level
NRC = National Research Council
OWRC = Ontario Water Resources Commission
PCBs = polychlorinated biphenyls
POPs = persistent organic pollutants
RS = re-suspension
SRB = sulphate reducing bacteria

TEK = traditional ecological knowledge
TGM = total gaseous mercury
UN = United Nations
UNECE = United Nations Economic Commission for Europe
U.S. EPA = United States Environmental Protection Agency
UNEP = United Nations Environmental Protection Program
WD = wet deposition
WHO = World Health Organization

Chapter 1

Introduction

There can be no peace, no security, nothing but ultimate disaster, when a few rich countries with a small minority of the world's population alone have access to the brave, and frightening, new world of technology, science and of high material living standard, while the large majority live in deprivation and want, shut off from opportunities of full economic development; but with expectations and aspirations aroused beyond the hope of realizing them.

-Lester B. Pearson, winner of the Nobel Peace Prize, former Canadian Prime Minister.

1.1. Introduction

Former Prime Minister Pearson's statement reflects the concern that many of us share about the inequalities that exist within developed countries and between developed and developing countries, where often the poor, renewable resource-based peoples are disproportionately impacted. Many decisions made by developed and developing countries do not fully consider either the long-term environmental implications or the diverse perspectives of groups that do not have the same power or influence. The threats of ecological damage to the Canadian Arctic ecosystem due to mercury pollution generated from southern regions are very serious. While damage to Arctic ecosystem may not be a priority in temperate and tropical regions, it continues to cause further stresses for northern Aboriginal peoples, whose lifestyles are undergoing significant changes as a result. What is at stake is the future of Aboriginal peoples' sustainable way of life with its roots in harvesting of renewable resources (Doubleday 1996; Wheatley 1996).

1.2 Statement of the Problem

Mercury contamination has caused serious environmental problems in the past. One of the most notable examples on an international scale occurred in the 1960s. An acetaldehyde factory discharged mercury compounds into Minamata Bay, Japan, causing a disaster. In that instance, thousands of people who lived in the area and ate the contaminated fish and shellfish from the bay, developed symptoms of what came to be known as Minamata Disease. Thousands of the region's residents fell victim to this neurological disease, which caused tremors, blindness and difficulty controlling movements. Numerous children suffered developmental problems and early death. In the early 1970s, Canadians witnessed the serious spiritual, social, cultural and health effects of mercury contamination in two northern Ontario Ojibwa communities, Grassy Narrows and Whitedog. Mercury was released from an industrial point source to a river that resulted in toxic levels in the wildlife that the communities depended upon.

Today, there is increasing concern among Aboriginal organizations, federal, provincial and territorial governments and others regarding the potential adverse human health effects related to the consumption of mercury contaminated wildlife in the Canadian Arctic. When mercury is released into the environment, bacteria can transform inorganic mercury into highly toxic methylmercury. In this form it can be absorbed by biota, and its concentration in the organisms increases (biomagnifying) as it moves up the food web. Elevated levels (i.e., levels that exceed Health Canada guidelines) have been found in some of the fish and wildlife that are significant in the diets of many northern peoples. In Aboriginal households in the Northwest Territories, up to 91 % consume

traditional foods and 22 % report that all of their food is obtained through harvest (GNWT 1990). Analysis of hair and blood from many Arctic Aboriginal communities showed that 20 % of Dene and 57 % of Inuit tested have blood levels that exceeded Health Canada's 20 ug/L mercury guideline in human blood (Chan 1998). As a consequence food advisories have been issued that ban or restrict consumption of traditional foods (CACAR 1997). Any reduction or elimination of traditional foods has significant nutritional, socio-economic and cultural impacts for northern Aboriginal peoples.

There is a growing realization of the importance of designing decision-making processes that are holistic and serve the interests of the Arctic ecosystem as a whole (Doubleday 1996; Wheatley 1996; Wheatley and Paradis 1996). Yet, there is still considerable debate and concern with regards to the adequacy of understanding of the complexities associated with the mercury contamination issue and how to design a strategy that considers all environmental components, interactions among those components and external influences on those components. This is a major gap in knowledge that this study seeks to address.

1.3. Objective

The objective of this thesis is to develop a conceptual model that takes into account: industrial and natural sources; biological, geological and chemical processes; Arctic lifestyles; and exposure levels relevant to the health of humans and other species.

1.4. Importance of this Research

Mercury is a classic example of a pollutant that requires Canada's policy

machinery to evolve further. In the 1970s and 1980s, the primary loading of anthropogenic mercury was thought to be originating from point sources, which were relatively few and easy to control. During this time period, mainly 'end-of-pipe' or command and control measures were employed to reduce mercury emissions in Canada. Over the past two decades there have been decreases in some industrial and agricultural point source releases. However, sources such as fossil fuel combustion, smelters and incinerators are still releasing significant quantities of mercury to the environment (D'Itri 1991).

The conceptual model developed by this study is a necessary prerequisite on which to base policy initiatives that will reduce and mitigate today's risks associated with mercury contamination in Arctic Canada. What sets my conceptual model apart from others is that it considers the Arctic ecosystem's feedbacks and loops among components. The usefulness and strength of this approach is that it is a simplified representation of reality that can help to formulate and frame a complex problem in order to provide managers with an ecological understanding and tools for the development of environmental policy that will protect the health of the Canadian Arctic ecosystem.

My research will challenge managers to re-think contemporary approaches that have focused on economic and political mechanisms. Meaningful solutions now require a transformation in decision-making processes, both domestically and internationally, to create development approaches that fully consider valid environmental concerns. Sustainable solutions will require that the framework used for making development choices everywhere be expanded to include consideration of the long-term global

consequences of those decisions. I will demonstrate that an appreciation of the subjectivity of human perceptions, the fallibility of science, the different knowledge sources and the political and cultural undercurrents of management must be built into any effort that will effectively address the mercury contamination issue in Arctic Canada.

1.5. Thesis Organization

This thesis is presented in eight chapters. Chapter 2 outlines the methods employed to effectively meet the objectives set out by this study. A summary of current information is provided in Chapter 3 to give the reader the necessary background to follow the line of inquiry examined in this study. The lessons learned from a case study of the mercury contamination issue that devastated the Grassy Narrows and Whitedog communities are presented in Chapter 4. The results of my interviews with Aboriginal organizations, academia and territorial and federal governments are summarized in Chapter 5. The needs for a conceptual model are outlined in Chapter 6. The conceptual model developed in this study challenges decision-makers and managers to replace fragmented, reductionist approaches with ecological, integrated approaches (Chapter 7). Chapter 8 pulls together the threads of discourse developed in the previous chapters and evaluates our current understanding of this issue and the priorities for action.

Chapter 2

Methodology

2.1 Introduction

This research strategy takes an all-encompassing approach. The strength of this approach is that it is highly capable of dealing with multi-data sources from a variety of disciplines. This chapter describes the data collection methods and the processes of data analysis that are employed to develop the conceptual model for mercury in Arctic Canada.

2.2 Data Collection

2.2.1. Literature Review

The literature review was carried out to examine existing research that is significant to the mercury contamination issue in Arctic Canada. The review targeted the key aspects of journal articles, books, conference proceedings, government and corporate reports, theses and electronic journals (internet) to determine the physical and chemical characteristics of mercury that are relevant to this study, the different sources of mercury in the environment, the environmental fate and transport of mercury, the environmental factors that influence mercury methylation rates, mercury levels in the Arctic ecosystem, and domestic and international actions that are currently being taken.

2.2.2. Case Study

The objective of the case study is to determine the lessons learned from the mercury contamination issue in the Aboriginal communities of Grassy Narrows and Whitedog, and to provide a basis on which to explore how management of this issue has changed in Canada since the 1970s. Data sources included administrative documents,

government publications, journal articles and newspaper articles.

Case studies are typically utilized when “how” or “why” questions are being asked, when the investigator has little or no control over the events, and when the focus is in a real life context (Yin 1994). Understanding the “how” of the social, spiritual and cultural impacts of contaminated traditional foods on an Aboriginal community is not only critical to the conceptual model developed by this study, but it is critical to understanding the nature of the mercury contamination issue in Canada.

2.2.3. Interviews

Interviews were conducted with managers and scientists who have served on committees that are currently addressing the mercury issue in Arctic Canada (Table 2.1.). A total of 14 focused interviews, were conducted representing the major stakeholder groups. There was a 75 % positive response from individuals invited to do an interview. Of the 14 interviews, 11 were conducted in person and 3 were carried out over the telephone.

Table 2.1. Summary of Participants Interviewed by Stakeholder Groups

Stakeholder Groups	Number of Participants
Aboriginal Organizations	2
Northern Governments	2
Federal Government	8
Academia	1
Consultants	1

Research questions were constructed to evaluate the issues that surfaced during the literature review and addressed the underlying research hypotheses. Instead of asking direct questions, participants were asked to share their knowledge and views on 5 open-ended questions. This approach allowed for a discussion on the participant’s thoughts regarding the best approaches to dealing with the mercury contamination issue in the Canadian Arctic. I favoured this approach because in most cases it was necessary to give the participants opportunity for discussion, to allow for the clarification of issues and to

promote meaningful participation. A copy of the interview questions and my ethics proposal to do the interviews are located in Appendix A.

The interviews ranged from 30 minutes to 1.5 hours. Most interviews were tape recorded and transcribed soon after the interviews were completed. Field notes and observations made during the interviews were recorded immediately after the interviews and added to the same file containing the interview transcript. All participants had the choice of remaining anonymous. Those that chose to remain anonymous were assured of their confidentiality both verbally and via a “confidentiality” letter that was signed by the researcher and provided to them. The respondents were asked to give detailed responses, but were able to refuse to answer any questions. The respondents were not informed on how their colleagues answered the questions. Tapes, computer files and paper transcripts were coded to ensure each participant’s confidentiality. All tapes and any other data related to the interviews were kept in a locked box in the author’s office at Carleton University and will have been completely destroyed upon completion of my thesis defense.

All research has its limitations. The relatively small sample size (i.e., 14 people) interviewed could be considered a limitation. However, this was necessary because the study required interviewing only those who are involved in some degree of decision-making authority with regards to the mercury contamination issue in Arctic Canada or with past practices. An effort was made to interview participants from all the stakeholder groups to investigate different perspectives on this issue.

2.3. The Theoretical Framework

The foundation of this thesis is based on several key concepts that are based on an extensive review of literature. These concepts are summarized below:

- Any use of the terms *environment*, *ecosystem* or *ecology* includes humans and human-related activities. Humans cannot successfully control nature to act in a

predictable manner. Humans are part of the entire ecosystem and totally dependant on its health;

- The use of the term *environmental management* is outdated. Use of this term infers something “out there” that is external to humans;
- *Sustainability* refers to the ability of a group or nation to reach their needs without compromising the needs for future or present generations of other groups or nations and without going beyond the resilient ability of the ecosystem from which their resources come; and
- From a direct clinical effects perspective, *risk* is based on extrapolation from lowest observed adverse affects level (LOAEL) or no observed adverse effects level (NOAEL). However, I see this theoretical approach to defining risk that is based on extrapolated figures as an over simplification of a very complex issue. The term *risk* is broadened in this paper to include a social science perspective for known impacts on health and well-being. For example, Wheatley and Wheatley (2000) argue that the “indirect negative effects of methylmercury on health, mediated through the disruption of lifestyle and eating patterns and the associated socio-cultural and socio-economic consequences among the affected native populations, have, in many cases been significant...the standard physical sciences approach of the past three decades now needs to be linked with the social sciences approach, with its focus on the indirect impacts of exposure to methylmercury, to provide a comprehensive approach to public health policy development.”

2.4 Summary

Considering that this qualitative research approach is distinctive from empirical inquiry, it has been viewed by some researchers as lacking in rigor. Those critical of this approach frequently overlook the fact that a bias can enter into any experiment in the physical and social sciences (e.g., questionnaires). The present research relied on different types of data sources, which include interviews and diverse forms of documentation and data. Considering the multi-disciplinary nature of this thesis, my methodological approach discussed in this chapter was necessary to effectively meet the objectives set out in Chapter 1. The strength of my approach is demonstrated in Chapter 8, where the analysis of different data sources converges to yield similar results.

Chapter 3

Background

3.1. Introduction

This chapter describes the Canadian Arctic region and synthesizes the physical and chemical characteristics of mercury that are relevant to this study, the different sources of mercury in the environment, the various pathways in which mercury enters the Arctic environment, the environmental factors influencing mercury methylation rates, levels in some Arctic biota and the domestic and international actions that are currently being taken. The information presented in this chapter improves our ecological understanding of mercury and it will help to answer questions raised by this study.

3.2. The Canadian Arctic Region

Defining Canada's Arctic region has been a challenging task to which some researchers have dedicated their careers (e.g., Hamelin 1972, 1979 and 1988). The Arctic boundary, as defined here, is the area north of 60°N latitude (Figure 3.1.). Considering the different ways of defining the Arctic, this definition is considered by some to be simplistic (e.g., due to different physical, biological and geographical characteristics or political aspects). For the purposes of this research, the relevance of this boundary in this study varies when considering different issues. For example, mercury levels in biota are discussed in relation to the geographical occurrence of the species concerned; the demographic data are presented in relation to administrative regions on which census data are collected (CACAR 1997).

Figure 3.1. The Canadian Arctic Region (CACAR 1997).

3.3. Physical and Chemical Properties of Mercury

In this study frequent use will be made of the terms “methylmercury” and “inorganic mercury”. These are convenient but loose classifications of the different species of mercury. Table 3.1. presents the different physical and chemical forms of mercury.

Table 3.1. The Different Chemical and Physical Forms of Mercury

Hg^0 (vapour)	Inorganic mercury Hg_2^{2+}	Hg^{2+}
	Organic mercury $\text{CH}_3\text{-Hg}$	

The term inorganic mercury is used to describe three chemical and physical forms. Mercury vapour (Hg^0) is the gas emitted from liquid metallic mercury. When one electron is lost, it gives the mercurous ion (Hg_2^{2+}), which consists of two atoms of mercury. The mercurous ion is still used in electrolytic reference cells as mercurous

chloride (Hg_2Cl_2). When two electrons are lost, the result is the formation of the mercuric ion (Hg^{2+}). A variety of stable compounds (e.g., mercuric chloride (HgCl_2)) form in this oxidation state. Mercuric mercury can form a stable covalent bond with the carbon atom to form various “organic” mercury compounds, such as methylmercury.

3.4. Process of Mercury Methylation

Figure 3.2. presents a conceptual diagram that describes the cycling of mercury in a natural aquatic system. Research has shown that most of the methylmercury in biota is a result of methylation of inorganic mercury within freshwater or marine environments. Numerous field and laboratory studies support the identification of sulphate reducing bacteria (SRB) as key mercury methylators (Compeau and Bartha 1985; Gilmour and Henry 1991; Gilmour et al. 1992; Gilmour et al. 1998). The speciation of mercury is an important consideration in any representation of mercury cycling. The speciation of mercury influences whether or not mercury is available for biogeochemical reactions. Biomethylation is a process in which living organisms cause a methyl group to become directly bonded through its carbon atom to one or more mercury elements. This process is localized where the bacteria concentrate, such as at the sediment/water interface or in algal mats. In sediments, methylation was found to be at a maximum in the top 4 cm (Choi and Bartha 1994; Gilmour et al. 1998) and to be mediated by SRB (Compeau and Bartha 1985; Compeau and Bartha 1987).

It appears that methylation occurs inside the cell and that mercury is taken up before methylation (King et al. 2000; Benoit et al. 1999). Methylation is generally considered among researchers to be a method whereby microorganisms can detoxify their own cells. The active agent in this is believed to be a derivative of Vitamin B_{12} with a CH_3^- anion bound to cobalt called methylcobalamine (Baird 1995; Fatoki 1997).

Figure 3.2. Schematic Depiction of Mercury Cycling in Aquatic Systems.

Methylcobalamine has an extensive chemistry and it is recognized as the only methylating agent for mercury capable of transferring a methylgroup to an inorganic mercuric ion (D'Itri 1991). It can transfer groups as a carbanion (CH_3^-) and a methylradical to produce methylmercury or dimethylmercury under both aerobic and anaerobic conditions (Wood 1974; 1987). The efficiency of this process depends on the metabolic activities of methylating organisms and the total concentration and biochemical availability of inorganic mercury. Once methylmercury is released, it is almost completely absorbed by aquatic organisms and is very poorly excreted. As a result, exposed organisms can increase their body burdens to high concentrations despite very low levels in water.

3.5. Natural and Anthropogenic Sources

How much do natural and anthropogenic emissions contribute to the global mercury budget? This question has in the past and continues today to be a subject of debate among researchers. Mercury is a chemical element, and consequently cannot be destroyed or manufactured. The same amount of mercury has existed on the planet since the earth was formed approximately 4.5 billion years ago (Briggs and Crowther 1990). Mercury, however, can cycle through environmental media due to both natural and anthropogenic processes. Natural sources of mercury emissions include wildfires, volcanoes, weathering of rocks, and geothermal sources (U.S. EPA 1997; AMAP 1998; Allan 1996). Anthropogenic activities continue to release geologically bound mercury to the environment, consequently perturbing the natural mercury cycle. Anthropogenic processes that release mercury are chlor-alkali plants, coal and oil combustion processes, such as electric power stations, heating and industrial plants, mining operations, smelting and refining, and waste incineration. Recent studies indicate that the mercury load in the

environment has increased between 2 and 5 times from the start of the industrial revolution (i.e., 100-150 years ago) to today (Nriagu and Pacyna 1988; Nriagu 1989; Rada et al. 1989; Lindqvist 1995; Slemr and Langer 1992; Swain et al. 1992; Mason et al. 1994).

Pirrone et al. (1996) have investigated regional differences in worldwide emissions of mercury to the atmosphere. The main anthropogenic source of mercury emissions to the atmosphere is believed to be solid waste disposal through incineration processes in North America (40%), Central and South America (34%), western Europe (28%) and Africa (30%). Coal combustion, however, remains the main source in Asia (42%) and eastern Europe and the former USSR (40%). In Oceania, Zn-Pb mining and smelting is the major source (35%). According to Pirrone et al. (1996) annual global emission of anthropogenic mercury to the atmosphere are increasing.

Numerous other studies support Pirrone et al. (1996) findings. Atmospheric input has increased an estimated 6-fold during the past 240 years in Immitavik (Hermanson 1998). Outridge et al. (2002 *in press*) found that the concentration in modern beluga teeth was about 4-times above pre-industrial levels in 10 year old beluga, rising with age to 17-times in 30 year olds. Ancient data from Greenland has found that 500 year-old seal hair contained significantly less mercury compared to modern seal hair (i.e., 0.6 ug/g vs. 2.6 ug/g) (Hansen et al. 1991). Not surprisingly, a similar trend was found in mercury levels in human hair from pre-industrial times until today (i.e., 3.1 ug/g vs. 9.8 ug/g) (Hansen et al. 1991). These studies suggest that anthropogenic inputs are significantly increasing mercury loads in Arctic Canada.

3.6. Mercury Transport to the Canadian Arctic

The atmosphere, northward flowing rivers, oceans, sea ice and biota are the main pathways that transport mercury into, within and out of the Arctic. The rapid movement of air makes the atmosphere a critical pathway for delivering mercury to the Canadian Arctic from distant point sources. Estimates have found that anthropogenic mercury emissions from Europe can reach the Canadian Arctic in as little as a few days (CACAR 1997).

3.7. Environmental Factors that Influence Mercury Methylation Rates

Recent research demonstrates that a variety of environmental factors such as temperature, acidity, sulphate and salinity can influence mercury methylation rates and consequently methylmercury levels in Arctic biota. Most of the methylmercury in biota is a result of methylation of inorganic mercury within freshwater or marine environments (Winfrey and Rudd 1990; Gilmour et al. 1992). The environmental factors that affect mercury methylation rates was found to be a complex area of research that is not fully understood by the scientific community.

3.7.1. Temperature

Temperature is a major factor controlling mercury methylation. In sediments, low temperatures inhibit the rate of methylation. Maximum methylation rates tend to be at temperatures around 35°C (Winfrey and Rudd 1990) where bacterial activity is expected to be high. Guimaraes et al. (1998) conducted experiments with surface lake sediments at temperatures ranging from 4 to 55°C. They found highest methylation rates in the 35 to 45°C range. At 55°C, however, methylation was almost completely inhibited. At these temperatures, many enzymes are inactivated and bacterial activity is probably reduced to such low levels that it is effectively stopped.

Chen et al. (1996) and Gilmour et al. (1992) found seasonality to play a role in mercury methylation rates. Methylation rates are commonly at a maximum during the

summer when temperatures are warmest. This observation lends support to the argument for biological control and/or regulation of methylation rates.

3.7.2. Acidity

Regnell (1994) examined the influence of pH on mercury methylation rates in sediment samples from Lake Straken in south central Sweden. This study demonstrates that a moderate difference over two weeks in pH, 6.6 vs. 5.8 in acidified and non-acidified systems, did not cause a difference in the rates of conversion of inorganic mercury into methylmercury. Possibly, the difference in pH was too small to influence the availability of inorganic mercury to methylating microorganisms. Seasonality may have also played a role in this finding. The sediment cores were taken in October when heterotrophic activity and mercury methylation activity is likely lower than during summer at these latitudes.

Xun et al. (1987) studied mercury methylation rates in lake water ranging in pH from 4 to 7, and in artificially acidified lake water at the sediment-water interface. Lowering the pH resulted in a 2-to-3 fold increase in the rate of methylmercury production. Xun et al. (1987) findings are similar to Winfrey and Rudd's (1990) comparison of methylation rates at the sediment-water interface taken from acidified and non-acidified basins of Little Rock Lake, Wisconsin.

3.7.3. Dissolved Organic Carbon (DOC) and pH

The availability of inorganic mercury for uptake and methylation is influenced by the pH of water, particulates and dissolved organic carbon (DOC). A unique aspect of mercury in aquatic environments is that inorganic mercury commonly binds to organic matter more strongly as the pH decreases (Gilmour and Henry 1991). DOC can be an important transport vehicle for mercury because of the association of mercury with DOC

in water. Depending on local conditions, DOC-Hg binding can either increase or reduce mercury uptake by organisms. It appears that if DOC-bound mercury is transported to a site where methylation is occurring, there is an increase in toxicity, however, if DOC-Hg binding is strong enough, DOC can limit the availability of mercury for methylation. The nature of mercury binding remains a poorly understood topic within the scientific research community because the pH response of methylation appears to be variable among and within lakes. More systematic and controlled studies are required to address this topic.

3.7.4. Sulphate

Currently, Mason and Gilmour, researchers from Maryland's Chesapeake Biological Laboratory and the Academy of Natural Sciences Estuarine Research Center, are investigating the role of sulphur in the production and fate of methylmercury in watersheds. They hypothesize that when there is little sulphur present as sulphate, little methylation occurs because many methylating bacteria need sulphate as a nutrient. This study will provide a more in-depth picture of soil and sediment processes that lead to greater or lesser production of methylmercury.

The addition of sulphate to sediment slurries has had different effects on mercury methylation rates depending on the sulphate content being examined and the resulting amount being produced in field and laboratory studies. Excessive amounts of sulphate can actually poison the mercury methylation process by limiting the availability of mercury to methylating bacteria. Gilmour and Henry (1991) point out that the sulphate concentrations in the lake water columns are significantly less than in oceans. As a result, the activity of SRB is less and so are the resulting sulphide concentrations in freshwater sediment. Gilmour and Henry's (1991) data suggests that the optimal sulphate

concentrations for mercury methylation by SRB in sediments are in the 200-500 μm range. Under these conditions, SRB would presumably remain active and sulphide would not interfere with the availability of mercury for methylation.

3.7.5. Salinity

Field studies have shown that mercury methylation rates are lower in sediments with high salinity compared to sediments with low salinity (Compeau and Bartha 1984; Compeau and Bartha 1985; Compeau and Bartha 1987; Choi and Bartha 1994). Compeau and Bartha (1984) have investigated the influence of salinity on mercury methylation rates in salt marsh sediments from Cheesapeake State Park (N.J.). Sediments range from 0.4‰ salinity landward to 2.5‰ seaward. They found that low salinity conditions (i.e., 0.4‰) are the most conducive to mercury methylation. Evidence can be seen by the highest net rate of methylation and by the relatively high equilibrium methylmercury concentration attained. Methylation activity was lower in high salinity (i.e., 2.5‰) sediments by 38%. Presumably, methylation is inhibited at high salinities by the sequestration of mercury by sulphide (Compeau and Bartha 1984; Compeau and Bartha 1987).

3.8. Mercury Levels in Arctic Biota

3.8.1. Terrestrial Food Webs

The current knowledge of mercury in the Canadian Arctic terrestrial biota has been reviewed and advanced by Lockhart et al. (1992), Thomas et al. (1992) and Braune et al. (1999). In a general sense, terrestrial food webs in the Canadian arctic are simple. This web often consists of plant or lichens at the primary producer level, a few herbivores, and one or two main predators (CACAR 1997).

3.8.1.1. Freshwater Food Webs

Spatial trends have been broadened for freshwater fish, revealing that mercury that often exceeds Health Canada's guideline limits for subsistence consumption or commercial sale. Health and Welfare Canada (1978, 1984) have restricted the sale of fish when mercury levels exceed 0.5 ug/g. For people who consume large quantities of fish or engage in subsistence fisheries, the recommended maximum is even lower (0.2 ug/g).

A review of Table 3.2. shows that there is considerable variation in mercury levels in fish located Arctic lakes. Lake trout and northern pike in the Canadian Shield lakes of the Northwest Territories, Nunavik and northern Quebec typically have the highest levels.

3.8.2. Marine Food Webs

Muir et al. (1999) compare changes in mercury concentrations in beluga liver sampled in 1993 -1994 to samples collected in 1981-1984 in Arctic Canada. The results of this comparison indicate that the mean mercury levels in beluga liver sampled in 1993-1994 was significantly higher (27.1 ± 24.7 ug/g wet wt., sample number = 77) than in belugas sampled in 1981 - 1984 (11.8 ± 12.1 ug/g wet wt., sample number = 66) (Wagemann et al. 1996). A similar trend was observed in ringed seals. The mean mercury concentration in liver samples collected between 1987-1993 was 32.9 ± 36.9 ug/g (wet wt.) (sample number = 145) was significantly higher those sampled in 1972-1973 (22.9 ± 28.7 ug/g wet wt., sample number = 42). This temporal suggests that levels are increasing in beluga and ringed seal.

Table 3.2. Mean mercury concentrations in freshwater fish. Numerous concentrations exceed Health Canada's 0.50 ug/g guideline (adapted from CACAR 1997).

Species	Region and Year	N ¹	Total Mercury (ug/g)	% 0.2 ug/g Guideline Exceedance	% 0.5 ug/g Guideline Exceedance
Arctic char (anadromous)	Queen Maud Gulf (1993)	20	0.062	na	na
	Dease Strait (1992)	10	0.027	na	na
	Foxe Basin (1992)	10	0.38	47.4	na
	Cumberland Sound (1992)	10	0.035	na	na
	Frobisher Bay (1993)	5	0.082	na	na
	W. Hudson Bay (1993)	25	0.064	na	na
	E. Hudson Bay (1994)	9	0.057	na	na
Arctic char (Landlocked)	Cornwallis (1992)	3	0.26	23.1	na
	Cornwallis (1992)	7	0.26	23.1	na
	Cornwallis (1992)	7	0.20	na	na
	Cornwallis (1992)	2	0.05	na	na
Lake trout	NW NWT (1993)	11	0.28	28.6	na
	N Québec (1990)	106	0.71	71.8	29.6
	W. Hudson Bay (1991)	9	0.24	16.7	na
	NW NWT (1993)	23	0.13	na	na
	NW NWT (1993)	11	0.95	75.8	47.4
	W. Hudson Bay (1994)	18	0.67	70.1	25.4
	S. Yukon (1992)	17	0.36	44.4	na
Lake Whitefish	NW NWT (1992)	23	0.02	na	na
	S. NWT (1992)	40	0.07	na	na
	NW NWT (1992)	11	0.82	75.6	0.32
	S. NWT (1990)	30	0.08	na	na
Northern Pike	N. Quebec (1990)	6	0.63	68.3	20.6
	S. NWT (1990)	40	0.32	37.5	na
	S. NWT (1990)	11	0.34	41.2	na
	NW NWT (1994)	30	0.44	54.5	na
Walleye	NW NWT (1994)	11	0.98	79.6	49.0
	NW NWT (1992)	30	1.34	85.1	62.7
	S. NWT (1990)	35	0.22	9.1	na
	S. NWT (1990)	99	0.34	41.2	na

¹Number of fish sampled for mercury.

In my review, I generally found higher mercury levels in aquatic rather than terrestrial ecosystems in the Canadian Arctic. According to the U.S. EPA (1997), there are several ways to explain this statement.

The transfer of metals up to higher trophic levels depends on where metals are stored within prey organisms. Birds and mammals, for example, accumulate mercury in their feathers and fur, which are usually not eaten. Piscivorous wildlife, however, consumes and digests most of the mercury in fish, which is contained in muscle tissue. Mercury in the terrestrial food chain commonly exists in an inorganic form, rather than methylmercury. Inorganic mercury accumulates to only a limited extent in plants and soil organisms and does not biomagnify in the organisms that feed on them. Finally, aquatic food chains often include more trophic levels than terrestrial food chains (U.S. EPA 1997).

3.9. Aboriginal Peoples of Arctic Canada

Aboriginal backgrounds and conditions in Canadian Arctic communities are not homogenous. There are different historical, cultural and ethnic backgrounds among Aboriginal peoples living in the Canadian Arctic. There is also a variance in socio-economic conditions, access to traditional and market foods, and living conditions. These differences in Aboriginal communities influence their susceptibility to mercury exposure and the related effects.

The Canadian Arctic, as covered by this study, consists of the Yukon, Northwest Territories, Nunavut, in addition to parts of northern Quebec (Nunavik) and Labrador. As presented in Table 3.3., 17.1, 48.2, 83.9, 88.8, and 73.8 % of the total population is Aboriginal in the Yukon, Northwest Territories, Nunavut, Nunavik and Northern Labrador, respectively.

Table 3.3. Percent Aboriginal Populations in Arctic Canada (adapted from CACAR 1997; Statistics Canada 1996).

Region	Total Population	% Aboriginal Population
Yukon	27 655	17.1
Northwest Territories	39 460	48.2
Nunavut	24 655	83.9
Nunavik	7 690	88.8
Northern Labrador	2 519	73.8

3.9.1. Aboriginal Perspectives on Food

Traditional foods play a vital role in social, cultural, economic and spiritual well-being of Aboriginal peoples. Harvesting, sharing, processing, and consuming traditional foods are critical elements to their cultural identity. Within many northern Aboriginal societies, exchanging country foods involves a complex set of socio-economic rules and procedures that relate to the structural organization of these societies. Food is exchanged within a socially constructed framework of reciprocity, which is the generosity that underlies the relationship between animals

and humans. The significance of elevated concentrations of mercury and other environmental contaminants in traditional harvested foods on personal and community well-being is illustrated in the following citation:

Human bodies stay alive by eating food. If we don't eat we starve to death. We become weak by not eating well. Nowadays, we have started to hear our natural foods are contaminated by chemicals like methyl-mercury or PCBs. They say that they are aware of the contaminants which are now in our food systems. One time, there was this person who was gathering animal names to do research on our natural food system. He said that the birds coming in from further south contain contaminants when they arrive. These are birds we like to eat. Also, they talk about the seals carrying PCBs in their fat; all the larger mammals carry PCBs and other contaminants. That, too, is food which we depend on.

Moses Novalinga, Sanikiluaq in CARC 1997

3.9.2. Aboriginal Perspectives on Health

There are many factors that contribute to the health of an individual and a community. Research has found that a holistic definitions of health is held by many Aboriginal peoples living in the Canadian Arctic (Usher et al. 1979; Wheatley 1996; Usher et al. 1995).

Wheatley (1996) has studied the Aboriginal concept of health and found that health represents wholeness and balance among all interrelated aspects of well-being (Figure 3.3.). Aboriginal peoples achieve balance through their close relationship with the environment. Cultural identity for Aboriginal peoples is expressed in traditional values such as respect for the environment, which promotes physical, cultural and spiritual health (Wheatley 1996). Harvesting activities provide the transfer of a traditional knowledge from Elders to younger generations. This reinforces the special relationship that Aboriginal peoples have with the Arctic ecosystem. This relationship is seen as a necessary pre-requisite for healthy individuals and communities (Wheatley

1994). A disruption of this view can have a major impact on the health and well-being of both individuals and communities (Wheatley et al. 1997).

Figure 3.3. Aboriginal Concept of Health (Wheatley 1996).

Traditional foods play a critical economic role for Aboriginal peoples. A disruption in the use of country foods affects the local economy over which they have the greatest control. Employment and incomes in the Arctic are typically low compared to southern Canada and other regions in the western world. Country foods make a significant addition to household incomes. The expenses to purchase southern foods have been estimated to be well over \$10 000 per Aboriginal household per year (Usher and Wenzel 1989). Non-Aboriginal people living in the Canadian Arctic are less vulnerable to exposure to mercury contamination. Their consumption of traditional foods is significantly less and traditional foods do not have the same social, cultural and economic significance for them (CACAR 1997).

3.9.3. Human Health

Mercury is primarily a neurotoxin in mammals that can cause effects such as, paresthesia, visual disturbances, mental disturbances, hallucinations, ataxia, hearing defects and stupor (USEPA 1997). It can also be responsible for damaging the reproductive capacity of a mammal as it interferes with spermatogenesis causing chromosome damage in connection with mitosis. Developing foetuses are particularly susceptible to mercury because of the intense cell division and formation of the central nervous system. Methylmercury can readily transfer from maternal to foetal tissue and accumulate to some extent in the foetal brain (ATSDR 1999).

Blood samples reveal a limited amount of data. It is similar to a 'snapshot' analogy. Hair samples can be used as a biological indicator to detect change, assuming that hair grows approximately 1 cm per month. Human hair samples give a temporal view of exposure, going back as many months as the hair sample was centimetres long. Blood levels below 20 ppb or 6 ppm in hair are classified by Health Canada (1999) as being in the acceptable range and levels greater than 100 ppb in blood or 30 ppm in hair as 'at risk' (Table 3.4.).

Table 3.4. Human Mercury Guidelines (Health Canada 1999).

Blood	<20 ppb 20-100 ppb >100 ppb	Normal acceptable range Increasing risk At risk
Hair	<6 ppm 6-30 ppm >30 ppm	Normal acceptable range Increasing risk At risk

The Medical Services Branch of Health Canada has carried out mercury analyses of hair and blood from 38 571 residents of 514 Aboriginal communities across Canada from 1970 to 1995. Out of this data set, 23% of the individuals tested, had blood mercury levels greater than 20 ug/l while 1.6 % had levels greater than 100 ug/L (CACAR 1997). In populations that consume little or no fish, such as southern Canadians, the blood mercury levels are typically low (i.e., 2 ug/L or less) (CACAR 1997).

The Inuit and Dene tend to have higher mercury levels relative to other Aboriginal groups in the Canadian Arctic (CACAR 1997; AMAP 1998). Blood mercury levels are commonly highest in the north-eastern Inuit communities (CACAR 1997; AMAP 1998). As presented by Table 3.5., of the Inuit and Dene who were tested, 57.2% of the Inuit and 19.6% of the Dene exceed Health Canada's 20 ug/L blood mercury guideline (adapted from Wheatley 1995; Wheatley and Paradis 1996).

Table 3.5. Blood Mercury Levels in Inuit and Dene living in Arctic Canada (adapted from Wheatley 1995; Wheatley and Paradis 1996).

Aboriginal Group	N ¹	Guidelines (ug/L) ²		
		<20	20-100	>100
Inuit	1511	42.8	55.9	1.3
Dene	711	80.6	19.3	0.3
Total/Average	2222	61.7	37.6	0.8

¹Sample Size: Total number of tests. ²Health Canada's Guidelines (1979, 1984, 1999).

Wheatley and Wheatley (1988) have determined the mercury concentration in archaeological hair samples from northern Baffin Island (400 and 1150 AD). As presented in Table 3.6., the archaeological samples have significantly lower mercury levels than the current human samples from the same geographical areas. The difference from present human mercury levels compared to archaeological mercury levels, suggests that the increase is related to anthropogenic increases.

Table 3.6. Historical levels from Mummified Remains (Wheatley and Wheatley 1988).

Aboriginal Group	Location	N ¹	Guidelines (ug/L) ²		
			<20	20-100	>100
Dorset	N. Baffin	3	8	na	na
Thule	N. Baffin	6	4	na	na
Greenland	Greenland	1	10	na	na
Total/Average		10	7.3	na	na

¹Sample Size: Total number of tests on hair. ²Health Canada's Guidelines (1979, 1984, 1999).

3.10. Domestic Action

3.10.1. Northern Contaminants Program

In 1991, the Northern Contaminants Program (NCP) was established to address concerns raised by environmental studies in the 1980s (e.g., Wong et al. 1985). This program is funded by the federal government and coordinated by the Department of Indian Affairs and Northern Development (DIAND). The NCP is investigating the current state of contamination in the Canadian Arctic environment, including the status and trends of mercury and other environmental contaminant levels and comparing these results to other areas of the world.

3.11. International Action

3.11.1. Arctic Monitoring and Assessment Program (AMAP)

In June 1991, eight Arctic countries (Russia, Finland, Sweden, Denmark, Norway, Greenland, Iceland and Canada) signed the Declaration on the Protection of the Arctic Environment, which adopted the Arctic Environmental Protection Strategy (AEPS). It represents a commitment to address environmental problems in the Arctic. The Arctic Monitoring and Assessment Program (AMAP) is an element of the AEPS that is currently conducting an evaluation of the many threats to the Arctic environment. The mandate of AMAP is to monitor the levels and assess the effects of environmental contaminants in all components of the Arctic ecosystem.

3.11.2. Canada/Russia Program on Scientific and Technical Cooperation in the Arctic and the North

In 1991, Canada and Russia reached an agreement for cooperation on Arctic environmental contaminants. Two major projects were achieved: the establishment of an air monitoring station in the Russian Arctic; and the exchange of environmental samples between Russian and Canadian laboratories for analytical intercalibration purposes.

3.11.3. United Nations Economic Commission for Europe (UNECE)

The United Nations Economic Commission for Europe (UNECE) has established a Task Force on trace metals. The Task Force completed an assessment in 1994 that indicated the need for a protocol to control the long-range transport and deposition of heavy metals.

3.11.4 United Nations Environmental Program (UNEP)

The United Nations Environmental Protection Program (UNEP) is conducting a global mercury assessment. The assessment will be presented in February 2003. At this meeting the governing Council will have a better basis for considering whether or not international action on mercury is called for, thus promoting the environmentally sound management of mercury and its compounds. It is addressing such issues as source use patterns, the environmental impacts and possible prevention and control technologies. The UNEP mercury assessment has the potential to provide a basis for needed global cooperation, which is clearly required to reduce the anthropogenic mercury emissions.

3.12. Summary

The intent of this chapter was to provide the reader with the scientific, cultural and political background that is important to this study. I have outlined some of the problems and complexities associated with the mercury contamination issue in Arctic

Canada. Clearly the topics discussed illustrate the global nature of this issue and that the problem cannot be mitigated by any single industrialized country. I have also emphasized the importance of traditionally harvested foods for northern Aboriginal peoples. They have deep and complex social, cultural and spiritual connections to traditional foods. As a consequence, solutions to this problem transcend the confines of public health and cannot be resolved by simple health advisories or food substitution.

Undoubtedly, the use of data generated by the NCP and AMAP has the potential of extending beyond the generation of research results. The results of these programs can be used at the political level to effect change through the regulation of mercury. The characteristics of the global nature of this issue, the characteristics of Arctic food webs, and the effects particularly on Aboriginal peoples give Canada a strong case for arguing against the continued global release of mercury from anthropogenic sources. The following chapters will build on and elaborate on these statements.

Chapter 4

Lessons Learned

4.1 Introduction

The objective of this Chapter is to investigate the case of mercury contamination and the Aboriginal communities of Grassy Narrows and Whitedog, Ontario. While these communities are obviously not in Arctic Canada, critical lessons can be learned from this tragedy. It is designed to provide a sound basis for the following chapters.

4.2. Overview

In the early 1970s, the Aboriginal communities Grassy Narrows and Whitedog in north-western Ontario (west of Dryden) were among the first communities in Canada identified to have a potential for high exposure to mercury pollution, and therefore, significant health risks (Figure 4.1.). A chlor-alkali plant (near Dryden) that was situated upstream from these communities released effluent that contained a significant amount of mercury directly into the English-Wabigoon River system. The aquatic ecosystem became polluted and mercury bio-accumulated to significant levels in fish that were regularly consumed by the Aboriginal communities. Some of the fish had very high mercury levels and, as a result of consuming the fish, so did some of the residents of the two communities. The introduction of high levels of mercury into the main river system that sustained the communities caused significant economic, social and cultural disruption to an already damaged community. While the exact medical consequences that can be directly attributed to the contamination were never fully determined, the negative impact on the people's livelihood, sense of community, and dependence on local resources is clear.

Figure 4.1. Grassy Narrows and Its Region (Shklinyk 1985).

4.3. Background

Prior to the mercury pollution crisis, the people of Grassy Narrows were relocated to a new location about 8 km south of where they originally lived. The government justified the move on the basis that the new site would be accessible by road to the town of Kenora, and that their quality of life would be improved by modern conveniences such as a school, the new Hudson Bay store, electricity, modern houses, and jobs on the new reserve. This type of thinking on behalf of the government symbolized the government's

policies with regard to Aboriginal peoples in the 1950s and 1960s (Shklinyk 1985).

Aboriginal peoples from Grassy Narrows recall the events leading up to the move differently from the government, and for them, many questions still remain unanswered. Why were the people of Grassy Narrows relocated? What were the motives behind the design of the new community that was so different from the old one? Investigations into existing articles from journals, government documents, newspapers and books, have only partially answered these questions. The history of the decision to relocate this entire community is difficult to piece together.

By 1963, only four families had moved to the new site, and by 1972, the last family had left the old reserve. According to Shklinyk (1985), the people of Grassy Narrows had little input regarding the move and the structure of the new community. The old reserve was spread out, organized by families and clans, and designed by its inhabitants. The new one was completely different. Houses were lumped together row upon row mixing up the families and clans. This caused a major disturbance in their way of life, how they related to each other, and added to the people's sense of helplessness, victimization and frustration. People were told that if they did not move to the new reserve, they would have their family allowances cut off. The outcome of the decision to move the Grassy Narrows community demonstrates the destructive social and cultural implications of forced relocation.

While this was happening, and one year prior to the relocation in 1963, the region's ecosystem was being poisoned by near-by industry. The people of Grassy Narrows would not discover what was happening until 1970. There was scarcely time to

develop a sense of place in their new surroundings before the reality hit, and the massive breakdown of their community and their culture had another strong thrust forward.

Dryden Chemicals situated about 129 km (80 miles), upstream from the Grassy Narrows reserve, operated a mercury cathode chlor-alkali plant in the adjacent pulp and paper mill of Reed Paper Limited (Dryden Division) that produced chlorine and other chemicals for use such as bleach. Between March 1962 and October 1975, scientists estimate that 18 000 kg (40 000 pounds) of inorganic mercury was released to the environment through atmospheric and aquatic discharges of which 9 000 kg (20 000 pounds) of mercury as effluent from its chlor-alkali plant was discharged into the English-Wabigoon River (Spence 1977). Over 480 km (300 miles) of the river system and biological life was polluted. This river fed the people of Grassy Narrows and Whitedog. It is an environmental disaster that had, and continues to have, enormous impacts on the health and well-being of the region (Usher et al. 1995).

Norvald Fimreite came to Canada to study environmental science in 1967. He had a special interest in mercury contamination, and played a large role in bringing the reality of it and its consequences forward in Canada. Fimreite's work led to the eventual cessation of mercury discharge from the chemical industry in Canada (Hutchinson 1977). Around the same time, scientists in Sweden described the process of biomethylation and identified that high levels of mercury found in wildlife were related to upstream chlor-alkali and pulp and paper plants. However, with the exception of the work of a few individuals, mercury was simply was not viewed as a problem in Canada (Hutchinson 1977).

Fimreite began to collect data regarding the mercury levels in wildlife in areas of the country that he believed were at risk of mercury contamination. He found levels that exceeded the federal standards. Fimreite went public with his findings in 1969. His research caught the attention of the Ontario Water Resources Commission (OWRC) who decided to re-examine previously lifted soil samples from the bottom of the St. Clair River that were collected as part of a general water-quality survey in the area. They had never been tested for mercury. The OWRC discovered that some samples were as high as 50 ppm, and a more intense investigation of the area's sediments began. Immediately upriver, there were only trace amounts of mercury, immediately downstream, the sediment was saturated with as much as 1,400 ppm of mercury (close to the concentration found in Minamata, Japan) (Shklynyk 1985). OWRC began to work with Dow Chemicals to reduce its mercury emissions, and asked Fimreite to assist with a sampling program and to help determine the impact on the region's fish. In January 1970, the OWRC had completed its own study and found mercury levels in the fish to be forty times the acceptable level for consumption by humans. Fimreite's study concluded in March 1970, and he found levels consistent with those of the OWRC. He went directly to the Canadian Wildlife Service who reported the findings to the federal authorities. As a result, the Lake St. Clair fishery was closed, and the political debates surrounding mercury contamination began. The response of the Ontario Ministry of Energy and Resource Management was an order to all companies in the province with substantial industrial mercury losses to stop discharging mercury into the environment by April 15, 1970. This included Dryden Chemical Company, Dryden, Ontario.

Days before the opening of fishing season that year (May 1970) in the Grassy Narrows region, the government wrote letters to tourist camp operators recommending that they not eat their catches. They were instructed to only "fish for fun". It was determined that the fish in the 480 km (300 miles) stretch of the river system from the Dyden, to the Manitoba boarder, had mercury levels compared to those in Minamata, Japan. This triggered the collapse of the commercial fishery industry and left the communities of Grassy Narrows and Whitedog shocked and devastated. The loss of nature as a provider and the economic base that the Aboriginal people relied on cannot be measured by conventional methods.

At this time, three of the fishing lodges, including Ball Lake Lodge, voluntarily closed because of the risks associated with the consumption of contaminated fish for the guests and guides. Ball Lake Lodge was one of the most luxurious and exclusive lodges in the area, and the closure was a blow to many Grassy Narrows people who had worked there since 1947. The commercial fishing industry had been one of the few things that sustained the people of Grassy Narrows after their relocation. This loss of commercial fishing and the loss of fish for food undermined any conditions left for self-sufficiency. It also caused a further fragmentation within the family unit. Children no longer worked alongside their fathers and mothers.

Politicians such as George Kerr, Minister of the Environment, demonstrated the ignorance of the general population at the time. He was quoted as saying that the situation would take about twelve weeks for mercury levels to return to normal after the clean up (Shkilnyk 1985). Scientists at the time were fully aware that mercury compounds were insoluble in water and almost indestructible. Many scientists of the

time believed it would take up to a century for the region to recover from the contamination.

A minimal amount of meaningful action by the governments and industry was taken over the next five years to protect and support the people. Between 1971 and 1975, Reed Paper Limited continued to release mercury to the environment as they appealed the date of the order to end its dumping. The Ontario Government's readings showed 60 to 6500 times the allowed mercury emission in effluents. Reed Paper knew that they would eventually have to comply with the regulations set out by the provincial government. Not until November 1975 did they shut down the mercury-cell chlor-alkali plant at Dryden and convert to a new process to produce chlorine and caustic soda that did not use mercury. Shortly afterwards, Reed Paper published its annual report stating that "the conversion to this new technology, which was done solely at the company's initiative, was undertaken to provide the most environmentally sound system available" (Hutchinson 1977). These attitudes and time lines are shocking, because even though the Ontario Minister of Energy and Resource Management ordered Reed Paper to stop discharging mercury into the environment in 1970 after discovering massive mercury contamination, they did not stop until 1975.

In April 1973, Leo Bernier announced that the Ontario Ministry of Natural Resources would assist the communities in dealing with the mercury in an attempt to mitigate this situation. His announcement came after a report from one of the many provincial and federal task forces of the time that were appointed to look into the issue. He promised that the people of Whitedog and Grassy Narrows would have access to uncontaminated lakes for commercial fishing and that they would receive supplies of

uncontaminated fish to eat. By 1975, the only mitigative effort by the provincial government was placing freezers in the Grassy Narrows and Whitedog reserves and stocking them with a supply of uncontaminated fish. The Grassy Narrows band had also requested that the government purchase privately held commercial fishing licenses on near-by lakes and transfer them to the band so the commercial fishing could once again resume. No action by the provincial or federal government was taken on this and many other requests. The federal government instituted a federal task force and a standing committee on mercury in the environment, but ultimately, there was little communication with the Native people, and no realistic programs or help had been identified. By 1975, it was relatively clear that the federal or provincial governments were not prepared to implement comprehensive measures toward social and economic reconstruction because it may have meant acknowledging responsibility for the damage (Hutchinson 1977).

Japanese victims and experts in Minimata disease reached out to the people of Grassy Narrows in 1975, and this marked a turning point for the people of Grassy Narrows. Doctors from Kumamoto University arrived for a visit with the people of Grassy Narrows and Whitedog reserves in March 1975. They examined the situation and reported their findings to academics, and questioned federal officials. The Japanese were quoted in a seminar at the University of Toronto saying "To we Japanese, who have made various mistakes in pollution, this situation is very shocking. Please don't make the mistakes we made in Japan." After the visit, a seven-person delegation from both reserves accepted an invitation to go and see firsthand the effects of environmental mercury contamination in Japan. The Japanese doctors returned to Canada to help the Aboriginal people. They participated in demonstrations in Kenora and in Toronto before

the Ontario legislature. The Japanese advised the Aboriginal people to actively pursue compensation and demand that an epidemiological study be done to determine the effects that mercury was having on their health. Up to this point, the government had not ordered one.

Towards the end of 1975, the politics of the mercury pollution issue became more complex. There were the inquiries of task forces, the visits of government ministers, the probes of doctors, and many broken promises. There was a debate on whether or not to close the river completely, but it did not happen. The lives of the Aboriginal people were still in upheaval and there had been no compensation for the loss of their livelihood. The drastic increase in welfare payments made matters worse (Hutchinson 1977; Shklinyk 1985).

By 1976, Grassy Narrows had become a busy place. Journalists, photographers, activists and researchers were all too common to the area. The people became more and more frustrated by the situation and by glaring lights of television cameras, and the confusion regarding the real and perceived dangers of mercury contamination. While the media helped in raising public awareness, their articles describing mercury as a slow killer, added to feelings of fear and apprehension. Concerned citizen groups visited the reserves to show graphic pictures and films that illustrated the health effects of Minamata disease. Dr. Peter Newberry, a witness of events in Grassy Narrows in 1975 was quoted in Hutchinson's book (1977) saying, "Just looking at the population, you can't say that mercury has done all of this to the people, because it's such a vague kind of thing. But they have blood levels, which it has been shown, have these effects in industrial populations. It has probably had a direct medical impact on the reserve, but a much more

profound effect is the interference with the economy – the disintegration of the family, the alcoholism ... it's horrendous." The public pressure forced the governments to begin action.

In 1979, an historic mediation process took place between representatives of Grassy Narrows, Reed Paper and the government. At the first and last all-day meeting, the Grassy Narrows Band put forward their requirements for social and economic reconstruction. Chief Fobister asked both governments to help them develop economic self-reliance and self-government through the development of an education and skill training fund. The socio-economic fund would be equal to the sum total of economic losses sustained by the community from mercury pollution. This request was basic and included typical building blocks of development. Only the federal government was able to make a tentative offer to settle the damages associated with the relocation. There was no action on the part of the provincial government. Russell Ramsey, Minister of Labour pointed out that "any liability for damages would appear to lie with those whose actions led to the presence of mercury in the water, and not with the government of Ontario" (Shkilnyk 1985). Clearly, the provincial government felt that it did not have a moral, legal or political obligation to the people of Grassy Narrows for the mercury related damages.

The provincial government made it possible for the sale of Reed's subsidiary, Dryden Chemicals to Great Lakes Forest Products, provided they took on any mercury-related damages that exceeded \$15 million. During this time period, no new offer of settlement was made by the provincial government, but they did subsidize Great Lakes Forest Products over the period of 1979-1982, whose profits in 1980 and 1981 were

about \$174 million per year, with about \$52 million from government grants (Shkinyk 1985). Finally, in 1985, the two communities were compensated with \$17 million in recognition of the mercury pollution (Usher et al. 1995).

4.4. Situating this Case Study into the framework of the Conceptual Model Developed by this Study

Based on the data presented in the previous sections of this Chapter, three key components to the mercury contamination issue that are emerging are: science, policy and culture. The following sections summarize details associated with each of these components and provide a foundation for the following chapters.

4.4.1. Scientific Issues

Many people at Grassy Narrows and Whitedog reported that their bodies were not working properly, their arms, legs and joints are hurting and their reflexes were delayed (Shkilnyk 1985). They had both the psychological effects of fear, apprehension and a sense of abandonment in addition to the possible physical health effects to deal with. Medical tests to determine whether or not individual neurological disturbances were linked to mercury, yielded inconclusive results. Dr. Peter Newberry, the first resident physician at Grassy Narrows, performed tests on 17 volunteers in 1974 to 1975. He found a high incidence of tunnel vision and at least one symptom of mercury poisoning in the 15 individuals (Shkilnyk 1985).

Dr. Masamumi Harada, one of the world's leading diagnosticians of mercury poisoning, measured mercury levels in some of the fish, aquatic birds, and fish-eating mammals (e.g., otter and mink) at Grassy Narrows and Whitedog. The mercury levels in the tissues that he analyzed were comparable to those recorded in Minamata. He also

observed that the behaviour of cats near Whitedog that ate contaminated fish were similar to the behaviour the cats in Minamata, where many had died due to mercury poisoning. Harada (1975) also did blood and hair tests and neurological examinations on 89 people (Table 4.1.). His study consisted of 89 people who ranged in age from six to eighty-four years (mean age was 44 years).

Table 4.1. Grassy Narrows and Whitedog Neurological Test Results (Harada 1975)

Symptom	Number of people exhibiting symptom (n=89)
Disturbance of eye moment	12
Impaired hearing	40
Sensory disturbance	37
Contraction of visual field	16
Tremor	21
Hyporeflexia (lessened reflexes)	20
Ataxia	8
Dysarthia	5
Sensory Disturbance	15
Paraconcentric contraction of visual field	9

Dr. T.W. Clarkson, a consultant hired by the Medical Services Branch of the Department of Health and Welfare, found that the highest blood mercury levels corresponded to periods of heavy fish consumption in the late summer and fall. At other times, mercury levels were typically lower. A well-known neurologist, Dr. J.S. Prichard of the University of Toronto tested the residents in 1976, 1977 and 1979. He concluded that his clinical examinations alone were inadequate for a definitive diagnosis of mercury poisoning. He found that neurological disturbances related to mercury were negative for 25 cases; positive and not related to mercury in five cases; and positive but possibly not related to mercury in ten cases.

From 1971 to 1978, the highest levels of exposure were in the range of 200 to 699 ug/L, with most findings at the low end of the scale (Health and Welfare Canada 1979). The symptoms observed at Grassy Narrows were relatively mild and many of them could have been related to other factors, such as alcoholism (Harada 1977). In the existing literature more is known about the consequences of large concentrations of mercury in the human body than about the effects of chronic, low-level and seasonal exposure. Considering the levels found in some individuals, however, there is cause for concern and it is possible that milder forms of mercury poisoning, although difficult to prove, were occurring. In addition, the very difficulties of diagnosis in this situation are a cause for concern.

4.4.2. Cultural Issues

People in Grassy Narrows struggled to comprehend the dangers associated with the "unseen poison" in the water because it had no taste or smell in the fish, and the source was far away (Hutchinson 1977; Shkilnyk 1985). In the absence of information and education, and an onslaught of contradictory messages from governments and industry about the threat associated with mercury, they did not understand what was happening to them (Hutchinson 1977). As one woman that Shkilnyk (1985) interviewed says: "People have been trusting the fish for many years, and suddenly you don't know whether to trust them any more...It's not so much a fear, it's a suspicion."

Up to this point, commercial fishing and fishing for food had provided some link to the traditional way of life that had been lost as a result of the relocation. The river that the people of Grassy Narrows and Whitedog were economically, socially, spiritually, and culturally strongly connected too, was now extremely contaminated. Among many

losses, one of the biggest was the loss of their ability to provide for themselves without being totally dependant on external sources. After the relocation and prior to the contamination, there had been some security left in knowing that the river would provide for the community.

The communities of Grassy Narrows and Whitedog were widely recognized to have higher rates of social problems than on any other reserve in the district during the 1970s (Shkilnyk 1985; Usher 1979; Usher et al. 1995). What is most concerning is the high number of violent deaths at Grassy Narrows. The number of violent deaths increased nearly 6-fold from 1963-1969 to 1970-1977 (Usher et al. 1995).

The closure of Ball Lake had a large economic and social impact on the community. It is estimated to have contributed to more than half of the total income of the residents from Grassy Narrows and Whitedog. Many residents were employed as guides at Ball Lake, which was seen as one of the most desirable places to work in the area. It is impossible to measure the true loss of the economic base that the Aboriginal people of Grassy Narrows depended upon (Hutchinson 1977; Troyer 1977; Shkilnyk 1985). The closure of Ball Lake Lodge, the loss of commercial fishing and the loss of fish for food, resulted in a shift from dependence on the land to dependence on the government for economic support. People did not feel as self-sufficient as before, and their traditional skills were not being employed to their maximum potential. Welfare payments one year after mercury contamination was discovered, rose to 6 times what they were before it. Essentially, the Grassy Narrows residents became dependent on welfare, or they moved away from the reserve, which many did.

Government officials did not recognize the significance of the loss of fish as food and the manner in which it sustained Aboriginal peoples lifestyles. A disruption of traditional food consumption has been shown to have significant adverse economic, cultural and social effects.

4.4.3. Political Issues

The politics of the mercury pollution issue at Grassy Narrows is a complex area of research. In the 1970s, the government and industry's mandate was perceived to be one that denied responsibility for Aboriginal peoples and one that avoided any legal, moral or social liability (Hutchinson 1977; Shkilnyk 1985). Throughout this decade, the failure of the governments to deal with this situation in a holistic and integrated manner left the community of Grassy Narrows with a feeling of powerlessness and frustration. It seems that decision-makers were more concerned about managing people's reaction to the problem, rather than managing the problem itself.

In 1971, the Ontario government became aware of the economic implications of mercury contamination, and the pollution debate focused on balancing the risks to health against the potential loss of tourist revenue in the region. The provincial and federal governments' views, actions and interests were fragmented. Ministers contradicted each other. In 1971, Richard Potter, Minister of Health, wrote the camp operators and advised them not to eat fish from the polluted river. However Leo Bernier, Minister of Natural Resources announced on the Kenora radio that the river would be fine for the average tourists to come up and eat fish for two or three weeks. Other cabinet ministers agreed with Bernier. In fact, Rene Brunell, Minister of Resources Development, felt that the mercury problem was getting too much attention and that the mercury issue was related

to the natural background levels in the Precambrian Shield (Shkilnyk 1985). The tourist industry was well represented in the political debate, and in 1971, the fishing advisories and “fish for fun” posters tapered off and were withdrawn from circulation. That year, the province spent \$70 000 promoting Ontario as a “superior” sports fishing province (Hutchinson 1977). After 1971, there was no more mention of possible compensation or relocation help to fishing camp owners as there had been in 1970.

In 1970, 1972 and 1973, Aboriginal people’s blood and hair were tested for mercury. The band council sent letters in 1973 to provincial and federal officials insisting that they be informed about the results. On March 8, 1973, the information was finally produced in an insensitive form that was difficult for the residents to understand. According to Shkilnyk (1985) government officials handed out the results in sealed envelopes, just before they boarded the airplane to go home. The letters were vague and did not cover the medical and technical aspects of mercury contamination. This situation reinforced the feeling that government officials were not concerned about their well-being. Clearly, the poor communication about the mercury contamination problem from the government and the media coverage heightened anxiety in the community.

The National Indian Brotherhood (today called the Assembly of First Nations) organized a mercury team to investigate mercury pollution in Canada in 1974. The team found that government had not been communicating facts appropriately with the Aboriginal people, and had mislead the public in terms of the seriousness of the mercury issue. Political pressure was placed on the federal government, which was reinforced by the publicity and media attention. Canadian citizens began writing letters demanding to

know why politicians would suppress information and why they would not act to deal with the problem.

4.5. The Lessons Learned

Little effort was made on the governments' behalf to communicate in a culturally sensitive manner to the Aboriginal communities. A number of politicians were quoted erroneously stating that the risk from mercury pollution was minimal or non-existent, and that the mess could be cleaned up quickly. Similar disasters had taken place in other countries and international conferences on heavy metals in the environment had taken place. Scientists had even described the process of biomethylation and identified that high levels of mercury found in fish and other wildlife were related to upstream chlor-alkali and pulp and paper plants. Yet, years went by before a comprehensive medical investigation was ordered. The science to justify such an investigation was there from the start. Looking back, it is difficult to understand how the governments in Canada were unaware of the hazards associated with mercury pollution.

The information that was communicated to those most at risk came too late and in a manner that was neither clear nor accurate. The series of events that followed the discovery of mercury in the river, demonstrated the government's insensitivity to the health and well-being of the communities at the time. Based on the evidence presented in this case study, it certainly seems that the economic loss of a damaged tourist industry in the area was far more important to decision makers than the ecological risks. It also appears that the governments' fear of incriminating themselves by taking the lead in any significant recovery effort outweighed the needs of the people.

The negative impact of the prior relocation of the residents of Grassy Narrows complicated the matter. Significant damage had already been done to the people of Grassy Narrows through the governments' disregard of their cultural beliefs and traditional ways. Mercury pollution in any society would amount to a crisis. For an Aboriginal community who has always depended on the harvesting of local resources, it marked the end of a way of life and a disintegration of their culture. The cultural impact of such a disaster should have been a major element in decision-making processes. This aspect of the issue has never been completely addressed (Hutchinson 1977). Any successful effort to support and compensate a community and its people after such an event, must include the full participation of those most affected.

Governments could have minimized the confusion and the negative social outcome in the community, by reacting in a timely manner and basing their decisions on scientifically reliable information. The risks to human health and the reality associated with the pollution should have been communicated to the people honestly and in a culturally sensitive manner.

Some measures were taken to try and mitigate the mercury pollution issue at Grassy Narrows, but they failed. In my opinion, they failed because actions that were intended to help were misguided, and were formulated based solely on the government's perceptions of what the Aboriginal people needed at the time. The governments' understanding of the people's cultural, spiritual and social background was inadequate and their disrespect was blatant. This unfortunate affair has brought about awareness of mercury pollution and its impact, as well as the devastating social outcomes that can result from the erosion of a culture and a people's way of life. The lessons learned will

serve to inform the future actions of governments, industry and society in general. The teachings go beyond the mercury contamination issue, and can guide other minority groups under pressure and threat of modern development and the decision makers who will direct it (Hutchinson 1977). This is certainly a lesson for the future.

To summarize, the key lessons learned from the mercury contamination issue that occurred at the Aboriginal communities of Grassy Narrows and Whitedog are:

- Contamination of traditional foods risk undermining confidence in the ecosystem and interfere with the quality of Aboriginal lifestyles;
- Decision-makers did not err on the side of caution (i.e., ecological health), but on the side of economic and political pressure;
- Communication of the risks associated with the consumption of contaminated traditional foods must be done with extreme caution and in a culturally sensitive manner. There are a number of cultural barriers which need to be crossed when talking about mercury contamination;
- While the media can play an important role in raising awareness, at times the media over-dramatized and oversimplified the mercury contamination issue. This caused unnecessary fear and anxiety for the Aboriginal communities of Grassy Narrows and Whitedog;
- Traditional institutional and bureaucratic thinking about the environment and development was not ecological; and
- Once biota is contaminated, the situation is very difficult to mitigate for those who depend on harvesting local renewable resources.

Chapter 5

Stakeholder Opinions

5.1 Introduction

This chapter summarizes the results of interviews with the managers and scientists from Aboriginal organizations, governments and academia involved in the mercury contamination issue in Arctic Canada. The result of this research gives insight into the potential for policy and regulation, gaps in the science and the potential for mitigation. The interview results, in combination with the literature review and the case study (Chapters 3, and 4) are applied to the model developed by this study (Chapter 7).

5.2 Policy Priorities

The most common response from the participants was that long-term solutions are required to be centred on legally binding agreements and a general willingness of developed and developing countries to address the problem rather than ignore it. Canada's policy direction must be focused on developing a mercury management scheme that includes all countries that release mercury to the environment from anthropogenic processes. Most participants clearly stated that the Arctic anthropogenic sources are minimal. There was no doubt among those interviewed that the primary concern is emissions from southern latitudes. While Canada is a small emitter in a global context¹, we are in a good position to provide financial

¹ Based upon available inventory information (Environment Canada 2001), it is estimated that in the year 2000 national mercury emissions were 12 tons.

assistance to developing countries to help improve their ability to deal with this issue. These types of strategies will bring us one step closer to solving the mercury contamination issue in Arctic Canada and they fit into our policy mandate of trying to protect Canada in a positive manner by looking at the global picture.

Mercury appears on the Canadian Environmental Protection Act (CEPA) list of toxic substances (Canadian Environmental Protection Act 1988). It is considered to be persistent, bioaccumulative and toxic and an eventual “zero discharge” policy applies to mercury under this agreement. Care, however, is required when describing mercury as an element that is targeted for “virtual elimination from the environment.” Mercury is a naturally occurring element in the earth’s crust, and consequently, there will always be a baseline mercury level in all components of the Arctic ecosystem. According to one of the participants, advertising that mercury can be eliminated from the environment can lead to serious communication problems between the governments and the public (e.g., Great Lakes Programs).

Two participants pointed out that the public and experts still do not fully recognize the need to think more ecologically and to consider all components of the ecosystem when making environmental decisions. Unless action is taken, the mercury contamination issue is only going to get worse because the global population is rapidly growing. To sustain most lifestyles in industrialized nations, we consume large amounts of energy and generate large amounts of waste. The necessary financial resources, technological abilities and political institutions to address the mercury contamination issue exist. The political leadership and public support do not. Unlike issues such as acid rain or PCBs, mercury has yet to catch the attention of

the media and public. Better public education and communication programs should be initiated to raise awareness about the mercury contamination issue in Arctic Canada.

Summarized below are additional policy priorities identified by the participants:

- Continued consumption of traditional foods in Arctic Canada, with the realization that there is a need for giving dietary advice in a culturally sensitive manner. This approach would allow Aboriginal peoples to make informed choices concerning the foods they eat;
- When delivering dietary information about the risks of consuming mercury contaminated traditional foods, complement this information with the nutritional benefits of consuming traditional foods;
- The polluted are the ones paying right now, not the polluters. Innovative strategies and stricter policies are required to force industry to clean up their act;
- Aboriginal populations in Arctic Canada are recognized by all participants to be the most vulnerable to potential adverse human health effects related to the consumption of contaminated biota;
- There is a need for greater awareness among people in industrialized nations that Arctic Canada, due to anthropogenic activities is no longer a pristine environment;
- Ecological decision-making processes must be designed that focus on the ecosystem as a whole and move beyond focusing on economic and political considerations; and
- Re-define what is meant by 'natural' and 'anthropogenic' sources of mercury. For example, the melting of ground ice in a permafrost region and the consequent increase of water (on a volumetric basis) in thermokarst depressions/lakes could be linked to increased levels of mercury in biota (this scenario would increase the number of environments that would favour mercury methylation). So, in fact, it looks like natural sources but it is really a factor of human agency. A re-examining of the definitions of 'natural' and 'anthropogenic' could lead to a clearer and improved understanding of this issue.

5.3 Gaps in Knowledge

The largest gap in research was identified to be the scientific uncertainty regarding the ratio of anthropogenic to natural sources of mercury. While there continues to be debate on this matter, many of those interviewed said that the anthropogenic: natural ratio was about 50:50. This knowledge gap is a “loophole” for industry and makes it difficult for policy makers to enforce stricter regulations. This debate could lead to further delay in domestic and international action. Time is at a premium because the Arctic ecosystem is susceptible to added burdens of mercury from distant sources.

A number of researchers (e.g., Lu et al. 2001; Schroeder 1998) during the spring have observed episodic depletions in mercury vapour concentrations and other environmental contaminants. In terms of the mercury mechanics associated with this phenomenon, the sudden appearance of sunlight after long polar winters drives chemicals in sea salt to convert Hg^0 vapour in the air into one or more less-volatile Hg(II) species which are deposited onto frozen surfaces more rapidly than the precursor and are more water soluble than the original substance. Melting snow transfers a pulse of oxidized inorganic Hg(II) into the Arctic ecosystem at a time when it is vulnerable to contamination, which is at the end of the winter when most plants and animals are growing fastest (Lu et al. 2001). By analogy with springtime troposphere O_3 depletion chemistry, Lu et al. (2001) believe that most of the oxidation of Hg^0 to Hg(II) takes place in the snow/snowpack on the Arctic Ocean and adjacent terrain. In the lithosphere and hydrosphere, oxidized inorganic Hg(II) can be converted to MeHg . This becomes concentrated as it passes through the food web.

This is an important area of research because the observed atmospheric springtime depletions in mercury could be linked to increased mercury levels in biota. The processes and mechanisms associated with this relationship remain as a large scientific gap. Clearly, further research is required.

While some temporal trend studies exist (e.g., Wheatley and Wheatley 1988), more data is going to be required to determine if control measures are effective, especially if there is going to be a global mercury treaty. There is a need for a temporal trend program that looks at key species in key areas. Temporal trend data is scarce for Arctic biota. There is some evidence of mercury increasing by a factor of 2-3 in some marine mammals over the last 2 decades. However, only liver, and in certain cases kidney show such an increase. There is uncertainty regarding the rates of annual increases and year-to-year variations. Many of the participants mentioned that it is critical that temporal trends be closely monitored in appropriate environmental media at a few locations and in some cases over wide areas.

Conventional health risk assessments are not appropriate for Arctic Canada. In the past, food advisories have resulted in a decline of subsistence fishing and a decline in fish consumption. This decline in traditional food consumption is linked to a growing concern about diabetes, cardiovascular disease and declining physical activity. These concerns raise the issue of the role of traditional foods in human nutrition and the importance of a larger, interconnected and culturally defined system of food production. Risk assessments require a better understanding of the social and cultural implications of food advisories in Arctic Canada. While some work has been done in this area, it remains as a large gap in the human health risk assessment

process. Further research is required to expand and improve risk:benefit studies and to move beyond a traditional scientific risk assessment framework. Increased cooperation among researchers, health professionals and Aboriginal communities are required in order to find solutions, reduce knowledge gaps and to provide a better understanding of the issue. More research is required in weighting the well-known benefits of traditional food consumption in risk assessments.

Several participants were very interested in the use of Traditional Ecological Knowledge (TEK), especially in the context of environmental monitoring. There are numerous knowledge gaps in the ecological information about northern regions that science alone cannot fill. According to one of the participants, TEK, which encompasses the biophysical, economic, social, cultural, and spiritual aspects of the environment, is in many instances better suited to answer scientists' many questions by emphasizing the inter-connections among components of the environment and avoiding scientific reductionism. In addition, TEK considers humans to be part of the natural environment, not controllers. But who benefits from the use of TEK? How will TEK be used? Should it be integrated into the Western science paradigm? I will address my concerns with TEK use in more detail in Chapter 7.

Summarized below are additional research gaps identified by the participants:

- Researchers need to re-examine Health Canada's mercury guidelines for humans and biota – are they appropriate for Arctic Canada?
- Further investigation of both the levels and the influence of mercury on fetal development are needed. This evaluation is a priority because the fetus may be 5 times more sensitive to the effects of mercury than the adult;
- More studies are required to determine the effects of chronic, low dose exposure on humans; and

- Not enough is known about mercury transfer at the abiotic-biotic interface.

5.4 Mitigation

Most participants clearly state that mitigation efforts should fully include Aboriginal peoples and that Aboriginal peoples should be given greater decision-making powers concerning research and subsequent public policies.

As many of the participants pointed out, selenium could be a naturally occurring mitigative factor. Generally speaking an adequate supply of selenium is provided through diet in populations depending on the food. While animal studies typically show that selenium protects against the effects of some heavy metals (i.e., mercury), its role as an antidote for metal toxicity in humans is at present hypothetical. According to several of the participants, the extent to which selenium may block the toxicology effects of mercury is debatable. For example, selenium did not inhibit the toxicological effects of mercury in the Minamata tragedy. Further research is required to investigate the selenium-mercury interactions in humans.

As presented in Table 5.1., there was a range in response about the various ways in which to mitigate the current situation in Arctic Canada.

Table 5.1. Stakeholder Mitigation Suggestions

Mitigation Suggestions	Notes
Alternative Dietary Choices	Avoid animal parts that are known to have high mercury concentrations such as muktuk (i.e., whale skin). Eating foods lower in the Arctic food web (e.g., Arctic char) would reduce exposure.
Improved Education and Communication	In the international arena, we need to build consensus not only among countries that are polluters but in all countries to raise awareness about the sensitive nature of this issue in Arctic Canada. Domestically, there is a need for a shared understanding between southerners and northerners about mercury pollution in the Arctic.
Focus on long term solutions, while minimizing exposure at the local level.	While focusing on a global mercury agreement to eliminate anthropogenic emissions to the environment, efforts must be made to reduce exposure for Aboriginal Peoples without disrupting traditional food consumption.

5.5. The Evolution of the Mercury Issue in Canada

When participants were asked how the mercury issue has changed since the 1970s, the majority of the participants saw mercury loading as an issue that was thought to originate from a few single point sources, to one that is now growing and transboundary in nature. The costs associated with reducing emissions from industrialized nations will be substantial. Some of the participants were optimistic that resistance by industrialized nations to a global mercury treaty will dissolve as the health, environmental and economic costs of mercury pollution become apparent and as the benefits of strict mercury controls become clear. As one participant pointed out, the complexity of this situation does not mean that we must accept the status quo. On the contrary, this difficult situation underscores the urgency to develop innovative methods of preventing mercury pollution.

5.6. Summary

The data generated by the interviews complemented the literature review (chapter 3) and the case study (Chapter 4). The open-ended nature of the interview questions led to somewhat of a discussion about each participant's thoughts on the main components of the mercury contamination issue. I found the discussions to be centered on cultural, scientific and political aspects of the mercury contamination issue. The findings presented in this chapter are closely aligned with those of Chapter 3 and 4.

Initiatives undertaken by various territorial, provincial and federal governments and Aboriginal organizations have determined that mercury is still a problem in Canada. All participants acknowledged that mercury is a substance that is predisposed to long-range transport and further policy is needed to address both local and long-range transport of emissions.

There was a general consensus among those interviewed that the complex interplay of processes underscores the need for an integrated approach to the management of the mercury contamination issue at the national and international levels. However, as many of the participants pointed out, integrated approaches introduce so many complexities that it is difficult for people to comprehend and manage. The challenge now is to design a flexible and dynamic management approach that takes an ecological focus, rather than an economic focus. Chapter 6 presents the needs for such an approach and Chapter 7 presents the conceptual model developed by this study.

Chapter 6

Conceptual Model Needs

6.1. Introduction

Chapters 3, 4 and 5 have investigated the issues associated with the contemporary situation in Arctic Canada, determined the lessons learned from the tragedy that occurred at the Aboriginal communities of Grassy Narrows and Whitedog (Ontario, Canada) in the 1970s and explored the stakeholders' opinions, respectively. As previously discussed, the three key components associated with the mercury contamination issue are: culture, policy and science. The objective of this chapter is to integrate and build upon the theories and insights previously discussed to detail what is needed in a conceptual model for mercury in Arctic Canada. This effort is a critical aspect of this study because it informs the conceptual ecological model presented in the following chapter.

6.2. Why is a Conceptual Model Needed?

Considerable progress has been made in the development of models for illustrating and conceptualizing ecological relationships. Koch proposed one of the first models in the late nineteenth Century (Forget and Label 2001). This model was based on the germ theory of disease (i.e., tuberculosis, typhoid, plague, cholera, etc.). While Koch's model is medically orientated and simple, it has given other researchers from a variety of disciplines a foundation for more comprehensive models to better explain the complexity of interactions between humans and the environment in which

they live. These types of models have been very influential in the political arena, and are typically based on broad environmental components such as the biophysical setting and social factors (i.e., individual lifestyle, economic and structural) (Forget and Label 2001).

Tansley (1935) was the first to employ the term “ecosystem” to describe a set of living organisms and abiotic environments that exist in the same space. Odum (1953) and other authors have developed this concept of ecosystems more fully, through emphasis on the importance of interactions between components of any system. Traditional ecosystem management literature typically assumes that scientific understanding is based on biological and physical science. Despite many attempts, there are a relatively small number of existing models that account for the entire range of biological, physical and sociocultural processes or adequately present the linkages and feedbacks between and among human and the environmental systems (Forget and Label 2001).

To date there have been no attempts to fully model mercury in the Canadian Arctic ecosystem because of the complex nature of this issue. As pointed out in the AMAP (1998) report modeling mercury (and other environmental contaminants) in the Arctic is extremely difficult because: it is a large area; monitoring (i.e., biological and physical) has not been done on a regular basis; there are many gaps in data and knowledge; and numerous cases data sets that are not comparable (i.e., due to collection and reporting). It is factors like these that present severe limitations to modeling mercury in the Canadian Arctic ecosystem.

Achieving solutions to the mercury contamination issue requires re-thinking traditional approaches that are no longer effective in managing the complex and

interrelated environmental problems that we face today. The traditional, fragmented and linear approaches are now being replaced with more integrated and comprehensive strategies (MacDonald 1991; Likens 1992). Consequently, a useful model must integrate the key processes and interactions that are related to the problem and properly reflect system dynamics. Models are not necessarily mathematical or predictive. In fact, there is an increasing realization among decision-makers and others concerned that “complex” systems will always have a degree of uncertainty, making prediction a elusive goal (Hartig et al. 1998a; Rapport et al. 1999). The components of an ecosystem are deeply connected and it is not the separate parts themselves but the interactions between the parts that are essential to addressing the mercury contamination issue in Arctic Canada.

6.3. Cultural Needs

Managers are currently being faced with the challenge of making high quality decisions while remaining responsive to the people those decisions affect. Meeting the challenge poses particular problems because the mercury issue is technically complex and value-laden, and multiple interests operate in an atmosphere of conflict and mistrust. The conceptual model needs to be flexible to accommodate and balance different objectives, values and ecological needs.

There is a need to design a decision-making process that develops a shared understanding about mercury contamination and accommodates ecological thinking. This is extremely difficult. The mercury contamination issue crosses boundaries and jurisdictions and affects different groups of people in different ways. There are many scientific gaps and a significant difference in the magnitude to which lifestyles of different populations are disrupted. Effectively managing the mercury contamination

issue requires all those who can mitigate the concerns to be involved. Conflicts can be minimized by a better understanding and appreciation of how different cultures perceive mercury pollution. While this increases the complexity of a model, the absence of a stakeholder group will inevitably lead to incomplete implementation and subsequent difficulties (Hartig et al. 1998a; 1998b).

6.4. Political Needs

As discussed the results of scientific studies funded by NCP and AMAP demonstrate that mercury and other environmental contaminants that originate from outside of Canada are accumulating in traditional foods and in the tissues of some Aboriginal peoples, and that they are of concern. Consequently, there are two different issues that a conceptual model for Arctic Canada must address: first is pollution, which originates within Canada (domestic policy); and second, is the pollution that originates from outside of Canada (international policy) (Doubleday 1996).

6.4.1. Domestic Policy

Mercury pollution in the Canadian Arctic still has many intrinsic questions associated with it, ranging from the adequacy of current scientific understanding, the basis for formulating policy, and the appropriate process for making decisions, to the participants necessary for effective management of regulation. Considering these complexities, solutions to this issue need to be innovative, integrated and holistic in nature (Doubleday 1997). While the NCP demonstrates that it is not necessary to abandon our customary institutional arrangements, there are still many uncertainties and resistance on the part of some industrial interests and government agencies to adopt well-reasoned precautionary responses to the mercury contamination issue.

6.4.2. International Policy

As discussed, traditional political mechanisms need to be expanded because anthropogenic processes that release mercury to the environment are increasing over time and are intensifying beyond national boundaries. The UNEP mercury assessment has the potential to provide a basis for needed global cooperation, which is clearly required to reduce the anthropogenic contributions to the global mercury budget. Reaching a global agreement, however, is far more easily said than done. Cooperation is required in both the developing and developed world to reduce anthropogenic mercury emissions. In the developed nations, producers of mercury or processes that release mercury may not be able to operate in certain jurisdictions where there are stringent regulations on production, methods or products, but they can move to other jurisdictions, including the third world, where it is possible to avoid regulation. While the sources may be moved farther away from the Arctic, the problems of atmospheric contamination due to transport into the Arctic may be delayed but are not resolved.

6.4.3. Lessons from the Stockholm Convention

Important lessons on what should be included in models can be learned from the recent global persistent organic pollutants (POPs) treaty that was signed in Stockholm, Sweden (Environment of Canada 2001). The global agreement, popularly known as the Stockholm Convention, focuses on protecting the health of ecosystems (including humans) by reducing or eliminating emissions of POPs that are subject to long-range transboundary atmospheric transport. Aboriginal organizations played a key role. In fact Fenge (1998) notes that five major organizations in Arctic Canada were responsible for getting federal government recognition of the POPs issue as a health issue.

Unfortunately, like many environmental issues there was an over emphasis on the part of the federal government on the economic and trade issues and not enough on protecting the ecological health of Arctic Canada (Fenge 1998; Keith 1998).

The federal departments of industry, natural resources, agriculture and agri-food and the pest management regulatory agency were concerned about the economic aspects associated with the POPs protocol (Fenge 1998). In a letter to the Department of Foreign Affairs and International Trade (DFAIT) they suggested that:

Actions on these substances can be expected to have significant economic impacts, by virtue of reducing or elimination markets for specific products and associated industries, and by requiring substantial investment in technology designed to reduce or eliminate by-products of a wide range of manufacturing processes.

(in Fenge 1998)

The letters reflect the competing interests that exist in society. Clearly this position was not uniform among government departments. Other federal departments saw it as a public health concern. As Fenge (1998) points out, it is not surprising that there was conflict in the midst of international negotiations between federal agencies on Canada's position. These events did not inspire trust in the federal government among Aboriginal peoples in the Canadian Arctic.

6.4.4. Issue Awareness

Some environmental groups are highly organized and regularly work with the media to raise awareness on issues at a national and international scale. Nevertheless, Fenge (1998) points out that there have been few groups that responded to the CACAR (1997) and AMAP (1998) reports. Environmental groups such as the David Suzuki Foundation or the Sierra Club have yet to address the mercury issue in the Canadian Arctic for many reasons that range from lack of sufficient funds to properly address this

issue to the perception that there are few people living in Arctic Canada or the resistance of northern peoples to southern non-governmental organizations (NGOs).

Mercury is invisible which makes it an issue that can be easily overlooked. As proven by the case study in Chapter 4, informing the public increases pressure on politicians to deal with and hopefully resolve the issue. As a start, a substantial effort needs to be made to raise awareness about the transboundary nature of this issue and of the implications for people living in the Arctic who rely on traditional foods.

6.5. Science and Social Science

Obviously both the social sciences and physical sciences have important roles in informing management decisions. However, there is a major debate between the social science and scientific community about which of the two sciences is more critical to its success. The controversy is based on the idea that science alone is inadequate to inform management decisions, and that we must adopt a broader conceptual framework that must include social, cultural and ethical considerations.

An effective model should take into account that modern science is a bridge between basic sciences of how the natural world works (i.e., both abiotic and biotic components) and the more applied sciences of how human society makes decisions for increasing the welfare of its members (Peacock 1999). Anthropogenic processes have perturbed the natural mercury cycle, creating an environmental problem that is both complex and dynamic. Consequently, science that is employed to address concerns must be founded on assumptions of unpredictability, incomplete control and a recognition of a plurality of perspectives from governments (i.e., territorial, provincial and federal), Aboriginal organizations, non-governmental organizations and others concerned about

this issue. The objectiveness of classical science is not capable of fully resolving the concerns associated with the mercury contamination issue in the Canadian Arctic ecosystem, because science continues to fail to acknowledge that humans are deeply involved in the dynamics and the outcomes of the ecosystems they are trying to influence.

There are a number of researchers (e.g., Wheatley and Wheatley 1996; Usher et al. 1995) that stress the importance of giving attention to aspects of social science including public participation, inter-agency cooperation, organizational and institutional change, values and ideology when making decisions affecting the north. The success or failure of an environmental management strategy, revitalizing economies, or restoring healthy ecosystems begins and ends with people and their choices, not with databases, technological tools or complex quantitative modeling studies (Milton 2001). Clearly solutions to the mercury contamination issue will require a meaningful value-based, holistic and integrated effort. Achieving a sustainable future with regards to the mercury contamination issue in the Canadian Arctic will require cooperation, communication and mutual respect from both disciplines.

6.6. Summary

This chapter has reviewed the cultural, policy and scientific needs for an ecological model that will address the mercury contamination issue in Arctic Canada. Currently, there is an increasing awareness that the complex subsystems (e.g., lithosphere, hydrosphere and atmosphere) are connected and that the disruption of one compartment affects the other compartments. We can only blame our ignorance, in part, for the mercury pollution issue. Governments in temperate and tropical regions have been

more focused on economically related objectives and have not fully considered the health of the environment in their decisions. Widespread mercury emissions from anthropogenic processes have returned to haunt us by degrading the ecological health of what once, not so long ago, could have been considered a pristine Arctic. Decision-making processes are not adequate for dealing with the complexities and uncertainty associated with the mercury contamination issue. In the following chapter, I present a conceptual model that frames the mercury problem in terms of environmental spheres of relevant structures, processes and interactions that are intimately interconnected.

Chapter 7

Integrated Policy and Science Conceptual Model (IPSCM)

7.1. Introduction

This chapter presents the Integrated Policy and Science Conceptual Model (IPSCM) developed in this study. In Canada, many government departments (e.g., DIAND) are starting to realize the importance of taking a holistic and integrated approach to address the mercury and other environmental contaminant issues. The strength of the IPSCM is that it: describes a complex problem; the system and its behavior; identifies the important processes; and describes how they interact. This integrated approach will help us define the issue, present possible options according to ecological principles, and inform managers and others concerned about this issue.

7.2. Application of the IPSCM

The conceptual model that I have developed, based on extensive literature reviews, a case study and stakeholder interviews, is illustrated in Figure 7.1.. The IPSCM outlines a method that accommodates ecological decisions. It is designed to serve as a tool that can be employed to address complex problems associated with the mercury contamination issue. It integrates a multitude of perspectives to provide an in-depth understanding of the system structure, dynamics, function and interrelationships. This model is not specific to any spatial scale or geographical location.

Figure 7.1. The Integrated Policy and Science Conceptual Model (IPSCM).

When dealing with particular aspects of mercury contamination various levels and parts of the model become more relevant than others. Those relevant levels and parts would be further developed to be more detailed and specific to the particular application. Consideration must be given to all processes, structures, contextual issues, influences and feedbacks. This diagram can be modified for a particular application that will help managers to attack similar issues associated with other environmental contaminants. In this sense, the IPSCM translates culture, scientific analysis, social science and policy into a decision making tool.

While including humans in the definition of an ecosystem complicates ecosystem modeling, the IPSCM includes humans in the definition of an ecosystem for both ethical and practical reasons. Anthropogenic activities that release mercury continue to shape ecological structures that in return, alter individual and community structures in Arctic Canada. For example, mercury released by anthropogenic and natural processes in temperate regions is transported to the Canadian Arctic by the atmosphere. It is then incorporated into the Arctic ecosystem, and biomagnified up the food chain. Consequently, there have been cases where food advisories have been issued because biota at the top of the food chain have been found to have unsafe mercury levels (CACAR 1997; AMAP 1998). As discussed, contaminated traditional food has significant social, cultural and spiritual implications for Aboriginal peoples. In brief, all environmental components are closely connected. The uniqueness of the IPSCM is that it explicitly identifies connections and relationships among the ecological spheres, allowing us to identify policy priorities, scientific research, and mitigation.

7.3. The Approach Taken

After reviewing several integrated management models (e.g., Hancock 1990; Rapport et al. 1999; Forget and Label 2001). Figure 7.2. illustrates the proposed management approach, where the cultural, policy and scientific components are merged together. The IPSCM proposes that the three components be examined jointly and accorded the same importance. Maintaining balance among all three spheres is essential to making sustainable decisions and ensuring that the future well-being of Arctic Canada is not compromised by mercury contamination. A conventional approach would be to complete a scientific study (e.g., predictive quantitative modeling) and use this information to decide on an appropriate strategy by decision-makers. I presented the pitfalls of this approach in the case study of Grassy Narrows and Whitedog in Chapter 4.

7.4. The IPSCM and Culture

7.4.1. Northern and Southern Perceptions of Arctic Canada

Developing a clear understanding of how different cultures perceive mercury pollution and identifying who is most affected by it will help us to resolve the mercury pollution issue. Within Canada, there are two dominant perceptions of the Canadian Arctic environment. The first perception is that of Aboriginal peoples, whose cultures have evolved over thousands of years of contact with and dependence on the ecological health of the Arctic. They see the Canadian Arctic as a homeland (Bone 1992). This view is a common thread that connects northern Aboriginal communities and provides a distinctive regional character. These are the people most likely to be immediately and

Figure 7.2. The IPSCM approach. The IPSCM approach gives equal importance to culture, social and physical sciences and policy and promotes sustainable ecosystems.

directly affected by mercury pollution in the Canadian Arctic. The second view is that of southern Canadians. Southern Canadians tend to view the Arctic as a cold, harsh and isolated environment that contains great wealth (Hamelin 1972, 1978, 1988; Usher 1987). It is difficult for southern Canadians, governments, or industries to fully realize how the unique geography, meteorology, ecology and culture can make the Arctic uniquely vulnerable to mercury pollution and other environmental contaminants. They typically have an understanding of culture, lifestyle and society that stems from the south.

Aboriginal people traditionally view the degradation of the environment by southern industrial development, including contaminants such as mercury, as a lack of respect (Wheatley 1996). Mercury contamination, is frequently the result of southern industrial development. Even in cases of northern industrial development, Aboriginal peoples receive few of the benefits of such activity and suffer the most disruption to their social and cultural well being, both at the community level and among individual members within the community. Consumption of resources by southern Canadians and others in industrialized countries is placing the ecological health of the Canadian Arctic ecosystem under threat.

7.4.2. Considerations for Managers

7.4.2.1. Cultural Considerations

Aboriginal peoples have been living as part of the Canadian Arctic ecosystem for thousands of years and continue to do so in most areas. What values can be drawn from Aboriginal culture that will guide policy development? The short answer is that many

Aboriginal peoples have not separated themselves from the environment, which is unlike the majority of southern Canadians. I believe that southern Canadians have yet to fully understand and appreciate the deep spiritual, cultural and social connection that Aboriginal people have to the Canadian Arctic ecosystem. Aboriginal people's economy, social structure, and communities are fundamentally dependent on the Arctic ecosystem. Aboriginal art, literature, poetry and perceptions reflect the prevalence of the Arctic ecosystem in their thinking.

Traditional Aboriginal cultures have the power to motivate a politically significant portion of the Canadian public to engage in various environmentally-related activities (e.g., writing newspaper opinion articles, creating world-wide-web pages) directed at protecting the health of the Canadian Arctic ecosystem. Emphasizing a low-level threat to survival and dangers to the integrity of the Arctic ecosystem and cultural treasures would urge action by bureaucrats on both the domestic and international fronts to solve the problem. A global reduction in anthropogenic mercury emissions to the environment would be a milestone in the international environmental arena.

7.4.2.2. Risk Management Considerations

Currently, the federal government is conducting risk-benefit studies. The concept of risk-benefit studies is problematic on many fronts. To start out with, these types of studies are potential ammunition for the government to justify the current mercury issue because they are very subjective and involve a great deal of uncertainty. It is easy for the results of such studies to be biased. Risk-benefit studies need to be regularly re-assessed as new health outcomes and social and economic data becomes available. Other

variables, such as socio-economic status, life-style, timing of exposure and age can influence the outcome of risk-benefit studies.

There are a number of nutritional and non-nutritional benefits of traditional foods (Wheatley and Wheatley 1998). Benefits of consuming traditional foods include: high nutrient density (protein, iron, zinc, Vitamins A,D,E, fatty acids); prevention of chronic disease (obesity, diabetes, cardiovascular); lower food costs; physical activity of the hunt and socio-cultural values (cultural identity, community sharing, education, responsibility). A change in diet from traditional foods to southern foods and the associated change from an active, socially cohesive lifestyle to a sedentary, less social, lifestyle can contribute to obesity and loss of fitness (Usher et al. 1995) and an increased incidence of adult-onset diabetes (Van Oostdam et al. 1999). In some areas, adult diabetes has risen from none, 50 years ago, to 4 times the Canadian average today (Wheatley et al. 1994). Consequently, public policies and management of this issue must take into account all social and cultural factors.

Turning to a medical perspective, the risk assessment process is based on extrapolation from lowest observed adverse affects level (LOAEL) or no observed adverse effects level (NOAEL). If the calculations show that there is a significant risk of neurological damage to adults or children, then advisories on reduction of intake occur. However, this is a theoretical approach to defining risk that over-simplifies and does not fully consider socio-cultural factors. Conventional risk assessment approaches need to be expanded to accommodate risk management issues such as nutritional benefits of country foods and related socio-cultural concerns. Integrating the risk and benefits of traditional food consumption continues to be a subject of debate (Inskip et al. 2001) and is a field

that clearly needs to be expanded. While some progress has been made in terms of partnerships being developed among researchers, health professionals and Aboriginal communities, there is still great uncertainty associated with how to conduct risk-benefit assessments of human exposure to mercury contaminated country foods.

Risk communication continues to be an incredibly difficult and controversial topic. As discussed in Chapter 4, there was no alternative but to advise non-consumption of locally caught fish in the communities of Grassy Narrows and Whitedog because of the high mercury levels in the fish. The damage that these communities experienced was catastrophic. The advice given by the government resulted in a change in diet, a significant reduction in lifestyle quality, and severe socio-economic impacts compounded the socio-cultural stressors already present (Shkilnyk 1985). At Grassy Narrows in 1995, there were a high number of violent deaths (i.e., 31 deaths over a 4-year period in a community of 400), a high incidence of substance abuse and an increase in suicides that continued until the 1990s (Wheatley 2000). These examples demonstrate that the provincial and federal governments did not fully consider socio-cultural factors when providing advice. Managers are now challenged to utilize both science and social science. This integration must be done with the cooperation and partnership of Aboriginal communities.

7.4.3. The Importance of Stakeholder Participation

Aboriginal organizations, such as the Council of Yukon First Nations, the Dene Nation, the Métis Nation of the Northwest Territories, and the Labrador Inuit Association, have outlined some of their positions and concerns. Considering that traditional food consumption has been called into question by recent scientific findings, it

is not surprising that Aboriginal organizations want to be involved at all levels of decision-making. With people's health at risk, it is clearly logical to include those most affected in decision-making processes (Usher et al. 1995; Doubleday 1996; Wheatley 2000).

Typically, a government's primary objective in international negotiations is to defend its interests and protect its sovereignty (Backstrand 2001). Aboriginal NGOs, however, have interests that do not recognize political boundaries and are capable of delivering an Aboriginal perspective. Participation of Aboriginal organizations in the development of Canada's position in the UNEP Global Mercury Assessment is critical, as it will facilitate the input of Aboriginal perspectives, contribute to a broader understanding of the mercury contamination issue and result in Canadian decisions that better reflect Aboriginal interests.

Stakeholder participation must go beyond simply providing information. An improved and shared understanding among stakeholders is required to make proper decisions that reflect different values, ideologies, and concerns, the socio-cultural implications, the magnitude of risk, the economic implications of solutions, and liability and responsibility for the mercury problem. All stakeholders should be involved as early as possible in any domestic and international (e.g., UNEP Mercury Assessment) decisions. It should be a consensus building process that allows for back-and-forth discussions about what the community thinks is important and the best avenue to proceed on attacking mercury related issues.

7.4.4. Traditional Ecological Knowledge (TEK)

Aboriginal cultures have, over time, developed knowledge and wisdom-based strategies that have allowed them to sustain local renewable resources, populations and the environment over thousands of years. Traditional Ecological Knowledge (TEK) refers specifically to all types of knowledge about the environment derived from the experience and traditions of a particular group of people. Numerous Aboriginal peoples consider TEK as unique and particular to their culture and locality and as a positive and empowering attribute of their Aboriginal identity (Usher 2000).

There is a great potential for Aboriginal peoples in the Canadian Arctic to play an important role in decision-making. TEK could strengthen the Arctic knowledge base and monitoring systems. There is still a great deal of uncertainty with regards to Arctic ecology and understanding the effects of human decisions within and outside of the region. In addition, considering the connections between the economics and science associated with the mercury contamination issue, clearly there is room for a different perspective that differs in purpose and focus. While any knowledge system is subject to biases, TEK could put a different perspective on the mercury contamination issue.

While many authors have outlined the benefits of TEK use, I do have concerns. Will TEK be adapted and integrated into a more scientific context, consequently taking away or separating the cultural context within which it operates? For example, Hobson (1992) argues, “an effective system must be developed to collect and classify native knowledge, particularly with respect to northern resources, environment and culture.” I see this statement as being presumptuous. Who is to say that Aboriginal peoples would want TEK to be integrated into the western science paradigm?

There is also the risk that any knowledge, be it scientific or TEK, could be manipulated and misused. A public policy-making process that is transparent and accountable is one way of minimizing the risks of error. Scientists do not have the right to document or utilize TEK without ensuring that the community needs and interests will be served first. Aboriginal peoples own the intellectual property rights to their TEK. Many Aboriginal peoples have been reluctant to share the depth of their TEK because they are concerned that managers and decision-makers do not fully understand and respect their cultures, customs or values and that TEK will be misrepresented and misinterpreted (CARC 1997).

It is important not to place TEK into a single category and define it in relation to western science. TEK is complex and deeply connected to the social, cultural and spiritual aspects of traditional Aboriginal cultures. While some elements of this knowledge may be recorded for future use, it is different from western scientific knowledge because it cannot be preserved without understanding the social, cultural and spiritual dimensions (Berkes and Henley 1997).

7.4.5. Towards Sustainable Solutions

Our perceptions about environmental issues are shaped by our culture, values, and environmental ideology and ethics. Consequently, these perceptions will have a significant influence on mercury-related decisions in the Canadian Arctic. In the problem-solving process, human perceptions on the mercury contamination issue and decision-making criteria play a critical role. As demonstrated by the Grassy Narrows case study (Chapter 4), the different beliefs, views and perceptions on the mercury contamination issue are incredibly complex and have proven to be highly controversial.

These difficulties are not impossible to overcome. Sustainable decisions demand the full participation of all stakeholders from different backgrounds. The IPSCM objective is to develop solutions to specific problems identified by stakeholders. While this process aims to be the best solution for all those concerned, it is critical that we fully consider and commit ourselves to developing solutions to the problems identified by those most affected by mercury contamination.

The government departments involved in the mercury contamination issue have allowed northerners to participate in environmental decision making to varying degrees. Integrating northern perspectives, such as seriously considering the recommendations from the ICC when making decisions, has led to substantial improvements, however there remains work to be done on incorporating them fully into successful decision-making processes. Many Northerners still complain that they are not involved to the extent that they should be (Wheatley 1998). The objective of the IPSCM is to provide a process that will provide an opportunity for experts who are proposing a regulation can be confronted by conflicting points of view and to give stakeholders the opportunity to educate each other. Whether or not the views voiced by Aboriginal communities from Arctic Canada are fully considered in the UNEP global mercury assessment will depend upon great political leadership and cooperation from all key Aboriginal, territorial and federal organizations.

7.5. The IPSCM and Policy

There are many challenging factors facing a global mercury agreement. One challenge is the absence of any international authority with powers greater than those of nation states. The success of treaties, such as the Stockholm Convention depends on the

nations interests, values and commitment to making them work. Another challenge is for the developed countries to support and get cooperation from the developing countries. Canada has the potential to play a critical role. First, we could increase our financial assistance given to the less-developed nations. This would take the form of a stronger effort in cooperation with other nations in a similar position to reduce developing nations' debt load that now puts them in an annual net loss position. The next step would be to increase our annual foreign aid payments. The last step would be to direct spending in support of institutions like the UNEP that allow for collective action. This approach would include both increased annual payments to international institutions and increased Canadian participation.

While there are costs and difficulties associated with adopting environmental foreign policy, there are also tremendous benefits. In the context of this thesis it would be a step forward to moving the Arctic closer to the pristine environment it was, a short time ago. It would be a sign of respect and improve the living conditions for Aboriginal peoples living in the Canadian Arctic who have in the past and who continue to be discriminated against. At an international scale it is a direct method of improving the quality of the global environment. It also would set an example and provide a framework for the international policy arena to attack other pressing environmental issues.

With a rapidly growing population, increased resource consumption and increased industrialization, the amount of mercury released to the environment is most likely to increase unless swift and effective action is taken immediately. Whether or not Canada takes the lead, we will eventually have to face the mercury contamination issue.

7.5.1. Domestic and International Action

As the recent Kyoto conference on climate change illustrates, negotiating with developed (e.g., the U.S.) and developing countries is not easy; there is a wide and perhaps growing gap between the views and objectives of developed nations in the North and developing nations in the South concerning environmental issues. Does the relatively small population in the Canadian Arctic have the right to act against interests in the South? Whose values are allowed to determine the future state of the Arctic environment? At the heart of mega-projects that release mercury (e.g., large waste incinerating plants, electrical plants that burn coal for electricity) is development, which inevitably leads to increased resource extraction and energy consumption. Until action is taken, industrialization will continue to compromise the health of the Canadian Arctic and other regions.

In the older methods, nations acted without regard for external effects in other parts of the world. This fragmented, reductionist and linear approach impedes the capacity of industrialized nations to see the relations between components of the ecosystem and are no longer appropriate for resolving the nature of the transboundary mercury contamination issue faced today. With a present population of 6 billion that is projected to be 9 billion by 2050 (Brown et al. 2000), there is going to be increasing energy demands to maintain the present lifestyles that exist in industrialized nations. Rapid population growth, coupled with increasing consumption habits, the growing intensity of human impacts on the environment and increased technological advances make international negotiations increasing complex and difficult. It is not surprising then, that the mercury issue is not only going to become a larger environmental problem,

but it is going to become increasingly complex through time. Clearly in this situation the only long term solution to significantly reduce or eliminate mercury is at the source of emission.

7.5.2. Is Technology Really the Answer?

To manage the mercury issue that the Canadian Arctic faces today, an effective action plan will require a mix of strategies and global cooperation. In order to implement a successful action plan, policy makers need to examine and assess whether or not emission reductions from the particular sources in question will lower the ecological risks. According to the USEPA (1997) there are four major types of control techniques that would reduce mercury emissions to the atmosphere: control technologies; pollution prevention measures; alternative approaches; and coal cleaning.

Using an end-of-the-pipe control technology inherently leads to the establishment of clear, quantifiable objectives and goals. This strategy is easily communicated and understood by the public and can be easily integrated into private decision-making procedures (USEPA 1997). A number of mercury *control technologies* are currently being evaluated for coal-fired boilers, but most are still in the research stages. Since there are various chemical species of mercury emitted from boilers from plant to plant, there is no single control technology at the present time that would remove all forms of mercury. As a consequence, there is a range in end costs associated with control measures for coal-fired boilers. In addition, this would eliminate some but not all of the mercury released to the environment.

The argument against the end-of-pipe strategy is that it simply changes the way in which mercury enters the environment and as a consequence does not fully address the

issue at hand. This brings up two key points that are worth thinking about: does this process make sense?; and do the costs exceed the benefits? As Macdonald (1991) points out, does it really make sense to capture mercury before it goes out of the stack or as liquid wastes before it is discharged to the environment and truck them to a nearby landfill site from where they are leached out into the ground water, only to eventually re-enter the ecosystem?

Pollution prevention may be a suitable option for those processes or industries where a mercury substitute is demonstrated to work and is available (e.g., mercury cell chlor-alkali plants). This type of strategy would involve changes in processes or inputs to reduce emissions of mercury from a particular product or process. For processes where products that contain mercury (e.g., batteries, fluorescent lights) are disposed of by incineration, or where mercury can be reduced in the fuel prior to the fuel being combusted (e.g., medical waste incineration), a material separation measure may be an appropriate approach. In the past, preventative strategies have been successful, as proven by the elimination of lead from most gasoline.

As an *alternative approach*, an incentive based strategy would provide industry with more flexible regulations than traditional ones have. A regulatory agency would set a ceiling on allowable emissions for each source and introduce penalties for missing the target. Incentive base strategies to reduce mercury emissions may be attractive for several reasons to: reduce mercury emissions at a lower cost, ensure against future regulation, reduce the compliance costs of regulation, build experience with technology and to demonstrate environmental leadership.

Coal combustion activities release a significant amount of mercury to the atmosphere (Pirrone et al. 1996). *Coal cleaning* is an option for removing mercury from the fuel prior to combustion. The reduction made by coal cleaning would certainly cause a decrease in mercury emissions released to the atmosphere.

As the U.S. EPA (1997) and others point out, technological advances can play a major role in resolving the mercury contamination issue. However, there are the political aspects of technological use to consider. Technological investments reflect the values, ideologies and power struggles among different nations. The mercury issue emphasizes dramatically different concerns, cultures and agendas between groups of nations and groups within nations (e.g., industrialized and non-industrialized nations, indigenous and non-indigenous peoples).

7.6. The IPSCM and Science

To provide a framework for this discussion, a 'sub-model' of the IPSCM is used. This approach improves our understanding of the physical processes and pathways, both within and among the main environmental compartments, which determine the fate of contaminants in the Arctic environment. Consideration is given to sources and emissions, transport mechanisms and the processes affecting the inter- and intra-compartmental interactions of mercury.

The main components of the IPSCM are the biosphere, lithosphere, hydrosphere and atmosphere. Mercury can be visualized as being distributed among all the major environmental spheres (Figure 7.3.). I have chosen to utilize spheres and two-way arrows

Figure 7.3. Interrelationships and Influences Among Components of the Canadian Arctic Ecosystem.

instead of boxes and one-way arrows to emphasize the close, dynamic, inseparable connection among the environmental components of the Canadian Arctic ecosystem. The two-way linkages symbolize the exchange processes that involve two-way transport, in addition to chemical and physical reactions as mercury moves across the interface. Some of the arrows show the transfer within a given compartment, which indicates the movement of mercury from one location to another without leaving the sphere. If one compartment or linkage changes, all the other compartments respond.

7.6.1. Atmosphere

As discussed in Chapter 3, the main physical international (I) and domestic (D) pathway that transports mercury from southern anthropogenic (A) and natural (N) sources in and out of the Arctic region is the atmosphere (Figure 7.4.). The 'i' or 'o' subscripts indicate input and output, respectively. Chemical and biological transformations resulting in removal of material from the compartment are indicated by a 'T' subscript.

In relative terms, the atmosphere has a small amount of mercury compared to other environmental compartments. Airborne mercury can reach Arctic Canada on the scale of days to months from distant temperate and temperate regions of the world (as represented by the thick, black arrow in Figure 7.4.), while transport in marine systems is on the scale of years to decades.

The remainder frequently exists as gaseous divalent (Hg^{2+}) mercury and mercury associated with particulates. There are only a few atmospheric chemical reactions of mercury. Oxidation processes for Hg^0 involving ozone have been identified in the gas phase and aqueous phase (Muthe 1992; Hall 1995). Poissant (1997) investigated

interactions between total gaseous mercury (TGM), O_3 and water vapour. Possibly oxidation of Hg^0 may be balanced by reduction processes occurring simultaneously in the atmosphere. In a global context, the importance of this specific reaction is probably limited.

There are a number of processes of atmosphere-surface exchange acting on Hg^0 , $Hg_{(II)}$ and MeHg. Wet deposition (WD) (of dissolved $Hg_{(II)}$ mercury species) and dry deposition (DD) (of particulate mercury) are commonly considered to be uni-directional processes involving the transfer of mercury from the atmosphere to the surface of the earth. The rate and mechanism by which mercury is deposited to the earth depends on the form. Oxidized and particulate mercury is commonly deposited before elemental mercury because they are more soluble in water and are scavenged by precipitation relatively easily. As a consequence, the majority of deposited mercury is oxidized and in particulate forms, even though it comprises a small percentage of the total mercury in the atmosphere. It is well established that mercury can be resuspended (RS) to great heights in the atmosphere and then transported long distances. Gas exchange (GE) can both add and remove mercury to the surface of the earth. Presently there is no way of measuring this process directly. During the winter, as snow accumulates at the surface of the earth as snowpack, it stores contaminants gained during its formation (WD – snow or rain) in addition to those delivered by particle dry deposition (DD) and gaseous exchange (GE). Run-off from snow pack melt contributes mercury to the terrestrial, freshwater and oceanic environments. The net exchange between the atmosphere and the surface of the earth is the result of all these processes.

Atmosphere

$$\text{MeHg} < \text{Hg(II)} < \text{Hg}^0$$

Figure 7.4. Atmospheric Transport and Transformation of Mercury in the Canadian Arctic.

7.6.1.1. The Arctic Sink

Scientists now consider the Arctic to be a “sink” for mercury and other environmental contaminants. The climatic conditions that exist in southern latitudes enhance the volatilization and emission or re-emission of mercury from the earth's surface to the atmosphere, by sudden exposure to the atmosphere of ocean water after being covered with ice or resuspension of dust or snow. It is important to keep in mind that this process is not a simple south to north transition. Processes such as prevailing winds further complicate matters. Gobi Desert dust, for example, has been found in snow in the Keewatin Region of the Northwest Territories (Welch et al. 1991; Barrie 1995, 1996). This is an important point to consider because research indicates that a minimal amount of mercury leaves the Arctic environment (represented by the dashed line in Figure 7.4.) (CACAR 1997; AMAP 1998). The chemical and physical properties of mercury cause it to condense out of the warmer air masses (from the south) when they pass over northern regions. The difference in temperature from the warmest place on earth such as the equator (in most regions) and the colder places on earth such as Arctic Canada, are sufficient to create the conditions necessary for global fraction/cold-condensation processes.

7.6.2. Lithosphere

There are a number of processes that determine the fate of mercury including the connective function among the lithosphere, atmosphere and hydrosphere. After mercury is deposited onto the surface of the earth, it is subject to a wide array of chemical and biological reactions. The form of mercury, which is typically inorganic Hg(II) compounds (HgCl_2 , $\text{Hg}(\text{OH})_2$) and inorganic Hg(II) compounds complex with organic

anions, is influenced by soil pH, temperature and soil humic content. Even though inorganic Hg(II) compounds are soluble (and, as a consequence theoretically mobile), they tend to form complexes with soil organic matter and mineral colloids. This process is largely the result of the affinity of Hg(II) and its inorganic compounds for sulphur-containing functional groups. As a consequence, the mobility of Hg in soil is greatly limited. Grigal et al. (1994), for example, determined that mercury concentrations in the soil are related to levels of soil organic matter. Higher mercury concentrations in the surface mineral layer of forests were found to be directly related to the soil organic matter.

Most of the mercury in soil is bound to bulk organic matter and is susceptible to elution in runoff only being attached to suspended soil or humus. Johnasson and Iverfeldt (1994) studied the relation between mercury content in soil and the transport of mercury from small catchments and found that humic matter plays an important role in controlling the transport of mercury from soils through watersheds.

7.6.2.1. Global Environmental Change (GEC) and the Reservoir Effect

A major research gap identified through this study was the link between global environmental change (GEC) and increased methylmercury levels in biota. Much of the Arctic has already warmed by 1°C, double the global rate (Green Peace 1996). As temperatures rise in the Arctic, permafrost melts causing it to release into the atmosphere a large amounts of greenhouse gases such as carbon and methane that has been locked away for thousands of years (CACAR 1997; AMAP 1998). An estimated 14 per cent of the world's carbon is stored in Arctic soils (AMAP 1998), which would accelerate the

greenhouse effect. This feedback is also linked to a possible increase in methylmercury levels in biota due to a phenomenon known as the reservoir effect.

It is possible that the Arctic terrestrial water balance may change due to elevated temperatures associated with GEC. This would occur through the complex interactions of land surface hydrology and the freeze/thaw cycles. The melting of ground ice in permafrost regions would increase the volume of water in thermokarst depressions/lakes. This would be an environment that would be prone to collect mercury from run-off and from mercury that was previously stored in the soil (it would be released into the water column). These areas would also provide a site for transformation of inorganic mercury to methylmercury by SRB. While this situation is far from straightforward, it does have the potential to increase mercury levels in terrestrial biota.

7.6.3. Hydrosphere

Rivers act as a conveyor that collects mercury within the watershed and delivers it to Arctic lakes and oceans. The interface between freshwater processes and the oceanic processes is highly complex and unique. Deltas and estuaries have a close connection with the marine environment and have important influences upon oceanic transport and mercury fate. Oceanic waters and sediments comprise a large reservoir of the total mercury on our planet. Oceans can be conceptualized as large reservoirs of mercury sources to the atmosphere and as environmental mercury sinks.

Sea-ice formation, drift and ice and snow are among the main factors that govern ocean surface metal concentrations (Melnikov 1991; Pavlov and Volkov 1993; Pavlov 1993). Spring run-off and river inflow may be an important localized source of contamination to the near-shore zone. Consequently, mercury accumulated through the

fall and winter is released during spring snowmelt and ice decay. Melnikov (1991) recognizes that this melt period coincides with the spring bloom of biological activity, which increases the potential for biological uptake. The relative contribution that the release of mercury by ice makes to levels in biota remains unknown.

A natural mitigation factor that may be important is that freeze-thaw cycling tends to aggregate particles into pellets on the ice surface (Barnes and Reimnitz 1974; Barnes et al. 1990). Pelletization results in increased sedimentation rates of the particles and their contaminant load moving them out of the surface layer more rapidly than if they were released as particles. There is very little data on this process, so the importance of particle aggregation cannot be determined at this time.

7.6.3.1. The Effects of Acid Rain on Mercury Methylation

The acidification of natural waters by industrially contaminated precipitation continues to affect large areas of the Arctic. Consequently, unproductive waters (i.e., those that are low in algae and plant growth) tend to have small ionic content, low pH and high concentrations of mercury in fish. Arctic lakes, especially if they are slightly acidic with well-oxygenated sediments provide an aquatic ecosystem with less dissolved and particulate organic matter. This causes more unbound mercury to be methylated and available to fish and other aquatic organisms. As discussed in Chapter 3, the specific methylation rate in lakes increases not only in the sediments but also in the water column as pH decreases (Xun et al. 1987; Gilmour et al. 1991).

This scenario could have implications for Aboriginal peoples who rely on traditional foods because acidic lakes provide an environment that has the potential to cause higher mercury levels in biota, and to stress the aquatic ecosystem because of an

inadequate food supply. As D'Itri points out, the plankton-feeding fish tend to disappear first because their food base, (phytoplankton and zooplankton) die off. Consequently, large predatory fish species are forced to feed on other predatory fish at higher trophic levels to survive (AMAP 1998). These older and larger fish tend to have higher levels of methylmercury. As this cycle continues (large predatory fish species die off), the result is a fish population that has slowly increasing body burdens of methylmercury (Jernelov and Johnsson 1984; D'Itri 1991; AMAP 1998).

7.6.4. Biosphere

Biota in the Canadian Arctic can be visualized as a thin shell of organic matter on the earth's surface. While biota occupies a relatively small volume, they are a major chemical pump responsible for the flow of mercury through nature. Because all organisms can accumulate methylmercury and mercury faster than they can rid their bodies of these toxicants, bioaccumulation and biomagnification is dramatic for most food webs. The total mercury existing as methylmercury is related to the age of an organism and its position in the food chain. It is not surprising that top Arctic predators such as seals and polar bears have elevated mercury levels (Chapter 3). Typically, the older a biological organism is and the higher its position in the food web, the higher the concentration of methylmercury. Most (i.e., more than 95%) of the mercury present in aquatic biota is methylmercury, which is typically obtained from their diet. As such, those organisms that remain in the same body of water have elevated mercury concentrations and will return the mercury in their tissues to that body of water when they die.

Numerous questions remain about the effects of mercury on humans. For example, if the exposure is intermittent, is the damage less or is it more? Does intermittent seasonal exposure cause the development of protective mechanisms or does damage accumulate over time? What are the factors that aggravate or decrease the health risks of mercury? Is malnutrition a factor? Is alcoholism a factor? What are the effects on the foetus?

What all this means for human health is still not clear. Our knowledge of the effects of mercury on human beings comes mostly from epidemics, such as those that occurred at Grassy Narrows and Whitedog, and Minamata. In the adult mercury can cause paresthesias, incoordination, tunnel vision, and even death. There is also the possibility of delayed effects, which have been shown in certain animal experiments. Other systems besides the nervous system are affected but these have been less frequently studied. Many of the studies are done during epidemics and in these epidemics exposure is often determined by retrospective analysis with all the uncertainties that this implies.

7.7. Mitigation

This section investigates different natural factors that may mitigate or enhance the toxicological effects of mercury in humans and discusses approaches that could reduce Aboriginal peoples' exposure to mercury.

7.7.1. Selenium

The effect of selenium on methylmercury toxicity has been well documented in animals, but not in humans. While the specific mechanism for protection is not fully understood, possible mechanisms for selenium's protective effect include redistribution of mercury (NRC 2000), competition by selenium for mercury-binding sites associated

with toxicity, and formation of a mercury-selenium complex that diverts mercury from sensitive targets (Magos et al. 1976). Selenium-treated animals can remain unaffected despite an accumulation of mercury in tissues to levels that are otherwise associated with toxic effects (Skerfving 1978).

It appears that the inhibition of toxicological effects depends on the level of selenium. Low levels of selenium have been associated with enhanced fetotoxicity following mercury exposure (Nishikido et al. 1987), while high levels of selenium can enhance the toxicological effects of methylmercury (Nobunaga et al. 1979).

Animal experiments do suggest that selenium might be protective. Selenium appears to have a protective effect in animals, but no association has been confirmed in humans (NRC 2000). While selenium may inhibit the toxicological effects of mercury, this element is also well known to be toxic if consumed in large quantities. In humans, symptoms of subacute or chronic toxicity include brittleness and loss of hair and nails, skin redness, vomiting, fatigue, various neurologic symptoms, congenital defects, and liver damage (ATSDR 1999). Clearly this is a major research gap that deserves attention from medical experts.

7.7.3. Garlic

Garlic could be an important effect modifier in humans because it could act as a complexing agent and increase methylmercury excretion. Since garlic contains selenium (typically there is 0.72-1.52 ug of selenium per g of garlic), it is possible that it is the selenium in garlic that is influencing the toxic effect of mercury. In an animal study, Cha (1987) compared methylmercury levels in rats that were simultaneously administered just methylmercury and both methylmercury and garlic. The results of this study indicate

there was a significant reduction in mercury tissue concentrations in rats that were administered both methylmercury and garlic as opposed to just methylmercury (Cha 1987). It is yet uncertain whether garlic removed mercury that had been deposited in the tissues or whether it prevented its accumulation before deposition

7.7.4. Alcohol

Ethanol allows elemental mercury to persist longer in blood plasma, resulting in prolonged diffusion of elemental mercury throughout the body. This means that ethanol can cause mercury to distribute more easily across the blood-brain barrier and the placenta (ATSDR 1999). As a consequence, this increases the risk of mercury toxicity to the brain and the developing fetus.

The effects of ethanol on methylmercury toxicity have been examined in mice. When methylmercury exposure occurred at the same time as ethanol ingestion, studies found that animals showed increased mortality (Tamashiro et al. 1986), increased severity and decreased time to the onset of neurotoxicity (Tamashiro et al. 1986; Turner et al. 1981), and increased renal toxicity (increased hematuria, renal weight, blood urea nitrogen and oliguria)(Tamashiro et al. 1986). The applicability of these findings to human alcohol consumption and methylmercury exposure patterns is still a knowledge gap.

7.8. Innovative Approaches to Minimize Human Exposure

Reducing and mitigating the toxicological effects of mercury is extremely difficult because the main source of exposure for Aboriginal peoples in Arctic Canada is from their traditional diet. As discussed, there are many social science and scientific complexities associated with the reduction methods and the details of exposure.

Consequently, any recommendations to reduce human exposure must be done with extreme caution. The aim here is to present ideas based on a synthesis of existing literature and stakeholder interviews.

7.8.1. Risk Communication

Dietary suggestions cannot be based on biomedical and toxicological data alone. Weighting these benefits in any risk assessment process has proven to be incredibly challenging and difficult. First, convincing any community to alter their traditional food consumption pattern because of an invisible health risk that is subtle and unproven in Arctic Canada is very difficult (CACAR 1997; AMAP 1998; Van Oostdam et al. 1999). Second, communicating about this issue is extremely complex (e.g., Chapter 4) because the message is difficult to deliver in the sense that traditional foods have benefits and the negative health effects are very subtle at low levels and difficult to prove. Many researchers, such as Usher et al. (1995), Furgal et al. (1995) and Wheatley (1996), have documented the need to develop and evaluate culturally appropriate communication strategies.

7.8.2. Reducing Human Exposure

Any strategy must include all stakeholders (e.g., Aboriginal organizations, health officials, hunters, and elders) and be a consensus-building process. Once a better knowledge of the risks and benefits associated with traditional consumption is gained, the challenge is to reduce the risks and promote health, while at the same time preserving the many benefits of traditional lifestyles. It is critical that health officials keep communities up to date on any new health information about the potential environmental health risks in a timely, culturally sensitive and balanced approach (Wheatley 1996).

The long-term efforts to reduce mercury concentrations in traditional foods must be focused on reducing mercury emissions and input to the Arctic on a regional basis. For the short-term, efforts that were focused on maintaining traditional food consumption and minimizing mercury exposure through the consumption of smaller biota within a species and consuming species that are known to have lower methylmercury concentrations, such as Arctic char, would reduce exposure.

7.9. Summary

The objective of this chapter has been to present a conceptual model that is capable of integrating a multitude of data that is relevant to addressing the complex issues associated with mercury contamination in Arctic Canada. The UNEP global assessment on mercury will provide a basis for considering whether any concerted international action on mercury is called for. Through this assessment process, the environmental costs and benefits will be explored. Ultimately, however, a decision must be made, and that decision will hinge on the relative costs and benefits that are subject to each government's perspective² of the mercury contamination issue. These value judgments are a key challenge facing those who wish to protect the Canadian Arctic ecosystem. Even the most basic components of this process are hotly debated. How does one place value on the ecological health of the Canadian Arctic ecosystem?

The problems presented in this chapter demonstrate that our mode of thinking about environment and development must become ecological. Our current understanding of mercury contamination issue speaks loudly to the inadequacy of past decisions and demands improvements. Domestic (NCP) and international (AMAP) initiatives are in

progress that will ensure that current levels of understanding are at least considered in the assessment of the state of the Arctic environment. Rapid progress towards focused responses to the recommendations of NCP's Canadian Arctic Contaminants Assessment Report and AMAP's State of the Arctic Environment Report would be an incredibly encouraging sign that a new framework is being used to make a real difference to the health of the Arctic environment.

²Submissions by governments to the UNEP Global Mercury Assessment can be found at <http://irptc.unep.ch/mercury/govsub.htm>

Chapter 8

Discussion and Conclusions

8.1. Introduction

This chapter assesses and synthesizes the evidence, analysis and arguments presented in the previous chapters. This study has brought together evidence that demonstrates that anthropogenic mercury emissions from southern industrialized nations are jeopardizing the future of Arctic peoples' traditional and sustainable lifestyles that are based on harvesting local resources.

8.2. Towards the Culture-Policy-Science Interface of the IPSCM

The proposed IPSCM developed by this study is a requisite first step to policy development to reduce and mitigate risk in the Canadian Arctic region. This model challenges conventional decision-making approaches that are not adequate for dealing with the complexity and uncertainty associated with the mercury contamination issue and that the current social and cultural understanding of the mercury contamination issue among societies with different languages, values and power must be improved. To effectively 'manage' the mercury pollution problem, this thesis highlights the importance of taking a broader, holistic approach that fully considers and accommodates the many complex, cultural, scientific and political elements. Some uncertainties with respect to the biogeochemical cycling of mercury and its potential effects on the Arctic ecosystem have not yet permitted a smooth interface between science and policy decisions on this issue. There are many gaps in knowledge

that need to be addressed to understand how mercury is affecting the Arctic ecosystem. In particular, we need further research to resolve the current debates about the contribution that natural and anthropogenic sources make to the global mercury budget, and to investigate the costs of inaction and action.

To summarize, the key priorities identified by this study are:

Culture

- Statistical data on social and environmental issues do not necessarily illustrate the fragility of the links between the environment and the Arctic people nor do they make clear the vitality of the cultures in Arctic Canada.
- For many Aboriginal peoples, contamination of traditional foods risks undermining their confidence in the ecosystem and interferes with their quality of life;
- Communication of the risks associated with contaminated traditional foods must be done with extreme caution and in a culturally sensitive manner;
- Decision-making must evolve to accommodate cultural dimensions in addition to scientific knowledge;
- There is a need for increased cooperation and shared understanding among stakeholders;
- Once biota are contaminated, the situation is very difficult to mitigate for those who depend on harvesting the local renewable resources; and
- Further research is required to expand and improve risk:benefit studies and to move beyond a traditional scientific risk management framework. In particular, the risk-assessment process needs to be expanded to accommodate the benefits-side of traditional foods.

Policy

- As discussed throughout this paper, we need to re-think our development choices both domestically and internationally;
- The polluted are the ones paying right now, not the polluters;

- Greater attention must be given to building stronger partnerships based on trust and equality with Arctic communities;
- Health Canada's guidelines for mercury in humans and wildlife need to be re-evaluated. Are they appropriate for Arctic Canada; and
- Through taking an ecological approach, managers will be able to see the many linkages and feedbacks among environmental components in the Arctic ecosystem. This is a needed step for policy decisions. It moves beyond focusing on economic considerations and will force managers to consider environmental concerns.

Science

- The processes controlling bioavailability of methylmercury are not fully understood;
- The link between the observed spring-time depletion of mercury from the atmosphere and mercury levels in Arctic biota requires further research;
- The environmental factors that influence mercury methylation rates were found to be a complex area of research that has not been fully understood by the scientific community. The linkage between increased temperature and increased methylation rates due to increased activity of SRB may become increasingly important in the future. Clearly this area of research needs more attention and increased cooperation between climate change researchers and biogeochemists.
- Global environmental change (GEC) is currently raising temperatures in the Arctic. This could lead to melting of permafrost, creating a favourable environment for mercury methylation (i.e., "the reservoir effect"). The linkages and feedback between GEC and increased mercury methylation in the terrestrial environment require further study;
- The possible effects of acid rain on enhanced methylmercury bioaccumulation in freshwater fish from soft water lakes requires investigation. Filling this knowledge gap would help managers make decisions whether or not additional reductions in sulphur emissions are necessary;
- The human effects of low-level, long-term exposure to mercury are unknown; and
- Selenium may mitigate the effects of mercury.

The NCP is providing funding for scientists in universities and governments to undertake regional studies that promote awareness and supply policy advice. These efforts will have greatly improved our understanding of the effects on the Arctic ecosystem. The present policy process makes it difficult to act in the absence of clear clinical symptoms. In a traditional sense it is generally accepted that low environmental concentrations are not a cause for alarm, since they were not thought to yield the serious health problems experienced in documented tragedies associated with acute exposures. New studies (e.g., USEPA 1997; ATSDR 1999), however, now show that low level exposure to methylmercury, once considered safe can indeed result in deleterious health effects. This knowledge makes risk-benefit assessments extremely difficult (Chapter 7). Will the effects of restrictions imposed on Aboriginal populations because of mercury be more deleterious than the exposure to mercury itself? What is the effect of restricting fish consumption and restricting fishing on Aboriginal peoples' societies? Because of the risks involved in giving wrong advice, it is important that research continue on mercury to determine more precisely what risks occur with low-level chronic exposure to mercury.

The IPSCM challenges managers to focus on a global mercury agreement to eliminate anthropogenic emissions, while making an effort at the local level to reduce Aboriginal peoples' exposure without disrupting traditional food consumption. Will improved technology in the south decrease stress on the Arctic ecosystem? To start with, the profit associated with technology use goes to those who created the problem in the first place (Chapter 7). Technical solutions provide a vehicle for continued growth and increased consumption of resources that release mercury to the

environment. Now, the same players that have caused degradation of the Arctic environment are producing new technologies to protect the environment. Could this technology in the future be a new sector of economic growth? This is a definite possibility. In fact, the U.S. and other industrialized nations are currently making significant investments in technologies that would eliminate or reduce anthropogenic mercury emissions to the environment (USEPA 1997). Ironically, the industries that have degraded the ecological health of the environment are now making a profit from protecting it.

8.3. What have we Learned?

In my opinion, there are currently three main structural differences in the mercury debate, than there were thirty years ago. First, government officials have shifted human health concerns from acute to chronic exposures generated from anthropogenic sources that are increasingly numerous, subtle and interconnected (Chapter 7). This type of human health research is extremely complex because it is difficult to establish the causality for increasingly complex, multifactorial processes. We are now able to measure mercury and other environmental contaminants in the various ecosystem compartments such as human biologics (e.g., hair, blood...etc.), air, water and soil, at the part per trillion (ppt) and parts per billion (ppb) levels as opposed to the part per million (ppm) standards of thirty years ago. In addition, there is presently a growing database of mercury levels in many components of the Canadian Arctic ecosystem. Increased sensitivity and large mercury databases offer advantages in the sense that experts are able to determine the variety of exposures. However, it also complicates acceptance by the public and can lead to some cases of

unnecessary anxiety among Aboriginal community members and other Canadians (Wheatley 2000).

The second difference is the increasing realization of the interconnections and complexity of the environment and the impacts of anthropogenic activities (Chapter 7). A large body of literature supports the growing realization (e.g., CACAR 1997; AMAP 1998) concerning mercury contamination in the Canadian Arctic ecosystem. Northern research continues to expand knowledge boundaries for governmental decision-makers through cautious research and aggressive debate. However, there is a problem here. Our present policy machinery still requires hard-hitting scientific data to supply a firmer basis for policy action. For those who argue that the existing policy framework is adequate, why is the Arctic ecosystem polluted with mercury and other environmental contaminants? I argue that there is urgency to re-think the effectiveness of the regulatory system that sets and, supposedly, enforces pollution standards. The existing policy framework must be expanded both domestically and internationally to be able to accommodate integrated approaches.

The third and perhaps most significant difference is that the issue has moved from focusing on point source releases of mercury to non-point airborne sources that are raising mercury levels in Arctic biota. In the early 1970s, industrial countries were not directly concerned until they discovered that inorganic mercury is biologically converted to methylmercury in the environment (Chapter 4). Sweden, Canada and the United States were among the first to identify and control point-source discharges from agriculture, chlor-alkali plants and other industries. Most governments and scientists thought that the problem was solved, until it was

discovered recently that remote areas, such as Arctic Canada, have elevated mercury levels in fish and other biota that exceed guideline levels. There is currently concern among officials with regards to increased airborne depositions in Arctic Canada, which are now known to be the result of burning fossil fuels, waste incinerators, and other natural and anthropogenic sources from southern regions (Chapter 3).

Consequently, the mercury problem is far from being resolved. To date, only the sources of contamination and the relative impact on the extent of contamination have been recognized in Arctic Canada. The mercury issue has been extended into the realm of geopolitics and has catapulted the issue into the international policy-making arena. Arctic Canada can be viewed as a benchmark for global mercury pollution. The spillover of industrial mercury pollution from southern latitudes via air, ocean, biota and northward flowing river pathways tells us a great deal about the ecological health of our planet; economics dictates that wastes will probably be released in areas that have the least political and economic power. Often the underdeveloped countries tolerate highly polluting processes because the governments are more concerned about international trade than about mercury emissions to the atmosphere and the consequences for 'remote' Arctic regions. This is a serious issue that is frequently overlooked by industrialized nations, but we cannot afford further delay.

The mercury contamination issue has clearly evolved from the 1970s. The IPSCM developed by this study is thus infused with concerns regarding the health of the Arctic ecosystem (including humans), a growing awareness of the interconnectedness of environmental components, and an increasing necessity for

meaningful action. The IPSCM presented in this study further complicates the mercury issue in a regulatory context, but it in no way diminishes the urgency for taking such action.

8.4. Do we Have Enough Information to Act?

Mercury cycling among the atmosphere, hydrosphere, lithosphere and biosphere is not fully understood. The current scientific understanding is insufficient to predict how fast mercury levels are going to change in the future or how the effects will be distributed geographically. However, let's review what is known:

- The mercury pollution issue is impossible to resolve without cooperation from the international community;
- Loading to the environment is increasing (Chapter 3);
- Anthropogenic emissions in areas outside of the Arctic region are responsible for making a significant contribution to the global mercury budget (i.e., at least 50%);
- Arctic Canada does not represent a major source of mercury pollution because of the relatively small human population and the general absence of large-scale industrialization;
- There are serious implications for Aboriginal peoples because the traditional sources of health and strength are now also sources of contamination;
- For southern Canadians and many others, it is the death of the myth that the Arctic is a pristine place;
- A number of recent studies have found that Arctic wildlife and humans exceed mercury guideline levels set by Health Canada; and
- Numerous scientific studies indicate that mercury levels are increasing in the Canadian Arctic biota.

It is my opinion that a lack of certainty on some details associated with this issue is no excuse for inaction. There are many parallels in scientific uncertainty between mercury and organochlorines (e.g., PCBs, DDT/DDE), whose use has been banned by most countries (Chapter 6). There is no doubt that we know enough to act on a global agreement that is signed and ratified by nations which are emitting mercury to the environment from anthropogenic processes. Provincial, territorial and federal governments and the general public make decisions everyday without knowing all the consequences of their actions. Large sums of money are spent regularly on protection against dangers or catastrophes. For example, governments spend large amounts of public funds on national defense, when they don't even know if a war or epidemic will cross their borders. The serious threat of mercury contamination is very similar and even more immediate. There is no doubt that we know enough about the potential short and long term effects of mercury contamination in Arctic Canada to take decisive global, national and local action now.

To not apply a precautionary approach will result in increased amounts of bio-available mercury in the environment. The mere fact that all components of the Arctic ecosystem are contaminated with mercury is a cause for concern and demands concerted action. Considering the persistence of the methylmercury already present in Arctic food webs, efforts must be directed at reducing anthropogenic emissions at source in industrialized nations. In the mean-time, public health policies must focus on the existing problems of reducing human exposure to methylmercury. Indirect impacts such as the disruption of lifestyle and eating patterns and the subsequent socio-cultural and socio-economic consequences among the affected Aboriginal

populations can be clearly seen in the case study (Chapter 4). Government officials are now challenged to attack these difficulties and effectively manage this issue in Arctic Canada for good reasons. If there is uncertainty regarding the extent of our knowledge, does it not make the most sense to stay within our knowledge boundaries of environmental risk?

8.5. The Search for Solutions

There are no easy answers to mercury pollution in Arctic Canada. We need to investigate what mix of policies will be required to implement the right actions. To achieve significant emissions reductions, we may have to turn to policies with higher costs. Some sectors and regions may benefit (e.g., the renewable energy industry), while others may bear costs (e.g., the coal-power energy industry).

Policy is required that would raise awareness on this issue and other environmental issues. Labeling all products sold in Canada with an environmental rating and a breakdown of the relative percentages of the most dangerous environmental contaminants (including mercury) that are in the product would be helpful. This idea is similar to the nutritional information that is typically found on all food items sold at stores in Canada. Items that contain mercury such as thermometers, petroleum products, blood pressure devices, fluorescent lights, certain paints and dental fillings would show the relative percentage of mercury and other environmental contaminants. Ideas like this would raise environmental awareness among the general public, help the public make informed decisions and put pressure on industries to be more responsible.

To avoid further inaction, the following factors need to be urgently addressed:

- Improved understanding throughout Canada on how mercury contamination is affecting Aboriginal peoples' traditional lifestyles;
- The lack of media coverage and minor NGO involvement;
- Inertia at the individual, corporate and government levels against changing perspectives and thinking ecologically; and

Why should governments take the mercury contamination issue in Arctic Canada seriously when the Arctic population is less than one percent of the Canadian population? First are the impacts that the current situation is having on the sustainability of traditional Aboriginal lifestyles. The Aboriginal people of Arctic Canada have lived in a sustainable and respectful way for centuries. They have not extracted resources on a large scale and destroyed their environment. From a traditional Aboriginal perspective, their cultures prohibit the destruction of the resources of the future generations (Chapter 7). The health of Aboriginal peoples depends on the health of the entire Arctic ecosystem.

Whose interests are allowed to finally determine the future? It is possible for Arctic communities to act against interests of the South? If the Arctic had sufficient wealth, power and influence could they put the mercury contamination issue high on the political agenda? The framework of southern development does not easily fit into the Aboriginal vision of sustainability. As a first step to bring about change, we must re-think the pervasive concept that extensive utilization of an ecosystem's resources leads to an improvement of our lifestyle (Chapter 7).

Today industrialization has changed the relationship between humans and ecosystems even further. Human growth is strongly connected to and dependent upon exploitation of resources. This also means that the way that humans in

industrialized nations view the world and understand social reality is connected to development. As such, it is not easy for governments to step outside of a framework that is constructed by modern society. This leads to the conclusion that no real solutions can be achieved without changing the way we think about the world that we live in. Mercury contamination in Arctic Canada and many other environmental problems are in the end cultural, political and scientific in nature. This study has developed a conceptual model that reflects this view. It is hoped that the application of the proposed IPSCM model would protect the ecological health of the Arctic ecosystem in the future.

8.6. Where do we go from here?

Mercury contamination in Arctic Canada is an excellent example of how our technological capabilities have far exceeded our understanding of the consequences of our actions. Now is the time to take responsibility and think ecologically about development and the environment and whose interests are being served. Solutions are going to require the design of decision-making processes capable of accommodating ecological thought and increased cooperation among stakeholders. Rather than focusing on one component of the ecosystem such as the biosphere, the objective here is to design a sustainable ecological approach that challenges the existing domestic and international decision-making processes to be more integrated, ecological and sustainable in nature.

This study has found that it is not simply the presence of mercury that makes this a concern for Arctic Canada. It is the unique meteorological conditions (i.e., the

Arctic “sink”), the linkages and feedbacks that have been identified (Chapter 7) and the possible biological effects on the Arctic ecosystem that make this issue a serious matter. This situation is an additional stressor above and beyond issues such as land claims and self-government for Aboriginal peoples because it threatens the traditional, land-based economy of northern Aboriginal peoples that is based on a deep respect for ecosystems. Protecting the health of the Arctic ecosystem and the safety of traditional foods consumed by Aboriginal peoples will require great effort and expense but it could eliminate a larger global problem in the future.

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Appendix A

Ethics Proposal and Interview Questions

Interview Research Proposal

Graduate Student: Shawn Donaldson

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**Carleton University
October 2001**

Background

On a geological time-scale, the Canadian Arctic could have been considered a pristine environment not so long ago. However, recent scientific research has found that some mercury levels in biota are not necessarily low. In fact, there are numerous cases of mercury levels in traditional foods such as predatory fish, seals and whales that are at the tops of food chains that are frequently consumed by Aboriginal peoples that exceed Health Canada's guidelines. Mercury originates from both domestic and international sources from natural and anthropogenic processes. The research undertaken by scientists through the Northern Contaminants Program (NCP), funded

by the federal government and coordinated by the department of Indian Affairs and Northern Development (DIAND), have proven that the majority of mercury (and other contaminants) originate from distant sources through out the world and are transported to the Canadian Arctic by the atmosphere, oceans, northward flowing rivers and migratory biota.

Definition of Study Area

The Canadian Arctic and sub-Arctic regions comprise the area north of 60°, extending from the Beaufort Sea in the west to Davis Strait in the east, and from north of Ellesmere Island in the north to Hudson Bay in the south. Mercury has been detected throughout Arctic ecosystems at unexpectedly high levels. From the standpoint of managers and others concerned about mercury levels in the Canadian Arctic the priority is to reduce the level of emissions and amount of mercury transported to and deposited in the Arctic region. However, like mercury itself, the development of appropriate policy in this area is complex. As a first step, this study will develop a conceptual ecosystem model for mercury in the Arctic environment based on current scientific knowledge; taking into account industrial and natural sources; biological, chemical and geological processes; arctic lifestyles and exposure levels relevant to the health of humans and other species. This ecosystem model for mercury will serve as a first step to policy development to reduce and mitigate risk in the Canadian Arctic. Using the conceptual model, priorities for policy initiatives to reduce mercury exposure for Aboriginal people living in the Canadian Arctic based on existing regulatory regimes and life cycle analysis of the behaviour of mercury in the northern environment will be made. In addition, the potential for mitigation of mercury pollution where significant occurrences exist at the present time will be assessed.

Approach or Viewpoint

Arctic ecosystems are particularly vulnerable to mercury pollution. Mercury bioaccumulates and biomagnifies in food chains. Unexpected high levels have been found in the long-lived animals at the top of the food chain, such as fish, seals and whales that are significant in the diets of many arctic residents. Contamination of these traditionally harvested foods provides a critical pathway of mercury transfer to human consumers, especially Aboriginal people living in the Canadian Arctic. In biota where elevated mercury levels have been found human health advisories have been issued which resulted in the banning or restricted consumption of these traditional foods.

Mercury contamination will have long-term effects on the health of the Arctic ecosystem, including humans. We must be careful not to repeat our mistakes through omission and inappropriate action. There are two key challenges to address. First, stronger regulation and policy is required to reduce global anthropogenic emissions. This is best achieved through a combination of elimination, technological, and substitution strategies. The second challenge is to establish a critical link between

thinking ecologically about development and environment, and to design decision-making processes capable of accommodating ecological thinking.

The mercury pollution in the Canadian Arctic is a complex issue. What complicates matters more is that the science of mercury is not fully understood and there are still debates within the scientific community regarding the contribution that anthropogenic activities make to the global mercury budget. This deficiency in knowledge is a 'loop-hole' for industry and makes it difficult for policy makers to enforce stricter regulations. Nevertheless, the Arctic ecosystem is fragile to begin with and it is susceptible to added burdens from distant sources. For aboriginal peoples living in the Canadian Arctic, mercury pollution is not a perceived environmental injustice; but a real environmental injustice because they benefit the least but experience the most disruption to their lifestyle.

Methodology

This dissertation will investigate policy options for elimination, monitoring and mitigation of mercury in the Arctic environment, based on existing scientific data and numerous relevant studies. To do this I will examine the mean, annual long range atmospheric transport and deposition of mercury and model the main ecological compartments in the Canadian Arctic. This investigation will be accomplished through the collection and review of extensive secondary resources. They will be collected from the library, government and the Internet.

The second component to this research involves interviews that will be conducted with senior policy-makers, decision-makers and scientists who are specifically involved with mercury in the Canadian Arctic. The interviews will provide insight into whether or not additional regulations are required and directions for future scientific research. Approximately 10 people will be interviewed once at the location and time of their convenience. Interviews are expected to last about 30 min to 1 hour. The interview questions will be 'open-ended'. They are intended to lead to somewhat of a discussion about their thoughts on the best approaches to dealing with the mercury pollution issue in the Canadian Arctic. This will be a key aspect of thesis research, as it will give insight into the potential for policy and regulation, gaps in the science, the potential for mitigation and the effectiveness of the existing monitoring programmes

No personal information will be asked. The questions will be clearly worded and straight forward. The respondents will be asked to give detailed responses and can refuse to answer any questions. The responses will only be viewed by my thesis supervisor (Dr. Nancy Doubleday) and myself and will be recorded by a tape recorder. All tapes and any other data related to the interviews (e.g., notes) will be kept in a secure location at Carleton University and completely destroyed upon completion of my thesis.

There are two key reasons for including humans in my research. First, I am interested in determining the reactions of individuals with knowledge of mercury pollution in

the Canadian Arctic and who have significant ability to make decisions or influence decision making. Their views will undoubtedly have a major impact on the actions that are taken to reduce mercury inputs to the Canadian Arctic and how the mercury pollution is handled by the federal government.

Second, I am very interested to gain insight into different perspectives on the mercury pollution issue in the Canadian Arctic and what they think the appropriate solutions are. Interviews will give me a chance to develop my ideas for policy and regulation, future scientific research, mitigation and monitoring. Gaining this knowledge will add to the quality of my thesis.

The manner in which I plan to obtain informed consent for this research is to deliver both the letter of introduction and letter of consent before the actual time of the interview. To ensure the comfort of the participants, I will provide them with a clear briefing on the purpose of my research, what is to be discussed and that I am willing to answer any question that they may.

Since those involved are very busy, the interviews will be no longer than 1 hour in length at a time and place that is convenient for the participant. The questions are designed to be open ended so that there will be a room for discussion. I intend to ask the participants if the existing regulations and policies, in a global context, are adequate to protect the Canadian Arctic for mercury pollution and what role Canada should play in dealing with this issue, to identify where further scientific research is required, if the current monitoring programs are effective and what needs to be done to mitigate the current situation. The respondents will be allowed time to add any additional suggestions, comments or question to the discussion. The instruments used to record the interviews will consist of a tape recorder and note taking.

All means possible will be employed to ensure confidentiality and anonymity will be employed to make certain that each respondent is comfortable. If respondents wish to be treated anonymously, they will be classified with a number (e.g., respondent #1) and in addition the institution they represent, if necessary will also be coded (e.g., Federal Government Department A). The only people who will have access to the results of the interview are my supervisor, Dr. Doubleday and myself. Respondents will not be informed in anyway on how their colleagues answered the questions. The notes and tapes will be stored in a locked box that only Dr. Doubleday and myself have access and they will be destroyed upon completion of my thesis. This box (small box with a combination lock) will contain all material related to the interview (audiotapes/transcripts). It will be kept in my desk in my locked office at Carleton University. If the respondents would like a copy of my thesis, I will provide it to them at no cost.

I fully agree to comply with the Tri-council Policy Statement concerning the "ethical conduct for research involving humans". I intend to maintain the integrity of all research preceding my own, by conducting my research in a responsible, professional and ethical manner.

Sincerely,

Shawn Donaldson

Individual:
Organization:
Date:

Dear _____;

I am a graduate student from the Geography & Environmental Studies Department at Carleton University, who is currently working on my master's thesis.

My research is focused on the impacts of contaminants on the environment (including humans). I am seeking ways to protect the health of the environment for the future. For my master's thesis I am looking at mercury pollution in the Canadian Arctic. Because of these interests I am would like to take with individuals from a various governmental departments and Aboriginal organizations that hold some degree of decision-making authority. A great deal can be learned from hearing about each person's view towards the mercury pollution issue in the Canadian Arctic and about the process of environmental decision-making.

The main objective of my study is to identify priorities for policy initiatives to reduce mercury exposure for Aboriginal peoples living in the Canadian Arctic based on existing regulatory regimes and the life cycle analysis of the behaviour of mercury in the northern environment. From the standpoint of managers and other concerned about mercury levels in the Arctic the priority is to reduce the level of emissions and amounts of mercury transported to and deposited in the Arctic region. However, like mercury itself, the development of appropriate policy in this area is complex. As a first step, this study will develop a conceptual ecosystem model (CEM) for mercury in the Arctic environment based on current scientific knowledge; taking into account industrial and natural sources; biological, chemical and geological processes; arctic lifestyles and exposure levels relevant to the health of humans and other species. The CEM for mercury will serve as a first step to policy development to reduce and mitigate risk in the Canadian Arctic.

Your participation in this study will involve an interview that is estimated to range from 30 min to 1 hour in length. This interview will be arranged at a convenient time and place for you. The interviews will be audiotaped and transcribed. It is my hope to use your words and ideas in my thesis. However, at your request, both your name

and organization will be excluded from the final report to ensure complete confidentiality. The audiotapes will be returned to you or erased at the completion of my research. I will ask you to sign a letter of consent that will further outline your rights and provide detail of the procedures of this study.

I am fully aware of that you must be very busy. Your participation in this study would be greatly appreciated. If you have any question or require additional information please contact me at 237-6561 or sdonald2@chat.carleton.ca. Thank you.

Sincerely,

Shawn Donaldson
Graduate Student
Geography & Environmental Studies
Carleton University
Ottawa, ON
Tel: (613) 237-6561
Email: sdonald2@chat.carleton.ca

Letter of Consent

I, _____, agree to participate in the study being conducted by Shawn Donaldson of Carleton University, Department of Geography & Environmental Studies. I am conscious of my implications and purpose of this research and aware that this study will examine my knowledge and opinions concerning decision-making, environmental protection and environmental management.

I understand that participation in this study will involve:

- One interview that will about 30 min to 1 hour in length at a convenient time and place;
- Audio-taping of this interview, which will be returned or erased at my request;
- Voluntary participation from which I may withdraw at any time;
- Only Shawn Donaldson (researcher) and Dr. Nancy Doubleday will have access to the audiotapes.
- All autiotapes/transcripts of the interviews will be kept in a small locked box (combination lock) in Shawn Donaldson's office (locked) at Carleton University. Upon successful complete of Shawn Donaldson's thesis defense, all interview material will be completely destroyed;
- Questions or concerns can be directed to the Chair of the Ethics Committee, Professor Klaus Pohle, email: klaus_pohle@carleton.ca, phone: 613-520-2600 ext. 7434.
- Using this information from the interview in a research paper, which will be circulated, deposited on file in the Resource Centre at Carleton University and may be published.
- The researcher at my personal expense will provide access to a final copy of the report.

Signed: _____

Dated: _____

- I here-by wish to protect my confidentiality through the elimination of my name, organization and other identify details from this report.

Signed: _____

Dated: _____

Interview Questions

1. How long have you been involved in northern research and/or decision-making?
2. Are the existing policies adequate to deal with mercury contamination in the Canadian Arctic:
 - a) Domestically?
 - b) Internationally?
3. What are the scientific research gaps?
4. What are the priorities for monitoring?
5. What can be done to mitigate the current situation in the Canadian Arctic?
6. Given the current situation in the Canadian Arctic, what are the priorities that need to be addressed?
7. How has mercury related research improved since the 1970s in Canada?
8. Are there any additional comments or questions regarding mercury contamination in the Canadian Arctic you wish to make?

Thank you for sharing your time and knowledge