MATERIAL SOCIETY AND THE SCIENCE-POLICY INTERFACE IN ENVIRONMENTAL DECISION-MAKING: UNDERSTANDING RISK AND MERCURY POLLUTION POLICY IN CANADA 1995 TO 2005

Bruce A. Lourie

A DISSERTATION SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
OF YORK UNIVERSITY IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

FACULTY OF ENVIRONMENTAL STUDIES
YORK UNIVERSITY,
TORONTO, ONTARIO
OCTOBER 2018

© BRUCE A. LOURIE, 2018

Abstract

The intrinsic conflict investigated herein is that on the one hand, scientific evidence is required as a basis for environmental policy decisions (natural scientific objectivism), however the socio-economic and political dimensions of risk dominate decision-making to the point where risk is no longer situated in the realm of science but rather as a social construct within the political economy. The science-policy interface is therefore a complex network of social, political, economic, historical and scientific factors. Ulrich Beck's risk society provides the dominant theoretical framework used to present the research and findings.

A case is presented that governments in Canada have failed to manage environmental risks due to a reliance on conventional regulatory risk management approaches that assume risk assessment is a calculable, objective technical exercise, whereas it is in fact a product of material society interests, largely the resource industry, designed to maintain status quo economic activity.

Governments faced with complex choices make policy decisions to protect the environment while considering economic interests. Whereas governments state that environmental policy decisions are based on science, the actual policy processes for undertaking scientific research, interpreting science and ultimately using science as an input to policy decision-making, are rooted in Canada's resource-dependent staples economy.

The research draws upon the idea that there are two conflicting and divergent pathways that appear to underpin challenges in environmental policy decisions. One is the recognition that ecosystem science is inherently complex, that humans have altered fundamental ecosystem functions dramatically, and the idea that we are living in a world risk society where humans are the uncertainty. This is contrasted with the second idea that Canada is trapped in the material society epoch where a political economy deeply rooted in material society thwarts environmental policy choices that threaten resource-dominated economic interests.

The dissertation investigates these tensions within the science-policy interface in Canada as it applies to toxic substances management and specifically mercury. The research explores the concepts of risk, uncertainty and precaution through a combination of literature review, stakeholder surveys, expert interviews and the author's participation as a policy actor during the period under investigation.

The principle findings of the research highlight the presence of two dominant paradigms described as the adaptive precautionary paradigm and the economic risk paradigm and the extent to which the followers of these paradigms adhere to a set of beliefs and practices that align with material society and risk society. This policy dichotomy has created an inherent conflict contributing to environmental policy incoherence in Canada causing weak decision-making and a loss of credibility and effectiveness in the environmental policy system. Examining toxic pollution policy and notably mercury pollution in the period 1995 to 2005 highlights the power of material society and policy disarray within the science-policy interface, and places in question the fundamentals of theoretical sustainable development. Contemporary environmental policy failures such as Canada's climate change policies can be explained by this analysis.

Acknowledgements

Many people over my professional and academic career have contributed to the ideas herein. I thank them all, particularly my family, those I interviewed, and the guidance of Dr. Ray Rogers and Dr. David Wheeler.

Dedicated to the memory of Dr. David V. J. Bell

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1: INTRODUCTION AND PROBLEM STATEMENT

"Great is the power of steady misrepresentation; but the history of science shows that fortunately this power does not endure." (Darwin, 1859)

1.1 Introduction

Mitigating the environmental effects associated with the use of toxic substances continues to present a challenge for governments, industry and the public. Lead, DDT, PCBs and mercury are examples of environmental contaminants affecting the health of ecosystems, humans and wildlife. Many countries have introduced policies to ban or severely restrict uses of lead, DDT, PCBs and other toxic substances. Some countries restrict most mercury uses as well.[1] In Canada, the restriction of toxic substances has largely followed on the efforts of other nations. Canada has been a policy taker not a policy leader.

There are several reasons why governments in Canada have been reluctant to restrict the use or release of toxic substances such as mercury, and one of the primary reasons for not acting is the presence of scientific uncertainty regarding the environmental or health benefits of restricting substances. There is frequently uncertainty regarding the causal relationship between toxic substances emitted from specific sources or used in specific products and measurable health effects or ecosystem damage. In the case of mercury, for example, one of the areas of scientific uncertainty that hindered decision-making is global mercury cycling and the relative contributions of anthropogenic versus natural mercury emissions (Mason et al., 1994).

Industry and several government departments in Canada argued that ubiquitous natural mercury in the environment renders control actions ineffective given the presence of natural mercury in the environment. The presentation of uncertainty as a strategic ploy to prevent or to defer

[1] See 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs) – enacted under the Convention on Long-range Transboundary Air Pollution – for an example of an international instrument supporting nations restricting DDT and PCB usage (Aarhus Protocol on Persistent Organic Pollutants, 1998).

regulatory action, largely with resource departments working in concert with corporate resource interests, is made clear in the mercury case study presented in Chapter 5.

Ulrich Beck's "new paradigm of risk society" (Beck, 1986) and related discourse provides a theoretical underpinning in which I argue that the science-policy interface debate in Canada can only be understood in the context of Canada's environmental policy framework being trapped in Beck's "material society" epoch. Layered onto that are the additional resource and environment policy challenges linked to Canada's historic development as both a settler society (Razack, 2002) and a colonial resource dependency society (Hessing et al., 2005), still bound in a staples economy (Watkins, 1963). All of which define and reinforce the idea of Canada being trapped in material society.

Material society and risk society are Beck's representation of the polarity between logical positivism and post-positivism. In simple terms, material society represents a combination of economic interest, traditional scientific methods, and a linear, rational world where risk is largely an external factor to be managed, and where resources and ecological capacity to absorb pollution are abundant. Material risks are evident, acute and immediate. Risk society, in contrast, embodies risk as a manifestation of human interactions. In risk society, risk is internal; produced by society as a by-product of economic growth. The risks are intangible and self-generated, often not perceived directly by society in the way that tangible risks in material society are perceived. Chronic low-level toxicity or climate change are examples. In risk society, the hazards are global, intangible, unavoidable and threaten limited ecological capacity; consequently, they are difficult to manage and require non-linear adaptive approaches.

A retrospective review of mercury policy decision-making in Canada, focusing on the period between 1995 and 2005, is used in this research as a focal point for understanding the on-going challenges Canadian policy-makers face in understanding and managing complex environmental risk in the face of uncertainty and colonial resource history.

Two contemporary environmental debates validate the relevance of the subject matter. First, is the multi-decade global debate regarding climate change mitigation policy, where there are strong similarities to mercury pollution policy regarding anthropogenic contributions and scientific uncertainty, with Canada's environmental policy apparatus trapped in a resource dependent material society.

Second, is the local Canadian example of the Grassy Narrows and Wabaseemoong First Nations where legacy mercury contamination, from pulp and paper operations that began in the 1960s, continues to poison the people and fish of the English-Wabigoon River system today. Fifty years of inaction in the face of evidence of the causal relationship between the mercury contamination of the river and the poisoning of the people is not simply a matter of scientific uncertainty. Whereas the research herein is not framed in the discourse of environmental justice, it is important to note that global environmental policy failures are compounded by local examples of environmental injustice and systemic environmental racism. The re-emergence of the Grassy Narrows mercury poisoning in 2017 adds to the failures of Canada's mercury pollution legacy. In this research I will demonstrate the nature and extent to which science-policy interface issues have led to conflicting and insufficient approaches to pollution control, specifically related to mercury.

The research will uncover the specific policy roles and activities in the Canadian federal government Departments of Environment and Natural Resources, and their differing perspectives on science, uncertainty and precaution as they are applied in risk assessment and risk management exercises. Furthermore, I will demonstrate how the policy conflicts and differing philosophical approaches to toxic substances management, particularly mercury, in the period under investigation are manifestations of material society and a staples economy. Several scholars have examined the connections between natural resources and environmental policy (Boardman, 1992; Doern and Conway, 1994; Colborn, Dumanoski, and Myers, 1997; McKenzie, 2002; Howlett, Hessing and Summerville, 2005; Adkin, 2009; Boardman and Van Nijnatten, 2009).

The research focuses on a specific element of the environmental and resource policy paradigm, namely the science-policy interface in decision-making, and the concepts of risk and uncertainty in risk management. These ideas are embedded in risk society theory as central to this thesis. Through expert surveys and interviews the research elucidates many factors that are important in influencing policy decisions, and where uncertainty plays a role in risk management decision-making. These include political, social and economic pressures, any one of which may be a deciding factor in environmental policy, with economic considerations taking primacy.

These factors are brought forward through the expert interviews and literature research and are critical elements in Canada's historic interplay of resource-dependency, settlement politics and staples economy; juxtaposed with aspirations of evidence-based environmental policy-making. The science-policy nexus is considered throughout as a binary concept, building on the ideas of "two cultures" as well as "material society" versus "risk society." In the language used herein the "economic risk paradigm" is the environmental policy framework for "material society" and the "adaptive precautionary paradigm" is the environmental policy framework for "risk society."

Another way of presenting these ideas beyond the science-policy tension is to include a temporal aspect whereby the modern environmental policy era, post 1970, can be divided into policy phases or epochs. The first phase or epoch called the "science paradigm" equating to the age of modern science and valuing the "technological fix," or in Beck's work, "modernity." The second phase or epoch is described herein as the "economic risk paradigm," equating to Beck's post-modern period and in essence a transitory epoch described by "material society". The third phase is the "adaptive precautionary paradigm" where adaptive management, "reflexive modernity" and "risk society" are analogous ideas.

These ideas are used to frame the research of the 1995 to 2005 period; also reinforced by contemporary scholarly research. Fahey and Pralle (2016) reviewed 793 articles across twenty-nine different policy journals in attempt to understand complexity in environmental policy. Their findings are discussed in subsequent chapters. Marshall et al. (2017) note that "the future of natural resource systems is uncertain" and that the "human dimension of environmental management is complex." The authors position environmental policy impasse as a conflict and "political turmoil" between policies and regulations to achieve sustainability goals and the restriction of human economic endeavour.

Bulkeley and Newell (2015) describe this as the science-policy paradox. My research contributes to the science-policy discourse by providing a strong theoretical and practical connection to the material society-risk society nexus, and the expression of Canada's environmental policy efforts trapped between two paradigms or epochs.

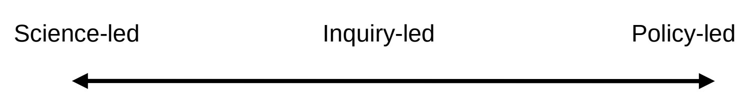
The research at hand addresses the science-policy interface regarding mercury pollution policy in Canada and the policy debates that took place between 1995 and 2005. It is relevant to policy debates in Canada today and explains the failed climate change policies of Canada past and present. The generic problem under investigation in this research is the challenge that decision-makers face when policy choices have important societal implications, yet uncertainty leaves relevant questions unanswered or only partially answered. More specifically, the research will focus on the conceptualization of uncertainty where I make the case that uncertainty, while often presented as scientific uncertainty, is in fact a socio-political construct best understood through the lens of Beck's world risk society. In Chapter 4, I describe the development of the risk management policy industry and the way in which the application of risk assessment and risk management are evidence of the extent to which the material society and staples economy theses have become embedded in Canada's environmental policy paradigm.

Alternative decision approaches, such as the precautionary principle and adaptive management, have been presented as a means to address policy-making in the face of uncertainty (Kriebel et al., 2001; Holling, 2005) and are referred to throughout the research as paradigms more in line with Beck's risk society.

The research herein describes the inherent internal conflict in contemporary approaches to environmental protection policy; namely, increasing demands to reduce scientific uncertainty amid the growing recognition of the uncertainty that accompanies the complexity and unpredictability of global natural systems. In other words, policy-makers and politicians want things to be clearer and simpler; while scientists are indicating that ecological systems are more complex and less clear. The political drive for scientific certainty, however, represents a combination of naivety and deliberateness; where the deliberateness is designed to forestall environmental policy decisions that restrain industrial activity and economic growth. The risk management process is the policy mechanism that facilitates material society intentions.

Science-policy interface discourse is used in this research to describe the tensions between the social sciences and natural sciences, or Snow's "Two Cultures", and moreover, to the central idea presented herein that Canada is trapped between two societies or epochs; material society and risk society.

The science-policy interface is defined as the intersection between scientific study and reporting, and policy development and decision-making. This includes a spectrum of interactions with at least three examples. The interface may be science-led, where scientists identify a problem and undertake research with an explicit goal of supporting decisions to solve a problem. At the other end of the spectrum is the policy-led interface where policy-makers commission scientific research in order to assist in making a decision to solve an identified problem. Somewhere in between is inquiry-led where science may be produced purely in the pursuit of knowledge and may or may not be used in a policy setting.



Risk society discourse leads one to question fundamentally the conceptual framework of sustainability as it is commonly known; as the intersection of economy, society and environment. With Canada trapped in material society, economic interests dominate social and environmental objectives rendering the concept of three equal intersecting spheres irrelevant to the political reality of Canada.

The research focuses on questions related to pollution policy decisions, particularly toxic chemicals management in Canada as an illustration of how scientific uncertainty was defined and used in environmental protection policy. The research is situated within the policy discourse of the period focusing on concepts of uncertainty, risk, precaution and ‘sound science’ as per the following quotes:

“However great our knowledge, our ignorance is also vast. In this ignorance we have taken huge risks and inadvertently gambled with survival.” (Colborn, Dumanoski and Myers, 1997).

“[T]hese cracks in the foundation threaten the federal government's ability to detect, understand and prevent the harmful effects of toxic substances on the health of Canadians and their environment.”

(Commissioner of Environment and Sustainable Development, 1999).

I argue herein that “sound science” and certainty are code words and disingenuous concepts used by industrial resource interests and as such affirm the reality of material society and staples theory as the dominant environmental policy paradigm in Canada. This idea contributes to an understanding of the need for scientists and policy-makers to recognize the *realpolitik* of environmental policy-making in the world risk society epoch.

There is also contemporary relevance to the material society thesis in settler society and colonialism discourse described as follows:

“Capitalism and industrialization are inherently anti-ecological processes that demand an infinite supply of natural resources to satisfy capitalism’s need for endless growth. Members of Grassy Narrows continue to actively struggle against these destructive colonial practices in their fight for environmental justice.” (Ilyniak, 2014).

Racism exhibited in colonial settle society can therefore be seen as an aspect of material society. Borrow’s (1997) definition of environmental racism as: “People's alienation from the natural environment through [the suppression of] their participation in its use" (Schlosberg, 2010) fits well with the conceptualization of Canada as a staples economy bent on resource extraction to the exclusion of indigenous and ecological values. Both the public and private sectors in Canada frequently laud resource extraction projects for offering "ethical economic opportunities" to Indigenous Canadians. Such cheerleading, however, "obscures" the ways in which these projects perpetuate environmental racism through the degradation of First Nations lands (Preston, 2013). Under this rubric, Canada's First Nations have clearly suffered – and suffer – from widespread environmental racism. Settler society, material society and staples economy are therefore interwoven complex interactions that dominate and describe the political economy of Canada throughout its development in the eighteenth, nineteenth and twentieth centuries, and provide a critical context for better understanding Canada's stagnant approach to environmental policy within the risk society theoretical frame.

1.2 Problem Statement

Governments in Canada, especially the federal government, have serious problems in delivering on environmental policy commitments, such as climate change policies. This has been a chronic problem in Canada. Specifically, as seen in the case of mercury, governments have been challenged to make decisions to protect human health and the environment, focusing instead on fears of undue burden on individuals or industry by ensuring that policy decisions are rooted in the impossible concept of the absence of scientific uncertainty.

At the heart of this debate is the role of science in public policy decision-making (Salter, 1988). Understanding the scientific complexities of natural global systems is essential to taking appropriate action and to making policy choices that balance competing interests (Organisation for Economic Co-operation and Development, 2008). Yet the problem as defined in this research, is that environmental policy making is not being presented in a material society – risk society frame, therefore the fundamental idea of uncertainty as a narrow empirical concept leads to misunderstanding and misapplication of policy and science-policy discourse.

Only by introducing material society, and Canada's historic resource dependent and staples economy thesis can the problem of weak environmental policy performance be explained. Writing in 2007, Mel Watkins, Canada's leading staples economy theorist wrote; "there is an urgent need for an ecological history of staples as a way of illuminating the rapacious character of the Canadian variant of capitalism with its bias towards resource exploitation".

The case for Canada's poor environmental performance is strong. Canada's Commissioner of Environment and Sustainable Development audits the implementation of commitments made by federal government departments.[2] Historically, the Commissioner's work has identified serious weaknesses regarding federal government coordination and capacity, describing:

"[w]eaknesses in the federal government's collection and use of scientific information on toxic substances. ... weaknesses in interdepartmental co-ordination of research efforts, incomplete monitoring networks, a lack of re-evaluation of pesticides, conflicting departmental agendas and priorities, and a growing gap between the demands placed on departments and the availability of resources to meet those demands. Cumulatively …these cracks in the foundation threaten the federal government's ability to detect, understand and prevent the harmful effects of toxic substances on the health of Canadians and their environment."
(Commissioner of Environment and Sustainable Development Canada, 1999)

The "cracks in the foundation" represent cracks in the understanding of risk society. More recently, Ontario's Environmental Commissioner has admonished the Government of Ontario for inaction in the Grassy Narrows community:

"The Ontario government has long turned a blind eye to pollution that adversely affects many Indigenous communities. The conditions faced by these Indigenous communities would not be tolerated elsewhere in Ontario, yet have long been deemed unworthy of priority, effort or expense. After decades of neglect, the province is finally taking some steps, but the pollution that

[2] See: http://www.oag-bvg.gc.ca/internet/English/cesd_fs_e_921.html.

these communities still face is outrageous. The poisoning of people in that area has gotten worse, not better. It's frightening."
(Ontario Environmental Commissioner, 2017)

Whereas the ideal of "evidence-based policy" is often referenced by governments working on environmental policy, the research herein explores the complexity of the science-policy paradox. Environment Canada described its environmental policy paradigm as "science-based," never "political-based", "social-based", or "economic-based" (Doern and Reed, 2000). The dissertation will therefore explore the validity of the notion of a "science-based" policy paradigm, recognizing the dominance of economic and political factors that frame and inform decision-making in material society.

Mercury fits well the definition of a "political chemical" described by Salter (1988) and is used in this research to demonstrate the politics of material society as a trap preventing environmental policy progress. Furthermore, mercury acts as a bellwether for environmental management decisions that have much broader implications with respect to the use and regulation of toxic substances and the environment. In the case of mercury, it has been highly politicized in several important policy arenas that will be described in the dissertation; for example, coal-fired power plant regulations in the United States (Morrone and Lohner, 2002; Union of Concerned Scientists, 2004), compact fluorescent lights/lamps, dental amalgam and dental waste disposal in Canada[3]; and as a representative of a toxic metal that threatens the Canadian metal mining sector's interests in avoiding the regulation of metal use.

Historically, the pulp and paper sector was the largest emitter of mercury in Canada and, as noted above, the legacy of mercury-polluted rivers has re-emerged in the Grassy Narrow and Wabaseemoong First Nations. The following quote from one of the world's leading mercury researchers situates the research within an academic and policy debate that was taking place in the 1995 to 2005 period under investigation in this paper.

[3] See Regulations Respecting Products Containing Certain Substances Listed in Schedule 1 of the Canadian Environmental Protection Act, 1999 (Environment and Climate Change Canada, 2011).

"The current disagreement between regulatory agencies concerning mercury should not be blamed on discrepancies in the epidemiologic evidence. A wealth of highly relevant information already exists on this pollutant. Given the existence of many other neurotoxicants about which we know much less, a regulatory stalemate on mercury is bad news for the protection of the brains of future generations." (Grandjean, 1999)

Two factors define the science-policy interface problem from an empirical science perspective. First, our understanding of natural systems needs to consider that human intervention in the major life-sustaining biogeochemical cycles is surpassing the role of natural processes, and little is known of the implications (Vitousek et al., 1997; Millenial Ecosystem Assessment, 2005). Second, basic scientific capacity to monitor environmental change and human intervention was on the decline through the 1990s and early 2000s under both the Liberal and Conservative federal governments of Canada, to the point where there were serious concerns expressed regarding Canada's ability to undertake the basic research needed to protect health and the environment (Commissioner of Environment and Sustainable Development Canada, 1999). These factors were taking place in the context of demands for more rigorous application of science in policy-making (Bradshaw and Borchers, 2000); conceptually connected to material society pressures.

The problem statement therefore, has both a scientific dimension and a policy dimension, as follows: humans, through individual and corporate behaviour, are dramatically altering global life systems; environmental science is increasingly complex and more uncertain as ecosystems become increasingly compromised and unstable; capacity to undertake science declined through the 1990s and 2000s as part of government cutbacks in both the Liberal and Conservative governments of Chretien and Harper respectively; and government policy-makers and corporate stakeholders are demanding certainty and clarity in making environmental policy decisions.

The research I present makes clear that Canada's policy decision models are driven by these conflicting and diverging factors, often politically and economically motivated, undermining the theoretical idea of science-based policy. Furthermore, the concept of scientific certainty, often presented in the highly politicized context of "sound science" has contributed to a policy environment where pollution control decisions have not protected the environment or human health; favouring a neo-liberal corporatized policy environment where economic interests connected to Canada's resource-dependent economy supersede science.

The science-policy interface regarding mercury risk management in the 1995 to 2005 period is used to demonstrate material society domination of Canada's pollution policies and to highlight the need for a risk society discourse to contribute to an understanding of science-policy interface.

1.3 Research Question

The problem statement leads to the following questions which frame the dissertation research. Processes and decisions concerning pollution control standards for mercury in the 1995 to 2005 period are used as a case study to illustrate toxic substances risk management policy in Canada, embedded in the complexities within the science-policy interface in Canada including the concepts of "risk society" and Canada's historic resource dependency as a "staples economy."

The primary research question under investigation is:

"In what ways does Beck's risk society theory explain the failure of Canada's science-policy interface in pollution control decisions not keeping pace with the evolving discourse of risk and uncertainty?"

Relevant elements of this question may be deconstructed as follows:

- Situated in **'Canada,'** implies national but does not exclude provincial, The Canadian Environmental Protection Act (CEPA) is the primary legislative reference point. Canada's historic position as a "staples economy" and the extent to which resource-dependency overrides "evidence-based" policy is investigated within an interdisciplinary framework of ecological, political, economic and social factors as described by Hessing, Howlett, and Summerville (2005);

- **'Science-policy interface'** refers to the larger context of policy decisions, including regulations, legislation, policy statements, and moreover, the idea that a pattern is emerging in contemporary policy analysis whereby environmental policy is trapped in material society and at the nexus of "two complex and evolving systems" Fahey and Pralle (2016). These ideas reinforce the concept of two paradigms or epochs under investigation with the idea that a lack of responsive or reflexive policy analysis or feedback leaves major gaps in our ability to understand policy complexity.

- A focus on **'pollution control'** is important because it distinguishes this work from risk literature that focuses mainly on substance risk assessment, and from the ecosystem adaptive management literature that focuses mainly on resource management. Ulrich Beck's concepts of "material society" and "risk society" (Beck, 1986) sets up the idea of policy epochs as a theoretical framework. Contemporary critiques of Beck, such as Berkamp (2017), provide useful insights into the gaps in Beck's work, related to the practical application of his ideas, where the research herein helps address;

- Keeping **'pace'** implies that there is a divergence between the policy paradigm and ecological system discourse. It does not specify that they are moving in opposite directions only that there is a gap and that the gap appears to be increasing as a dynamic and complex system, as described by Wesselink et al. (2012);

- **'Evolving discourse of risk'** refers to the changing nature of how we describe and discuss issues in the literature where Perez and Snir (2013), for example, question the conventional conceptualization of the science-policy interface. This shifts the focus from the science itself to a discussion and interpretation of science findings and the politicization of science in policy discourse or how risk society creates reflexivity (Elliot, 2002). "Reflexivity" is a core element of Beck's risk society, derived from the work of

Giddens (1990) and Beck's concept of "reflexive modernization" (Matten, 2004). World risk society discourse is used to explain Canada's environmental policy failure.

- **'Uncertainty'** provides a clarity of focus on a critical aspect of science-policy interface. Uncertainty discourse therefore becomes the element that links the science literature with the policy literature where Udovyk (2014), for example, describes uncertainty "paralyses" in toxic chemical management. With anthropogenic disruption of ecosystems creating "political turmoil" in environmental policy as described by Marshall et al. (2017). There is also an anticipatory element of risk in Beck's conceptualization which add elements of fear and uncertainty, as is the case with global risks of nuclear war, climate change or toxic chemicals (Mayer, 2016).

In summary, the research focuses on risk and uncertainty in the environmental policy sphere using mercury pollution policy in the 1995 to 2005 period to highlight the intersection of three areas of increasing complexity: ecological complexity, governance systems complexity and stakeholder complexity, juxtaposed with a growing, neo-liberal political environment bound in Canada's historic resource-based political economy; or material society.

Using interpretive qualitative research methods, and a quantitative survey, combined in minor part with appreciative inquiry action research methods (described in Chapter 2), the research involves five distinct elements; literature review, primary data collection (expert interviews and on-line survey), a case study on mercury, discussion and analysis of the findings; and in the Appendix a written account of self-experimentation research.

The purpose of these research activities is threefold, designed to disprove the conventional policy understanding that Canadian environmental policy practices are "science-based" or "evidence-based":

1. To establish the nature of the problem as it is presented, namely ecosystem discourse diverging from policy discourse and the nature of uncertainty discourse as it relates to the

science-policy interface and concepts of risk and risk society. These will be explored through the literature review, tested with the expert interviews and investigated in the case study.

2. To explore the risk and precaution paradigms through expert interviews and an on-line survey of environmental representatives, experts and stakeholders in government, industry and non-government organizations and demonstrate with quantitative research the binary tension between the economic risk paradigm ("material society") and adaptive precautionary paradigm ("risk society").

3. To highlight a practical example of the science-policy interface presented as a focused case study of material society using mercury pollution policy in Canada in the 1995 to 2005 period. The case study contributes to the understanding of Beck's world risk society theory as a manifestation of material society and specifically addresses the empirical analytical shortcoming of Beck's work. This is combined with a response to Watkin's call for a contemporary ecological analysis of the role of staples theory in defining Canada's "rapacious character" and "bias towards resource exploitation."

In addition to the primary research undertaken and described in the main body of this document is the inclusion of action research in the Appendix in the form of a popularly written account of self-experimentation with mercury that was published as Smith and Lourie (2009).

Several areas from the perspective of the role of science in policy-making, below, are considered as part of the research, recognizing that the larger political economic context of Canada's historic resource-dependent economy drives the broader policy development agenda.

Following are some elements of the research that will be investigated:

- Terms such as "sound science" and "precaution" used to describe the science-policy interface.

- Ideas of “uncertainty” and “risk” related to “precaution” and “pollution prevention” in pollution policy in Canada.
- The extensive body of literature on mercury science and pollution, and what can be learned from examining mercury pollution control policy as a case study of uncertainty and the science-policy interface.
- The nature of the science-policy interface as it relates to the period under investigation and in contemporary science-policy literature.
- A better understanding of the policy implications of toxic chemical regulation in risk assessment and risk management.
- Binary concepts in the science-policy nexus building on the “materials society” and “risk society” paradigms described by Beck.
- An empirical distinction between stakeholders who are inherently more aligned to an ‘economic risk paradigm’ versus an ‘adaptive precautionary paradigm’.
- Canada’s political economy and the dominance of Canada’s resource dependency or “staples economy” on the science-policy interface.
- Innis’s “staple theory” (Watkins, 1963) and resource “dependency theory” (Hessing et al. 2005) as defining characteristics of Canada’s modern environmental policy.
- The relationship between Beck’s “material society”, “staple theory” and Hessing, Howlett and Summerville’s “resource dependency”.
- The relationship between the historic policy treatment of mercury pollution in Canada to climate change and other contemporary environmental policy debates.

CHAPTER 2:
THEORETICAL FRAMEWORK AND METHODOLOGY

"In the public arena and in specialist discussions there are above all two interpretative attitudes, poles apart as to their assessments and political consequences, competing against one another: 'natural scientific objectivism about hazards' and 'cultural relativism about hazards'. (Beck, 1995)

"These subjects appeared to behave not as risk takers but as rationalizers engaging in the perceptual distortion of environmental information for the purpose of reducing cognitive dissonance." (Adams, 1973)

2.1 Introduction to Theoretical Framework

The intrinsic conflict in the thesis presented herein is that on the one hand, scientific evidence is required as a basis for environmental policy decisions ("natural scientific objectivism"), however the socio-economic and political dimensions of risk dominate decision-making to the point where risk is no longer situated in the realm of science but rather as a social construct within the political economy.

In this dissertation I make the case that the reason governments in Canada have failed to manage environmental risks is due to a reliance on conventional regulatory risk management approaches that assume risk assessment is a calculable, objective technical exercise, whereas it is in fact a product of material society interests, largely the resource industry, designed to maintain status quo economic activity.

The work of Ulrich Beck provides the dominant theoretical framework used to present the research and findings. Beck's work, *Risk Society: Towards a New Modernity* argues that modern society is in transition from a "material society" focused on the distribution of industrial goods and wealth to a "risk society" that is increasingly focused on the distribution and avoidance of risk, notably global environmental risk (Beck, 1992). The tension between material society and risk society provides the framework to explain Canada's failed history at managing global environmental risk.

Added to this are the related theoretical frameworks of "staples economy" and "resource dependency" as major economic and political drivers in Canada. In the words of staples theorist Mel Watkins (2007):

"There is an urgent need for an ecological history of staples as a way of illuminating the rapacious character of the Canadian variant of capitalism with its bias towards resource exploitation. The popular mind may tend to equate environmental degradation with the smokestacks of industry and to ignore the persistent damage done to nature by staples production. Presently, the development of the Alberta tar sands threatens to be the greatest of Canada's contributions to ecological disaster, probably ruling out any possibility of Canada meeting even the modest Kyoto standards for reductions in carbon dioxide emissions. The bottom line on the staples trap is that, on the Canadian list of fundamental freedoms, the very first is to export anything, anywhere, regardless of the consequences.

If in doubt, consider asbestos: Canadian and Quebec governments continue to shill for its export. As Canadian firms that have developed around Canadian staples, such as minerals and petroleum, go abroad, they export that deficient domestic environmental record. They also export a tendency to violate human rights and foment conflict — something long done in Canada with respect to the rights of aboriginal peoples (e.g., mine their land and leave it spoiled) and the rights of workers as well. This serves to remind us, however, that there is, as there long has been, a successful and dominant staples fraction within the Canadian bourgeoisie that is able to operate abroad from its strong domestic base."

With respect to this researcher's epistemology, it became clear throughout the research that the science-policy interface conflict at the heart of the dissertation is in fact embodied in the researcher's own conflicted views on the role of science; science as necessity and science as captured by material society. The work concludes with the recognition that science and policy cannot be viewed separately from the perspective of political or social advancement of ideas.

The efforts of science historians and related philosophies to discredit the role of science in its entirety, have been unproductive. At the same time the tendency of the science community to view science as the pure and objective truth that will lead to a clear pathway for decisions is unrealistic and misinformed.

It is in Beck's main thesis that "material society" or "modernity" or "industrial modernity" began to transition to "risk society" or "reflexive modernity" in the late twentieth century as the concept of modern global risk emerged at the heart of this research. Specifically: "*the failure of techno-scientific rationality in the face of growing risks and threats from civilization"* (Beck, 1992). It is this failure manifested in Canadian pollution policy under investigation.

2.2 Risk Society

Beck (1992) describes "two epochs" as a relationship between the "production" and "perception" of risks where in material society risks are tangible and immediate; in risk society, risks are diffuse and intangible. The risk in risk society is produced by society, as a by-product of economic growth, yet the risks, being intangible and self-generated are not perceived directly by society in the same way that tangible risks in material society are perceived. There is little to debate regarding the uncertainty around starvation whereas there is plenty to debate in the uncertainty of the health effects of toxic pollution or the uncertainty regarding the level of risk of harm caused by climate change to different populations.

Beck recognizes that there is validity to elements of both the scientific and cultural aspects of risk and he is critical of each aspect. I share this critical perspective. His conceptualization of risk and hazard management is an interplay between the two. Whereas Beck is highly critical of the limitations of technocracy he accepts the indispensability of technological solutions to global risks. His main criticism of scientific objectivism is in that it ignores the political dynamic behind the creation of large-scale global hazards; global pollutants and climate change being excellent examples. Beck's criticism of cultural relativism is in the lack of recognition of the socio-historical factors behind large-scale hazards. Global hazards in risk society are a result of social choice and deliberate decisions; whereas in pre-industrial society global hazards were caused by “demons” or “Gods” and in material society caused by “accidents”. Social relativists, according to Beck, therefore need to understand the political anthropogenic nature of hazards in risk society.

It is precisely this theoretical dynamic of being trapped between the two epochs of science and culture, or material society and risk society, that I use to contribute to the understanding of Canada’s inability to craft effective policy responses to toxic pollution and climate change.

In material society risks tend to be localized or regional, voluntary, and a result of direct economic or industrial activity (Beck 1995). Moreover, Beck sees risk society superseding the traditional class society theoretical frame in that the global risks of toxic pollution or nuclear contamination do not distinguish between classes. They are global. Although clearly other elements of societal structure leave disadvantaged classes more vulnerable even to global risk. In the case of mercury, Grassy Narrows is a classic material society incident whereby the effects are local and tangible with direct causation, and consistent with social class theory of vulnerable populations.

In risk society, the hazards are global, intangible, unavoidable and ecologically systemic. The airborne release of mercury from coal-plants or garbage incinerators filled with mercury-containing products is a risk society hazard. The risks are anthropogenic, the economic activities themselves create the risks versus single “accidents” that can be “managed” or “cleaned-up.” As the activities continue the risks increase until they blur from the intangible to the tangible, yet the questions of uncertainty, causation, societal vulnerability and liability are often unknowable and disputable. This creates an environment conducive to the obfuscation of facts, and the presence of uncertainty or the creation of uncertainty, leading to the deferral of efforts that impinge upon economic activity.

“We are still acting out the play according the script of industrial society” (Beck, 1992).

Beck separates the ideas of risk from hazard or danger, whereby hazard and danger are largely pre-industrial concepts, and that it is only through modern attempts to manage hazards do we create the concept of risk and henceforth "risk society" (Elliott, 2002). Risk is therefore a direct reflection of efforts to manage or control risks, such as the release of toxic pollutants to the environment. Industrial society, according to Beck, is therefore largely responsible for the construction of risk; "risks are made; hazards occur" (Jarvis 2007). As the understanding of those risks becomes more global, diffuse, anthropogenic and ecologically existential, the proof of cause mechanisms such as Risk Assessment/Risk Management (RA/RM) become less and less effective to the point of having little relevance to the prevention of risk; an idea expanded upon throughout the research herein.

Having a temporal context within which to understand Beck is relevant in that it helps to explain Beck's focus on the failure of modern (as in late twentieth century) institutions to manage the consequences of modernization (Matten, 2004) which I describe in the Canadian environmental context. Matten (2004) provides a constructive analysis of Beck's work noting the relevance of the period in which Beck was developing the "risk society" thesis; namely following the 1980s period which saw significant development of environmental laws and policies, most notably the establishment of regulatory risk decision frameworks. Yet the regulatory frameworks created were not sufficient in managing the growing global risks of persistent pollutants, as shown in the research.

In Chapter 4, I describe the history and evolution of the risk assessment and risk management regulatory frameworks (RA/RM) and the "risk industry". Canada's Toxic Substances Management Policy (1995) is the reference point for a risk-based system whereby risk assessments are used to determine potential environmental harm and risk management is employed to set priorities and implement substance management plans. For Beck, risk management is inextricably linked to the "very fabric of industrial society" which also explains how the risk industry and risk science are a professional embodiment of industrial material society (Jarvis 2007).

Elliot (2002) describes one of Beck's most important critiques of social theory as a "lack of comprehension of the manner in which dangers to societal preservation and renewal infiltrate the institutions, organizations and subsystems of modern society itself." In this respect, not only are "we" (industrial activity and institutions) the uncertainty, but we are trapped in an evolving feedback loop of uncertainty, adaptation and new forms of society and uncertainty. Canada's management of mercury risk illustrates this idea.

In Chapter 5, the failure of RA/RM to mitigate the legitimate health hazards associated with mercury use in industrial society is presented. The research addresses one of the critiques of Beck's work, which is the lack of empirical analysis of risk society theory to substantiate the reality of global risk society (Bergkamp, 2009). In this way I am contributing to both a practical and theoretical understanding of risk society theory and the extent to which Canada's pollution policies and specifically regulatory risk frameworks are incapable of managing risk society challenges in a material society framework.

In Beck's theory of risk society, human-caused hazards create a repetitive societal reflection and response mechanism referred to as "reflexivity". "Reflexivity" is a core element of Beck's risk society, derived from the work of Giddens (1990) and his concept of "reflexive modernization" (Matten, 2004). Reflexive modernization as described by Giddens (1990) is in contrast with rationalist modernization in that reflexivity introduces the idea of constant examination and reformation of societal norms and practices as information about those norms and practices becomes available. Beck's "reflexive modernization" includes parallels to the notion of being in between phases, trapped in "paradigm disarray" in "transition from the industrial to the risk epoch of modernity" (Beck, 1995) as I demonstrate through the case study of Canada's past approach to mercury pollution policy.

"Reflexivity" has parallels in the ecological management approach of "adaptive management" where "the central goal of adaptive management is to improve natural resource management by learning how ecosystems respond to human intervention, and then adjusting actions in response to that learning" (Layzer and Schulman, 2017). More specifically, adaptive management was designed to respond to the “disastrous results” of the “rigid adherence to the status quo” which was “becoming the norm” (Layzer and Schulman, 2017). Giddens (1999) states: “Risk needs to be disciplined, but active risk-taking is a core element of a dynamic economy and an innovative society.” Thus – in Gidden’s view it is about striking the right balance: not eliminating all risk (which he argues would also eliminate innovation), rather taking the right amount of risk.

Both reflexive modernization and adaptive management seek to enable more sophisticated actions (policy, societal, or in the case of adaptive management, the actions of resource managers) in response to uncertainty in complex systems. The critical aspect being reflection and adaptation to the alterations and responses following a deliberate human intervention in a system; for risk society, the response is largely societal in scale, whereas in adaptive management, the response to a human management intervention is seen through an ecosystem adaptation. The concept of “status quoism” as an embedded contributor to policy failure is relevant across the various theoretical dimensions of “material society”, staples economy” and “settler society” whereby a lack of willingness or ignorance or deliberate and intentional efforts to maintain the status quo, have led to policies that favour economic interests at the expense of ecological and human, notably Indigenous, imperatives.

There is an anticipatory element of risk in Beck’s conceptualization, which add elements of fear and uncertainty, as is the case with global risks of nuclear war, climate change or toxic chemicals (Mayer, 2016) and where I argue adaptive precaution is a relevant concept. Despite the considerable environmental degradation today, Beck states the “social impetus” of risk is related to “projected dangers of the future” that may be so great as to make any kind of remedial action of no use. This idea foreshadows in many ways the contemporary policy discourses on precaution and climate change.

2.3 Risk Assessment and Precaution

By describing the concept of significant future danger Beck (1992) touches on, although does explicitly acknowledge, the concept of precaution. In *Ecological Politics in an Age of Risk* (1995) Beck references precaution obliquely as it relates to the way in which risk is calculable in risk society. He does not, however, develop the idea of precaution as a specific response to risk society. It is this specific connection of precaution and adaptation (and elements of reflexivity and flexibility) within risk society theory, where I am contributing to the understanding of Canada's pollution policy history and mechanisms.

Precaution focuses on a response to scientific uncertainty and the "sound science" debate; specifically, the use of precaution in the face of uncertainty in the application of environmental policy. The "precautionary principle" is the manifestation of the non-governmental organization response to scientific uncertainty. The theoretical framework for the dissertation is rooted largely in the discourse of risk, uncertainty and precaution as they relate to the idea of transitions and tensions between "material society" and "risk society" or the "economic risk" versus "precautionary adaptation" paradigms.

Boyd (2015) states that "Canada is failing to keep pace with the world leaders in regulating health threats from toxic substances". His comparative analysis of laws and policies in other jurisdictions finds that Canada "lags far behind" Australia, the European Union and the United States with respect to environmental policies to protect health and adopt precaution (Boyd, 2015). As it relates to the discussion of scientific uncertainty in policy-making, Boyd proposes that Canada adopt the precautionary principle as "critical in addressing uncertainty" (Boyd, 2015).

The discourse of science and precaution was active in Canada during the case study period, as noted in the federal government publication *'A Framework for the Application of Precaution in Science-based Decision-making about Risk*' (Government of Canada, 2003), as well as numerous publications representing different perspectives on risk and precaution (New Directions Group, 2004; NERAM, 2000; Pollution Probe, 2001; Government of Canada, 2001).

The most common definition of the precautionary principle emerged from the United Nations Conference on Environment and Development (the "Rio Declaration") which states; "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Many health and environmental groups in Canada and other countries have challenged the definition used in the Rio Declaration.

The most prevalent alternative definition of the precautionary principle emerged from the Wingspread Conference on Implementing the Precautionary Principle (1999). The Wingspread definition reads as follows;

"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."

According to the Wingspread participants; "scientific uncertainty and ignorance about the effects of anthropogenic stress on ecological systems are the underlying rationale behind the Precautionary Principle" (Raffensperger and Tickner, 1999).

A tension exists between the desire to apply precaution as a "trigger" for an alternative decision-making process versus the need to consider precaution within traditional risk management frameworks (New Directions Group, 2004). Analysis of risk-based decision frameworks and the precautionary principle is often presented in an adversarial nature, with the precautionary principle presented as a reaction to risk-based systems.

Contemporary examples of toxic chemicals management, namely the regulatory process regarding bisphenol A in Canada is explored in Chapter 3 to better understand how risk, uncertainty and precaution, along with stakeholder influence, interacted at the science-policy interface in Canada's decision to ban Bisphenol A baby bottles (Maguire and Hardy 2012; Sjostrom and Stenborg, 2014; Kiss, 2015; Edge and Eyles, 2017). A number of consistent ideas are drawn from the comparison.

The precautionary principle is a concept introduced into decision-making to manage a risk where there is uncertainty. Efforts to understand and address risk and uncertainty have been undertaken by economists for decades, notably with the publication of *Risk, Uncertainty and Profit* (Knight, 1921). The Knight publication and many of the early publications on risk and uncertainty focus on economic risks associated with making decisions. More specifically, the focus has been to address the risk of economic loss, individually or in corporations, when making decisions in the face of uncertainty. In the language of economics; "a decision-maker typically exposes himself, subjectively at least, to possible losses when maximizing his objective function" (Hester and Pierce, 1968).

The goal of many economists writing on risk and uncertainty was to develop the calculus of risk decision-making; "nothing more satisfying than a well-axiomatized decision theory" (Menges, 1968). While economists continued to pursue the theoretical underpinnings of the risks involved in losing money, another aspect of risk and uncertainty was emerging, namely the introduction of precaution when faced with uncertain health and environmental risks.

The concepts of risk, uncertainty, risk management and precaution, and specifically the idea that Canada's regulatory risk framework is a manifestation of material society interests are described in detail in Chapter 4. Moreover, I will make the case that adaptive precaution is an appropriate policy response to risk society. In Chapter 6, I demonstrate through survey research an empirical approach describing two dominant paradigms of material society (economic risk paradigm) and risk society (adaptive precautionary paradigm) and moreover that risk society aligns with the theoretical underpinnings of precaution and adaptation.

Figure 2.1 illustrates the alignment of the economic risk paradigm and the adaptive precautionary paradigm with epistemologies across different disciplines. The economic risk paradigm conforms to a belief system as does the adaptive precautionary paradigm, hence the reference to epistemology. Based on an extensive review of literatures from many fields of study, one finds that there are commonly two dominant ways of understanding or framing risk from an ontological perspective.

Given that each paradigm comprises a language and over-arching frame, the presentation of cross-cutting dichotomous epistemologies is consistent with the definition of ontology (see Chandrasekaran et al., 1999). From an environmental ethics perspective there are those that disagree with the "atomism" "holism" ontological dichotomy in favour of an ecological perspective (Buege, 1997). The relevant idea is the pluralist and inclusive nature of an ecological or adaptive precautionary perspective, which permits a more holistic ontology consistent with risk society.

The adaptive precautionary paradigm may be more usefully described pedantically as the reflexive ecological paradigm. The fact that there are debates regarding the philosophical pedigree of precaution, or lack thereof (Whiteside 2006) may contribute to undermining the principle and adding to the perception of critics that it is not a serious aid to decision making. Embedding precaution more deliberately in the theoretical underpinnings of Beck's risk society and reflexive modernity provides a relevant philosophical pedigree in social theory.

I have created the Risk/Precaution Epistemic Theory Alignment Table (Figure 2.1) to situate the "economic risk paradigm" and the "adaptive precautionary paradigm" relative to the dominant epistemologies. The table provides utility in assisting the reader (and the author) to understand risk from a multi-disciplinary perspective. This research finding is a helpful organizational tool and provides an area of research worthy of further investigation, namely the concept of dichotomous ontologies as they relate to risk and precaution.

The primary purpose of Figure 2.1 is the presentation of the idea that material society (the economic risk paradigm) aligns with a set of epistemologies, or perhaps ontologies, that are identifiable and distinct from the set associated with risk society (the precautionary adaptive paradigm). A few of the epistemologies that highlight the character of each paradigm include conservatism, modernism, objectivism and empiricism as dominant in the material society versus liberalism, post-modernism, subjectivism and phenomenalism being dominant risk society traits. The nature of material society risk-based decision-making as compared to adaptive precautionary approaches in risk society becomes clearer with the alignment of these characteristics in mind.

Material society imagines a world of limitless resources, limitless capacity to absorb pollution, where nature is natural, where humans are hapless recipients of the Earth's bounty, and governments allocate access to, and benefit from, natural resources. Material society is local and social networks are small and interrelated. Risk society, in contrast, is one where the world has physical limits in terms of resources and pollution, where nature is no longer natural but a human-dominated construct, where humans can destroy the planet, alter nature and transform humanity. In risk society governments allocate risk, not benefit, and Beck's "cosmopolitanization" of society means risks are global as are the consequences of social interactions that no longer require a spatial element.

Furthermore, the distinction between Beck's material society and risk society emerge as unique and critical to Canada's environmental and resource policy, where Canada's material society interests align with neoliberal epistemology. Beck's emergence of "world risk society" as a sequential, temporal extension of material society fails conceptually in Canada. Rather than exhibiting legitimate, democratic, reflexive elements characteristic of risk society, Canada is trapped in a rationalist, neoliberal epoch where tight policy networks of economic interest dominate environmental policy-making. In this respect, Canada differs from Beck's European experience in that the science-policy interface in Canada exhibits contemporary neoliberal cynicism toward science combined with material society economic realities that make for a dysfunctional policy system.

The economic risk paradigm, as a rationalist material society paradigm, is also, in part, a simplified human response to the uncertainty and complexity associated with ecological systems. According to the theory of "bounded rationality" humans, including scientists, construct plausible, simple models in the face of uncertainty to address "ill-definedness" (Arthur, 1994). The concept of bounded rationality supports the idea of Type II error bias and the risk decision sphere. The early scoping phases of risk assessment (problem identification and risk evaluation) institutionalizes bounded constraints. The risk paradigm pushes uncertainty beyond the boundaries of "bounded rationality."

The precautionary principle and related ideas of weight of evidence, burden of proof and adaptive management are specific mechanisms that remove or enlarge the "rationality" boundaries and permit a combination of pluralism and heuristics, as opposed to strict adherence to objectivism and empiricism. This is similar to post-normal risk governance in response to uncertainty regarding anthropogenic risk within existing risk regulation systems (Klinke and Renn 2014); and consistent with the thesis that Canada is trapped in the regulatory risk systems of material society, incapable of keeping pace with the degree of complexity and uncertainty related to human intervention in ecosystems, described by risk society.

Figure 2.1: Material Society-Risk Society Epistemic Theory Alignment Table

Material Society Economic Risk Paradigm	*Risk Society* Adaptive Precautionary Paradigm	Dominant Discipline
Conservatism	Liberalism	Political science
Objectivism	Subjectivism	Pervasive
Structuralism	Post-structuralism	Linguistics
Logical positivism	Post-positivism	Philosophy
Modernism	Post-modernism	Pervasive
Constructionism	Deconstructionism	Philosophy
Behvariorism	Cognition	Psychology
Rationalism	Mysticism	Religion
Technocratism	Pluralism	Political Science
Weberian	Longian	Philosophy
Rationalism	Incrementalism	Decision Theory
Normal	Post-normal	Philosophy
Yin	Yang	Taoism
Humanism	Naturalism	Conservation Biology
Empiricism	Phenomenalism	Philosophy
Industrialism	Post-industrialism	Political science
Valuation attitude	Recognition attitude	Decision theory
Atomism	Holism	Ethics
Scientific method	Heuristics	Research methods
Modernity or material society	Reflexive modernity or risk society	Ulrich Beck
Analytical ecology	Integrative ecology	C.S. Holling and resilience alliance

Epistemology, normative assumptions, boundaries and inherent uncertainty need to be made transparent by scientists to policy makers if knowledge is to be applied successfully and strategically to problems of environmental sustainability (Grunwald, 2004.) These ideas echo Beck's contention that science has failed society in addressing risk by becoming constrained by its own technocratic rationality (Beck, 1992). Criticism of science may be misplaced since it is not so much science that is creating the technocratic constraints Beck refers to, but the larger techno-bureaucratic infrastructure that subscribes to the rationalist risk-paradigm.

The "technical minutiae of risk analysis" need to be situated within a framework of public policy and social justice (Jasanoff, 1993). The ecological elements of the precautionary paradigm have the requisite science rigour, one could argue more rigour than in the risk paradigm, in that they recognize the legitimacy of science uncertainty. Furthermore, the adaptive precautionary paradigm introduces a post-positivist, heuristic element to decision-making that allows for the social, moral, cultural and adaptive elements needed to make long-term decisions regarding complex, global ecological systems.

Risk assessment, rather than "science," may have therefore become Beck's "protector of a global contamination of people and nature" with uncertainty at the crux of the policy ambiguity. The implications for Canada are clear with respect to the Canadian government's implementation of CEPA, or lack thereof, and reliance on technocratic regulatory risk models that have failed to restrict the use and emissions of toxic pollutants, such as mercury, leaving the legacy of human devastation still seen in Grassy Narrows Wabaseemoong. Here, the connection between settler society, staples economy and risk society are made, whereby colonial-era power structures continue to exploit and disenfranchise the Indigenous population (Preston, 2013).

Moreover, as illustrated in the case study in Chapter 5 and reinforced in the survey research in Chapter 6, Canada's historic resource economy is a powerful lens through which any decisions related to the environment-economy nexus must be viewed (Hessing et al., 2005).

With respect to society's risk obsession with proof of cause and effect and Beck's "system of organized irresponsibility", Elliot (2002) describes risk society as "technically oriented legal procedures designed to satisfy rigorous causal proof of liability" which in the end fail in the globalized risk environment leaving corporations free to pollute. An apt description of the way in which the Canadian government implemented CEPA, as shown in Chapters 4 and 5.

Jarvis (2007) describes Beck's work as "an attempt to understand this remarkable transformation in social attitudes and fear, and an attempt to examine the forces at play between technology, science, political and social institutions, including an assessment of their consequences". Elliott (2002) reduces Beck's central ideas to three main ones, namely: the risk society thesis; reflexive modernity; and individualization. Beck's risk society thesis is rooted in the idea that modern societies face risks that previous generations did not (Elliott, 2002); risks that are complex, uncertain, global and involuntary.

A central tenet of the research is that the environmental policy processes of the Canadian government can be described as trapped in a "material society" or "economic risk paradigm." Hence the global risks from toxic chemicals and climate change in an emergent "risk society" cannot adequately be managed within the institutions of "organized irresponsibility" nor absent institutions able to embody "reflexive modernity" or the "adaptive precautionary paradigm." Moreover, Canada's especially poor historic environmental policy performance, relative to other industrial nations, can be explained by the extent to which the concepts of "material society" are exaggerated and more relevant in Canada, given the lingering dominance of "resource dependency" as a discourse and as an institutional reality.

I will lay out a case in the research that in the reflexive modernity epoch, the notion of scientific uncertainty has a very different role in policy given that uncertainty is human-caused and iterative; the Anthropocene, defined as the human-dominated epoch of industrial society, is the embodiment of world risk society. Reflexive modernity is concerned with itself. Ecosystems cannot be understood without understanding social interactions, discourse and the adaptive feedback loops of precautionary decisions and actions.

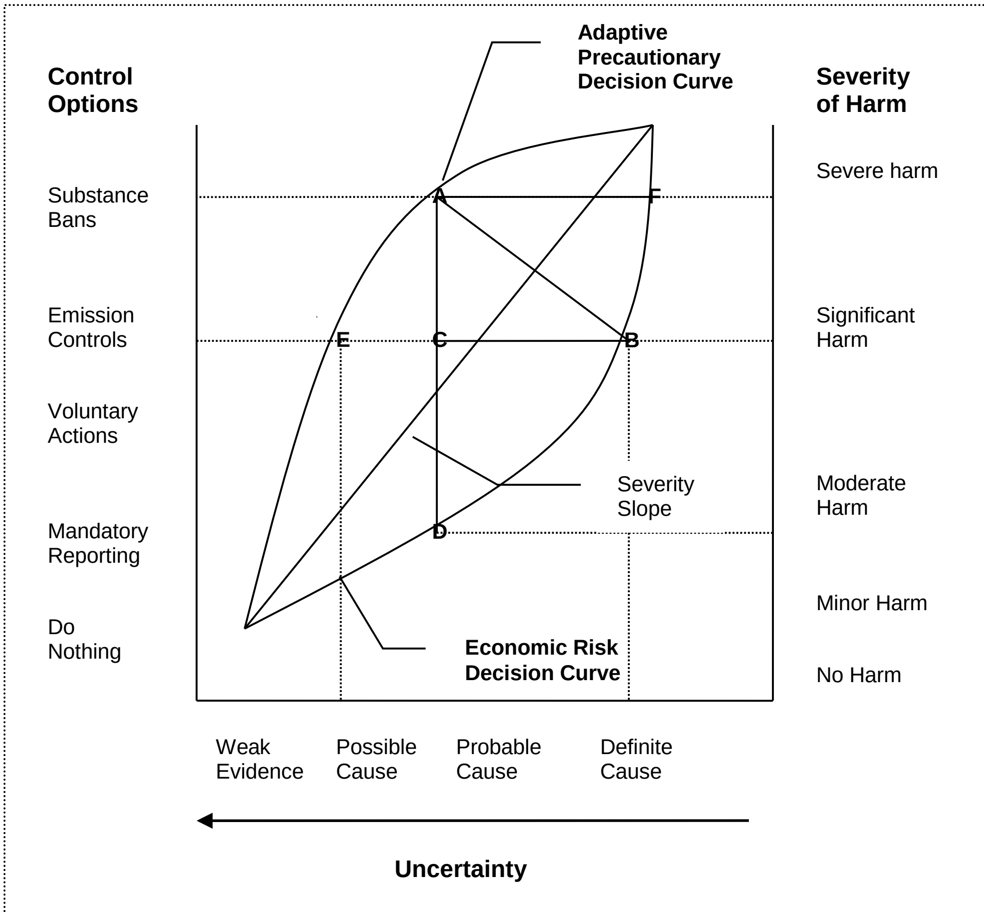
2.4 Theoretical Risk Society Decision Pathways

The precautionary principle as it is widely conceived is not, in and of itself, an effective decision-making tool. The role of precaution and its relationship to risk management will be explored as part of the dissertation and in the context of alternative decision models. Figure 2.2, below, has been developed as an initial graphical representation of the relationships between risk, precaution, uncertainty, harm and control options. The dissertation research will involve the further clarification, refinement and testing of these ideas within the material society and risk society theoretical frame.

Figure 2.2 introduces the concept of "gap" in several instances. Bradshaw and Borchers also describe the science-policy gap. Gap is therefore an important concept that requires clarification.

The research will explore the operationalization of Figure 2.2 and specifically issues related to the description, quantification and relevance of the risk-precaution decision pathways.

Figure 2.2: Theoretical Risk-Precaution Decision Pathways



AB = Precautionary Gap – AB is measured at its widest point, generally in the Probable Cause range.
AC = Control Gap – AC represents the difference in proposed control options for the same degree of uncertainty.
AD = Risk Perception Gap – The greater the severity slope, the greater the Risk Perception Gap.
AF = Uncertainty Gap 1 – As information improves and uncertainty reduced, the Uncertainty Gap becomes smaller.
EB = Uncertainty Gap 2 – In the probable cause range, the Uncertainty Gap is at its greatest

Figure 2.2 describes precautionary and risk-based decision path curves in relation to control options. A critical caveat to the usefulness of this figure is that this describes one aspect of the decision-making process, typically at the risk management phase of a policy decision. The purpose is to attempt to better understand the narrow science-policy decision process recognizing that apart from the formal bureaucratic risk management policy exercise is the reality of the power of economic interests aligned with political interests in Canada's resource economy, which often erase the intent or outcomes of the formalize policy process.

The Adaptive Precautionary Decision Curve is characterized by a steeper slope as it moves through the higher uncertainty ranges, indicating a propensity to support more restrictive control options in the face of uncertainty. At point E on the precautionary curve, control options range between voluntary actions and mandatory emission controls where significant harm is present but cause of harm is in the possible range. At point A on the precautionary curve, substance bans are supported where severe harm exists and where there is a more highly probable cause. The Economic Risk Curve is characterized by a more gradual slope in the higher uncertainty ranges with a steeper curve as information becomes more certain.

At point B on the Risk Curve, emission controls are warranted where harm is significant and where certainty exists. The line AB represents the Precautionary Gap and occurs at the greatest point between the Adaptive Precautionary Curve and the Economic Risk Curve, typically at a point directly above the Probable Cause range. The Precautionary Gap (AB) illustrates how the precautionary approach accepts a greater degree of control with greater uncertainty. The greater the distance AB the greater the degree of curvature in the Precautionary and Risk Curves, signifying greater divergence between the precautionary perspective versus the risk-based perspective.

Line EB represents the Uncertainty Gap, the difference in acceptable levels of uncertainty between the Precautionary Curve and the Risk Curve where the same control option is adopted. For stricter control measures a much higher degree of confidence is required on the risk-based curve.

The Severity Slope represents the severity of harm; the greater the severity of the problem the greater the severity slope. The Risk Perception Gap (AD) generally increases as the Severity Slope increases. In this model the degree of severity may represent the perception of severity, since severity may not be known, particularly where uncertainty is great. The Severity Slope represents a point between the precautionary and risk-based perspectives.

There is also a temporal aspect to the relationship between the precautionary and risk-based curves. As issues mature over time, there is generally less uncertainty. The Precautionary Gap and Risk Perception Gap typically narrow as research proceeds and more information is made available to stakeholders. The two curves begin to converge with the Severity Slope as consensus regarding the understanding and acceptance of uncertainty is achieved.

In order to validate this hypothesis a detailed survey was undertaken of individuals representing corporations and non-government organizations (NGOs). The objective of this research was to investigate whether there are consistent, statistically valid differences between the actions of individuals in corporations versus those in NGOs regarding assessments of risk and precaution. If so, can we describe these differences in terms of an "economic risk paradigm" and an "adaptive precautionary paradigm." The findings show that there is a clear difference in the responses of the two cohorts conforming to the idea that the precautionary adaptive group reflects 'risk society interpretive intent' and the economic risk group reflects 'material society interpretive intent'.

Several authors writing during the study period (Sheffer et al., 2002; Yorque et al., 2002; Leiss, 2001; Bradshaw and Borchers, 2000; Lee, 1993; Ludwig et al., 1993) commented on the challenges posed in environmental decision models by suggesting a range of options that include: improving communications, engaging stakeholders, recognizing uncertainty, understanding values and the role of politics. Ludwig (1993) makes reference to "magical thinking" whereby policy-makers assume that science can solve environmental problems when in fact they are political problems. A more explicit recognition of uncertainty in decision models may strengthen decision processes, however Ludwig's observation of "magical thinking" is an apt descriptor of the rigid risk management approach applied to mercury policy in the 1995 to 2005 case. Other scholars at the time, for example Lee (1993) and Holling et al. (2002) proposed adaptive management as the policy response to Lee's assertion that "we do not understand nature well enough to live harmoniously within environmental limits."

In order to overcome the challenges posed by the complexity and uncertainty inherent in environmental policy, a conceptual framework that has its foundation in uncertainty, not certainty may be needed. The precautionary principle is a valid reaction to risk science but so far appears to be an inadequate response, based on the extent to which it is applied with respect to mercury control and other environmental issues in Canada. The language of precaution may be present to some extent, and courts have been more explicit in referencing the precautionary principle, but as a working policy instrument it is rarely used in Canada. The role of precaution, defined broadly, is not exceptional in environmental decisions, but commonplace. There is, however, a distinction between precaution, the precautionary principle and risk-based models that requires further consideration. The research builds on the science-policy literature and more specifically the integration of discourses on precaution, adaptive management and risk society.

2.5 Risk and Uncertainty in Material Society

The second concept is situated within the discourse of risk and uncertainty as it relates to environmental policy decision-making. In *Risk Society: Towards a New Modernity* Beck argues that modern society is in transition from a "material society" to a "risk society" (Beck, 1986). Beck's transition from material society to risk society mirrors the idea that Canada's pollution policy decision-making is also in transition from the "economic risk paradigm" to the "adaptive precautionary paradigm" described in Chapter 6. The semantic distinction I am making is that Beck's "material society" reflects the economic risk paradigm whereas "risk society" is a more apt description of the adaptive precautionary paradigm. The adaptive precautionary paradigm is in fact a response to the uncertainty challenges associated with a growing recognition of the reality of a risk society. The risks of terrorism and climate change increased following the publication of Beck's *Risk Society,* adding credence to Beck's theory, and climate change (Beck, 2015), became a focus of his later work.

Scientific uncertainty is often presented as the primary source of conflict in toxic chemical risk management policy decision-making, together with the related notion that reducing uncertainty will reduce conflict (Shackley and Wynne, 1996). This idea must be presented in the broader political-economy context of how and why the uncertainty is being created, recognizing that in the case of climate change for example, where substantial scientific consensus exits, political-economic factors override policy-making that might restrict economic activity.

There was a considerable body of literature on scientific uncertainty written in and around the 1995 to 2005 study period from varying perspectives, addressing uncertainty in the contexts of risk management, precaution, science and sustainability (Ehrlich and Daily, 1993; Ludwig et al., 1993; Policansky, 1993; Lele and Norgaard, 1996; Raffensperger and Tickner, 1999; Leiss, 2001). Governments, commercial interests, scientists and non-governmental organizations (NGO's) were grappling with concepts of uncertainty, and reducing scientific uncertainty was a dominant theme in environmental policy in that time period (New Directions Group, 2004). There was also a growing sense that the complexity of "modern" life was unsustainable, from an ecological, economic and cultural perspective, as described in Homer-Dixon's "Ingenuity Gap" (2001).

One of the issues with respect to the use of environmental science is the integration of science in the policy process. When science becomes too close to policy or too close to the adoption of a particular position (e.g. Salter's mandated science), as is often the case in science funded by industry, there is a tendency to under-report or underestimate certainty, or put another way to over-emphasize uncertainty. Scientists are in the habit of minimizing the perception of uncertainty or understating uncertainty (Shackley and Wynne, 1996). This increases the likelihood of a false negative in risk terms. By simplifying the degree and nature of uncertainty as well as omitting obvious aspects of uncertainty that scientists would intuitively consider, but policy-makers may not, uncertainty can be misunderstood.

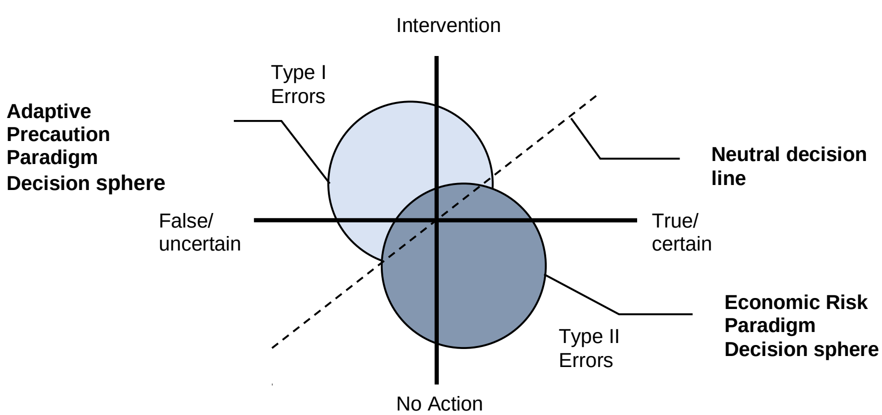
There was a disconnect between the stated principles of environmental policy decision-making in Canada (Government of Canada, 2000) and the actual decisions made. One of the most striking features of policy failure in Canada is the contradiction between the science-based language and the policy decisions where science (uncertainty) is used to avoid acting, or where actions chosen are inconsistent with the science that is presented. Adams (1973), in describing the concept of cognitive dissonance, noted that individuals are predisposed to maintaining a course of action even if new information indicates that their actions are contrary to their stated goals. This psychological phenomenon exacerbates and reinforces the status quo motivations of economic interests.

One of the outcomes of uncertainty in risk management is that a decision outcome to "do nothing" is still considered to be a legitimate outcome, on equal footing with a decision that may require significant investment on the part of government or industry. The bias in the "do nothing" outcome is not adequately addressed, nor is the idea that vested interests use uncertainty to encourage no action as an outcome. Mechanisms to level the decision playing field, such as governance models that introduce adaptation and flexibility, together with greater independence and transparency, may be needed to counteract the prevailing pressure to maintain Canada's resource dominated political status quo. This is also related to the reciprocal effect of decision-making and policy on science.

The relationship between, and implications of, Type I errors or false positive (acting upon false information) and Type II errors of false negative (not acting upon true information) has received extensive attention in environmental policy literature. One of the primary observations is that scientists and policy decision-makers favour a bias toward Type II errors (Lee, 1993). Figure 2.3 is a graphical representation of the relationship between Type I and Type II errors. For example, a Type I error occurs in the upper left quadrant where there is an intervention based on information that is subsequently determined to be false. The "neutral decision line" represents the continuum along which "knowability" and "intervention" intersect. The concept of "neutral" being based on total "knowability" and absent of political pressures. This is highly improbable in that it assumes a depoliticized decision context, clearly not the case with respect to environmental policy decisions in Canada. The idea is more closely related to the "science paradigm" phase (described in Figure 6.10) which in turn is analogous to Beck's "material society" and from an environmental conservation perspective fits McEvoy's (1990) "progressive era" comparison of the early development of environmental law and policy in the United States to early nineteenth century "progressive era" social and economic policies.

A decisive intervention may be warranted where there is confidence in the accuracy of the science and this would be represented in the far upper-right quadrant. The assessment of Type I and Type II errors is retrospective. Uncertainty and certainty may also be represented as the prospective aspect of intervention. Where there is greater certainty there may be greater confidence in acting higher on the "no action – intervention" continuum. Figure 2.3, below provides further illustration of these ideas. The '"decision sphere" indicates the bias against Type I errors and in favour of Type II errors and illustrates the idea that '"no action'" even where action may be warranted is a more common outcome then taking action where none is warranted. The dynamics with respect to these tensions will be examined as they relate to mercury control decisions.

Figure 2.3: Error Bias Decision Diagram



Shackley and Wynne (1996) note the difference between indeterminacy and ignorance, often presented as uncertainty or risk; "ignorance refers to situations in which it is not known what is unknown." Yorque et al. (2003) refer to the idea of "fundamental unknowability" and this is a principle theme in Taoism, sometimes called collective "unknowing" (Chuang Tzu). These concepts of “unknowability” are a useful basis to explore uncertainty as a necessary consideration in environmental decision models.

Where public policy is involved scientists are obliged to describe the limits inherent in the model being used and policy-makers in turn are irresponsible when asking scientists to verify models or use models for anything more than heuristic endeavours, supportive investigation or scenario testing. “No general empirical proposition about the natural world can ever be certain” (Oreskes et al., 1994). Scientific uncertainty is inherent in most situations regarding risk management decisions to address chemicals management (Wahlström, 1999).

Two specific discourses have emerged in the literature linking scientific uncertainty and policy: “sound science” and “precaution”.

2.6 Sound Science

Sound science is a term most often used by stakeholders and policy-makers who disagree with scientific outcomes and attempt to discredit the science by suggesting that it is not “sound” (Morrone and Lohner, 2002). “Sound science” can be described as a fundamental material society expression. Sound science is “normatively conservative” and reinforces a regulatory status quo (Cranor, 1995) as it is firmly embedded in the political and economic status quo. According to Leiss (2001), sound science is “an industry code-word,” also used by governments and academic institutions, as part of a divisive strategy to suggest that scientists deal with “facts” whereas other stakeholders (e.g. environmental organizations) deal with “fear and misinformation.”

Leiss (2001) describes the case of biotechnology and genetically modified organisms in Canada to illustrate the various tactics used by universities, industry, and the Canadian government to mislead deliberately the Canadian public, using their collective “sound science” as a means to discredit valid public concerns. Rampton and Stauber (2001) describe even more serious incidents of corrupted research in the name of “sound science,” where independent research scientists have had their files destroyed and lost their jobs when scientific findings do not support the direction of the corporate research sponsors.

The language of "sound science" is an important consideration in understanding the science-policy interface. "Sound science" implies that there is also science that is "unsound." "Junk science" and "pseudo-science" is the language used to discredit opinions that diverge from the "sound science" agenda. The Precautionary Principle, for example, is often described as not employing "sound science", in contrast to risk management (Santillo et al., 1999). There is a paucity of academic discourse on "sound science" versus "junk science;" however, it is a common theme in the media and public press (Morrone and Lohner, 2002). An example of the "sound science" agenda can be found at www.junkscience.com, where problems associated with climate change, second hand tobacco smoke and children's exposure to chemicals are described as fabricated issues based on junk science.

An excellent example of the politicization of a toxic pollutant, as described by Salter (1988), is in a report from the Competitive Enterprise Institute, a conservative American "think-tank," titled *'Fishy Advice: The Politics of Methylmercury in Fish and Mercury Emissions*' (Szwarc, 2004). Swarcz is a member of the neo-liberal "sound science" movement writing for conservative blogs and think tanks disputing the science around the health effects associated with mercury contamination, junk food, obesity, and phthalates, among others. In the report, Szwarc herself describes mercury as a political chemical claiming; "there is no evidence that the levels of methylmercury in the fish Americans consume are cause for any health concern" and adding, "Agencies and activist groups have issued these unfounded advisories based on tenuous risk portrayals." Her assertions include that the U.S. Environmental Protection Agency adopted unnecessary restrictions on mercury emissions and that U.S. Food and Drug Administration warnings on consuming mercury contaminated fish are unnecessary and in fact detrimental to maternal health by scaring pregnant women into not eating fish.

Furthermore, Szwarc, a trained nurse, writes detailed critiques of the most comprehensive longitudinal studies on mercury-related cognitive deficit in children, disputing the conclusions where they demonstrate a health risk, and makes claims contrary to the findings of an expert panel convened by the U.S. Centers for Disease Control and Prevention (CDC) on the health risks of mercury to children. Szwarc's report was referenced repeatedly in right-wing newsletters and additional Competitiveness Enterprise Institute reports, as well as prominently featured in a U.S. House Resources Committee and House Energy and Mineral Resources Subcommittee report released in 2005 on the health risks of mercury. The Chair of the House Resources Committee, armed with the Swarcz report, stated: "it is very clear that the current knowledge does not support the rhetorical campaigns of special-interest groups."

A common theme within the discourse of civil society is the anti-science rhetoric that Snow (1959) refers to in the "Two Cultures." The issue of "sound science" is not so much anti-science, or even a mistrust of science, but more accurately centred on the use of science to achieve policies that are not in the public interest. The fundamental difference between risk-based and precautionary approaches is not whether they use science or not, but how science is used to make decisions (Santillo et al., 1999).

Bradshaw and Borchers (2000) describe the science-policy interface as a gap represented by the difference in levels of confidence expressed by scientists and society regarding a scientific finding. They call this the science-policy gap. This contributes to one of the challenges of policy-making but is very different from the science-policy interface issues under investigation. Figure 2.4 (below) illustrates the conceptualization of the gap as it is being described in the dissertation.

One aspect of Bradshaw and Borcher's analysis, and the earlier thinking they report on, is the idea that the gap is due to a lack of public confidence in science. Observations of mercury policy in Canada, along with many other environmental issues, demonstrate that this was not the case (Boyd, 2003). It is possible that their line of thinking is in itself leading to the creation of the science-policy gap. In fact, the public is in many cases well ahead of policy-makers in accepting the need to take regulatory action to protect the environment. When surveyed, a majority of Canadians at the time of the mercury policy debates believed environmental laws and regulations were not strong enough. Seventy-two percent of Canadians said regulations were not strong enough; nine percent said they are too strong; the remaining seventeen percent thought they struck the right balance (Environics, 2003). This gap between apparent public concern and actual policy actions may be related to policy mechanisms that have a bias toward not acting in the case of scientific uncertainty; often manufactured uncertainty designed to protect economic or political interests.

Sound science can be thought of as an attempt to minimize the science-policy gap described by Bradshaw and Borchers (1993). The primary flaw in the sound science agenda is the presentation of science as “truth.” Science is based on experimentation and diversity of opinion, yet to the public and policy-makers, diverse opinions “may signal confusion and ignorance, thereby supporting a rationale for inaction” (Bradshaw and Borchers, 1993). The proposition being that with enough “evidence” society will begin to understand and therefore the science-policy gap will narrow.

In the context of the Canadian political-economy the extent to which the gap is able to narrow is largely bound up in the degree of political and economic influence. Cordner (2015) argues that in the environmental debate regarding brominated flame-retardants, power dynamics within policy relationships have more influence on policy outcomes than science. This argument can be extended to the mercury debate where historically the power dynamic rested with the extractive resource industry (Lourie, 2009) as well as the Bisphenol A debate where environmental actors secured the policy power in Canada (Kiss, 2015).

Science is not truth and moreover science can never provide complete or definitive understanding. At best, science describes a limited approximation of reality. An examination of the mercury pollution policy processes in Canada between 1995 and 2005 provides an opportunity to explore these issues, in a case study, as they relate to the science-policy interface of environmental decision-making and their relevance to on-going science-policy challenges in Canada.

2.7 Science-Policy Interface in the Material Society-Risk Society Epochs

In his 1959, “Rede” Lecture entitled “Two Cultures,” C.P. Snow initiated a controversial debate that is relevant today with respect to the role of science in policy decision-making. The “two cultures” Snow spoke of are represented by natural scientists and by non-scientists based on his observation of the increasing polarization between the two, supported by the education system. He noted with concern the inability of scientists to communicate with non-scientists to the point where “traditional culture” is turning “anti-scientific” hampering the ability of decision-makers to “take good action.”

For Beck (1986) the “two cultures” or “two epochs” in opposition can be seen in the relationship between the “production” and “perception” of risks whereby material society sees risk as tangible and immediate (e.g. lack of food) and in risk society risks are diffuse and intangible (e.g. global toxic pollution).

Westley et al., (2003) provide a context for the “two cultures” debate as it relates to the environment. The authors define two competing perspectives. One held by natural scientists who want to include “a box called ‘people’” in their model of the world. The second view is held by social scientists whereby “a box called ‘natural environment’” is included in their world view. Social theorists see “nature” and “ecosystems” as social constructs used primarily as a form of political discourse “to secure use of resources by different social groups” (Westley et al., 2003). Economists, in turn, view the world through the lens of production models where nature is a production input, environment is an uncosted externality receiving waste output, and humans are product consumers. Growth makes the system go around.

The role of science in policy decision-making is a topic that has garnered much attention since C.P. Snow’s famous lecture and continues to have contemporary scholarly interest (e.g Fahey and Pralle’s (2016) review of 793 articles across twenty-nine different policy journals). In the 1995 to 2005 period used for the case study on mercury the subject was addressed by M’Gonigle, (1999), Commissioner of the Environment and Sustainable Development, (1999) and Holling (2001). The mercury policy debate in the late 1990s was highly fractured along the science-policy axis with respect to environmental policy decision-making, where considerable polarization between scientists and policy-makers was observed. The division, as described in Chapter 5 is all the more instructive from a material society and staples theory perspective in that scientists representing industry interests were battling scientists representing an ecological perspective.

A number of historic cases of science advice being ignored or misinterpreted by governments in Canada have been cited as contributing to major health and environmental tragedies; including contamination of the Canadian blood supply (Hoey,1997), the collapse of the east coast cod fishery (Milich, 1999; Rogers, 1998), and the Walkerton *e. coli* outbreak (Boyd, 2003). In each of these cases the advice of scientists was ignored or seriously downplayed by policy bureaucrats and politicians. It is not clear whether a lack of scientific certainty led to a lack of preventive action or whether improved decision-models would have provided clearer direction. For more than a decade, Canada's Commissioner of Environment and Sustainable Development describes Canada's failure to apply science effectively as chronic and systemic (Government of Canada, 2000).

The abolition of the National Roundtable on Environment and Economy (NRTEE) in 2013 is emblematic of growing neoliberal disregard for science, and moreover, a possibly cynical gesture on the part of the Conservative government of the day to suggest that integrating the economy and the environment is either not possible or not desirable. Either way the NRTEE, founded in 1987, was one example of a governance institution designed specifically to advance the integration of science and policy, and more specifically to support the advancement of policies that integrate environment and economy.

The case of lead as an additive in gasoline has been widely cited (Salter, 1988; Montague, 1999; Rampton and Stauber, 2001; Leiss, 2001) as a classic example of the failure of decision systems to assess and respond to the neurological effects of the toxic heavy metal. The literature on science-policy issues related to lead use and emissions is particularly relevant to the dissertation research since lead has similar properties and characteristics to mercury, in that they are both neurotoxic, naturally occurring, heavy metals.

Climate change is the most prominent environmental policy debate that, similar to mercury, includes issues of scientific uncertainty, anthropogenic versus natural contributions, and resource sector conflict. Academic literature regarding the climate debate is vast and mostly beyond the scope of this research. It is instructive to look at hydraulic fracturing as a subset of climate policy as it offers opportunities for interesting contemporary analysis of the science-policy debate. Hydraulic fracturing has both a climate policy dimension regarding associated greenhouse gas emissions, as well as a local toxic pollution dimension based on the toxic substances added to hydraulic fracturing fluids that contaminate local groundwater. Neville and Weinthal (2016) use hydraulic fracturing in the Yukon to investigate the science-policy interface in environmental policy.

Colborn et al., (1996) describe several historical cases where scientific evidence of serious harm was available but essentially not "trusted" by conventional doctors and scientists. This may have created an element of uncertainty for policy-makers that led to the introduction and continued use of products such as Thalidomide and DES, both causing serious deformities in children; and DDT, causing cancer and reproductive failure.

Minamata, Japan, a small fishing village on the southern island of Kyushu brought the modern era of mercury poisoning to light in the 1950s when local doctors first became aware of the direct causal relationship between mercury contaminated seafood, and birth deformities and other serious illnesses. Despite the clear evidence of catastrophic poisoning found by local doctors, Japanese government officials refused to accept the science and allowed the continued releases of methylmercury. This combined with no restrictions on local fish consumption, for nearly a decade, led to hundreds or possibly thousands of preventable deaths, and morbidity in the tens of thousands.

A decade later Canada's mercury disaster began to unfold when nine tonnes of mercury were released to the English-Wabigoon river system over a nine-year period from 1960 to 1969 from a local pulp and paper mill. Mercury is used as a catalyst to produce chlorine and caustic soda from salt (sodium chloride). The chlorine and caustic soda are used in the Kraft-pulping process for paper-making; the caustic soda breaks down the lignin to produce pulp and the chlorine is used to bleach the paper. The nine tonne quantity is according to government estimates at the time. Reed Paper, the company operating the mill, had no record of their discharges.

There are two distinct aspects to the story, that mirror to some extent the disconnect between the scientific challenge and the social challenge, also reflected in the bifurcation of responsibilities within government where departments of fisheries and environment tended to act more swiftly than health departments.

First, was the ecological response to the problem; dramatically reducing effluent into the river, thereby stopping the source of the problem. Due to the massive quantity of mercury released this did not prevent the fish from continuing to be contaminated. Mercury, with a density greater than that of lead, sank quickly to the bottom of the river where it continues to be slowly released into the biota through organic mechanisms, likely for centuries to come. This points to another particular failure in Canada's environmental policies and that is the lack of any effective legal or regulatory mechanisms to address *ex post* contamination versus *ex ante* pollution. Environmental regulations have been designed to stop the activity of a business causing pollution but little is done to hold companies liable for their actions and on-going environmental and health liabilities once the pollution event has stopped. The legacy of contaminated, abandoned mine sites across Canada's north speaks very much to this problem.

Second, was the socio-economic response to the mercury contamination; proper notification of the risk, protecting the community from poisoned fish, ensuring adequate food to replace the local fish diet, adequate health protection from contaminated water, destruction of cultural identity, and elimination of the commercial fishing economy. None of these problems were ever adequately addressed, representing "settler society" attitudes in the long-standing perpetuation of environmental racism linked to resource exploitation (Preston, 2013) and material society interests. Ilyniak (2014) calls the contamination of the Grassy Narrows community a textbook example of "environmental injustice". She defines this injustice in relation to the "distributional patterns of environmental hazards", the "historical processes [determining] hazard distributions", iii) "patterns of non-recognition"; and "unequal access" to levers of decision-making (Ilyniak, 2014). All well-established in Grassy Narrows.

Had similar levels of toxic pollution been present in a Canadian urban setting it is almost certain that much more comprehensive and swift action would have been taken to protect population health and local economic interests versus the economic interests of the resource sector. These cases raise several questions and point to what can only be described as an abject failure in the science-policy interface, contributing to the cause and perpetuation of these pollution incidents.

The dissertation questions are situated within a larger policy discourse on the tensions between ecological imperatives and economic interests; reflected in Beck's "risk society" and "material society" and Canada's resource-dependent economic history which continues to trap environmental policy debates in "material society".

As noted previously, and described by Salter (1988), debates regarding the use of science in environmental policy decision-making are not new. There are, however, aspects of the debate introduced in the dissertation that bridge two concepts that have received less attention. First is the uncertainty associated with the understanding of human interventions in global environmental systems; to the point where humans are the uncertainty. Second is the neoliberal trend in environmental policy decision-making whereby greater levels of scientific and economic certainty are demanded prior to taking environmental policy action as a deliberate tool of material society interests to thwart policy progress.

In a review of the contemporary literature on science-policy interface several themes emerge. First, the extent to which risk and uncertainty are confounding elements in environmental policy. Second, the extents to which anthropogenic contributions to natural systems are adding to complexity and uncertainty, and the idea that humans are the uncertainty. Third, whether existing policy and regulatory regimes are capable of managing increasingly complex formulations of uncertainty and risk. Fourth, the extents to which regulatory regimes are susceptible to political influence regardless of the empirical understanding of the level of risk. Fifth, the idea that two paradigms, although characterised in different ways by different scholars (e.g. Snow's "two cultures" or Beck's "material society" v. "risk society"), emerge from the literature.

In general terms the binary themes align with the dissertation proposition of a risk-based paradigm and a precautionary paradigm whereby risk and uncertainty can be described as a tension between technocratic objectivism versus pluralistic subjectivism. Sixth, considering the extent to which the precautionary principle may be an approach for addressing uncertainty in policy; notably "Knightian uncertainty" in complex systems. Finally, there is an exploration of the literature on new forms of risk governance and the extent to which the ideas of "new", "evolved", "innovative", or "reflective" risk governance are instructive.

Perez and Snir (2013), as with many others, raise the need for new risk governance models and point out the need for research into the linkages between the "scientific" and the "political" again resembling the binary policy paradox described by Bulkeley and Newell (2015). Klinke and Renn (2014) use a binary model for describing challenges in public policy processes. Scientific uncertainty and socio-political ambiguity are the two characterisations they use, which can be equated to the policy paradox described by Bulkeley and Newell (2015). Wesselink et al., (2012) note that expertise as well as interests and rhetoric in an "interweaving of interests and politics" influence science-policy interface discourses.

The explicit addition of the "material society" – "risk society" frame not only contributes to a clearer understanding of the different binary tensions highlighted by science-policy scholars but places the science-policy discourse within a more comprehensive discourse of world risk society. Moreover, the research indicates an <u>intentional</u> interpretive paradigmatic attitude that can be correlated with material society interests and risk society interests.

The research has demonstrated that virtually all proponents of environmental policy regardless of affiliation view increased integration of science and policy as necessary if we are to succeed in addressing the pressing environmental problems that face modern "risk society." This is a complex exercise to be sure. Contemporary literature is focusing increasingly on the organizational aspect of the science-policy interface (Pallett and Chilvers, 2015). In their research synthesizing organizational theory as it applies to science-policy organizations, Pallett and Chilvers (2015) focus on the growing conceptualization of organizations as dynamic, co-produced, unbounded "entities in-the-making" versus the conventional management view of organizations as solitary, stable structures. Holling (1978) introduced the idea of "adaptive management" in ecological systems to identify uncertainties and use management tools to manage and learn about systems change with adaptive feedback loops.

Whereas pedantic relativism has favoured the presentation of the science-humanities interface as a rigid dichotomy, this idea appears now to be a limited didactic exercise. The stated preferences of science-policy actors together with a review of the literature makes it reasonable to infer that the interface is slowly moving toward some form of hybridized middle ground. A new science-policy dialectic may be emerging through the middle as the end points of the left-right political continuum expand and self-marginalize.

At the heart of this debate is the inherent scientific uncertainty with respect to our understanding of global biogeochemical cycles and ecosystem science. More importantly, the discussion focuses on the recognition of the human domination of the Earth's ecosystems (Vitousek, 1997; Salzman, J. 2007). This includes the observation that human activities are now influencing natural element cycles as much or more than natural processes (Vitousek, 1997; Smil, 1997). Moreover, these interventions in Earth systems may be detrimental to human survival (Steffen et al., 2004; Millenium Ecosystem Assessment, 2005; World Wide Fund, 2010).

This is not merely a scientific question, but also a political and economic question, given that it is economic activity, within the political context of wealth generation and economic growth, which has led to the ecological crises described by scientists.

The following statistics demonstrate the extent of human intervention in the Earth's ecosystems:

- Humans use more than half of all accessible fresh surface water.
- Thirty percent of the carbon in the atmosphere is from human sources.
- Over 50 percent of mercury entering the atmosphere is from human activity.
- Since 1960, flows of reactive (biologically available) nitrogen in terrestrial ecosystems have doubled, and flows of phosphorus have tripled.
- Humans fix (make bioavailable) more atmospheric nitrogen than all natural terrestrial sources combined.
- Marine fish numbers have declined globally by 90 percent due to human fishing.
- More than half of the species in the Great Lakes, the world's largest freshwater ecosystem, are non-native species introduced by humans.
- Species extinction rates over the last century have increased 1000 times over historical background extinction rates. Humans have made one-quarter of bird species extinct and it is estimated that species extinctions are taking place at 100 to 1,000 times the rate prior to human domination of the Earth.
- The Atlantic cod fishery, the world's most productive, has collapsed and is never expected to recover.

McKibben (1989) described how the human footprint on the Earth has led to such dramatic change that we can no longer consider nature to be natural. The research framework for this dissertation assumes humans are part of nature, but recognizes that some aspects of science and policy under represent human contributions. This is a complex idea and one that is critical to understanding environmental policy discourse and warrants further investigation. These observations introduce a new aspect to the discourse of scientific uncertainty as it relates to the science-policy interface in policy decision-making, namely that our conception of natural systems may be invalid due to the significant and unknown role of human intervention. The primary argument being that these factors are leading to a general decline in the degree to which scientists are able to identify or predict ecosystem processes or responses.

In other words, there does not appear to be a perceived increase in scientific certainty with respect to the environment and there may be a greater degree of uncertainty today than in the recent past. Moreover, the intersection of three areas of increasing complexity: ecological complexity, governance systems complexity and stakeholder complexity are juxtaposed with a growing neo-liberal political environment bound in Canada's historic resource-based political economy. Several specific debates regarding the science of mercury in the environment are used to illustrate this point. This includes the debate regarding anthropogenic versus natural contributions of mercury to the environment (Munthe et al., 2001), described in detail in Chapter 5.

The global nature of environmental decisions is becoming increasingly important for several reasons. First, many of the pressing environmental issues facing humanity are global, both in scale and requisite action. This is due in part to the recognition of the inter-connectedness within and between natural global systems (e.g. the atmosphere, ocean currents, element cycling) (Smil, 1997). Climate change is the most obvious example of a global environmental threat; others include atmospheric ozone depletion and persistent organic pollutants. The issue of scale has not been well addressed in the literature and remains problematic in environmental management (Pritchard and Sanderson, 2002). There is, however, a recognition that coping with complexity is central to human decision-making (Simon, 1986). Mitchell (2002) describes the complexity associated with uncertainty in resource management particularly "where interactions between natural and social systems are incomplete" noting the need for "adaptiveness, flexibility and social learning" in resource management.

The science of biogeochemical cycles is fundamental to understanding global ecosystem processes and interactions (Bolin and Cook, 1983). It is here that scientific uncertainty presents a problem for decision-makers. For example, one of the growing methods for understanding natural systems is the use of numerical models, yet verification and validation of these models is "impossible" (Oreskes et al., 1994).

The dissertation research draws from scientific texts that describe major biogeochemical cycles (Bolin and Cook, 1983), texts that place cycling in a human context (e.g. Smil, 1997), the extent of human domination of natural systems (Vitousek, 1997), research papers that present the most recent scientific literature on mercury in the biogeochemical cycle (Jackson, 1997; Mason, R. P., Fitzgerald, W. F. and Morel, F. M. M., 1994; and Lucotte et al., 1999) and the adaptive management and ecosystem work of Gunderson, Holling, Ludwig and others affiliated with the Resilience Alliance.[4] The Resilience Alliance scholars support adaptive management and continuous learning as the mechanism for moving beyond the politics of "sound science" recognizing that progress must not be impeded by economically or politically motivated calls for the illegitimate notion of "scientific certainty."

2.8 Science-Policy Discourse and Contemporary Relevance

There are three aspects of the dissertation that are highly relevant to contemporary conversations on environmental policy. First, there are few environmental debates where the use of science in policy decision-making is not a central issue. Increasingly, the discourse in scientific literature concerning the science-policy interface refers to the complexity and uncertainty associated with human intervention in global systems and cycles creating a dynamic uncertainty (Steffen et al., 2004; Wallström et al., 2004; Boyd, 2015; Buckely and Newall, 2015; Marshall et al., 2017).

Second, the science-policy nexus is a subset of the larger social discourse on "material society" and "risk society" as defined by the many works of Ulrich Beck. Beck's work is very much global in context. A related policy discourse with domestic relevance to Canada includes the ideas of "staples theory" and "resource dependency." These ideas, among others frame much of the research around concepts of binary tension between the socio-economic versus ecological science disciplines; dominant themes in environmental policy literature attempting to address uncertainty and complexity (Elliott, 2002; Matten 2004; Jarvis 2007; Bergkamp, 2017).

[4] See http://www.resalliance.org/.

Third, the research is highly relevant to several on-going policy issues in Canada where failures in environmental policy can be linked to the insufficiency of mechanisms to better address the science-policy interface in light of the political and economic forces at hand. Climate change policies, for example, are a clear representation of this challenge, as are debates on hydraulic fracturing (Neville and Weinthal, 2016). Canada's historic failure to address mercury use, emissions reductions, and clean-up, in the 1995 to 2005 period investigated, foretells of the difficulties seen today in managing perhaps the most politicized natural element, namely carbon, with the same political and economic pressures, tactics, and science-policy nexus breakdowns embedded in Canada's resource-dominant political economy; leading ultimately to the inability of governments to achieve their stated greenhouse gas reduction targets.

As a historic "political chemical", mercury received considerable policy attention in North America in the early 2000s with active debates on mercury in dental amalgams, products, tuna, and coal-fired power plant emissions (e.g. dental amalgam standards in Canada, 2002; New York State product bans in July 2004; California mercury in tuna lawsuits in 2004; CEI "Fishy Advice" Report, 2004; coal plant emissions in New York Times, April 2004; and Ottawa Citizen, July 2004). Canada's legacy of inaction on mercury reemerged in 2017 with the Grassy Narrows Wabaseemoong mercury poisoning still on-going after five decades, demonstrating in a very public way the highly politicized nature of mercury as well as the importance of understanding and documenting the policy and political thinking that contributed to this tragedy.

With respect to the focus on the science-policy interface Perez and Snir (2013) note the recent recognition among scholars that the conventional conceptualization of the science-policy interface can be called into question. Contemporary literature is focusing increasingly on the organisational aspect of the science-policy interface (Pallett and Chilvers, 2015). Marshall et al. (2017) claim to distill 348 years of cumulative experience on science-policy interface with a focus on the role of social scientists in influencing environmental policy. The authors describe ten "tips" to inform social scientists on being more effective in supporting environmental policy. These are described in Chapter 7.

The most apparent, and perhaps relevant example of science-policy interface failure for Canada as it relates to government environmental policy action is climate change. The climate challenge is presented by Bulkeley and Newell (2015) as a binary paradox of; increasing scientific certainty regarding the characterization of the problem, together with an increasing sense of the inability to achieve policy responses within the existing global governance model. In some ways this relates back to C.P. Snow's two cultures whereby the global governance stalemate represents the "literary intellectual" endpoint of C.P. Snow's dichotomous proposition.

As I argue throughout the dissertation, Canada's science-policy interface regarding politicized natural chemicals (e.g. mercury or carbon) is characterized by limited understanding, feeding into a process of limited capabilities to consider complex options, whereby inconsistent information is routinely rationalized or distorted to suit predetermined economic outcomes. Simon's (1986) concept of bounded rationality and cognitive dissonance described by Adams (1973) present provocative perspectives on limitations to decision-making in the face of complexity. More than complexity challenges the Canadian environmental policy situation; it is politically and economically motivated. Policy outcomes that protect ecosystem and public health will only emerge by embracing complexity and uncertainty within a risk society frame.

The period under investigation identifies Canada's poor environmental record at the time. Boyd (2015) undertakes a comprehensive assessment of Canada's continued weak environmental performance, providing detailed evidence of Canada still being among the poorest environmental performers of any western country, noting in particular the federal government being "wilfully blind", and having inadequate laws and regulations, notably regarding climate change.

Climate change, Bisphenol A regulations and hydraulic fracturing are discussed in subsequent chapters and offer useful insights into contemporary science-policy interface and science-policy discourse, suggesting little has changed following the science-policy debates around mercury in the 1995 to 2005 period. Hydraulic fracturing and climate change are examples that fit well the material society, staples economy, resource dependency theoretical frame. BPA is shown to be more emblematic of the regulatory risk failure as a manifestation of material society and the competing roles of policy actors in a high-profile media campaign.

The work is therefore situated within several theoretical debates that centre on the science-policy interface in regulatory risk systems together with concepts of material society and risk society, staples theory, resource dependency and settler society. The integration of human intervention in natural cycles contributes further to Beck's conceptualization of risk society where "modernism undermines modernization" (Beck, 1995). By that Beck is referring to the idea that anthropogenic global pollution causes political, cultural and social responses that shift the realm of the debate from scientific ecology to political ecology. This poses a challenge to the pressures underway to reduce scientific uncertainty if the uncertainty is no longer scientifically quantifiable; an idea, that while described in academic literature with respect to precaution and adaptive resource management, tends to be lost when applying a risk society lens.

Moreover, conventional pollution policy practices such as risk assessment and risk management are shown herein to be highly inadequate even from a strictly scientific perspective, notably as they relate to the cumulative impact of toxic chemicals, global cycling, the extent of anthropogenic contributions and the complexity of ecosystem response. These concepts were nascent in the 1995 to 2005 mercury policy debates, although have contemporary relevance with respect to Canada's application of environmental policy under the Canadian Environmental Protection Act (CEPA) and the five-year parliamentary review of CEPA underway in 2017 and 2018.

2.9 Methodological Theory Framework

The research is situated within the tensions of a rationalist empiricist "material society epoch" and a post-modern "risk society epoch" playing on the risk-precaution dialectic. Dialectic in this case refers to the exchange between policy discourse and science discourse where opposing propositions may be integrated or synthesized in some way that leads to a qualitative transformation in the direction of the discourse; a variation of Beck's two "interpretive attitudes". In aligning ontology, epistemology, and methodology according to Guba and Lincoln (1994) the research methodology uses the following definitions as described in Kurucz (2005) as:

- Ontology: What is the nature of reality and therefore, what is there that can be known about it?
- Epistemology: What is the relationship of the knower, or would-be knower and what can be known?
- Methodology: How can the inquirer (would-be-knower) go about finding out whatever he or she believes can be known.

The research ontology can be described as "relativism" (Gephart, 2004), referencing the idea that diverse meanings of language and local realities have a bearing on how information is understood or interpreted. Beck's reflexive modernity is itself relativistic in that responses to global risk are interpreted culturally and socially, which in turn redefine perceptions of risk.

The epistemology is based on "interpretive" research (Gephart, 2004) in that much of the research describes specific meanings and definitions of real policy structures and processes, and actual policy circumstances. "Interpretive research considers that scientific knowledge is not captured in hypothetical deductions but through the understanding of the human and social interactions by which the subjective meaning of the reality is constructed" (Walsham, 1995) in Halaweh, et al. (2008). Interpretive research assumes that the world is constructed and interpreted by human actions and beliefs (Orlikowski and Baroudi, 1991) again consistent with Beck's risk society theory. An explicit objective of this research is to contribute to the understanding and practice of policy in Canada rooted in a strong theoretical framework.

The research methodology relies largely on traditional qualitative research incorporating literature review, expert and stakeholder interviews, and the analysis and interpretation of expert and stakeholder surveys within the context existing theoretical frameworks. As such, the research methodology is interpretive qualitative research with an action research element, described below; I describe this as "interpretive action research". The research approach of combining practical experience with quantitative survey data and multiple theoretical underpinnings makes interpretive qualitative research a logical methodological approach. This approach will help contribute to both an enhanced understanding of risk society theory and its relationship to the practical understanding of environmental policy in Canada.

2.9.1 Role of the Researcher

The researcher's history and experience as an active policy actor in Canadian environmental and toxic pollution policy is drawn upon, introducing a minor element of phenomenology, whereby intuitive experience of phenomena, in this case policy behaviour, is used to inform the nature of the inquiry and the basis upon which essential features of the policy behaviour under investigation can be interpreted and explained. The case study in Chapter 5 is based on my direct participation as a policy actor in Canadian mercury policy processes and as such I recognize and acknowledge the risk of interpretive bias.

One of the goals of the research is to situate the theoretical elements of the research within a pragmatic policy-relevant discourse. To this end, the research methodology draws upon elements of interpretive action research only made possible by the direct policy actions of the researcher. Specifically, the research method includes reflective observations and interpretation of the researcher's direct involvement in mercury and pollution policy processes in Canada, combined with notes, correspondences, research studies and government documents produced over the course of the investigation period.

The author's direct policy interventions describe the nature of the "action research" and specifically the sub-set of action research known as appreciative inquiry. Appreciative inquiry "... refers to both a search for knowledge and a theory of intentional collective action which are designed to help evolve the normative vision and will of a group, organization, or society as a whole" (Cooperrider and Srivastva, 1987).

In this sense, the epistemologic method may also be described as "heuristic interpretive action research," referring to the incorporation of general knowledge gained by experience (heuristics) integrated with conventional interpretive research methods in an active policy setting. An important potential for the dissertation is the manifestation of action research whereby the dissertation outcomes include both a research component and an action component in terms of influencing future policy actions in Canada. The research component is designed to contribute to our understanding of science and policy as they relate to pollution control decisions in Canada, and the action component seeks to apply this understanding to an historic policy process in Canada, namely mercury debates in the 1995 to 2005 period, with a goal to improve future environmental policy processes.

The methods used to undertake the dissertation research are qualitative and based largely on a review and critical analysis of pertinent literature sources. The literature-based research is augmented with semi-structured interviews of Canadian pollution policy experts from government, industry and non-government organizations active in the period under investigation.

The action research method employed is in the form of direct participation in the policy processes described in the Case Study in Chapter 5 and self-experimentation (Appendix) where I tell a personal story of ingesting tuna and measuring the increases in mercury levels in my body over a three-day period. The results of this research were published in a popular book co-written by the author titled Slow Death by Rubber Duck: How the Toxic Chemistry of Everyday Life Affects Our Health (2008). As a demonstration of the success of action research, the book has become an international best-seller and is available in seven languages. Figure 2.4 provides details on particular aspects of interpretive action research compared with positivist science research (Susman and Evered, 1978).

Figure 2.4: Comparisons of Positivist Science and Interpretive Action Research

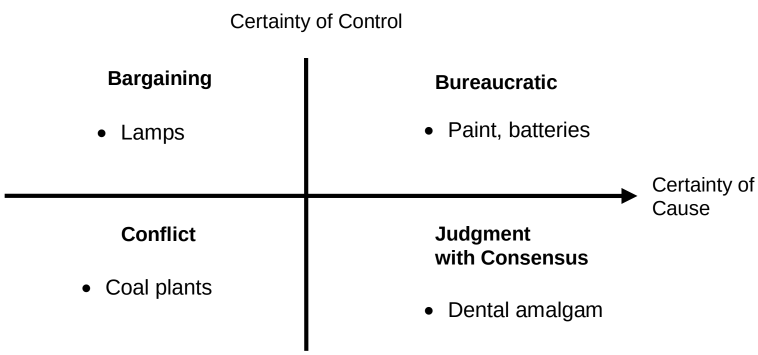
Points of Comparison	Positivist Science	Interpretive Action Research
Value position	Methods are value neutral	Methods develop social systems and release human potential
Time perspective	Observation of the present	Observation of the present plus interpretation of the present from knowledge of the past, conceptualization of more desirable futures
Relationship with units	Detached spectator, client system members are objects to study	Client system members are self-reflective subjects with whom to collaborate
Treatment of units studied	Cases are of interest only as representatives of populations	Cases can be sufficient sources of knowledge
Language for describing units	Denotative, observational	Connotative, metaphorical
Basis for assuming existence of units	Exist independently of humans	Human artifacts for human purposes
Epistemological aims	Induction and deduction	Conjecturing, creating settings for learning and modeling of behavior
Criteria for confirmation	Logical consistency, prediction and control	Evaluating whether actions produce intended consequences
Basis for generalization	Broad, universal and free of context	Narrow situational and bound by context

Source: Modified after Susman and Evered, 1978.

The theoretical framework will explore policy formulation and specifically pollution control decisions as a binary tension between the dominant bureaucratic policy paradigm of logical positivism, as seen in "material society" and represented in the traditional risk decision frameworks; against "risk society", "reflective" or "precautionary adaptive" paradigms, which more closely resemble post-positivist heuristic ideas. The dissertation research is therefore exploring the validity or invalidity of, or effectively disproving, the idea that science-based policy exists, given the cases under investigation where governments have been challenged to integrate the science-policy interface within Canada's resource-dependent political economy and material society.

The theoretical framework assumes the hegemony of the intent of risk-based paradigms and the concomitant economic risk epistemologies that dominate policy discourse. The actual presence, relevance and efficacy of the economic risk paradigm is tested in relation to mercury pollution control decisions for the period under investigation. The theoretical framework is used to frame the role, value, language, and use of science and uncertainty, using mercury pollution policy as a case study. The chronology of critical mercury science decisions is identified together with the chronology of mercury policy actions, and an attempt to correlate the science and policy within the theoretical framework. Figure 2.5 provides, for example, an illustration of specific mercury control cases plotted according to the relationship between certainty of control benefits and certainty of cause of potential harm.

Figure 2.5: Cause and Control Certainty in Mercury Decision-Making



Source: Adapted from Lee (1993) and Tuden (1959)

2.10 Methodological Workplan

Using qualitative interpretive research methods, together with a quantitative survey and appreciative inquiry action research methods, the research involves five distinct elements; theoretical literature reviews, descriptive reviews of policy processes and practices, primary data collection (expert interviews and on-line survey), a case study on mercury with the researcher as policy participant, and discussion and analysis of the findings.

As noted in Chapter 1, the purpose of these research activities is threefold:

1. To establish the nature of the problem as it is presented, namely ecosystem discourse diverging from policy discourse and the nature of uncertainty discourse as it relates to the

science-policy interface and concepts of risk and risk society. These will be explored through the literature review, tested with the expert interviews and investigated in the case study.

2. To explore the risk and precaution paradigms through expert interviews and an on-line survey of environmental representatives, experts and stakeholders in government, industry and non-government organizations and demonstrate with quantitative research the binary tension between the economic risk paradigm ("material society") and adaptive precautionary paradigm ("risk society").

3. To highlight a practical example of the science-policy interface presented as a focused case study of material society using mercury pollution policy in Canada in the 1995 to 2005 period. The case study contributes to the understanding of Beck's world risk society theory as a manifestation of material society and specifically addresses the empirical analytical shortcoming of Beck's work. This is combined with a response to Watkin's call for a contemporary ecological analysis of the role of staples theory in defining Canada's "rapacious character" and "bias towards resource exploitation."

Taken together, these three research objectives are designed to disprove the conventional policy understanding that Canadian environmental policy practices are "science-based" or "evidence-based".

The first phase includes a compilation and review of the literature relevant to the dissertation question and sub-questions. The literature review focuses on several concepts including: a backdrop of ecosystem stress resulting from human intervention in natural cycles, and discourses on uncertainty, risk, precaution, adaptive management, pollution control decision frameworks, science-policy nexus, and political economy in Canada.

The second phase of the research involves primary data collection in the form of expert interviews and an extensive on-line survey used to gather and quantify expert opinion.

Approximately 30 experts and expert stakeholders were interviewed according to an interview protocol. All interviewees signed written statements and the interview process underwent ethical review procedures and received ethics review approval. Experts included government bureaucrats (active and retired), NGO leaders, scientists and academics. Interviewees were selected based on their known professional affiliation and that relationship to the subject matter at hand. They were not random. Interviewees were asked questions that pertain to their expertise and professional experience in environmental policy settings in Canada. Participants received an advance copy of the interview protocol. Interview questions followed the interview protocol but were semi-structured to allow for expansive insights beyond the structured protocol. All interviewees provided consent to be quoted with the exception of one who remained anonymous.

Appreciative inquiry techniques were used to identify potential positive futures. Each interview was approximately 60 to 90 minutes. Interviews took place in person or via telephone. Interviews were scheduled a minimum of 24 hours in advance. No costs were incurred by the interviewees. The purpose of the interviews was to gather primary data related to direct experience of policy-makers and policy actors. This information was analyzed against the theoretical frameworks developed through the literature review. There are several important benefits of the interviews. First, they provide a Canadian perspective on issues, second, they contribute to primary research findings, and third, they ground the theoretical literature with pragmatic, applied experience.

An on-line survey tool was developed and sent to approximately 1,500 individuals in Canada. Individuals were identified as representing corporations or NGOs. Each group received the same survey questions. The hypothesis being tested is the idea that there is an economic risk paradigm (aligned with material society) and an adaptive precautionary paradigm (aligned with risk society) and that individuals representing corporations share the economic risk interpretive attitude whereas individuals representing NGOs share an adaptive precautionary interpretive attitude. Names and emails for the survey were gathered from industry associations and lists of participants at environmental conferences and events. The survey was distributed to approximately 1700 individuals in Canada with environmental responsibilities. The response rate was nearly 30 percent with 492 completed surveys returned. The relatively high response rate may be attributed to the focused nature of the information being sought. Only the results of those respondents self-identifying as "industry" or "NGO" were used. Surveys returned by those who either did not identify their occupation or where they self-identified as government, academic or other were removed. This was to ensure that the data were separated into the corresponding paradigms of Adaptive Precautionary, as represented by NGOs, and Economic Risk, as represented by "industry" in order to see if there was a correlation between the proposed theoretical risk-precaution curves and the survey data. Results of the survey were analyzed using standard statistical tools and SPSS software.

The dissertation research includes a case study of material society debates in the form of the science-policy interface conflicts in mercury pollution management policy in Canada between 1995 and 2005. Given the extensive body of literature on mercury science and pollution, there are relevant lessons in mercury pollution control policy that may be extracted through a case study approach focused on uncertainty and the science-policy interface. Findings from the literature review and expert interviews are explored and tested against the findings of the case research. The case study is specific to the science-policy interface regarding mercury using the following example:

The role of global cycling and the relative contributions of anthropogenic versus natural mercury emissions in the 1995 to 2005 mercury policy debates. The case examines a debate that centered largely on scientific consensus and uncertainty regarding the relative contributions of anthropogenic mercury to the global cycle. Specifically, the extent and role that scientific uncertainty play in the development of national mercury management in Canada. Embedding the case study in Beck's risk society theoretical frame, the case study contributes to a more complete understanding of how the science-policy interface debate at the time represents an example of Canadian environmental policy being trapped between the material society epoch and the risk society epoch. This understanding in turn informs a broader understanding of the chronic failure of environmental policy in Canada, notably Canada's historic failure to address climate change.

The dissertation provides a critical review of risk discourse and risk society theory within the science-policy interface in toxic pollution control in Canada. The investigations and analysis contribute to several contemporary discourses including, science-policy discourse, risk and uncertainty discourse, precautionary discourse, risk society discourse, staples theory discourse, resource dependency discourse and settler society discourse. Moreover, the research provides a practical contribution to government policies and processes for better understanding the limitations and contributions of science in environmental policy decision-making.

New critical thinking contributes to the literature on challenges and opportunities related to uncertainty and the science-policy interface as constructs of material society trapped in Canada's staple economy. Finally, the action research elements of the dissertation provide evidence of styles of research and communication that advance popular understanding of complex environmental and toxicological information. A goal of the research is to support improvements to Canada's approach to the control of toxic substances and related environmental science-policy debates including CEPA review and chemicals management, hydraulic fracturing, resource policy and climate change policy.

CHAPTER 3:
CANADA'S RESOURCE ECONOMY AND THE ENVIRONMENTAL POLICY CONTEXT

"Can you not see what has happened? Visitors were welcomed to a paradise. But within 300 years they have turned it into a living hell and garbage dump. They destroyed and destroyed until there is little left to destroy."
(Grassy Narrows Grand Chief Andrew Rickard, 1976)

3.1 Environment and the Resource Economy in Canada: Background

The nexus between resource extraction and environmental protection is at the heart of much environmental conflict, also portrayed as the environment versus jobs debate, or the growth versus sustainability debate. In some ways each of these captures the same dialectic whereby the prospect of unbridled resource development is tempered by the antithetical notion of limits, restraint, or controls, leading to the conceptual territory defined as sustainable development. Sustainable development incorporates a third dimension, societal interest, creating a "trialectic" whereby the contradictions and conflicts between the social, economic and ecological paradigms are optimally synthesized. Environment Canada's history and track record of managing resources sustainably, protecting people and ecosystems from mercury contamination or achieving climate change objectives point to the failure of sustainable development in Canada.

In the words of Hessing et al. (2005) "a political economic approach perceives environmental and resource policy as the product of the interplay of interests and ideas in the policy process". Furthermore, Canada's predominant political economic focus on resource extraction dismisses Indigenous interests as merely "a challenge to other productive interests" (Hessing et al., 2005) thereby connecting the discourses of material society, resource dependency and settler society.

This chapter provides an overview, with increasing granularity, of the Government of Canada's approach to environmental policy starting with a brief history of the environmental and resource policy context of resource-dependency, followed by the historic establishment of Environment Canada, subsequent modifications to Environment Canada and the early establishment of pollution policy, with an analysis of the Canadian Environmental Protection Act, the Canadian Council of Ministers of the Environment, and various related aspects of Canada's pollution policy framework.

This chapter includes important descriptive material setting the stage for Canada's pollution policy framework as a remnant of material society and out of touch with risk society, as described in Chapter 2. Chapters 4, 5, 6 and 7 provide theoretical and analytical assessments of this idea.

3.1.1 A Staples Economy History

Canada, as with other colonies in the eighteenth and nineteenth centuries, was viewed by the colonizers (British and French) as a resource repository. Fish, furs, lumber and minerals were the primary resources first sought and extracted (Innis, 1963). It is therefore not surprising that the initial responsibilities of early governments in Canada were to oversee fisheries, inland and marine waters, and generally to facilitate access to, and control of, natural resources, along with the income they generated. The nature of early resource exploitation favoured monopolistic development and a strong role for government (Woodrow, 1980).

The British North America (BNA) Act (1867), now called the Constitution Act (1982), delineated federal and provincial powers, with primary jurisdiction over natural resources and lands going to the provinces, except for oceans and fisheries, and interprovincial matters, which were retained by the federal government (Hessing et al., 2005). Powers to address the environment are not assigned to either the federal or the provincial governments and there is no explicit reference to the environment or pollution found in the Constitution (Cotton and Zimmer, 1992). The most important constitutional federal powers are those that address criminal matters and the provisions of federal authority under the "peace, order and good government" ('POGG clause') (Cotton and Zimmer, 1992).

Managing resources was one of the first priorities of early Canadian governments and therefore departments charged with "managing" resources were among the first created in Canada. It was in 1867 that the Fisheries Department was created, from which Environment Canada later emerged. Canada's historic development and growth patterns not only affected the extraction and distribution of resources but the country's ability to address related environmental problems (Woodrow, 1980).

Any discussion of Canadian resources and the environment would be incomplete without reference to the work of Harold Innis. Innis provided an historical analysis of economic and resource development in Canada known as "staples theory" or the "staple thesis" (Innis, 1963). Innis used staples theory to explain the development of Canada's economy in relationship to the exploitation of four basic resources or staples: cod, fur, timber and wheat. Resource extraction and the export of largely unprocessed raw materials (staples) defined Canada's early economic development and arguably define much of Canada's economy today.

According to staples theory Canada's economy grew and diversified around a small number of staple resources with forward and backward economic linkages (Nesbitt, 2006). For example, forest products as a staple, led to the development of saw and pulp mills, hydro dams, canals, and logging roads, all to support forest resource extraction; as well as lumber, building products and paper as forward market linkages. The Canadian economy grew around these staples, becoming increasingly dependent on specific available resources through the chain of economic linkages that developed around the resources.

The resource industry has been successful at appealing to political interests around regional development and job creation so that resource policy in Canada is primarily concerned with exploitation, not conservation, and government subsidies have focused on access to resources (Dwivedi, 1980) as opposed to conservation of resources. The intersection between environmental policy and the resource sector in Canada, particularly involving the federal government, is often through subsidies to achieve environmental objectives (Schrecker, 1990). These subsidies may include industrial modernization programs or subsidies for emission control technologies that have benefited, for example, pulp mills, smelters and municipal sewage treatment plants. This is still common practice in Canada, particularly in cases where resource sectors are facing economic hardship. In 2010 the Government of Ontario provided the Ontario forest sector with $200 million in electricity subsidies and the Government of Canada created a $250 million incentive for using spent pulp liquor as fuel, both to reduce the energy costs within the forest sector, and as a direct subsidy to support the struggling forest sector.

Watkins (2007) argues that despite ongoing criticism by Marxists and orthodox economists alike, staples theory remains relevant not only to Canada but for many other nations dependent on the export of raw resources, including Australia and several South and Central American countries. Quoting Judith Stamp, Watkins (2007) says that for Innis: “a staple was not simply a commodity: it had more than quantity and price. It had special qualities that gave rise to a distinctive set of institutions.” Furthermore, in language reflective of Beck, but speaking to staples theory, Watkins (2007) quotes anthropologist Sidney Mintz in his book on the sugar industry: “In understanding the relationship between commodity and person we unearth anew the history of ourselves.” It is this relationship with staples commodities that ultimately defines Canada and Canadians and “the history of ourselves” and our relationship to the environment and to Indigenous peoples.

Watkins (2007) implores a contemporary analysis of the relevance of staples theory and invokes a connection to environmental policy stating: “If this [staples theory] causes us to take “nature” more seriously as an object of study and to understand a central way in which it is degraded in Canada, that can only be beneficial in a world that has, at its peril, lost its respect for nature.”

Hessing et al. (2005) note that a staples economy creates a number of challenges for resource and environmental policy development. They describe four characteristics of Canada’s economy that affect resource and environmental policy. They are:

1. The production of wealth in Canada has been and remains largely dependent on the resource sector;

2. Regional differences in resource wealth and export opportunities have created different interests and actors across Canada;
3. Most resources are exported, resulting in a small domestic economy subject to international pressure (also described as "resource dependency theory"); and,
4. The economic and regional inequity described in points one and two, combined with Canada's small, export dependent economy, expose Canada to economic instability that is mitigated by large-scale government expenditures to protect jobs, often at the expense of the environment.

Hessing et al. (2005) reference "the long-term shift away from a staples, or resource-community-based, economy" as "the most significant factor driving the evolution of Canadian resource and environmental policy." This comment may have represented the short-live trend of Canada's declining share of resource versus non-resource exports in the late 1990s. Hessing et al. (2005) tapped into the prevailing sentiment of the day, backed up by a popular political commentary, suggesting that Canada was shifting from a resource economy to a knowledge economy.

Canada, however, is demonstrably more of a staples economy in 2018 than it was in the 1970s, based on the declining economic importance of secondary and tertiary manufactured products versus the export of raw staples, as a representation of a staples economy. Using employment as a proxy for the economic strength of the manufacturing sector, nearly 20 percent of Canadians worked in manufacturing in 1976 and that share fell to under 10 per cent in 2014 (Capeluck, 2015).

Hessing et al. (2005) also describe the extent and significance of the resource sector in Canada's economy, and the implications for environment and resource policy, noting the shift toward a "post-staples" economy, with a reduced reliance on resources. Economic data for the period however show that in the five-year time frame from 2001 to 2005 the GDP ratio of the service sector to the resources sector remained constant in Canada (Statistics Canada, 2006). For example, Canada's energy production increased 80 percent from 1980 to 2005 and oil resource revenues in Alberta at the time reached record levels (Government of Alberta, 2006), moreover, Canada became the largest source of foreign oil and natural gas for the US market, with 85% of US gas imports coming from Canada (US EIA, 2006).

There has been active debate as to whether Canada is still dependent on a staples economy (Hessing et al., 2005; Nesbitt, 2006; Stanford, 2014), however, the data clearly shows that there is no debate to be had. Natural resources exports totaled $308.4 billion in 2014, or 58.3% of all merchandise exports and this is up from a low of 39% in 2000 (Cross 2015). Natural resources, mostly exported as unrefined raw resources, have become the dominant force in business investment in Canada, particularly the energy sector. In 2013 natural resources accounted for $144.5 billion or 61 percent of all business investment in plant and equipment, up from 38.2 percent in 1999.

In other words, Canada remains a “hewer of wood and drawer of water”, or more accurately, “a hewer of wood and drawer of petroleum”. The former is an expression used in common parlance to describe Canada’s resource economy, more so than “staples theory,” and is worthy of a brief commentary. The phrase originates in the Bible (Joshua 9:21) and is also used by Charles Dickens (in Barnaby Rudge, 1841), and George Bernard Shaw (in Caesar and Cleopatra, 1899). Each of these references implies that a “hewer of wood and drawer of water” is a servant of low social standing. Sir John A. Macdonald used the phrase to describe the superior attitude of the British in Lower Canada toward the French, noting the lack of British sympathy towards linguistic and cultural equality (Macdonald, 1856).

Canada’s role as a hewer of wood and drawer of water therefore carries a connotation not only of being trapped in material society with a resource dependent, staple economy but of being subservient to other nations, those to which resources are exported. Others have used the phrase in reference to Canada’s resource economy and export dependency (see for example Laxer, 2006; and Udin, 2006).

3.1.2 Settler Society as a Material Society Aspect

“Settler society” describes the conditions whereby colonial-era “power structures” continue to exploit and disenfranchise Indigenous people especially with respect to the way in which natural resource projects perpetuate environmental racism through the degradation of First Nations lands and cultural identity (Preston, 2013). Environmental racism refers to instances of racialized communities being subject to disproportionate environmental hazard (e.g. pollution or toxic contamination) and/or denied access to fundamental resources (e.g. clean air, water and healthy ecosystems). By nearly any standard, Canada’s First Nations have suffered both types of discrimination (Razack, 2002; Cavanagh and Veracini, 2016).

Using the case of water borne disease, Thompson (2011), describes how "Disadvantaged communities often bear the lion's share of [the] negative impacts of development without receiving [their] fair share of [the] benefits”, as an example of environmental racism. Grassy Narrows is one of the clearest examples of the intersection between settler society and material society, whereby access to resources, in this case lumber for pulp, resulted in not only disproportionate economic benefit to the owners, but catastrophic poisoning of the Indigenous population, the elimination of the local food source, and devastation of the cultural identity of the people of Grassy Narrows. The Grassy Narrows case is described in more detail below.

Environmental racism and settler society fall within the rubric of “environmental justice”, a movement with a history in toxic waste siting and contamination in African American communities in the United States. The “environmental justice lexicon has penetrated official environmental discourse and research agendas around the globe” although “conceptual take-up” “has been mixed” (Baehler, 2017).

There is an important connection to be made between the societal disregard and exploitative natural resource features of settler society and similar characteristics in Beck’s material society. Canada’s economic reliance on natural resources has long generated negative environmental externalities. Settler society governance structures that alienate and undermine Indigenous participation stem from an insidious mix of environmental racism and the country's resource-centric strategies for economic development (Murdocca, 2010).

Settler society discourse contributes to an understanding of how Canada's resource economy has contributed to widespread "environmental racism". "Since many First Nations still live close to the land, [they are often] first to face any [future environmental] problems" and "people's alienation from the natural environment through [the suppression of] their participation in its use" has led to widespread environmental racism toward Canada's Indigenous communities (Borrows, 1997).

Murdocca (2010) describes the plight of the Kashechewan First Nation as an example of hazard-based environmental racism in Canada noting one of the most critical aspects defining settler society, namely resettlement. The government "forcibly moved" the region's Cree to an "isolated plain on James Bay" in the 1950s, ignoring the warnings of experts that this would expose them to calamitous flooding and waterborne disease. In the decades that followed, the community experienced a "slow destruction" of their land through a toxic combination of "legal decisions, social policy, hydroelectric and mining incursions and government neglect" (Murdocca, 2010). Abusive resettlements constitute a second form of environmental racism: denial of access to environmental resources as described by Hanrahan (2017) where such denials perpetuate "vast [resource] disparities", which are, themselves, products of colonial Indigenous disempowerment.

A risk society frame places settler society and the future rights of Indigenous people within a broader understanding of global risk, versus an isolated and marginalized understanding of Indigenous communities as "out there" and "disconnected". With this in mind, "the suppression of Indigenous input" has potentially "detrimental consequences" for "all human settlements" (Borrows, 1997). With Canada's political economy trapped in material society, it perpetuates settler society environmental racism, along with environmental policies that place industrial resource interests ahead of ecological protection.

3.1.3 Policy Actors in a Material Society

Viewing Canada's environmental policy through the lens of material society, staples theory and the primacy of the resource sector in Canada's economy contributes to a clearer understanding of the policy barriers faced by Canada's political leaders, and the environmental and resource bureaucracies, in addressing issues of sustainability. Hessing et al. (2005) describe environmental policy as "reactive" and "incremental" due to the "configuration of state and societal actors." By this they are referring to the tight monopoly control of environmental policy by corporate interests and regulators.

Environmental policy decisions are made jointly by bureaucrats and industry, creating a decision-making climate that "is understood to be biased, political and bilateral rather than neutral, rational and open" (Hessing et al., 2005). Or, in the words of J. K. Galbraith: "a government that is accommodated not to reality or common need but to the beliefs of the contented" (Galbraith, 1992) where the contented are those who benefit from the resource economy; a powerful segment of material society and Canada's political economy. As a form of power imbalance, it helps to explain why the jobs versus environment "blackmail" practiced by resource companies is effective (Schrecker, 1990). The socioeconomic benefits of resource exploitation have accrued at the cost of ecological integrity.

Regarding lack of success in Canada's ability to provide substantive protection of health and the environment, Hessing et al. (2005) see a clear pattern in the form of complex policy networks and subnetworks dominated by industry; hence the policy outcomes tend to be incremental, and based on bargaining, versus comprehensive and based on "rational maximizing" of environmental benefits. This was clearly the case in Canada's approach to pollution policy.

Using the policy actor taxonomy of Hessing et al. (2005) the dominant policy actors in Canada's pollution policy activities related to mercury were "appointed officials" (government bureaucrats from provincial and federal governments), "societal actors" (largely resource industry players) and NGOs (where I was one of the dominant NGO actors in the 1995 to 2005 time period) and where, as described in detail in Chapter 5, the influence of the resource sector dominated the environmental policy outcomes. "The ability of industry to affect the regulatory process has contributed to the fact that environmental protection has usually occurred as a back seat to resource exploitation throughout Canada's history" (Hessing et al., 2005). The authors explain that the nature and size of the policy networks involved in the regulatory decisions regarding Canadian resource and environmental policy influences the policy outcomes and reduces public participation. This is seen clearly in the case of pollution policy processes in Canada (described in Chapter 5) where the policy networks are small, comprising representatives of industry and government (in some cases working in concert), and with modest participation of ENGOs and Indigenous people.

3.2 Environmental Bureaucracy and Administration: The History of Environment Canada

One can only begin to understand the nature of environmental policy decision-making in Canada by reviewing the historical development of Canada's environmental institutional frameworks, particularly that of Environment Canada (now the called the Ministry of Environment and Climate Change but referred to herein as Environment Canada). Officials appointed or hired to administer public policy are collectively referred to as "the bureaucracy" (Hessing et al., 2005). Bureaucratic and administrative dynamics within Environment Canada add a layer of complexity to the historical resource policy paradigm.

The federal Department of the Environment (Environment Canada) was created in 1971 with the amalgamation of a number of services from resource-based departments (fisheries, forests, wildlife, meteorology, land and water) (Government of Canada, 2003). The Department was based on the existing Fisheries and Forestry Department with the addition of the newly established role of environmental protection (notably the pollution regulation function) (Macdonald, 1991). Woodrow (1980) describes Environment Canada as a renewable resources department with an environmental perspective.

Doern and Conway (1994) provide an enlightening history of the establishment of Environment Canada, as follows. Two visions for the new department emerged, one coming from the political leadership, including then Prime Minister Pierre Trudeau, and the other from the resource departments and the industry interests they supported; namely energy, mining, forestry and agriculture (Doern and Conway, 1994). Trudeau and others within the bureaucracy were initially envisioning a comprehensive role for Environment Canada as an ecosystem or resource manager; they saw the need for an ambitious agenda within Environment Canada (Doern and Conway, 1994). According to Doern and Conway (1994), the "mandarins" in Ottawa who headed-up the resource and industry departments were "determined to clip [Environment Canada's] wings, and they succeeded" to the point where the department became "something more akin to an end-of pipe service," an ironic analogy given the end-of-pipe pollution management approach adopted by Environment Canada's pollution regulatory regime.

Moreover, jurisdictional turf wars at the time meant that Environment Canada's powers were further limited as the resource departments (Natural Resources and Fisheries) retained power over certain environmental functions (Hessing et al., 2005) creating an "inherent weakness" that undermined environmental protection in Canada (Macdonald, 1991).

The wing clipping continued well beyond the formative days of Environment Canada. Doern and Conway (1994) describe the considerable tension that existed during the first decade at Environment Canada with former Fisheries Service personnel who regarded their new status under Environment Canada as a demotion. Tensions mounted until "organizational disruption was a huge burden" and in 1979 the fisheries and marine services group departed to return to their previous independence as Department of Fisheries and Oceans (Doern and Conway, 1994). The Fisheries Act continues to be one of Canada's most important pieces of Environmental Legislation, first enacted in 1857 by the Province of Canada and then in 1868 by the Government of Canada. It is now administered jointly by Fisheries Canada and Environment Canada.

The Forestry Service encountered similar friction within Environment Canada, largely regarding pesticide use in forests (especially the fact that the Forestry Service was subsidizing pesticide use); and in 1984, the Forestry Service left Environment Canada (Doern and Conway, 1994). The departure of the two most prominent resource management functions signaled that resource management was not to be a role for Environment Canada. Moreover, the “resourcist” paradigm, where resource management regimes are supported preferentially over ecological needs, continued to be a “conundrum” within environmental and resource policy in Canada (Hessing et al., 2005). What may therefore appear to be disarray and/or incompetence in how Environment Canada managed issues can often be traced to the initial development of Environment Canada, including the allocation of federal authority across departments and the provinces. This jurisdictional divide has constrained Environment Canada’s ability to develop national policies related to environment and resource issues (Woodrow, 1980).

In many instances, the bureaucratic and administrative structures at Environment Canada reflect Canada’s historical power dynamics, whereby resource development and “dependency” takes precedence over ecological integrity (Hessing et al., 2005). Doern and Conway (1994) described Environment Canada as “a house divided” reflecting on the extensive bureaucratic battles between environmental protection and fisheries activities within the department, among other conflicts between Environment Canada and other resource departments. Torgerson and Paehlke (1990) noted that environmental bureaucratic administration is unlike conventional administration in that it needs to be “non-compartmentalized, open, decentralized, anti-technocratic, and flexible” or “neutral, rational and open” according to Hessing et al. (2005).

The on-going battles within the department appear to have set the policy foundation for Environment Canada’s lack of cohesion and lack of legitimacy within the federal bureaucracy at the time. The policy climate therefore favoured strongly “disjointed incrementalism” as described by Lindblom (1959) and Hessing et al. (2005), contrary to the “rationalist” model espoused by Environment Canada. Moreover, the internal inconsistency of these conflicting positions may be reinforcing the incremental behaviour. Lindblom’s idea of “muddling through” is an apt description of the Canadian Federal government’s approach to environmental policy, with “material society” attitudes contributing to the muddling.

In addition to administrative matters unique to Environment Canada, there are characteristics of bureaucracy that are universal. Torgerson and Paehlke (1990) debate the potential disconnect between conventional centralized administration and the more flexible needs of environmental administration that may benefit from broader democratic input. Webb (1990) focuses on the role of the bureaucrat noting that they may be viewed as “faceless purveyors of state policy”, “benevolent servants of society” or “pawns manipulated by the capitalist power elite.” Reviewing Environment Canada’s approach to pollution policy in the period under investigation, one is tempted to conclude that elements of all three are appropriate descriptors.

Dryzek’s (2005) definition of “administrative rationalism” fits well the situation in Canada; a combination of liberal capitalism, managers and experts controlling the state, with nature, and the public subordinate. According to Dryzek (2005) environmental administration was in crisis, partly because governments were having more difficulty achieving environmental gains now that the relatively simple, gross and acute, environmental problems have been solved. CEPA, the primary legislative mechanism addressing pollution, was designed to prevent basic local pollution problems, such as contaminants, from polluting local watersheds or air sheds. Neither CEPA nor related centralized administrative bureaucracies have been able to manage “complex, invisible, contentious” matters, such as low-level toxic pollution or climate change (see Appendix). The end of administrative rationalism as an effective means of environmental governance coincides with the “Disarray – Paradigm Shift” phase of the three phases of environmental policy described in Figure 6.8).

One of the biggest challenges for Environment Canada has been securing the financial resources necessary to deliver its mandate. After a relatively brief period following its inception, Environment Canada was faced with on-going budget cuts. Significant budget cuts were made in 1975, 1976, 1978, 1979, 1985, 1986, 1987 and 1988. Most notable were the 1985 cut backs as part of the “Blais-Grenier debacle” which saw Environment Canada reaching its nadir (Doern and Conway, 1994). By 1990 environmental issues reemerged as a priority, reflected in the Conservative government “Green Plan” accompanied by a $3 billion environmental budget commitment. The “heady days” of large environmental budgets were short-lived. Another series of deep cuts were made when the Liberal government returned to power in 1993 under Jean Chrétien. The Liberal government cut Environment Canada's budget by approximately 33 percent over the next four years (IJC, 1997). These budget cuts followed the government "Program Review" and included "large cuts in departmental programs" and "the loss of scientific and technical capabilities" (Government of Canada, 2001). Environment Canada's history, especially the period leading up to the 1995 to 2005 period under study, can therefore be characterized as one of on-going budget battles, most of which were lost, leaving the organization incapable of delivering its programming or mandate effectively.

In 1999 the Commissioner of the Environment and Sustainable Development referred to the "substantial gap between talk and action on the federal government's environmental and sustainable development agenda" and noted the following with respect to Environment Canada's management of toxic substances:

- gaps in applying the fundamentals of good management
- a lack of implementation against stated commitments and policies
- unclear working relationships, roles and accountabilities
- competing mandates and "compartmentalized thinking"
- a lack of performance measurement (Government of Canada, 1999).

Institutional memory is a powerful force and once set in motion administrative processes are difficult to change or forget (Paehlke and Torgerson, 1990). Environment Canada's history is characterized by an unfortunate pattern of chronic lack of capacity due to frequent budget cuts, internal and external conflict, and political marginalization.

Leiss (2001) sums up the "permanent disarray" in Canadian environmental policy at the time noting Environment Canada's "long-standing structural woes," "endless turf battles with other departments" referring to the situation as "politically induced chaos." Weakened, ineffectual, politically powerless, and representing the "opposite side" of issues that matter most to the powerful departments and center of government, Environment Canada was a second-tier department struggling for relevance and influence. Not surprisingly, the context for effective science-policy debates or constructive policy outcomes regarding pollution management was far from desirable.

3.3 Environment Canada and Pollution Policy

In the period under study, Environment Canada had three primary functional responsibilities; weather (the Meteorological Service also known as the Atmospheric Environment Service or the Weather Office), conservation (the Environmental Conservation Service including in-land waters, the Wildlife Service and Parks Canada), and the Environmental Protection Service (that oversees emissions standards including toxic substances management, CEPA and Section 33 of the Fisheries Act). The analysis in this study focuses on environmental contaminants and pollution policy, which fell under the Environmental Protection Service within Environment Canada.

The Environmental Protection Service (EPS) was created within Environment Canada by taking elements from the departments of Health, Natural Resources and Fisheries, respectively; Air Pollution and Control, the Water Resources Sector, and the Water Pollution Control and Environmental Quality Directorates (Doern and Conway, 1994). The Environmental Protection Service was the largest component of Environment Canada with nearly two-thirds of the department’s budget (Government of Canada, 2003). It fell under the “clean environment” business line with the primary objectives stated as: 1) Adverse human impact on the atmosphere and on air quality is reduced; 2) The environmental and human health threats posed by toxic substances and other substances of concern are prevented or reduced (Government of Canada, 2003).

Environmental issues in the post Rachel Carson era of the 1960’s were defined largely by major pollution events: pesticide spraying, the Minamata mercury poisoning, the Cayuhoga River catching fire and Love Canal. Toxic contaminants were emerging as a serious threat to human health and the environment and became the focus of attention of the Environmental Protection

Service. An internal government discussion paper in 1972 noted the "pervasiveness of many environmental contaminants" concluding that "existing federal controls need expanding" (Doern and Conway, 1994). The Environmental Contaminants Act was proclaimed in 1975 in response to the recognition of the health and environmental risks of toxic chemicals and the lack of a federal mechanism for addressing these risks.

The Environmental Contaminants Act gave Environment Canada important new powers to control toxic substances (Macdonald, 1991). Although established with the objective of providing a strong regulatory role (Woodrow, 1980) the Environmental Contaminants Act proved incapable of delivering effective pollution control, due to problems that were "virtually inevitable" (Doern and Conway, 1994) as described above. Paehlke and Torgerson (1990) question the ability of the administrative state to manage environmental problems created by an industrial economy, using the mismanagement of toxic wastes as an example. When Minister of Environment Tom MacMillan was told by senior officials that there was "nothing" the federal government could do to address a "toxic blob" in Lake St. Clair, he set about strengthening pollution regulations which led to the creation of the Canadian Environmental Protection Act (CEPA) in 1988 (Doern and Conway, 1994).

Under CEPA the federal government continued to have difficulties delivering on toxic pollution reduction. Canada's Commissioner of Environment and Sustainable Development audits the implementation of commitments made by federal government departments. The Commissioner's work identified serious weaknesses regarding federal government coordination and capacity, describing:

"weaknesses in the federal government's collection and use of scientific information on toxic substances. ... weaknesses in interdepartmental co-ordination of research efforts, incomplete monitoring networks, a lack of re-evaluation of pesticides, conflicting departmental agendas and priorities, and a growing gap between the demands placed on departments and the availability of resources to meet those demands. Cumulatively …these cracks in the foundation threaten the

federal government's ability to detect, understand and prevent the harmful effects of toxic substances on the health of Canadians and their environment."
(Government of Canada, 1999)

The federal government's lack of success in addressing pollution control was systemic. Environmental bureaucrats in Canada had difficulties managing toxic pollution for several reasons, including: the "extremely close relationship" between government and industry, the fact that pollution is a byproduct of otherwise positive economic activity, the shared administration of environmental legislative mandates with other federal departments, and fear of legal action (Webb, 1990).

The "visible and overtly political stages of environmental policy-making is the implementation of policy", which is "complex, internally orchestrated between bureaucrats and proponents, and much less accessible to public scrutiny" (Hesssing et al., 2005) is clearly seen in Canada's approach to pollution policy. Large corporations often find it more attractive to invest in efforts to prevent new legislation through lobbying and litigation than investing in environmental improvements (Schrecker, 1990).

The same issues that constrained Minister MacMillan's bureaucrats in dealing with the "toxic blob" persist with the Canadian Environmental Protection Act. It was not the legislation that was problematic but the political willpower to act historically (Webb, 1990) and which still persists today (Boyd, 2015). The division of responsibility between the provinces and the federal government, based on the BNA (1867), contributed to the perceived inability of the federal government to address pollution. A central purpose of CEPA was to assert federal authority in managing pollution issues in Canada (Doern and Conway, 1994) but this has not been the case as most researchers and commentators have documented. A more detailed review of Canada's pollution control record and CEPA follows.

According to Hessing et al. (2005), pollution control legislation (CEPA and provincial equivalents) "has extended the role of the state in the activities of resource management and environmental protection” in six ways. The analysis herein demonstrates where the six ways are shown to be relevant.

1. *Governments, not industry must determine acceptable levels of pollution and which abatement technologies are practicable.* This is clearly shown in the CCME policy procedures.
2. *An increased administrative foundation for pollution control.* The risk assessment/risk management regulatory structures described in detail in Chapter 4 represent such an administrative foundation.
3. *Public information on pollution sources and compliance is more readily available.* One example not mentioned by Hessing et al. is the National Pollutant Release Inventory (NPRI) an important public resource on pollution.
4. *The specification of more stringent standards and the introduction of the precautionary approach.* Although with limited success.
5. *An increase in state enforcement activities,* described in Hessing et al. as largely inadequate and which can be attributed to material society bias.
6. *New “sustainable development” initiatives that include alternative regulatory mechanisms such as pollution trading,* although in the case of toxic pollution, trading schemes are inappropriate given the local effects of toxicity, versus, for example greenhouse gas emissions trading.

When it comes to the selection of a policy instruments Hessing et al. note several factors that come into play, including: characteristics of the instrument, nature of the problem, past experiences, subjective preference of decision-makers and potential reactions of affected groups. The research herein supports the premise of Hessing et al. that Canadian environmental policy is for the most part “a bargaining relationship between government and industry”. Furthermore, the research findings reinforce the material society thesis of the significance of a resource-based staples economy, combined with lack of competition, contributing to Canada’s political reality whereby “economic forces have provided the impetus for most existing regulation”.

Doern and Conway conclude their assessment of environmental policy failures in Canada at the time with a two-fold dynamic framework; the first being Environment Canada's historic lack of political leadership and power within the federal system, exacerbated by severe funding cuts. The second being biophysical scale and uncertainty inherent in ecological problems, which according to the authors had received inadequate attention in Canadian environmental policy literature at the time. Perhaps most important in their conclusion is the assertion that "the tension between the two dynamics is growing, not abating" due primarily to issues related to ecological scale and scientific uncertainty. The tensions between science and policy, material society and risk society, and the context and discourse regarding uncertainty that are at the heart of the research herein.

3.4 CEPA: Prevention and Precaution, the Missing Pieces

3.4.1 History of CEPA

The Canadian Environmental Protection Act (CEPA) was promulgated in 1988 following nearly twenty years of various attempts to manage pollution in Canada. Prior to CEPA the primary environmental legislation at Environment Canada's disposal to address pollution was the Clean Water Act of 1970, the Clean Air Act of 1971 and the Fisheries Act. Despite these legislative tools, the Environmental Protection Service met with marginal success regulating toxic substances due to internal conflict, lack of resources and resistance from industry and the provinces, leading to the establishment of new legislation, the Environmental Contaminants Act (ECA) in 1975 (Doern and Conway, 1994).

Doern and Conway (1994) provide an informative history of the Environmental Contaminants Act describing how as far back as 1979 resource constraints were seen to be a dominant concern, particularly science and monitoring capacity. According to the authors, Canada's lack of capacity to address toxic substances resulted in a reliance on legislation in the United States, and fear of Canada becoming a dumping ground for substances regulated in the United States. This same theme emerged in the assessment of contemporary actions to control mercury (see Chapter 5), where legislation in the United States was found to be responsible for most of the mercury product and pollution controls in North America at the time.

Weaknesses in the implementation of the ECA combined with widely publicized pollution events of the day led the Environmental Protection Service to begin exploring options for tougher legislation that would assert federal authority and better address toxic substances management (Doern and Conway, 1994). The difficulties implementing the Environmental Contaminants Act foreshadow the controversy and conflict around the early development of CEPA, including many similar systemic failures.

Following extensive internal deliberation, two Task Forces and external consultation, Bill C-74 was created by amalgamating the Clean Air Act, the Clean Water Act, and the Ocean Dumping Control Act. Bill C-74 was proclaimed in June 1988 as CEPA 1988. The primary provisions of CEPA are: to regulate toxic substances; establish environmental quality objectives; regulate the content of fuels; regulate nutrient concentrations; control ocean dumping; regulate environmental matters within the Federal government; regulate air pollution (where there is an international dimension and where provinces will not act) (Government of Canada, 2005). CEPA is administered by Environment Canada but Health Canada participates in the assessment of substances where human health issues may be at risk. In issues that involve natural elements, including mercury, lead, arsenic, asbestos, carbon etc., Natural Resources Canada participates actively in the policy debates.

Federal-provincial jurisdiction was an important consideration in CEPA 1988 as it remained a critical issue in pollution regulation in Canada. The Provinces expressed concern over the perceived expansion of federal authority through CEPA 1988 and a series of consultations led to the introduction of the concept of “equivalency” (Macdonald, 1991). Equivalency allows for a province to demonstrate that they can meet a federal environmental standard or equivalent, whereby the equivalency agreement assigns legal powers to the province to meet the standard. Equivalency agreements were “designed to assuage provincial concerns” regarding federal jurisdiction in provincial matters (Government of Canada, 2005). In this sense, they undermine one of the explicit political objectives of CEPA 1988, namely providing the federal government with greater authority to regulate toxic substances.

Reviewing the Environmental Protection Service and specifically ECA and CEPA 1988 Doern and Conway (1994) concluded that “environmental regulation has never lived up to expectations” due to three main factors: the increasing complexity of environmental issues; the difficulty regulating powerful industrial interests; and the limited capacity and inadequate resources of the Environmental Protection Service. These three themes continue through to the present as illustrated in the legislative reviews of CEPA 1988, CEPA 1999 and in 2017.

3.4.2 CEPA Review Analysis: “More of the Same”

CEPA requires that the Act undergo a parliamentary review every five years. The five-year review of CEPA 1988, which took place in the 1995 to 1999, period stimulated extensive analysis and commentary related to CEPA implementation, much of which is captured in the Report of the Standing Committee on Environment and Sustainable Development titled “It’s About our Health! Towards Pollution Prevention (Government of Canada, 1995). The five-year review of CEPA 1988 not only began five years following the promulgation of the Act but took five years to complete leading to the revised Act known as CEPA 1999.

The CEPA 1988 review was notable for the divisiveness of the debate as well as the depth of the analysis recorded in the Report of the Standing Committee. The 350-page report documents a wide spectrum of issues related to the federal government’s role in managing toxic substances, including:

- the need for federal government leadership and coordination
- the need to shift from pollution management (post release) to pollution prevention
- the need to improve the efficiency of substance assessments and increase the pace of action on designated substances
- the need for flexible and efficient control measures

- globalization pressures and increasing global adoption of pollution prevention concepts
- support for public information and public participation
- adequate funding to support effective monitoring and implementation.

The Canadian Environmental Protection Act, 1999 (CEPA 1999 or the Act) came into force on March 31, 2000 following an extensive Parliamentary review of the "original" CEPA 1988. Its full title is "An Act respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development."

CEPA 1999 continues to be Canada's primary environmental protection legislation focusing on the management of toxic substances, although it is limited to substances "not otherwise regulated by law."[5]

CEPA 1999 provides legislative authority to:

- protect human health and the environment, including its biological diversity
- promote pollution prevention
- apply the precautionary principle
- effectively manage toxic substances within strict timeframes
- virtually eliminate releases of man-made substances determined to be persistent, bioaccumulative and toxic
- achieve the highest level of environmental quality while taking into consideration social, economic and technical concerns.

Substances are deemed "CEPA-toxic" if they:

- have or may have an immediate or long-term harmful effect on the environment or its biological diversity; or

[5] Supreme Court Decision *Canada v. Hydro-Québec*.

- constitute or may constitute a danger to the environment on which life depends; or
- constitute or may constitute a danger in Canada to human life or health.

Much of the criticism regarding CEPA relates to the implementation of the Act. The Act itself is generally regarded to be comprehensive and is a reasonable reflection of environmental priorities and stakeholder interests. There appears to be little need to modify the Act in any substantive way. In practice however, the Act is widely regarded to be ineffective and much of this is attributed to the failure of the Federal Government to demonstrate leadership and/or exercise authority. Furthermore, there are many legal, administrative, inter-departmental and intra-departmental barriers to using the Act to regulate toxic substances, however, it appears that the greatest barrier can be found in the analysis of Canada's political economy and history as a resource dependent "material society".

The references to mercury pollution control in Canada, presented below, will be used to illustrate some of these barriers. Stakeholders are well aware of the lack of action and litany of excuses for inaction but cannot be expected to understand the internal bureaucratic complexity and/or disarray that seem to be at the heart of the problem. The Act provides a wide range of powers to the Federal Government that includes the ability to impose requirements to collect information, label products, and restrict or ban the use, disposal or release of substances. The extent to which the Act incorporates systemic or administrative barriers leaving most of these regulatory options still untested is less well understood. Understanding Canada's history as a staples economy helps to shed some light on the matter.

Any discussion of Federal authority with respect to toxic substances management in the 1995 to 2005 period would be incomplete without reference to the Canadian Council of Ministers of the Environment (CCME). The *Canada-Wide Accord on Environmental Harmonization*, was signed in January 1998 by the CCME members. A sub-agreement to the Accord, the *Canada-Wide Environmental Standards* (CWS) is a framework to set priorities, develop non-regulatory standards in consultation with stakeholders, and implement work plans to address potentially toxic substances. The CCME endorses "the principles of sustainable development, pollution prevention and the precautionary principle" to manage toxic substances, however the standards are generated by the stakeholders in the process.

The CCME does not, however, have the authority of the Federal Government to set national requirements for action, but rather provides for "regional flexibility" and allows jurisdictions to use a "variety of regulatory and voluntary measures" to achieve set goals.[6] These provisions, however, do not appear to result in significant sector-wide reductions.

Having been involved in numerous CCME and CWS activities myself, it is clear that the process is seriously flawed. In essence, the CCME creates the impression of Federal action, when in fact the Federal Government has no authority. Without authority and without a legislative mandate, participants in the CWS process use it as a vehicle to introduce *status quo* industry proposals for voluntary action, typically achieving the lowest common denominator interest in Canada. In the case of product restrictions, standards (often regulatory), that are being met by multi-national industries in other jurisdictions are typically presented as voluntary initiatives in Canada and endorsed by the parties to the Accord. Considerable time, effort and resources are expended with the result being a series of voluntary actions that differ little from the business-as-usual scenarios for the industries involved.

Looking at mercury, the case can be made that it was a perfect candidate substance for Federal action and that Canada had good reason to act:

- it is a global air pollutant
- there are inter-provincial pollution and trade issues
- much of the mercury in Canada is imported from other countries
- Canada has signed numerous global agreements to address mercury
- the primary exposure pathway is through fish, a federal responsibility
- mercury is found in many medical devices

[6] Canadian Council of Ministers of the Environment. Policy Statement for the Management of Toxic Substances. Accessed at: http://www.ccme.ca/3e_priorities/3ec_toxic/3ec1_toxic/3ec1a.html#statement.

- the Canadian Arctic is at particular risk
- many First Nations in the North are living well above WHO mercury risk levels

All the above suggest a valid and important role for the Federal Government and CEPA, yet control measures have been left to others.

The federal Minister of the Environment primarily administers CEPA 1999. The Minister of Health administers human health issues under CEPA. The Minister of the Environment administers all other aspects of the Act. CEPA 1999 stipulates that a Parliamentary Committee must review the Act every five years.

Much of the material in Chapter 3 (and Chapter 5) is based on the author's firsthand experience in the mercury policy debates in Canada in the 1995 to 2005 period, supplemented by government documents. This is an element of the participatory action research used to investigate the science-policy interface related to mercury policy in Canada. One example of this research was a contribution the author made to the five-year review of CEPA underway in 2006. The author was invited as a representative of a national environmental NGO called Ecojustice to present before the Senate Standing Committee on Energy, the Environment and Natural Resources on their behalf. The Committee was one of two (Senate and House) reviewing CEPA. The invitation was based on the author's research on mercury policy and CEPA at the time. Following is a verbatim excerpt from the author's testimony at the Senate Standing Committee.

Mr. Bruce Lourie (Toronto):

Thank you, Mr. Chair. I'll do my best. Just so you know, I've submitted a lengthier version of my remarks to the committee. I'll just try to highlight a few things. Thank you for having me. I've worked for many years on toxic pollution issues in Canada, both as a consultant to government and industry and also working with NGOs. I ended up doing quite a bit of work on mercury pollution. What I thought I would do, rather than spend a lot of time looking at specific details of CEPA, is highlight some examples using mercury that might provide us with some direct understanding of how precaution is being used or not used. I thought too that it's very hard to comment on precaution without also commenting on pollution prevention, which I think is a related concept and also something that is fundamental to CEPA.

In the paper I've provided a number of pages of background of the history of the previous CEPA review, comments made by the Commissioner for Sustainable Development since that CEPA review, and some comments on the scoping paper we have before us for this review. To summarize it very quickly, it really seems that not a whole lot has changed since the last CEPA review. The same kinds of remarks that were raised then are being made today, and the same kinds of criticism around inaction are really still present.

I would say they fall under four main themes, the first being a lack of federal leadership, the second being an emphasis on industrial or economic interests and decision-making above ecological interests, the third being a lack of science-based decision making, and the fourth being a failure to implement pollution prevention and precaution. It's very hard to separate these, but I'm going to touch on a few of those things.

I also describe in a little bit of detail the story of mercury, which is really quite interesting. Canada has a long history of undertaking research and being active globally on mercury issues. In fact, we were a leader approximately 35 years ago in doing mercury research and attempting to address mercury in Canada. Unfortunately, over the past number of years and particularly the past decade, we've really fallen behind. I've provided a number of examples of restrictions and regulations and product bans globally that have taken place, but have not taken place in Canada.

The reason I'm raising the issue of mercury is that it's one of the most well studied toxic substances. There's little doubt that it causes harm. Yet in the past decade, unlike most of Europe, the United States, and many other industrial countries, we have not issued any regulations on restriction of the use or emissions of mercury. I think, looking at it, that if we cannot restrict mercury use under CEPA and apply precaution and pollution prevention, it seems unlikely that there's any substance we'll be able to regulate effectively under CEPA. This is because mercury really is a bellwether for how we address toxic substances.

I don't want to touch too much on federal leadership and authority. Perhaps that will come up in your other panels. But I should point out that the issues raised around the term "national cohesion" in the scoping paper present some concern. I think much of CEPA really has devolved responsibility to other organizations, other parties, and other jurisdictions. In fact I touch specifically on the CCME and the Canada-wide standards process, which really haven't delivered on the kinds of restrictions and regulations we see in most other industrial nations. So I've described some of those issues.

One of the reasons, again, we look at mercury as a good example where the federal government should be taking action and should be exercising its authority is that it's a global air pollutant. There are interprovincial trade issues. It's imported from other countries. We've signed numerous global agreements. The primary exposure pathway is through fish, which is a federal responsibility. It's found in medical devices, which are overseen by Health Canada. The Canadian Arctic is particularly at risk, and many first nations in the north are living well above WHO mercury risk levels.

So with the fact that all those things apply to mercury, we know more about it than almost any other substance. Yet still, for some reason, in Canada we're unable to apply concepts like precaution and prevention in terms of developing even a national strategy on how we're going to deal with mercury. Ten years ago we were writing that Canada had fallen behind the rest of the industrial world, and in the intervening years very little has happened, whereas I point out in here that last year alone there were 251 mercury-related bills in the United States. That's after several years of mercury product regulations throughout the United States. So I think there's certainly reason to be concerned about these things.

I'll touch briefly on pollution prevention. Pollution prevention is referred to in almost every federal document relating to toxic substances management. The CCME describes pollution prevention as our toxic substance management policy, CEPA, and for good reason: it's a simple and powerful concept. Basically, pollution prevention says it's easier to not put things into products than it is to attempt to control the release of the substances at the end of the pipe.

Again, if we look specifically at examples of how we've implemented things--and I touch on quite a few in here, but I'll just use one example, which is mercury dental amalgams--we still have about three million grams of mercury imported into Canada each year going into people's teeth. The response under the Canada-wide standards, rather than looking at pollution prevention--even though we have easy alternatives, even though more than half of dentists no longer use it--has been pollution control. We set up a voluntary guideline for putting a little trap in the drain in dental offices to collect the mercury. So that's not pollution prevention; that's pollution control.

Mercury switches in cars, thermostats, and thermometers are all examples where pollution prevention could easily be applied. Alternatives exist. They're cost-effective. They're simple. Again, if we can't do it where we have alternatives, where it is cost-effective, and where we know what we do about mercury, then really we question how we can implement any kinds of measures under CEPA around substances where there is greater uncertainty.

That really takes us to the issue of precaution. As I'm sure you all know, the precautionary principle is a specific response to uncertainty. What we've seen over a number of years is an increasingly rigid application of risk management and risk assessment, but particularly risk management, to the point where I would say, in Canada, we're interpreting risk management the way most other countries don't. Wherever there is any kind of uncertainty, even the slightest uncertainty around whether it's an exposure pathway, an emission, or the ecosystem response, it's continually used as an excuse to not act. That's a serious problem, and that's where precaution comes into play.

So when we look at all those things together, the need for some leadership at the federal level, the need to use tools, such as pollution prevention, that are cost-effective, and the need to better to understand issues around uncertainty and risk...particularly we're still referencing this notion of sound science in the scoping paper and we see sound science referenced in federal documents. "Sound science", if you read any of the literature on it, was a term created by industry deliberately to interject uncertainty and doubt into decision-making. So the fact that we have *"sound science" still in our federal documentation suggests that we're really lining ourselves up with the kind of language that industry uses deliberately to undermine action.*

I think it's problematic. I did a survey of about 30 people across industry, government, NGOs, the legal profession, and academics. The only people who thought sound science was a valid word were the people in government. Even people in industry recognized it as a deliberate strategy to delay action.

That touches on a particular point I have some trouble with.

To conclude, I think the CEPA amendments must address federal accountability and toxic substances management in Canada. We're relying too much on voluntary efforts and on other governments. We've got references to first nations and other federal mechanisms. Clearly, they haven't worked in the past; there's no reason to expect they will work in the future. I think the review must address mechanisms that assert federal regulatory authority to manage toxic substances.

On pollution prevention, we really haven't used the mechanisms under CEPA to implement pollution prevention, even in the most obvious and cost-effective cases. CEPA needs to somehow be strengthened so that, in this regard, explicit direction and authority are provided to Environment Canada to implement pollution prevention.

Finally, on precaution and risk, I would say that CEPA has not facilitated precautionary action at all in Canada, particularly with respect to substances management. Unless we can address the inherent barriers to precaution, particularly our rigid application of risk management and false concepts such as sound science, I really don't think we will get there. Perhaps the federal government should require that Environment Canada and Health Canada prepare some kind of internal guideline on understanding and incorporating uncertainty. It may help guide decision-making. We need to make sure that uncertainty isn't used as an excuse for inaction and that we truly apply precaution.

Given a survey of most countries, I would imagine that CEPA would be probably one of the least precautionary pieces of legislation dealing with toxic substances. I'd be happy to answer any questions.

Thank you very much.

Ten years after the CEPA 1988 review several similar themes were highlighted in the federal scoping paper prepared as part of the CEPA 1999 consultation process, as follows:

- **National Leadership and Coherence:** The federal government should recognize and use CEPA 1999 as the central Act for preventing pollution, setting national standards and establishing a coherent set of environmental laws and policies in Canada. In particular, CEPA 1999 should champion cooperation and collaboration both within the federal government and among the various jurisdictions involved in protecting the environment and human health.

- **Smart Regulation:** CEPA 1999 itself should provide for an optimum mix of incentives and disincentives and ensure that risk managers have easy access to a comprehensive toolbox to ensure the most effective management strategy for substances to be managed under the Act.

- **International Collaboration:** Many participants recognized the international dimensions of environmental and human health protection, especially as it relates to the assessment and management of existing and new substances. In this regard, participants were generally of the view that international collaboration is useful and necessary.

- **Sound Science and Informed Decision-Making:** CEPA 1999 should provide high quality science and information (including information derived from traditional aboriginal knowledge, traditional ecological knowledge and community- based knowledge) to support timely, preventative, precautionary and transparent decisions by government. CEPA should also provide user-friendly and free access to high-quality, plain language information to support informed choices by all Canadians.[7]

3.4.3 CEPA Reviews: Past Failures, Present Hopes

Many of the issues raised in 1995 as part of the CEPA review were the issues of concern raised in the 2006 review and again in the 2017 review (underway at the time of writing). The lack of progress toward these objectives is one of the central criticisms of CEPA implementation and the CEPA Review process. Critical comments tend to focus on a small number of serious short-comings. For example, an unpublished survey in 2005 of environmental practitioners and experts

[7] http://www.ec.gc.ca/CEPARegistry/review/CR_workshps/CR_WS_sum/c4.cfm#s4_1.

from industry, government, academia and NGO’s familiar with CEPA provided near unanimous condemnation of CEPA implementation using phrases that include:

- “fundamentally flawed” (Provincial government policy rep.)
- “glacial in pace” (academic scientist)
- “not a great success” (industry scientist)
- “not good” (Federal government policy rep.)
- “implementation weak” (academic lawyer)
- “burdensome” (academic lawyer)
- “miserable” (NGO scientist).

The 1999 Report of Canada’s Commissioner for Sustainable Development found that Canada’s approach to toxic substances management was sorely lacking, noting “cracks in the foundation [which] threaten the federal government's ability to detect, understand and prevent the harmful effects of toxic substances on the health of Canadians and their environment,” such as:

- a high degree of conflict among departments
- failure to develop and implement risk management objectives and associated plans for many toxic substances
- failure to implement key federal policies as intended, including the Toxic Substances Management Policy
- little action on substances assessed and declared toxic under the *Canadian Environmental Protection Act*
- failure to develop a risk reduction policy or strategy for pesticides
- inadequate tracking of toxic substance releases and pesticides
- lack of effective accountability, reporting, and monitoring of voluntary programs used to manage high-priority substances
- many weaknesses in the federal government's collection and use of scientific information on toxic substances.

Three years later the Commissioner reviewed progress against the concerns raised in 1999 and found that:

The processes we observed seem to defy timely, decisive, and precautionary action. Many of the root causes of problems we found in 1999 continue today: under-resourced commitments; major gaps in scientific knowledge; and burdensome regulatory processes. In our opinion, the current situation and future prospects are not environmentally, economically, or socially acceptable.

In the book *In the Chamber of Risks: Understanding Risk Controversies (2001)* Bill Leiss describes Canada's handling of environmental issues as "symptomatic of … underlying policy weaknesses in our policy-making competence in environmental matters." Specifically, he describes the CEPA 1988 review process as "torturous" suggesting that if we are unable to do things better, the next CEPA review "inevitably will be an exercise in utter futility similar to [the CEPA 1988 review]."

The criticisms generally fell under four main themes:

i. lack of federal leadership (including lack of clarity/political will regarding authority and jurisdiction)
ii. emphasis on industrial/economic interests in decision-making above ecological or human health interests
iii. lack of science-based decision-making and inadequate science capacity to undertake assessments, inform decisions, and monitor results
iv. failure to implement pollution prevention and precaution.

One might ask why such a broad range of stakeholders and academics together with the federal Commissioner provided this unusually consistent and strongly worded criticism of Canada's management of toxic substances and implementation of CEPA? And why have the many criticisms raised throughout the past CEPA reviews and repeated on a regular basis since not been addressed? Clearly the political dynamics and structural weaknesses that plagued Environment Canada at the time are partly to blame. Past and present challenges are connected to the ideas described herein of Canada being trapped in a resource dependent, staples economy or material society, whereby resource interests, both corporations and resource-client aligned federal departments, exert policy authority.

3.4.4 CEPA, Mercury and Pollution Prevention

The Canadian Council of Ministers of the Environment as defines pollution prevention:

The use of processes, practices, materials, products or energy that avoid or minimize the creation of pollutants and wastes, at the source.

It is a simple and powerful concept; rather than costly investments in an attempt to control the release of harmful substances; it focuses on investments in technological improvements and alternatives that avoid the use or creation of harmful substances at the source. Using alternative substances, either voluntarily or with regulated bans, may be the best and final expression of pollution prevention. If a substance is not being used, then the pollution is clearly being prevented. The CFC ban is a good example of a successful global effort in this regard.

Pollution prevention is at the heart of all of Environment Canada's programs, polices and legislation related to toxic substances management. As will be shown with the case of mercury, it is a practice that was rarely used under CEPA. Consistent with most of Environment Canada's policies and programming in the 1995 to 2005 period, pollution prevention was relegated to awareness raising and voluntary programs; very different from the CFC ban or earlier bans of other toxic chemicals, notably DDT and PCBs.

Once again, the issue was not whether CEPA enables effective pollution prevention activities, it can; it is whether the Government is interested in using the authorities vested in CEPA to take meaningful pollution prevention actions that lead to measurable pollution reductions, in the case of mercury, it did not.

Mercury pollution control and prevention of use is used as an illustration to highlight specific instances where mechanisms under CEPA have not been implemented. Each of the sections below include specific mercury stories to exemplify issues in CEPA implementation.

Mercury is a heavy metal, a neurotoxin and is used in a wide range of products. Due to its many fascinating and commercially useful properties, mercury can be found in cosmetics, medicines, consumer electronics, industrial equipment, manufacturing processes, fluorescent lights, thermostats, and our teeth. It is also emitted as a by-product of smelting, coal-fired electricity generation and incineration. It is one of the most extensively studied toxic substances and is infamous for causing death and massive human health catastrophes in Minamata, Japan and in Iraq, as well as the poisoning of the indigenous peoples of the Grassy Narrows Wabaseemoong First Nations in Canada. In each of the first two cases hundreds, if not thousands, died and tens of thousands were born with serious mental and physical disabilities.

3.4.4.1 Mercury Pollution in Settler Society: The Case of Grassy Narrows

In Canada, the people of Grassy Narrows are still suffering from the mercury pollution of the 1960's. The story of Grassy Narrows, a northern Ontario First Nations community, is illustrative of many of the political and economic dynamics under investigation. More importantly, Grassy Narrows exemplifies the connection between settler society discourse and material society discourse.

"There are going to be high levels of mercury in the Wabigoon River for a good long time," were the words spoken by Grant Mills a director for the Ontario Ministry of the Environment, in 1976 (Hanlon, 1976). It is hard to know whether Mr. Mills was imagining years or decades, but it is forty years later, and the mercury is still present in the English-Wabigoon River at dangerous levels. It originated from mercury spills and dumping by a local pulp and paper company called Reed Paper.

Mercury was being used as a catalyst to produce chlorine and caustic soda from salt (sodium chloride). The chlorine and caustic soda were used in the Kraft-pulping process for paper-making. The caustic soda breaks down lignin to produce pulp and chlorine is used to bleach the paper. Largely as a result of the mercury used in the process, most Kraft-pulp mills were closed in Canada in the 1970s and 1980s and replaced by mechanical pulping. Nine tonnes of mercury were released to the river over the nine-years that the plant operated (1960 to 1969) according to government estimates at the time. Reed paper, the company operating the mill had no record of their discharges.

The mercury control action itself was relatively swift, with the government issuing a control order reducing further mercury discharges from the estimated one tonne per year to a few grams per day, within several months of the high mercury levels being first detected. In Minamata, Japan, the even more poisonous methylmercury effluent continued unabated for years. The damage in Grassy Narrows, however, was done and subsequent efforts to protect the local Indigenous population failed to protect or respect the local population.

Reed Paper was not the only mercury-based chlor-alkali operation in Canada, eleven pulp mills across Canada used the process. When high levels of mercury were discovered in the fish in the Wabigoon River in 1970 it took five years for the Chlor-Alkali Mercury Liquid Effluent Regulations to be brought into force in Canada under the Fisheries Act in 1975. The regulations were effective in that they caused nine of the eleven operating mills in Canada to replace the mercury-based pulp process entirely; an example of a pollution prevention outcome with a pollution control policy.

There are two distinct aspects of the Grassy Narrows story, that mirror to some extent the disconnect between the scientific challenge and the social challenge, also reflected in the bifurcation of responsibilities within government where departments of fisheries and environment tended to act more swiftly than health departments.

First, was the immediate environmental response to the problem; dramatically reducing mercury entering the river, thereby stopping much of the effluent source. However, due to the massive quantity of mercury released this did not prevent the fish from continuing to be contaminated from *in situ* mercury. Mercury, with a density greater than that of lead, sinks quickly to the bottom of any river where it is slowly released into the biota through organic mechanisms, likely for centuries. This points to another failure in Canada's environmental policies and that is the lack of any effective legal or regulatory mechanisms to address *ex post* contamination versus *ex ante* pollution.

Environmental regulations were designed to stop the activity of a business *causing* pollution, but little was done to hold companies liable for their actions and ongoing environmental and health liabilities once the pollution event was stopped. The legacy of Grassy Narrows as well as the many contaminated, abandoned mine sites across Canada's north speaks very much to this problem.

Second, was the longer term socio-economic response to the problem; proper notification of the risk, protecting the community from poisoned fish, ensuring a safe food supply to replace their largely fish diet, and health protection from the contaminated water. Over the decades that followed, Ontario shuttered the fishery, depriving Grassy Narrows of an important source of income and cultural identity, while mismanaging efforts to decontaminate the local ecosystem and rehabilitate community members stricken with mercury-related ailments and disabilities. (Ilyniak, 2014). None of these problems were ever adequately addressed. Had similar levels of toxic pollution been present in a Canadian urban, non-Indigenous setting it is almost certain that a much more comprehensive and swift action would have been taken by governments to protect people.

Ilyniak (2014) says such blundering speaks to a history of "capitalism and colonialism", through which "racism [and] exclusion" expose First Nations to unchecked "industrial hazards". Moreover, while "overt racism" has declined, she argues that environmental racism remains an existential threat to communities across the country (Ilyniak, 2014). It is this combination of a long history of resource-dependent industrialization with colonialism that connects settler society with the staples economy-material society discourse, explaining in large part Canada's failure to protect indigenous peoples and the natural environment.

In the words of then Grassy Narrows Grand Chief Andrew Rickard, "Can you not see what has happened? Visitors were welcomed to a paradise. But within 300 years they have turned it into a living hell and garbage dump. They destroyed and destroyed until there is little left to destroy" (Hanlon, 1976).

3.4.4.2 Mercury and Pollution Prevention Policy

The poisoning events in Japan, Iraq and Canada led to the beginning of half a century of research and global effort to understand and restrict mercury use. In Canada, the first regulation of mercury was the Chlor-Alkali Mercury Liquid Effluent Regulations in 1975, much later mercury was banned from use in children's toys. These were the only mercury use regulatory restrictions in Canada until the 2011 Products Containing Mercury Regulations were introduced, which is a weak regulation in that it exempts virtually all products in common use that contain mercury (e.g. batteries, fluorescent lamps, dental amalgam, and pesticides to name the major uses). Most European countries and many U.S. states adopted strict regulations for many mercury products and uses well before 2011.

At the time of Canada's policy inaction in the early 2000s, hundreds of mercury Bills were introduced at the state level in the United States, and this is after years of regulatory activity banning, restricting, labeling or otherwise controlling mercury in that country and the European Union.

By 2000, Canada had fallen far behind most of the western world in addressing mercury pollution. By 2005, global mercury studies reinforced that there is no safe level of mercury, and that fetuses and children are at risk when exposed to even tiny amounts of mercury at certain times in their neurological development. With this information most western countries increased their attention to mercury, introducing more widespread product bans and emission controls. Outside of the chlor-alkali regulations, Canada remarkably stood alone in not having issued a single regulation to control mercury use or emissions up to 2000. The reasons for this failure in environmental responsibility will be explored in the context of risk and uncertainty in the science-policy interface as they relate to Canada's resource dependency.

There are few substances better suited to applying pollution prevention and other regulatory policies than mercury. It was, and still is, deliberately added to many commercial products where there are numerous, cost-effective alternatives widely available. Mercury thermostats are a good example. For nearly a decade Canada was involved in discussions regarding modest and ineffective voluntary efforts to have mercury thermostats collected and recycled; the same with mercury thermometers and mercury vehicle switches and mercury dental amalgams.

Pollution prevention suggests that pollution is avoided by preventing the use of the substance or product. This is not always easy or cost-effective. With mercury it is. In the case of mercury thermostats (or thermometers or electrical switches), alternatives were widely available and easily purchased. Mercury free programmable thermostats, the alternative to mercury switch thermostats, have the added benefit of providing energy savings to the consumer (further reducing mercury emissions attributed to coal-fired generation). There is therefore a net economic benefit to the consumer and considerable environmental benefit in banning mercury filled thermostats. Many other jurisdictions managed to implement mercury thermostat bans in the 2000s whereas Canada had no requirements of any kind to manage mercury thermostats.

Mercury dental amalgams were, and still are, the single largest source of raw mercury imports into Canada; still in the range of 5 million grams per year. The CCME developed a Canada Wide Standard for mercury amalgams that was described at the time by the government as a "pollution prevention" initiative when in fact it was a traditional pollution control measure. Despite the ease of applying pollution prevention to mercury dental amalgams (requiring the use of widely available and commonly used non-mercury alternatives), the CCME chose to introduce voluntary pollution control measures not pollution prevention, recommending that dental offices install traps to capture the mercury that is flushed down sinks. The mercury is then collected and disposed of or recycled, adding risk of re-release.

In the case of mercury vehicle switches, they have been banned in many countries and were phased out by many international carmakers (e.g. Swedish and Japanese) in the 1990s, and more recently in North America. Twenty-five years ago, simple alternatives existed to allow for pollution prevention, but the Federal Government bowed to industry opposition and did not implement any measures in Canada, save for some modest voluntary collection programs undertaken without the support of the automobile or steel industries, the two relevant sectors involved. In the case of North American automakers, they chose to use the switches in their manufacturing process when alternatives existed, and in the case of the steel sector they end up with the emissions problem when cars are recycled, and the mercury is released to the environment, mainly when the automobile steel metal is melted down to produce new steel.

In another example, Environment Canada officials have claimed that CEPA cannot be used to control mercury use in household fever thermometers, since these are medical devices and are therefore the responsibility of Health Canada and the Hazardous Products Act. According to Health Canada officials, if a substance is contained within a product in normal use, it is not considered to be hazardous; therefore, the Hazardous Products Act does not apply. In the end, again, actions fell between the cracks and Canada fell behind the rest of the industrial world as the practice of placing thin glass tubes containing a powerful neurotoxin in the mouths of Canadian children continues. Clearly there is no sense of precaution, no efforts at pollution prevention and if not for regulatory action in the U.S. and Europe, no progress in Canada.

These are examples where pollution prevention was a simple and obvious option but was not implemented under CEPA. Because of the failure to use pollution prevention, millions of grams of mercury have entered Canada's environment through unnecessary emissions and discharges, directly and via the waste stream. If, given the many relatively well-understood, widely used and low-cost opportunities for mercury pollution prevention, it cannot be applied to mercury under CEPA, it is unlikely it will be applied to any other substance.

3.4.4.3 Risk, Precaution and "Sound Science"

Risk assessment and risk management have grown rapidly in use to become the dominant international decision tools for managing toxic substances. Risk assessment involves making a determination on the extent and nature of a risk, and risk management aids the decision-making activity in identifying options to manage the risk. Risk assessment can be viewed as the science of risk and risk management is the policy. Risk assessments are an important aspect of CEPA and the risk assessment process has improved considerably; perhaps to the point where CEPA appears to be used exclusively as a risk assessment and substance-listing tool, not toxic substances management legislation. General approaches to risk assessment and risk management together with academic conceptualizations of risk and uncertainty in the context of Beck's risk society are described in Chapter 4.

One downfall of CEPA appears to be over reliance on risk management; this may be a root cause of the failure to manage toxic substances under CEPA and connected to the resource dependence paradigm of material society. The problem at the time of the mercury debates is that risk management had become increasingly demanding of scientific certainty, fueled by industry calls for "sound science" in decision-making. Bill Leiss and others describe sound science as "an industry code word" and a deliberately divisive strategy to undermine decision-making where uncertainty is present. There is only peer-reviewed science; to suggest that there is form of science called "sound" is a misnomer. The reality is that there is always uncertainty in science, and in fact an increasing sense of uncertainty exists in ecological systems and environmental management science. The fact that the Federal Government was using the term "sound science" is a practical example of the extent to which corporate, "material society" framing entered government policy discourse.

Industry groups created the concept of sound science in a deliberate effort to manufacture uncertainty and insert doubt in environmental and health decision-making. The Federal Government fell in line with this thinking and used “sound science” as one of the primary excuses for not acting in the public interest. In the survey of stakeholders (see Chapter 6), only government officials viewed sound science as a useful concept, all other stakeholders, including industry, saw it as a deliberate tactic to delay or undermine policy action.

The precautionary principle is a specific response to recognizing inherent uncertainty, and more specifically the inability of risk management tools to accommodate uncertainty. Precaution is the basic idea of taking reasonable actions to prevent harm in the face of uncertainty. CEPA and other Federal documents reference the precautionary principle, but as with many of the progressive elements of CEPA, there is no evidence of the precautionary principle being applied to decisions to manage toxic substances in Canada.

3.4.4.4 Mercury Risk and Precaution

Canada was one of the least precautionary of industrial countries regarding toxic substances management. If it were not for the courts, there would be little evidence of precaution at the Federal level and certainly no evidence of precaution under CEPA. General ideas around the precautionary principle are described in more detail in Chapter 4.

A core principle of precaution is weight of evidence. For mercury, the weight of evidence was clear and based on weight of evidence many industrial nations acted to restrict mercury use and emissions. With respect to mercury CEPA appears to entrench the opposite behaviour. One-by-one the evidence of harm caused by mercury has been established: evidence of emissions, evidence of transport routes, evidence of deposition, evidence of release, evidence of biological uptake, evidence of exposure pathways, evidence of neurological impairment, and even evidence of ecosystem response to emission reduction efforts, yet still this overwhelming weight of evidence was not translated into pollution prevention or other policy actions to restrict mercury use and release.

This represents a clear example of the science-policy interface collapse in Canada, whereby the dominance of political economy considerations, reflected in staple theory and resource dependency demonstrates the weakness of the science arguments, both ecological and human health, in moving public policy in the "material society". As seen in the Case Study in Chapter 6, with emerging consensus on the "certainty" of health and ecological risks associated with mercury, the Canadian government, namely Natural Resources Canada, played a lead role in manufacturing uncertainty to undermine the mercury risk management process.

3.4.4.5 Science-Policy Interface Issues and CEPA

Issues around the bureaucratic aspects of the science-policy interface further exacerbate many of the CEPA implementation challenges. In addition to the larger political economy challenges, CEPA and mercury brought to light additional science-policy interface failings including: a lack of clear science mandates, lack of capacity and resources, lack of independent science review bodies in Canada, and poor translation of science advice to senior policy-makers. CEPA is described as "science-based" legislation yet the historic management of mercury, as with the contemporary management of carbon and climate change, suggests that implementation of CEPA is anything but "science-based".

The Federal *Toxic Substances Management Policy* (1995), CEPA's principal management tool, is described as "a science-based management framework." Given the emphasis on science and the government's extensive work on science advice, CEPA provides a useful case for reviewing federal science-policy advice. Pollution prevention, an idea routed in science, for example, is a stated priority in CEPA, also a priority in Canada's Toxic Substances Management Plan and a priority for the CCME. So why, if it is a priority, did the Federal Government not apply pollution prevention to a substance like mercury, when it is so well-suited? The theory posited herein is threefold and investigated in greater detail below and in Chapter 5. In essence, the three reasons are as follows. First, mercury fits the definition of a “political chemical” or element, with similar characteristics to carbon in the climate change debate, in that it is a naturally occurring element.

As will be shown in detail in Chapter 5, the fact that mercury is a natural mineral drew in the resource sector as a major political stakeholder triggering the federal Department of Natural Resources to become actively involved in the bureaucratic policy setting and risk management processes. This shifted the bureaucratic power dynamic from Environment Canada to NRCan and the debates focused on manufactured uncertainty in the form of scientific uncertainty regarding risk mitigation, and anthropogenic versus natural sources, again similar to carbon, as described in detail in the Case Study in Chapter 5. Consequently, the Federal Government’s reliance on a strict interpretation of risk in risk assessment and risk management excludes prevention and precautionary actions by requiring a level of proof of harm, or proof of benefit that is virtually unattainable, and far exceeds normative standards of proof being applied in other industrial nations.

Second, CEPA appears to be structurally ill-suited to address pollution prevention with respect to mercury and other toxic substances, especially in products. The government departments with shared authority over CEPA, namely NRCan and Health Canada, are aligned with the economic interests of corporate stakeholders who have a vested interest in the on-going use of mercury (e.g. thermostat manufactures, automobile manufacturers, medical device manufacturers, the dental industry).

Third, by introducing a shared governance approach, the Federal Government has abdicated its responsibility in providing national leadership on mercury pollution prevention by devolving responsibility to the CCME to undertake voluntary stakeholder exercises that do not produce environmentally rigorous outcomes.

The concepts of material society, settler society, staple theory and resource dependency define the science-policy interface as it has been applied through CEPA to mercury pollution issues in Canada. The quantitative research in Chapter 6 explains the extent to which economic interests, and moreover the ideology of not restricting substances that are tied to the resource economy, "beat out and beat up" the science in the science-policy interface.

CHAPTER 4:
RISK, UNCERTAINTY AND THE REGULATORY RISK FRAMEWORK IN MATERIAL SOCIETY

The key to the whole tangle will be found to lie in the notion of risk or uncertainty and the ambiguities concealed therein. (F. H. Knight, 1921)

4.1 Introduction to Environmental Risk

"Environmental risk is likely to continue to be one of the most important concepts in policy for decades to come" (Kraft, 2017). Chapter 4 is devoted to the description of traditional risk assessment and risk management as it was understood and practiced through the late 1990s and into the mid-2000s. Although the application of risk management has evolved over the past three decades, the fundamental concepts of environmental risk assessment and risk management have changed little from the risk approach developed and enshrined in legislation through the late 1980s and early 1990s. In 1987, for example, the US Environmental Protection Agency released a definitive report on environmental risk management that redefined the "fundamental mission of the Environmental Protection Agency" as reducing risks (Kraft, 2017). The focus of this research is on Canada's regulatory risk framework and how it can be viewed as a clear representation of institutional governance supporting material society interests.

The risk assessment/risk management (RA/RM) process has been the dominant environmental decision-making approach for assessing and controlling toxic substances in Canada for many years (Canada, 1995). Risk assessment and risk management received considerable attention over the past several decades due to the increased critical scrutiny of decision-making (Health Canada, 2000 and 2010). There have been a number of severely critical accounts of risk management decisions in Canada, notably the *Krever Commission on Canada's Blood Supply*, the failed MMT fuel additive regulation, and the handling of mad cow disease (bovine spongiform encephalitis) (Leiss, 2001). Tickner (2002), Bocking (2006) and Whiteside (2006) provide additional in-depth critiques of risk assessment together with perspectives on the precautionary principle.

According to Health Canada (2000) “the public is no longer satisfied with merely being presented with the results of risk management decisions after the fact.” Bocking (2006) goes further stating that risk assessment was introduced to restore credibility to environmental policy making yet “now, ironically, undermines the legitimacy of decisions based on it.” Perhaps the primary irony of risk assessment is the way in which it has been used in Canada as a mechanism to prolong exposure to potentially harmful substances, as is the case with methylmercury.

This section provides the context for environmental risk management in setting pollution standards and is both descriptive and analytical. The terms risk-based decision making, the RA/RM process and risk management frameworks are used interchangeably in this discussion. Risk analysis is the inclusive term used to describe the overall RA/RM process. Mercury risk management is referred to periodically throughout this section for illustrative purposes.

The basic elements of risk analysis are discussed in this section including a brief history and evolution of the field of risk management, definitions of risk-related terms, exploration of the issue of uncertainty and precaution as a response to uncertainty in risk management. Specific emphasis is given to the work of Ulrich Beck and his treatise on risk titled *Risk Society: Towards a New Modernity* (1992).

The section provides additional support for the idea of environmental policy in transition from “economic risk-based” to “adaptive precautionary-based” environmental policy development, fitting several theories of dichotomous transition. Moreover, it highlights Beck’s parallel concept of pre-modern natural risk and post-modern anthropogenic risk as it relates to the central thesis of this dissertation regarding a global shift from natural ecology to anthropogenic ecology, or material society to risk society. Beck’s natural versus anthropogenic description of risk in society also parallels the mercury case study discourse in Chapter 5.

The risk management framework (the risk analysis process) includes three major elements: risk assessment; risk management and risk communication. In simple terms, risk assessment calculates the risk, risk management is the response to mitigate the risk and risk communication is the public explanation of the process and the decision. RA/RM is therefore a two-step process. Simply stated, risk assessment (RA) is the activity of estimating potential harm to humans or the environment from hazardous activities or substances, and risk management (RM) is the process of recommending and/or taking specific courses of action to minimize the potential harm or more specifically the policy decisions that governments make (Leiss, 2001; Kraft, 2007).

RA/RM is of particular relevance to the science-policy interface where risk assessment represents the science input phase and risk management is the policy response phase. Together RA/RM can be thought of as an integrated process that encompasses the science-policy interface. Kraft (2017) describes the early conceptualization of environmental risk management in the US EPA as a strategic policy tool to present environmental policy as "the professional work of scientists and other experts" in response to increasing criticisms from industry that the EPA was "advancing its own political agenda."

The primary focus in this research as it relates to RA/RM is on the risk management phase, less so on technical risk assessment, for risk management is the stage where policy-makers are making decisions regarding the control of toxic substances and the protection of the environment and human health.

The precautionary principle may be viewed as an alternative to, or a complementary aspect of, risk management. Making policy decisions where scientific uncertainty and issue complexity are high is emerging as a critical issue for policy-makers. The precautionary principle is the dominant "alternative" approach to decision-making that considers the uncertainties associated with science generally and risk assessment more specifically, and provides guidance that favours safety, where the risk of harm is significant, and where uncertainty exists regarding the extent and/or probability of harm. Health and environmental protection advocates are the main proponents of the precautionary principle in Canada. It gained global prominence through the late 1990s and early 2000s and is cited in legislation and legal decisions in many countries, including Canada.

The roles of risk assessment and risk management are an important element in the dissertation for several reasons: first, RA/RM acts as the wedge in the science-policy interface and second, it is the risk assessment process that frames uncertainty in policy decision-making. Finally, risk analysis exhibits the same dichotomous transition as Canadian environmental policy itself, as supported by the research herein; Canadian environmental policy is trapped in a material society "economic risk paradigm" when the policy response to complex global ecological threats in risk society needs to reflect an "adaptive precautionary paradigm."

The chapter highlights the concepts of the "economic risk paradigm" and the "adaptive precautionary paradigm" introducing a graphical representation of the risk and precautionary paradigms related to Type I and Type II risk management errors. The risk and precautionary paradigms are also presented in the context of the three phases of environmental policy described in the previous chapter. A table is introduced that compares epistemologies of the economic risk paradigm versus the adaptive precautionary paradigm related to various disciplines in order to situate the two ideas within fundamentally different epistemological foundations.

4.2 Defining Environmental Risk in Canada

Risk can be described as "the chance of harm" (Health Canada, 2004) or "a situation involving exposure to danger" (Oxford dictionary). "Chance of harm" best characterizes the two principal concepts of risk, namely; that there is the probability of an occurrence and second, a consequence resulting from the occurrence that may be harmful.

Risk is commonly represented as follows:

Risk = Probability of harm x severity of consequences

The Privy Council Office's Risk Management for Canada and Canadians defines risk as: "A function of the probability (chance, likelihood) of an adverse or unwanted effect, and the severity or magnitude of the consequences of that event." Hazard is defined in the same report as: "A source of harm or action (situation) which is known to, or has the potential of, causing an adverse effect."

The Network for Environmental Risk Assessment and Management (NERAM) is an example of a material society institutional structure in the risk field. In a NERAM (2000) report on risk assessment the following definition of risk is provided:

Risk = Probability of exposure x severity of consequences

The use of the term "exposure" instead of "harm" changes the meaning of risk in this instance and reduces the accuracy of the definition. It is not the probability of exposure but the probability of harm that defines risk. Exposure is an element of the probability of harm. If there is no exposure there is zero probability of harm. The NERAM definition is consistent with industry and industry-focused bureaucracies where emphasis is placed on probability of exposure, as opposed to probability of harm or hazard as a means to undermine the stringency of environmental policy.

The critical and difficult challenge in risk assessment is to estimate the probability of harm, which typically has a direct relationship to frequency and duration of exposure. Exposure is one element of risk that is often misused by industry to suggest that decision-making exercises are designed to reduce the risk of exposure, as opposed to reducing risk of harm, implying that substances need not necessarily be controlled, but that human exposure patterns may be modified. For example, if outdoor air quality is poor, reducing risk of exposure means staying indoors, not restricting the emissions that cause poor air quality; or when mercury levels in fish are toxic for human consumption the risk exposure response is simply to tell people not to eat the fish versus eliminating the mercury source, as seen in Grassy Narrows.

With respect to toxic substances, risk management measures are considered valid if they emphasize strategies to avoid exposure, as opposed to strategies to find alternative substances or processes. In the case of mercury, not eating fish reduces the risk of exposure, whereas lowering mercury levels in fish by restricting mercury releases to the environment reduces the overall risk of harm to living things.

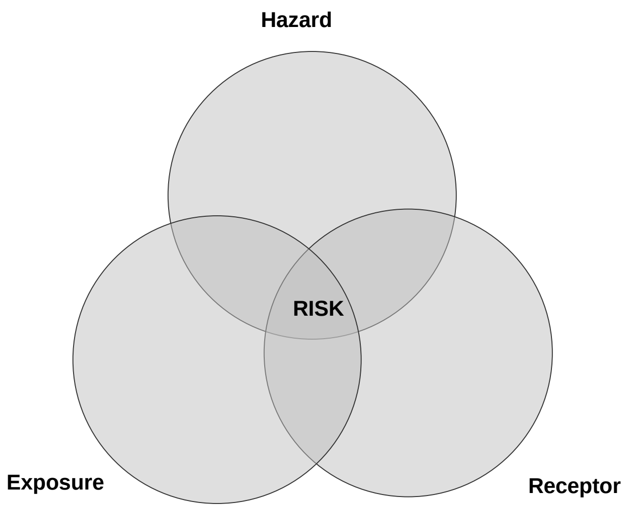
Natural Resources Canada, a central policy actor in the small and intermingled policy sub-network involved in Canadian mercury policy (see Chapter 5), advocated the use of the terminology "risk of exposure" in developing the North American Regional Action Plan on Mercury, attempting on many occasions to define risk management objectives in terms of reducing "risk of exposure" as opposed to reducing "risk of harm."[8] This language was consistent across industry-funded institutions such as NERAM and in the language used by industry.

A British court has ruled that risk conveys the idea of a "possibility of danger" and that this is similar to the concept of "hazard;" the term "exposure" does not change the meaning of risk and is "a red herring" (Regina v. Board of Trustees of the Science Museum [1993] 3 All ER 853).

In the field of environmental contaminants, risk is commonly defined by the relationship between the toxicity of a substance, a receptor that may be damaged by the substance, and exposure to the substance. These three elements can be presented as circles of a Venn diagram, with "risk" occurring at the intersection as illustrated in Figure 4.1 (Kemper et al., 1997, Health Canada, 1994).

[8] The author was a member of the North American Regional Action Plan for Mercury Task Force.

Figure 4.1: Health Risk Venn Diagram



Source: After Kemper et al., 1997

The Canadian Standards Association Risk Management: Guidelines for Decision-Makers (CAN/CSA-Q850-97) provides a comprehensive definition of risk as: *"the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment or other things of value."*

The November 1, 2000, working draft of the International Organization for Standardization (ISO) Risk Management Terminology adopted for use in ISO Guide 73 defines risk as the *"combination of the probability of an event and its consequences".*

Risk can be characterized in two basic ways. Voluntary risk is the risk that one takes when deciding to drive a car or walk across the street. Individuals expose themselves to voluntary risks on a regular basis in daily life. Involuntary risk refers to the risk of a particular consequence where the threat may be unknown or is outside of the control of the individual at risk. These two categories of risk are also referred to as internal risk and external risk (O'Riordan, 1995). Individuals are typically more willing to accept a voluntary risk than an involuntary risk, particularly given that a voluntary risk is generally taken in order to gain some personal benefit.

Participating in sports, for example skiing, mountain climbing or sky-diving, are classic examples where individuals expose themselves to a high degree of risk of injury, but where the risk is voluntary, and the individual determines that the personal benefits of the experience outweigh the risks of injury. In some cases, overcoming the fear associated with the risk may in fact be one of the benefits derived.

There are significant differences in how experts define and interpret risks; largely based on quantitative and technical information, whereas public perception of risk considers social, cultural and community factors (Kraft, 2017). Kraft (2017) references studies undertaken by the US EPA describing the variance between US EPA "expert" perception of risk and US public perception of risk. The public, for example, is not very concerned about biodiversity loss or climate change, two high priorities for the US EPA, whereas they are very concerned about hazardous waste sites, a low priority for US EPA. Herein lies a fundamental science-policy interface challenge in that the science, which technically defines "actual" risk, does not motivate public understanding of risk.

Right wing government efforts to reduce or eliminate the use of science in environmental policy are consistent with the idea that eliminating knowledge of complex global problems will reinforce cultural biases toward less significant local matters that do not impinge on global economic interests. In this regard, Beck's "risk society" is not only descriptive of the complexity faced in reflexive modernization but can be seen as a representation of a future societal state that is antithetical to economic interests. Material society interests are therefore engaged in a vigorous and intentional war against science to perpetuate and enhance status quo neoliberal institutional arrangements.

Involuntary risks, such as being exposed to toxic substances in food or to chemical pollutants in the air, are generally not tolerated if the risk is perceived to be significant. In the case of involuntary risk from chemical pollution, not only is there a risk of harm, the harm is often unknown, potentially life-threatening and more importantly, the source of the harm may provide little if any direct benefit to the individual at risk. The following quote from a concerned citizen expressing fear to the Canadian Chemical Producers' Association illustrates this point clearly:

... not only do we not know what's going on, but we're scared to death about the involuntary risk you create for us in your plants and in the chemicals you sell and handle. And, by the way, it really is an invisible industry because we don't know how we benefit from these damn things and yet there are risks for us ... and you're not telling us what you already know.
(Berland, 2008)

Gardner (2008) asks (and answers) the question: "why are we so afraid?" citing, but not necessarily agreeing, with Beck's assertion that the answer is because we face greater risks. In Gardner's assessment of the risks associated with toxic chemicals (he is a journalist), the issue is largely one of heightened perceptions of risk, fomented by environmental organizations and poorly reported in media. He is equally critical of the "sins of omission" regarding the nature and extent of chemical risk as presented by environmental organizations, citing Environmental Defence Canada; as he is of "anti-environmentalists" and, for example, "the elaborate mythology" they have created around DDT whereby environmental activists are preventing poor Africans from access to this "perfectly harmless" chemical which prevents malaria.

The field of risk management, and particularly risk communication, has emerged and evolved in part to help address political and public concerns regarding "misinformation" such as those above.

Government responses to minimizing environmental risks have led to the development of the environmental and health risk management field, which includes theoretical and practical considerations of risk from many perspectives and disciplines. It has also led to the development of many related sub-disciplines that include; risk assessment, risk estimation, risk evaluation, risk issue management, risk-benefit assessment, risk communication, risk perception and a number of traditional areas of analysis prefaced with "risk."

Given the many terms requiring definition in the risk field, a list of the basic terms and their meanings is warranted early on in this text. The Canadian Standards Association (CSA, 1997) uses the following definitions:

Hazard: a source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment, and other things of value, or some combination of these.

Hazard Identification: the process of recognizing that a hazard exists and defining its characteristics.

Risk: the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment, or other things of value.

Risk Analysis: the systematic use of information to identify hazards and to estimate the chance for, and severity of, injury or loss to individuals or populations, property, the environment, or other things of value.

Risk Assessment: the overall process of risk analysis and risk evaluation.

Risk Communication: any two-way communication between stakeholders about the existence, nature, form, severity, or acceptability of risks.

Risk Control Option: an action intended to reduce the frequency and/or severity of injury or loss including a decision not to pursue the activity.

Risk Estimation: the activity of estimating the frequency or probability and consequence of risk scenarios, including a consideration of the uncertainty of the estimates.

Risk Evaluation: the process by which risks are examined in terms of costs and benefits, and evaluated in terms of acceptability or risk considering the needs, issues, and concerns of stakeholders.

Risk Management: the systematic application of management policies, procedures, and practices to the tasks of analyzing, evaluating, controlling, and communicating about risk issues.

Risk Perception: the significance assigned to risks by stakeholders. This perception is derived from the stakeholders' expressed needs, issues, and concerns.

4.3 Risk Assessment

Risk assessment is the first major stage of the risk assessment/risk management process. Risk assessment is an analysis of what contributes to a potential hazardous situation, what is the likelihood of that situation arising and what are the consequences if that situation should arise. Probability and consequence are the two factors critical to understanding risk. The estimation of probability and the assessment of the severity of a consequence define the practice of risk assessment.

Risk assessment is a relatively new field, developing in the 1960's and 1970's in response to cancer risks associated with nuclear energy and pesticides (Health Canada, 2004).

Risk assessment is an analytical process designed to identify and evaluate the relationship between exposure to a potential danger and the effects of that exposure on humans or the environment (Presidential Congressional Commission, 1997). The objective of the risk assessment is to determine an acceptable level of safety. The risk assessment phase is the scientific evaluation component of the risk management process.

There are four parts to a typical risk assessment as follows (EPA, 1991):

i. Hazard Identification

Hazard identification is a preliminary process where potential toxic effects are determined based on a review of the available scientific evidence. New scientific research is typically not undertaken in this phase. Epidemiological and toxicological studies are reviewed together with data on the physical and chemical characteristics (e.g. persistent, bioaccumulative, toxic) of the substance under investigation (NERAM, 2000). The CSA Q-850 Framework (CSA, 1997) refers to this as the "Risk Identification Stage." Given the industry involvement in the CSA process it is consistent to see a change in language from the use of the term "hazard" to "risk." The CSA process places the hazard identification stage as a separate activity that occurs in advance of the risk assessment process.

ii. Dose-Response Evaluation

Dose-response evaluation determines the relationship between the *amount* of exposure to a substance and the *extent* of toxic injury or disease it causes. Dose-response relationships are defined through experimental studies with animals and epidemiological studies of human populations where inadvertent exposures to environmental contaminants have taken place. Dose-response relationships for mercury were derived largely from the accidental mercury poisonings that occurred in Japan and Iraq. Dose-response relationship are often expressed in numerical terms, such as one in a million (1×10^{-6}) or 0.000001, so that the risk associated with a specific substance can be compared to other similar studies. Dose-response relationships provide the basis for estimating toxicological thresholds; the no-observed-effect level (NOEL) and lowest-observed-effect level (LOEL) (NERAM, 2000). Health guidelines are set using the toxicological thresholds developed by plotting the dose-response curves to arrive at Tolerable Daily Intake (TDI) for a substance (Health Canada, 1999).

iii. Exposure Assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposure to a contaminant present in the environment (NERAM, 2000). Exposure assessment relies on research on actual populations exposed to contaminants. Studies for the general population as well two specific sub-groups are generally required: sub-populations that are highly exposed and sub-populations that are highly susceptible. In the case of mercury pollution; native Canadians are highly exposed, due to their reliance on in-land fish as a primary source of protein, and a small sub-set of the population has acute sensitivity to mercury and are therefore highly susceptible.

iv. Risk Characterization

Risk characterization is the final step of risk assessment, combining the findings of the first three steps, in order to describe the nature of the hazard and provide a numerical estimate of the risk. Risk characterization includes important qualitative information describing the assessment and the assumptions, uncertainties and interpretations that led to the conclusions (NERAM, 2000).

4.4 Risk Management

Risk management has been evolving over the past several decades (Health Canada, 2004). Risk management is the central piece of the risk management framework; it is preceded by risk assessment and followed by risk communication. The history of risk management and the early definition of risk from a public policy perspective is summarized in a report of the Atomic Energy Control Board (AECB, 1994) as follows:

… the first "virtually safe" dose proposed in the United States was designed to limit the risk of cancer to one in one hundred million (10^{-8}) for a lifetime of exposure …

Soon after, it became clear that this criterion placed an almost intolerable burden on regulatory agencies charged with guaranteeing the safety of food additives, while ensuring that the considerable advantages of these additives could be exploited. The majority view then became that a risk of one new case of cancer per million inhabitants could be considered negligible. At this rate, only three new cancer cases per year would occur if all Americans were exposed. Over the course of the next few years, the standard of "one in one million" became institutionalized as an "acceptable" risk, and when it became understood in the latter part of the 1960s and early

1970s that ambient exposure carried a risk of cancer, the concept of a negligible lifetime risk (set at one in one million, or 10^{-6}) was frequently applied, especially in the United States …

Early on, the greatest source of concern was generalized risk, such as that induced by exposure to polychlorobiphenyls (PCBs) or pesticide residues in the environment. Later, the same standard was applied to risks that are far less generalized, such as the risk encountered in the areas surrounding industrial sites and hazardous waste disposal sites. In time it became clear that a risk of one in one million (10^{-6}) was in fact a highly rigorous standard in cases where the number of individuals exposed was relatively small …

For the U.S. Environmental Protection Agency (EPA), risk levels equal or higher than one in ten thousand are considered acceptable in setting maximum levels of contamination by cancer-causing agents in drinking water, when it is technically or economically unfeasible to achieve greater reductions. However, the general view is that risk levels higher than one in ten thousand are excessive, even when very few individuals are exposed, and require the implementation of measures to reduce both exposure and risk.

Canadian governments followed the American lead and adopted a similar approach to risk management. A number of important definitions for risk management emerged including the U.S. National Research Council (NRC, 1983) definition:

"a decision-making process involving the consideration of information of a political, social, economic and technological nature, in addition to data concerning risks, in order to develop, analyze and compare regulatory options; the goal of this process is to select the most appropriate response with respect to potential risks that may pose a chronic threat to health."

This definition contains some of the clearest language regarding the need to consider "political, social and economic factors" while also focusing on "regulatory options." Later definitions of risk management used in Canada (see CCME, Health Canada and NERAM definitions below) use vague language and shift the purpose of risk management away from comparing "regulatory options" and "appropriate responses" to defining "a rational level of acceptable risk."

The Canadian Council of Ministers of the Environment (CCME) has the responsibility of overseeing national environmental standard setting through the Canada Wide Standards process and has defined risk management as:

"the selection and implementation of a strategy to control risk, followed by the monitoring and assessment of that strategy to determine its effectiveness; the choice of a particular strategy can be based on an examination of the information obtained in the course of the risk assessment."

Health Canada is the lead federal agency in Canada investigating risk management approaches since risk management is used primarily to address human health risks (as opposed to ecological risk). Furthermore under CEPA, Health Canada has jurisdiction regarding toxic substances that pose a risk to human health and therefore carries the responsibility of undertaking risk assessments of potential toxic substances. Health Canada (2004) uses a similar definition to that of the CCME, with a simplified version as: "*the identification, assessment and actions taken to reduce risks*."

According to NERAM (2000), *"the risk management process is the means by which governments and other regulatory organizations seek to define a rational level of acceptable or tolerable risk for an environmental hazard – by considering the severity and probability of harmful health effects, the sources and means of control for the contaminant and the expected costs and benefits of various risk reduction strategies."*

In contrast to the US NRC (1983) definition, the objective of the Canadian risk management field, as represented by NERAM, focuses on identifying the quantity of a harmful substance that should be permissible. This definition undermines the idea that a potentially valid risk management strategy may be to find an alternative to the substance or product in question.

Risk management has received considerable criticism from industry, environmental groups, and academics (NRC, 1994). In response to the criticisms several organizations reviewed the initial conceptual framework developed by the U.S. National Research Council in 1983 (NRC, 1994, 1996; California EPA, 1996; Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997a, 1997b; NERAM, 1999; Health Canada, 2000; INSPQ, 2000).

One of the most important reviews was the 1997 Presidential/Congressional Commission on Risk Assessment and Risk Management. The Commission was created by the U.S. Congress in the wake of changes made to the *Clean Air Act (1990)*. The study reviewed the role and political factors within risk assessment and risk management in U.S. federal programs designed to prevent cancer and other chronic diseases associated with exposure to chemical substances.

The Commission concluded that traditional approaches to assessing and reducing risk were inadequate and numerous recommendations were made including the introduction of a more comprehensive integrated definition of risk management, as follows:

"Risk management is the process of identifying, evaluating, selecting, and implementing actions to reduce risk to human health and to ecosystems. The goal of risk management is to apply scientifically sound, cost-effective, integrated actions that reduce or prevent risks while taking into account social, cultural, ethical, political, and legal considerations."

Most government regulatory bodies in North America use a definition similar to the one noted above, followed by detailed operating guidelines on the use of risk management. The Agency for Toxics Substances and Disease Registry, the Canadian Food Inspection Agency, Health Canada, the US Department of Energy, the Canadian Council of Ministers for the Environment, to name a few, have guidelines on the use of risk assessment and risk management. The Presidential/Congressional Commission (1997), Health Canada (1999) and the Canadian Standards Association (1997) reports on risk management set the benchmark for the application of risk management in North America (Shortreed et al., 2000).

The risk management framework defines the overall methodology that comprises the assessment, communications and control of risks. It is sometimes shortened to "risk management" but in most working definitions, “risk management” is confined to the post-assessment phase where the risks, once identified, are mitigated or managed. Figure 4.2 illustrates the relationship between the risk management process, risk assessment (and related sub-components), and risk management activities. This illustration depicts the common elements of risk management, as described in the Canada Standards Association Framework for Risk Management (CSA, 1997), but with a clear distinction drawn between the three main stages of risk assessment (A), risk management (B), and risk communications (C).

Figure 4.2: Risk Management Framework (modified CSA Q850)

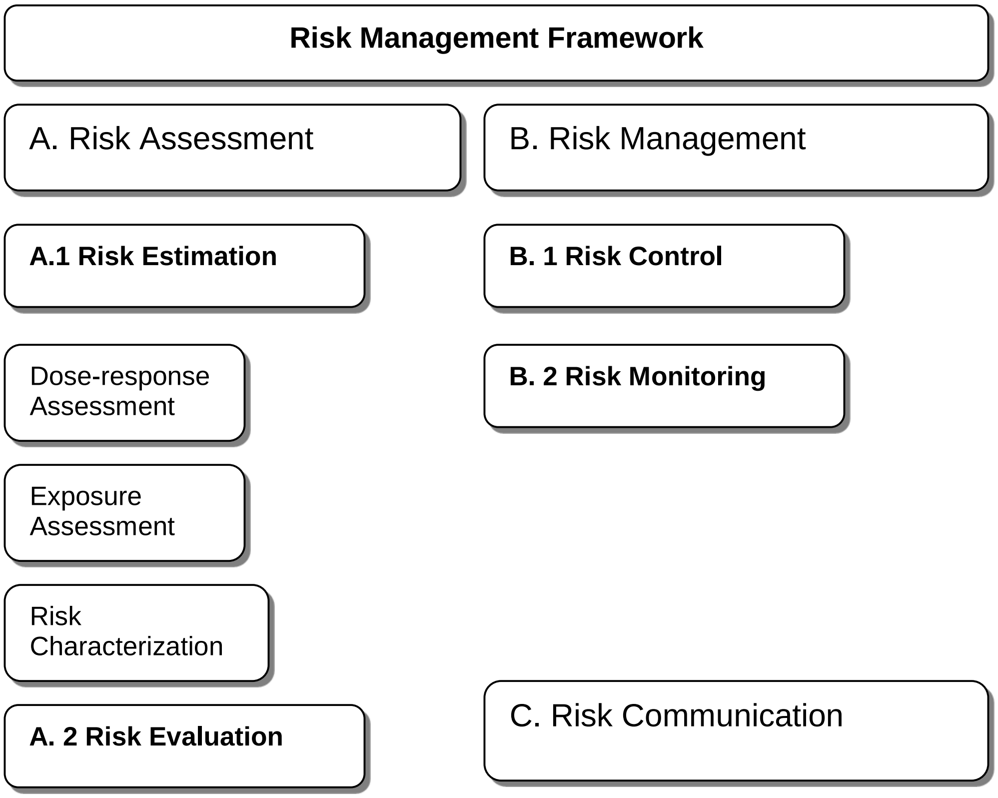
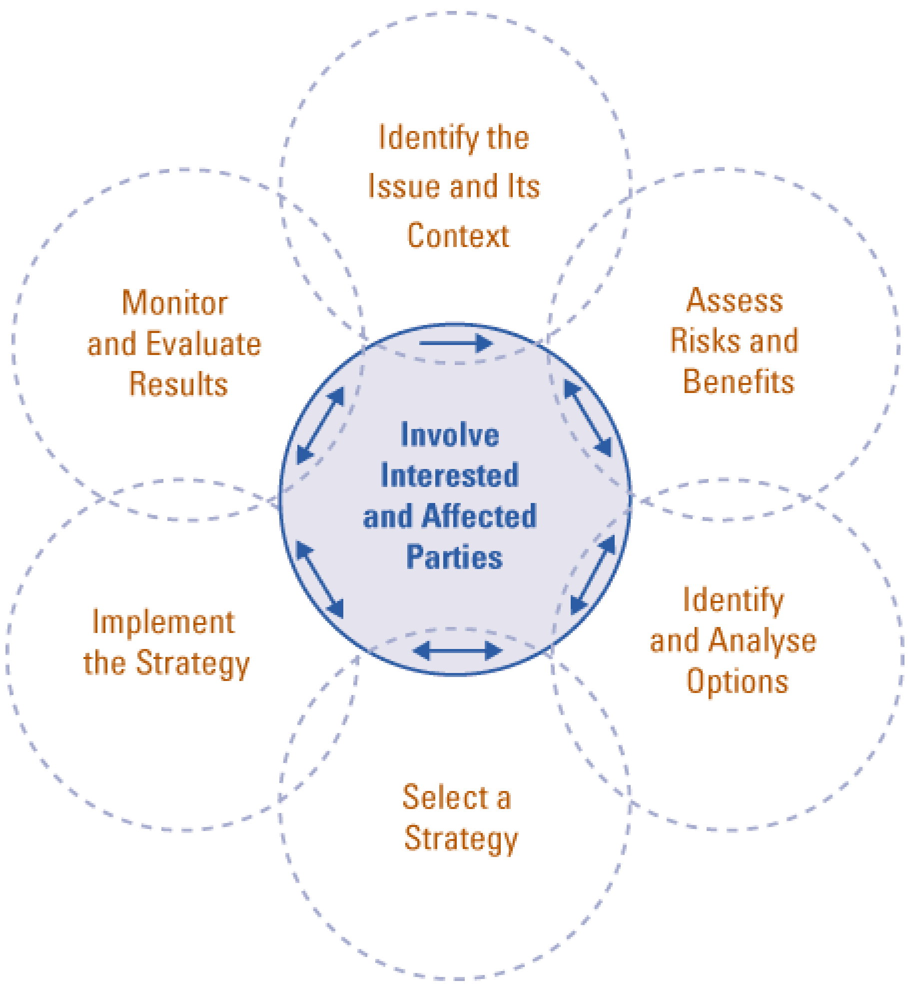


Figure 4.3 is a graphical representation of the Risk Management Decision-making Framework that Health Canada has adopted. It is virtually identical to the model developed by the 1997 Presidential/Congressional Commission on Risk Assessment and Risk Management. The only difference between the two is that the Health Canada figure replaces the “decision” step with “strategy” and the “action” step with “implementation.” This may be nothing more than semantics or it may reflect the Canadian federal government’s proclivity to “strategize” versus “decide” and “implement strategies” versus take “action” on decisions, as noted in detail in the many critical reviews of Canada’s poor performance on managing toxic substances conducted by the Commissioner for Sustainable Development (Government of Canada, 2002 to 2016).

The risk-based decision-making process begins at the top of Figure 4.3 and proceeds clockwise through each of the steps represented by the circles. A decision is required at each step in order to: proceed to the next step, gather more information, or cease the process.

Figure 4.3: Risk Management Decision-Making Framework Adopted by Health Canada



Source: http://www.hc-sc.gc.ca/hpfb-dgpsa/hcrisk_e.pdf.

The conclusion of the risk assessment phase marks a natural break between researching the problem (risk assessment) and developing the solution (risk management). Early risk management frameworks (e.g. National Research Council, 1993) appear to make a clearer distinction between these two phases than the more recent frameworks.

The Health Canada Framework mimics the more recent US EPA approach where there is greater involvement of stakeholders throughout the RA/RM process. This may be helpful in establishing context and aiding risk communication however it poses a potential threat to the perceived objectivity of science where social, economic and political judgements become intertwined with the scientific risk assessment. The active involvement of stakeholders is necessary within the risk management phase where socio-economic and political considerations are a valid aspect of risk management. This is noted by Saner (2001) where: “At the conceptual level it appears that there is a clear division between; (a) objective science at the risk assessment step, and (b) value-laden decision-making at the risk management step.”

Saner suggests the benefits of involving stakeholders in the risk assessment phase are not clear (Saner, 2001). Arguments can be made that it is more “sound” to maintain the scientific objectivity of risk assessment without the influence of stakeholders. This assumes that science assessments of risk are otherwise objective, which, as has been demonstrated in the numerous critical reviews or risk assessment is not generally the case in practice (Raffensperger and Tickner, 1999: Leiss, 2001; Kraft, 2017).

Alternatively, arguments can be made in support of stakeholder participation at all stages, as per the framework, since risk management involves value judgements throughout the process and recognizing values is one of the most important aspects of decision-making (Keeney, 2001). Stakeholders may have values that are separate from but related to the risks being assessed and it is preferable to have these values expressed as well as the values implicit in the research acknowledged (Shrader-Frechette, 1995).

From the standpoint of public policy, risk assessments are a means to the ultimate goal of reasoned public dialogue, wise risk management, and sensible priority-setting in the allocation of resources to risk control and reduction. Given both the inherent limitations of risk assessments, especially the irreducible uncertainties usually associated with them, as well as legitimate differences in society over how to assign priorities for risk reduction, however, even the best risk assessments cannot lead automatically to wise risk management decisions. (Leiss, 1999c)

Health Canada (2000) promotes the participation of "interested and affected parties, including partners, the public and other stakeholders" in issue identification, risk assessment and risk management, noting that: "they can provide valuable information, knowledge, expertise, and insights throughout the process, and should be involved as early as possible."

One downfall of active participation throughout the RA/RM process, based on the author's experience in Canadian risk management exercises, is the influence that economically vested stakeholders exert regarding the scope of risk assessments and the procurement of research to aid risk assessment, as described in Chapter 3. Limiting the scope of the risk assessment limits the range of available risk management options, which is often the objective of the vested stakeholders.

Much of this strategic manipulation of the RA/RM process can be explained through the lens of Beck's material society and Howlett et al.'s resource dependency and is borne out in the quantitative research and analysis in the subsequent chapters. Defining a risk issue according to the narrow definition of risk analysis is a strategy employed by industry interest groups to avoid the introduction of political or moral concerns (Bocking, 2006).

4.5 Risk Management and Toxic Substances

Risk management is the decision-making phase of risk analysis. Governments use risk management to make decisions on how best to limit or reduce the potential environmental and health effects of toxic substances. The risk management step is where a decision to "reduce risk," if warranted, is made. Managing risk may include banning a product, setting an environmental standard or regulation, or facilitating any action that a corporation or individual may take to control or limit the use or release of a toxic substance.

In managing the risks associated with toxic substances actions may be taken throughout a product's life-cycle; including product design, distribution, sales, purchasing, use and disposal. These decisions are primarily a federal responsibility in Canada and the Canadian Environmental Protection Act (CEPA) is the main legislation guiding risk management decisions for toxic substances. Regardless of the risk management action proposed or whether any specific actions are recommended or not the risk management step requires that a decision be made.

Figures 4.4 illustrates a comprehensive risk-based decision framework for toxic substances management and Figure 4.5 is an application of the framework to mercury risk management.

Figure 4.4: Risk Decision Model for Toxic Substance Management

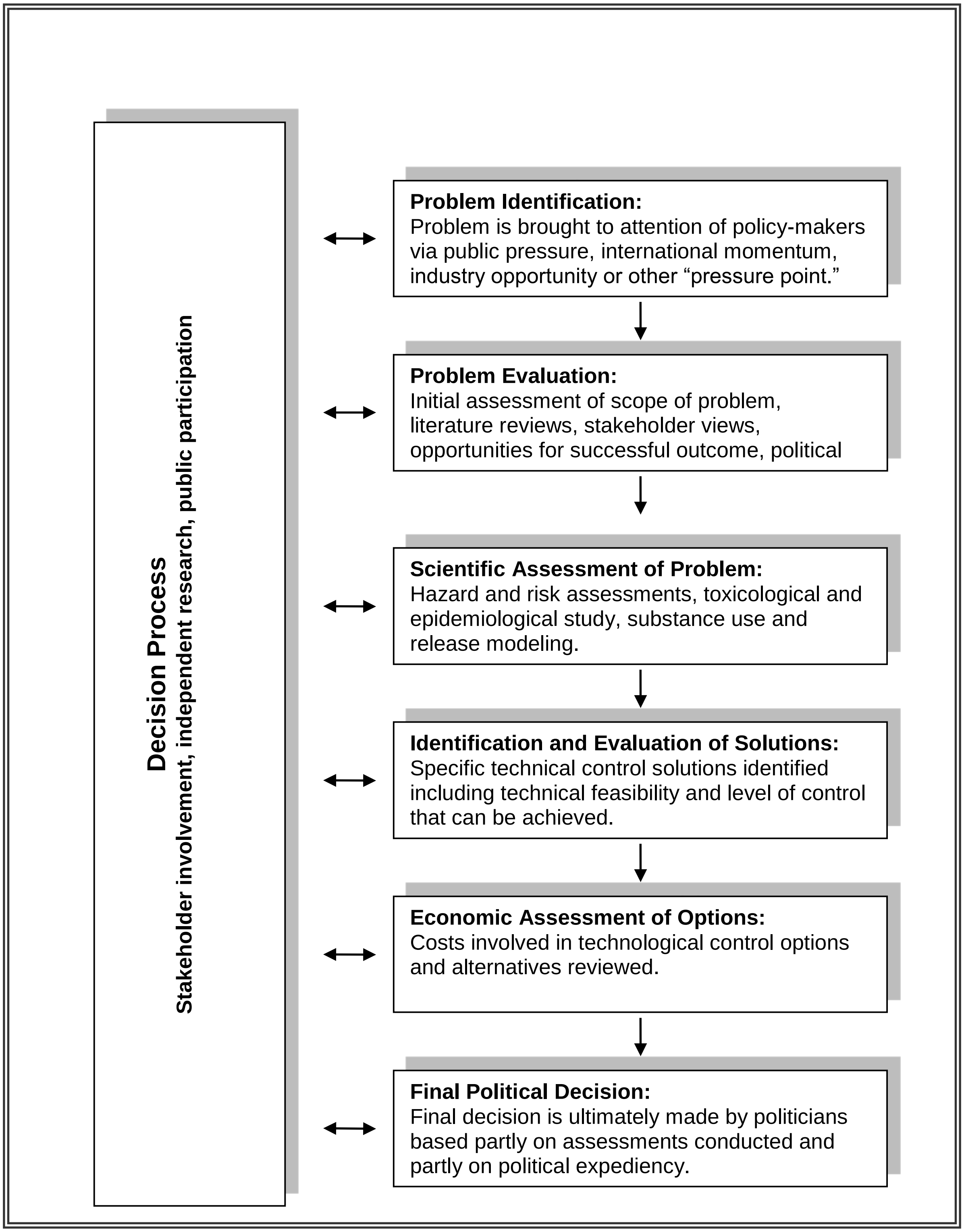
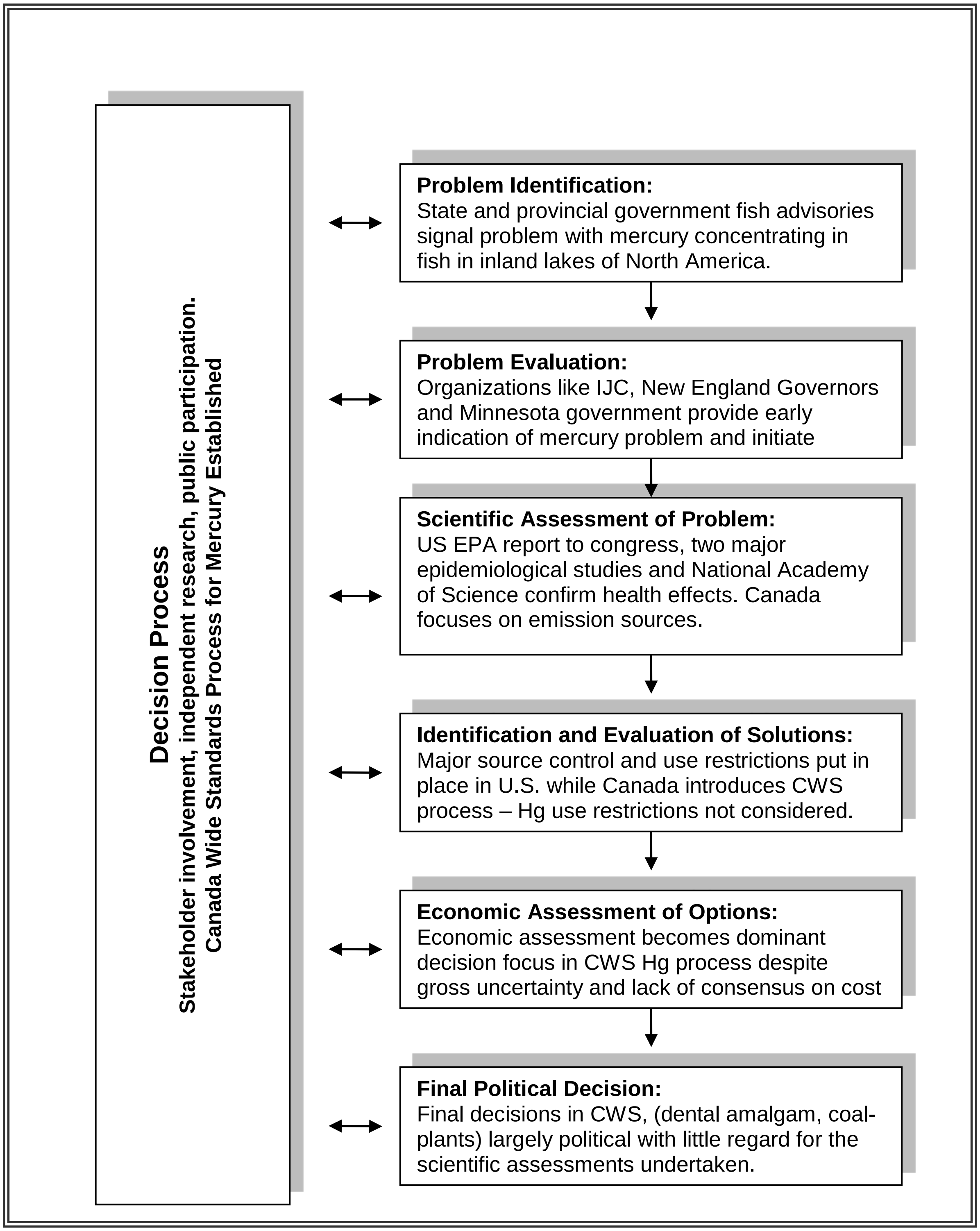


Figure 4.5: Risk Decision Model for Mercury Management



Risk management decisions are generally based on many factors, including an assessment of the risk of acting or not acting. A decision not to act constitutes a valid outcome of risk management and is therefore an accepted and common policy decision. The shortcomings of, and tendencies toward, inaction regarding regulatory risk management options are addressed more fully below. In brief, a decision to maintain the status quo is generally much easier politically than a decision to intervene in personal or corporate behaviours, particularly where there are costs associated with changes in industrial practices.

Risk management is the dominant decision-making framework used to set environmental health and safety guidelines for toxic substances in most western countries. The United States, Great Britain and Canada have undertaken major reviews of risk management decision-frameworks, (e.g. the Presidential/Congressional Commission on Risk Assessment and Risk Management (1997), described above).

The reasons for these international efforts are twofold. First, technological complexity and ubiquity have heightened policy-makers awareness of the need to have appropriate mechanisms in place for reviewing and accepting new technologies and substances. Second, public awareness is heightened regarding the potential risks of new technology and there is a higher demand for public participation and public accountability. In Canada, there is a third issue of importance that has led to increased federal government attention, namely critical scrutiny of poor risk management processes (Health Canada, 2000).

According to the British Health and Safety Executive, rapid technological developments over the past several decades have introduced new hazards but also enhanced our ability to control hazards (HSE, 1999). Society places an expectation on advances in science and technology such that:

- Those who create risks should be made responsible for ensuring that adequate measures are in place to protect people and the things they value from harmful consequences that may arise from such risks;

- States should be proactive in protecting people from risks as distinct from reacting to events (HSE, 1999).

"A thing is safe if its attendant risks are deemed to be acceptable." This 1976 quote of William Lowrance, according to NERAM (2000), "constitutes the bedrock of modern risk management theory and practice." These are interesting statements, both the quote from Lowrance and the assertion of NERAM. The quote represents the perspective of a risk assessor, who has the job of "deeming" a thing to be acceptable and therefore safe. A classical definition of "safe" is the concept of being "out of danger," (Oxford Dictionary), whereas the risk-based concept of "safe" is to identify an acceptable level of harm, and to deem this to be "safe." Risk implies degrees of safety (HSE, 1999) not a threshold deemed to be safe.

Acceptable risk is therefore not so much being out of danger but understanding how dangerous the situation is and choosing to accept, or deem to be acceptable, that level of danger. This is one of the primary philosophical differences between proponents of risk management who hold the position that there are risks in everything we do versus the precautionary stance of non-government organizations who aspire to the principal of "elimination of risk," generally believing this to be attainable. The risk management options vary considerable depending on to which perspective one subscribes.

There are three fundamental problems with the notion of "deeming a risk to be acceptable" when dealing with toxic substances in the environment. First is the premise that any amount of a toxic substance placed, for example in the air or water of populated places, can be considered safe. Second, is the assumption that enough is known about the possible harm that may occur in the environment to deem "a thing" to be safe. Much of the literature on precaution is in response to the limitations of scientific understanding of nature (Santillo et al., 1999). Third, is the activity of "deeming," whereby experts pass judgement on scientific information that is at best, difficult for the public to understand, and at worst prepared by those with a vested interest in the outcome. This was one of the most contentious aspects of risk management raised by public interest organizations (e.g. CELA/OCFP, 2000; Greenpeace, 1999). It is perhaps this rather shaky foundation that has led to controversial and unsatisfactory outcomes when risk management theory is applied to modern environmental concerns in Canada; most notably toxic substances and climate change.

Leiss (2001) describes in detail several examples in Canada where risk controversies were created due to government and/or industry misunderstanding public reaction to potential risks. In some cases, it relates to bungled government risk management efforts (e.g. mad cow disease in the UK and Canada) and in other cases it is related to general public fear of the unknown (e.g. climate change or genetically modified organisms) and mistrust of corporate actions (Leiss, 2001). In all cases public suspicion of risk managers is heightened when risk issues are poorly managed, undermining the credibility of risk analysis.

There are also different values and perspectives among scientists depending on where they are employed. Lynn (1986) in Kraft (2017) states that industry scientists are more conservative than government or university scientists and choose assumptions that decrease the risk of harm and increase the safe level of exposure to harmful substances. This is borne out in the empirical research in Chapter 6, where the industry policy actors are described as being part of the economic risk paradigm and non-industry actors connected more to the adaptive precautionary paradigm.

Criticism of practical aspects of risk management, especially risk assessment, is common. The weaknesses associated with the theoretical structure of risk management decision-making as an effective policy process are less well-articulated. Risk management theory assumes that environmental decision-making falls exclusively within the domain of risk. All aspects of decision-making are redefined in relation to risk. Risk managers use risk frameworks to organize risk assessments in order to make risk decisions on risk control options that are presented with risk communications. The use of “risk” in this sentence adds little to the understanding of generic decision-making processes used to set environmental standards.

Except for "risk assessment," the use of "risk" as a modifier does little more than introduce the presumption that the activities described in risk management are somehow different than in other decision processes. For example, "risk control" is assumed to be somehow different from any other form of environmental control measure, when in fact it simply refers to the traditional policy tools at the disposal of decision-makers. The same applies to risk communications; no different from any other form of communicating a decision process, with the exception that it references risk and thereby places risk as the subject of the activity.

Risk management is therefore being put forward as a framework for decision-making that reduces all aspects of a decision to a central concept of risk. One substantive matter related to the addition of "risk" to otherwise common environmental management terminology is that it shifts the focus from control of substances to control of risk. This strategy was employed by Natural Resources Canada (NRCan) in the development of Canada's international positions on the control of heavy metals, for example the United Nations Heavy Metals Protocol, the Basel Convention and the North American Regional Action Plan on Mercury. Negotiators from NRCan lobbied vigorously for language that stated the objectives of these international agreements is "managing risk" or in even less restrictive language "reducing risk of exposure." The critical distinction with this language is that it is possible to manage risk and certainly reduce risk of exposure without managing or restricting the use of the toxic substances themselves.

As noted, a specific example of reducing risk of exposure to mercury is to avoid eating fish, which is a very different risk management outcome than controlling mercury emissions from smelters that are contaminating the lakes where the fish live. Risk management, by its nature, therefore helps shift the discourse toward the former. Moreover, it is a tool that, when combined with a cost/benefit lens, leads to risk management decisions that are narrowly focused on individual behavioural approaches to reduce risk (e.g. public education). These risk exposure reduction approaches do nothing to address the source of the problem nor do they do anything to address the broader ecological risks, and finally in the case of fish advisories for mercury they are of questionable effectiveness and ignore the risks associated with commercial fish consumption. The risk management process regarding toxic substances in Canada therefore avoided regulatory risk management solutions that reduced direct ecological and human health risk, not simply the exposure factor. This was the intentional objective of industry stakeholders working to avoid any requirements for regulatory actions that may place the cost burden on industry, as opposed to public exhortation programs funded by government.

Simpson and Jaccard (2007) describe the very similar situation of climate change risk management in Canada. The players, the tactics and the outcomes are essentially identical, only the environmental issue they describe is climate change. They argue that the federal government (under the Chretien Liberals), led largely by NRCan, avoided any form of regulatory action on climate mitigation in favour of public education and exhortation with a deliberate strategy to shift the burden of climate mitigation away from industry and onto the public. Hundreds of millions of dollars of climate-related program expenditures were made in this way over many years with virtually no discernible benefit to climate mitigation, in fact Canada's greenhouse gases increased dramatically while these programs were in place.

Risk management is presumed to be a scientific methodology however many of the components of the process are clearly not within the realm of science, and those that are, are fraught with difficulty. The fact that perceptions of risk vary widely, assessments are frequently inconclusive, and political factors generally override objective analysis, leads one to the conclusion that there is a fundamental flaw in risk management.

4.6 Risk and Science

There is a tension between risk and science which is related to the need for risk managers to make definitive, timely and sometimes politically charged decisions whereas scientists work within a slowly evolving, highly uncertain and often apolitical environment (Leiss, 2001). Risk assessors often portray risk assessment as an "objective" science-based activity devoid of political considerations. Given the extensive literature identifying the highly politicized nature of risk controversies this is clearly not the case. Moreover, the very idea that risk assessment is largely a scientific exercise contributes to the lack of credibility of the field of risk assessment for it portrays an ignorance of the politics, values and socio-economic realities of risk management policy outcomes.

Ulrich Beck positions risk as the defining characteristic of post-industrial society in *Risk Society: Towards a New Modernity*. As a post-modern critique of science, Beck asserts that "science is one of the cause, the medium of definition and the source of solutions to risks." One of the primary distinctions Beck makes regarding pre-modern experiences with risk versus modern or post-modern experiences is the extent to which risk is anthropogenic. Regarding many of the most well-known modern risk controversies (e.g climate change), and in the case of toxic chemical pollution, technology and science are both the cause of the problem and are required in order to find the solution. Pre-modern risks were largely not a direct result of human actions.

The mercury case study presented herein amplifies the anthropogenic versus natural risk dichotomy with the traditional risk assessment oriented stakeholders working to reinforce the industrial society risk paradigm while independent scientists and environmental non-government organizations recognize the anthropogenic element of risk, as described in Chapter 6.

Science, according to Beck, has become "the legitimating patron of global industrial pollution and contamination in the face of growing risks and threats from civilization." The challenge to risk managers is therefore to invoke or preserve the authority of science without using science as a means to eschew the concerns of citizens. One of the primary critiques of risk assessment is the way in which it limits public participation and thereby democracy by focusing on inaccessible scientific studies and expert participation (Bocking, 2006). The precautionary principle is envisioned as a more democratic and less technocratic mechanism.

The fact that risk in a risk society is largely anthropogenic and yet imposed by others creates a situation similar to the voluntary versus involuntary risk where a voluntary risk (e.g. driving a car) is generally more acceptable to an individual than an involuntary risk (exposure to toxic substances in food). Beck in some ways is expanding the concept of risk to modern society at large whereby the involuntary risks to society related to exposure to a vast array of scientific and technological advances are qualitatively and quantitatively different from pre-modern societal risks which may not have been voluntary but were not third-party anthropogenic risks.

Gould describes the self-marginalizing of science by scientists and Beck attributes the origin of the critique of science to the “failure of technocratic scientific rationality.” According to Beck whereas “the access to reality and truth” was “imputed to science” it is now replaced by “decisions, rules and conventions.” Risk analysis is a fine example of the application of rules and conventions and in many cases the rules and conventions are such that science cannot be accommodated in a way that aids decisions related to complex ecological matters. Beck seems to be saying that science is no longer practiced in the way that it has in the past and should still. This seems more directly the case when one considers how science is used in environmental policy and risk management.

According to Leiss (2001) governments have “seriously mismanaged risk issues” as opposed to actual risk assessments and the most poorly managed “risk issue” is “the need to establish an appropriate relationship between science and the public in risk controversies.”

Beck’s argument that science as a discipline is at fault is in some ways naïve or perhaps as Bocking (2006) suggests, is specific to German societal and environmental policy circumstances. The contention in this dissertation is that science has served Canada well in early environmental policy development and that the primary problem with environmental policy in Canada is the misuse of science by non-scientists due to a combination of poor decision structures, vested interests, the diminution of science capacity in Canada, and the lack of accounting for the transition from ecological nature to anthropogenic nature.

This inability to transition from ecological nature to anthropogenic nature can also be described as Canadian policy-makers being incapable of making the transition from material society to risk society. The theoretical conceptualization of Canada being trapped in material society is reinforced in this way. Moreover, whereas the science-policy situation in Germany, as noted by

Bocking (2006), is domestically prescribed, Canada's science-policy interface too is a creation rooted in Canada's historic staples economy. This in turn explains, in credible theoretical terms, why Canada's global standing across a wide-range of environmental and resource policy indicators is much poorer than almost all European countries. European countries developed over the past three centuries with largely stable local populations focused on meeting domestic needs through local supply and trade; unlike Canada's colonial resource history.

4.7 Risk and Uncertainty

Knight (1921) identified a truly "crucial" issue that continues to challenge the field of risk management today as follows:

The essential fact is that "risk" means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomenon depending on which of the two is really present and operating.

(Knight, 1921)

There are many forms of uncertainty that prevail in risk management processes. The most common, particularly within the risk assessment phase, is scientific uncertainty. Scientific uncertainty is often presented as the primary source of conflict in policy decision-making, together with the related notion that reducing uncertainty will reduce conflict (Shackley and Wynne, 1996).

There is a considerable body of literature on scientific uncertainty that is written from varying perspectives, addressing uncertainty in the contexts of risk management, precaution, science and sustainability (e.g. Holling, 1973, 1996, 1998; Ehrlich and Daily, 1993; Ludwig et al., 1993; Policansky, 1993; Lele and Norgaard, 1996; Raffensperger and Tickner, 1999; Leiss, 2001; Tickner, 2002; Bocking 2006; Whiteside 2006; Klinke and Renn 2014; Udovyk, 2014; Neville and Weinthal, 2016; Edge and Eyles, 2017; Marshall et al., 2017). Governments, commercial interests, scientists and non-governmental organizations (NGO's) have been grappling with concepts of uncertainty, and reducing scientific uncertainty is a dominant theme in environmental policy (NDG, 2004).

Uncertainty is defined as a:

"Term used to describe the level of confidence in a given estimate based on the amount and quality of the evidence (data) available. Uncertainties in the results of a study arise primarily from limitations related to existing measurements, absence of some kinds of measurements because of lack of environmental monitoring at certain locations, lack of knowledge about some physical processes and operational procedures, and the approximate nature of mathematical models used to predict the transport of released materials."

Former U.S. Defense Secretary Donald Rumsfeld provides an excellent quote on uncertainty that, although the source of much amusement, is an accurate portrayal of varieties of uncertainty: "as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know." These same concepts are common in contemporary academic literature and ancient Chinese philosophy. Shackley and Wynne (1996) note the difference between indeterminacy and ignorance, often presented as uncertainty or risk; "ignorance refers to situations in which it is not known what is unknown." Yorque et al. (2003) refer to the idea of "fundamental unknowability" and this is a principle theme in Taoism, sometimes called "collective unknowing" (Watson, 1968).

These concepts of "unknowability," or "unmeasurability" as Knight (1921) noted, are critical aspects of risk management particularly related to environmental risk and decision-making. A lack of attention to these concepts is presented herein as a serious flaw in risk management processes and environmental decision-making more generally.

When “something is distinctly not” measurable, uncertainty enters into the risk equation and as Knight notes, this is “the key to the whole tangle.” According to Leiss (2001) “risk is by definition a situation of uncertainty” or stated another way “uncertainty permeates the whole process of assessing risks” (HSE, 1999). “Most if not all of the environmental problems faced by society are ‘complex all the way down’. They are rife with uncertainty and there can be numerous plausible solutions, leading to numerous possible futures” (Kinzig and Starrett 2003). According to Leiss, from a pragmatic regulatory risk management perspective, the key is to look to see if we are applying qualitatively different kinds of uncertainty. Following are types of uncertainty encountered in policy-making that may contribute to lack of confidence in decision-making and which are encountered in the pollution regulation in Canada:

Scientific Uncertainty

Uncertainty stemming from scientific caution in the interpretation of experimental data

Model Uncertainty

Uncertainty resulting from the use or application of a mathematical model

Methodological Uncertainty

Uncertainty arising from the use or application of a research methodology

Data Uncertainty

Uncertainty following from observational or measurement error in experimental data

Application Uncertainty

Uncertainty in outcomes resulting from the application of a policy or regulation

Causal Uncertainty

Uncertainty as per a cause and effect relationship

Parameter Uncertainty

Imprecision stemming from a parameter’s data or causal uncertainty

Normative Uncertainty

Uncertainty as to how to address a particular problem or challenge

Risk Uncertainty

Uncertainty as to potential social, economic or environmental losses or gains

Policy Uncertainty

Uncertainty resulting from the application of a policy or regulation (*see Application Uncertainty*)

Legal Uncertainty

Uncertainty arising from ill-defined and/or ambiguous laws and/or legal precedents

Jurisdictional Uncertainty

Uncertainty following from disputes in legal and/or regulatory authority

Economic Uncertainty

Uncertainty vis-à-vis future output, investment and employment

In addition to the specific way in which uncertainty contributes to lack of confidence in policy-making, related concepts that may confound decision-making are:

- ***Ignorance***
- ***Knowledge level***
- ***Understanding of circumstances***
- ***Judgement***
- ***Clarity***
- ***Consensus***
- ***Ambiguity***

Scientific uncertainty is an important element of uncertainty and one that requires particular attention and further refinement. There are many aspects of scientific uncertainty. For the purposes of this paper, scientific uncertainty includes the broad notion capturing the many sub-sets of uncertainty within science and may be defined generally as a lack of consensus among the science community regarding phenomena.

4.8 Adaptive Precaution in Risk Society

West Germany is credited with introducing formative applications of the precautionary principle in environmental planning during the 1970's (Jordan and O'Riordan, 1999; Boehmer-Christiansen, 1994; VanderZwaag, 1999; Weale 1992, 1993). The *Vorsorgeprinzip* is the German phrase for the Precautionary Principle. *Vorsorge* has many meanings in German (Weale, 1992) but in this context means foresight or taking care, while also incorporating concepts of good husbandry and best practices even in the absence of risk (von Moltke, 1988). These two historical roots, financial risk and environmental planning, set the value framework for the risk paradigm and the precautionary paradigm; respectively characterized as the risk of losing money versus careful planning. Economic risk is not intended to be an explicit element of health risk assessment, although it becomes a dominant consideration in risk management and often in the scoping or risk assessments. Trade-offs between the risk of economic loss (or future opportunity cost) and environmental/health risks are therefore defining characteristics in the risk/precaution debate, including the interaction of these ideas as frameworks, concepts, principles and values.

"Scientific uncertainty about harm is the fulcrum" at the centre of the precautionary principle (Raffensperger and Tickner, 1999). According to the authors of this important text on the precautionary principle, decision-makers need to "bridge the gap" between uncertainty in science and the need for political action to avoid harm; and risk management frameworks are not able to do this in a timely, safe, cost-effective manner (Raffensperger and Tickner, 1999).

The precautionary principle is now embedded in various forms of legislation in many countries (e.g. Australia, Canada, EU, New Zealand, United States), however, the definition and application of the precautionary principle remains controversial, inconsistent and difficult at best, particularly when addressing complex global threats (Iverson and Perrings, 2011). Iverson and Perrings (2011) offer interesting technical analyses of decision-making under uncertainty using minimax and maximin analyses to assess the costs of false negatives and false positives. Their model confirms that a feedback loop learning scenario lowers future cost relative to a "no learning" approach, suggesting iterative non-linear risk governance models are superior. Their research approach relies heavily on objectivist notions of economic modelling and avoids a discussion of the subjective challenges described in Chapter 6 of the dissertation and notably Figure 6.9 Error Bias Paradigm Decision Diagram.

In *The Politics of Precaution* Vogel (2012) describes the ascendency of Europe over the United States, particularly California, in the setting of environmental standards related to heath and toxic chemicals. He attributes the adoption of the precautionary principle as a major reason for European leadership noting that it allows policy makers to take regulatory action in the face of scientific uncertainty. In Chapter 5 the case is made that as a result of Canada being trapped in material society with a political economy based on resource dependency and staples theory, precautionary approaches have not been adopted.

The need for precaution in pollution policy is critically important to protecting public health based on the historical record of managing toxic substances in Canada and abroad. Early warning signs based on scientific evidence of health or environmental harm are often ignored and this has been the case with respect to lead, benzene and Agent Orange (Ashford, 1999). Mercury is another example where this is true as shown in detail in this dissertation.

Precaution and risk decision-making approaches are often treated as mutually exclusive ideas and this may relate to epistemologies of the proponents (see Figure 2.1). Risk-based decision making is favoured by industry, whereas non-governmental organizations favour precautionary approaches. A more accurate representation may be a continuum with a high degree of uncertainty at one end of the scale and a low degree of uncertainty at the other end. Risk and precautionary approaches fall along the continuum depending on the nature and degree of scientific uncertainty.

The practical integration of the precautionary principle with risk-based decision-making frameworks has been challenging for policy-makers. Unlike risk assessment, precaution is not formulaic. According to Whiteside (2006), the precautionary principle:

"… is a commitment to develop a wide array of prospective procedures, institutions and social practices, all of which work together to make societies more responsible in relation to long-term, large-scale, uncertain risks."

There are wide-ranging perspectives on the implementability of precaution and a number of examples are presented here to illustrate the nature of the debate.

There are those who see no role for the precautionary principle, painting it as a vague and impractical conceptual notion. This was the general sentiment of presenters brought together by the Harvard Center for Risk Analysis for a workshop on the precautionary principle held in Washington, D.C. in June 1999 (Precaution Workshop, 1999). The "anti-precautionary" movement is being led by industry (Tait, 1999) with the aid of industry-funded academic institutions (e.g. Harvard Center for Risk Analysis). Industry opposition to the fundamental values behind the precautionary principle are evident in the literature prepared most notably by the chemical industry in the United States and Canada (e.g. CCPA, 2000). The chemical industry (Chlorine Institute) sponsored the Washington Precautionary Principle Workshop and provided an over-bearing influence on the Precautionary Principle Workshop held in Toronto in October, 2000, organized by the Network for Environmental Risk Assessment and Management (NERAM).

Rampton and Stauber (2001) describe in considerable detail efforts of the chlorine and agrichemical industries to attack the precautionary principle, including detailed public relations tactics such as having industry-hired scientists undertaking media and community tours to refute studies that question the safety of chlorinated products. They describe specific examples of using industry friendly scientists and sympathetic media outlets to brief politicians, legislators, and influential medical associations. The 1999 Harvard Precaution Workshop held in Washington D.C. was a perfect example of this strategy, including the rather obvious incentive provided to the government officials they were intending to influence, for whom there was no fee to attend, versus a significant registration fee charged to any other participants, including charitable non-government organizations.

Environmental non-government organizations often hold a diametrically opposite view to industry, whereby risk assessment is described as "voodoo science" used to promote profligate industry practices and the continued use of poisonous chemicals (Greenpeace, 1999). Advocates for "strong precaution" argued that the precautionary principle should replace risk assessment altogether where there is a high degree of scientific uncertainty and the potential for significant harm (see for example CELA/OCFP, 2000).

Shere (1995), an industry lawyer, noted that "close analysis of the methods used in risk assessment, however, shows that the process is so laden with uncertainty as to render the quantitative results meaningless." The alternative suggestion in this case is not a precautionary approach but a call for a limited role for government in environmental regulation. Governments were faced with the challenge of attempting to balance these approaches and "countries throughout the world are grappling with challenges posed by precautionary approaches" (Government of Canada, 2001).

The risk and precautionary perspectives are often portrayed as unique and separate, particularly among each end of the industry – environmental NGO continuum, reflected in the material society versus risk society dialectic. Government efforts to integrate precaution and risk management were fraught with internal inconsistency and typically represented minor variations on position papers prepared by industry (see, for example, Government of Canada, 2001 and WHO, 2004).

The research challenge in addressing this hurdle caused difficulties for international authorities attempting to integrate risk-based approaches with the precautionary principle. In some cases, this appears to have been a genuine intellectual challenge, in other cases it was related to the vested interests of material society concerned that a precautionary approach would lead to standards or regulations that constrain the economic activities of major industries. The research challenge is further complicated by the need to appreciate and account for the values and history that accompany different approaches to risk and decision-making, noting Canada's significant "staples economy" challenge of overcoming the long history of resource dependency and the institutional momentum it created.

The goal of this section is to explore the relationship between risk and precaution in decision-making. The risk-based approach and the precautionary approach have different characteristics that are sometimes at odds for decision-makers. The research identifies the need to better understand and integrate precaution and risk in environmental decision-making. The issues that appear to be at the heart of the dispute between the two approaches are:

1. The precautionary principle is primarily a guiding approach, whereas risk management is a comprehensive methodology with rigorous analytical protocols. Those who favour precaution claim environmental matters require flexibility in decisions and those who favour risk management see the precautionary principle as an unscientific process that lacks rigour and is therefore open to abuse.

2. The precautionary approach implies a set of values and ethics that favour protection – greater weight is placed on action in the absence of scientific certainty. Risk-based approaches favour scientific certainty before any control action is taken. In this sense, there is a clash of values, respectively a distrust of science and industry, versus faith in science and industrial solutions. The precautionary approach being more closely aligned to Holling's adaptive management and Beck's reflexive modernity; and risk-based approaches being more aligned to Beck's industrial society, and concepts of resource dependency and Canada's historic staples economy.

3. The precautionary approach is typically supported by non-governmental organizations in the health and environment fields where it represents the common good. Economic considerations are less important in a precautionary approach (or costs and benefits would be calculated differently to represent environmental externalities more accurately). Moreover, the precautionary approach tends to be pluralistic and democratic as "an inclusive, transparent process" (Bocking, 2006). Industrial and economic interests

> typically support risk-based approaches, “the very fabric of industrial society” according to Beck. Risk-based approaches are technocratic, typically exclude civil society, and place significant emphasis on the costs and benefits of action versus non-action. Costs and benefits in this context are often presented in ways that are very specific to narrow mitigation actions of targeted industrial interests versus global societal costs.

Risk analysis is an engineered decision tool, often practiced by engineers, whereas the precautionary principle is a discourse on an ethos. This is not to say that precautionary approaches are unworkable; it does however explain how the fundamental clash between technocratic practitioners of regulatory risk management, versus those espousing adaptive and reflexive precautionary concepts makes it exceedingly difficult to implement the precautionary principle as an alternative to risk analysis. They are not directly comparable or and not necessarily substitutable activities. Precaution helps us ask the right questions about uncertainty and “diversifies the contacts at the interface of nature and humanity” as opposed to making decisions about technologies (Whiteside, 2006). The differences between their ontologies reinforce “industrial society” status quo influence and help to explain the challenges that limit the implementation of the precautionary principle.

Risk assessment and management are difficult when dealing with environmental risk and uncertainty (Neville and Weinthal, 2016). The authors postulate that the extent to which hydraulic fracturing risks are less well known than the risks of conventional oil development creates a degree of uncertainty that shifts the decision-making from a regulatory exercise into a political arena. The authors also use broad characterizations of risk and uncertainty that extend to regulatory risk, business risk, and investment risk noting the divisive and hostile tactics of both proponents and opponents of hydraulic fracturing contributing to a general mistrust of science and scientists; ultimately creating uncertainty and lack of confidence in the regulatory outcome. Opposition to hydraulic fracturing has increased sharply with an increasing public appetite to regulate the industry, especially disclosure around chemicals in fracking fluids, while industry maintains that the risk posed by these chemicals is negligible (Kraft, 2017).

In this vein, Hurlbert and Gupta (2016) look at risk and uncertainty as frames for adaptive governance as it relates to climate risk. Risk, they posit, has both a realist, scientifically calculable aspect as well as a constructivist element based on social norms. Whereas risks may be “real” they are also socially transformed. The authors propose “adaptive governance” as a means for managing the two elements of risk, whereby adaptive management, co-management and anticipatory governance mechanisms, such as scenario planning, are combined. They suggest that the failure of environmental policies, based on an analysis of several jurisdictions, “stems from the dismal application of a comprehensive adaptive governance approach” and “the failure to consider diverse constructions of risk” (Hurlbert and Gupta, 2016). Their research, however, lacks consideration of stakeholder influence and the power dynamics of economic interests in the material society influencing the construction of risk they allude to, and therefore contributing to policy failure.

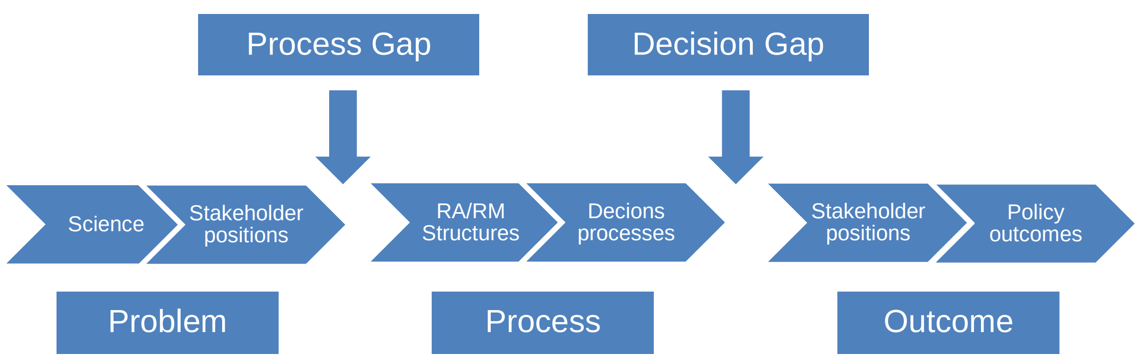
Adaptive management may offer “a pathway out of the conflict, paralysis, and environmental degradation” that has contributed to many failed environmental management programs; while noting that “practitioners have struggled to transfer it from theory to practice” (Layzer and Schulman, 2017).

Cordner (2015), on the other hand, developed the concept of “strategic science translation” to describe the way in which stakeholders claim to use “evidence-based” science arguments however presented selectively to reinforce their policy goals. Richards (2017) provides an enlightened perspective on evidence-based policy-making (referring to it as EBPM) noting that academic proponents of the EBPM approach are often naïve in their confidence in science as a driver of policy change, consistent with Beck’s critique of technocracy. Richards’ findings, based on interviews with policy-makers and scientists, reinforces the dissertation research herein on the gap between science and policy in environmental decision-making, noting in particular the need for specific mechanisms such as “research-policy partnerships” focused on short term policy objectives as a means to move the environmental policy agenda incrementally, given the challenge of long-termism (Richards, 2017).

Uncertainty and unknowability are often linked to complexity. There is widespread recognition that the complexity of "modern" life is unsustainable, from an ecological, economic and cultural perspective, creating "an ingenuity gap" Homer-Dixon (2001). Beck identified many of these forces and refers to them collectively as the underpinnings of global risk society. Applying Homer-Dixon's central tenet of social ingenuity to risk frameworks, one may conclude that a rigid application of risk management, which is unable to accommodate uncertainty and complexity, may stifle social ingenuity and limit successful options for adaptation to change. In Beck's language, the need for reflexive modernity.

In Figure 4.6 I have illustrated these "ingenuity gaps" in the linear risk process as a "process gap" and a "decision gap" where in both cases uncertainty hampers decision outcomes. The process gap is where "science uncertainty" appears and the "decision gap" is a manifestation of material society stakeholder interests which, return to dominate decision processes, with political interventions, following the formal risk management exercise.

Figure 4.6: Gaps in Science-Policy Interface



According to Rosenhead (2007) a combination of fear of uncertainty and the uncertainty inherent in complexity leads to poor management decisions:

"Given that the key finding claimed for complexity theory is the effective unknowability of the future, the common assumption among managers that part of their job is to decide where the organisation is going, and to take decisions designed to get it there is seen as a dangerous

delusion. Management, afflicted by increasing complexity and information overload, can react by becoming quite intolerant of ambiguity.

*Factors, targets, organisational structures all need to be nailed down. Uncertainty is ignored or denied [my emphasis]***.** *The management task is seen to be the enunciation of mission, the determination of strategy, and the elimination of deviation. Stability is sought as the ultimate bulwark against anxiety, which might otherwise become overwhelming. All of these managerial reflexes, many of them seeming unassailably commonsensical, are …counter-productive when viewed from a complexity theory perspective."*

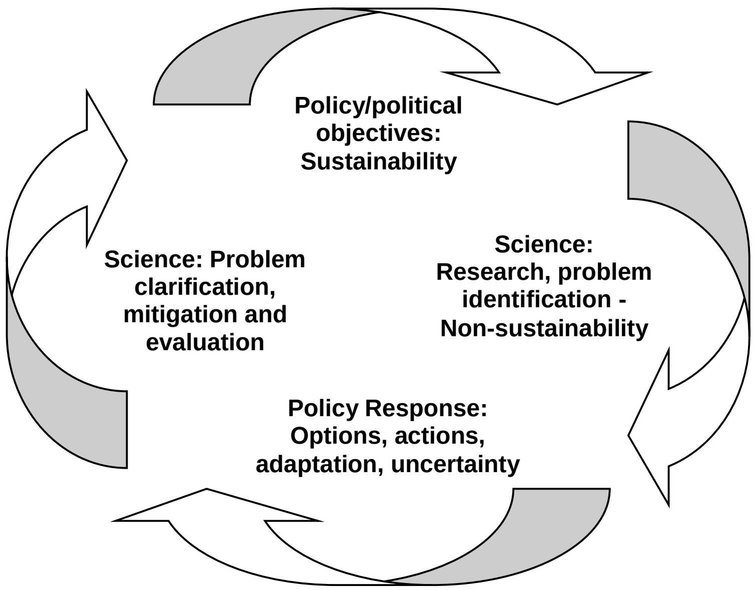
In general terms, uncertainty is described by certain policy experts as reliability and is related to the concept of confidence. The greater the uncertainty, the less reliable the information is considered to be and therefore the less confidence, often expressed in terms of "level of confidence." Uncertainty, however, is a dynamic process with spatial, temporal and social elements that appear to be not well considered in policy-making. Uncertainty is a complex and variable issue with many dimensions. According to Bocking (2006) modern environmental risks have inherent in them "pervasive uncertainties and ignorance."

Applying complexity to ecology, the conclusions drawn from analyses that have been aggregated are described as the "ecological fallacy" (Robinson, 1950). This early reference predates ecosystem complexity literature but points to the idea that ecological systems are sufficiently complex that they cannot be explained based on studies disaggregated to a smaller scale of species or individuals, a concept at the heart of Holling's work, described below. In essence, this is a validation of the idea that ecological systems have a complex dynamic separate from the study of individual sub-components or actions. Science used in risk analysis is inevitably highly specific and disaggregated, while often being employed to solve large and complex problems, and therefore fails to address ecology adequately.

C.S. Holling has written extensively on scientific uncertainty in ecological systems and describes the "two cultures" of ecology being "analytical" and "integrative" (Holling, 1998). Holling's characterization is another form of the binary tension between positivist (analytical) and post-positivist (integrative) although within the narrow confines of what is generally considered to be the rational, scientific study of ecological sciences. Holling notes that knowledge of ecological systems is always incomplete; therefore "surprise in inevitable. Not only is the science incomplete or uncertain, but due to anthropogenic interventions in fundamental ecological systems, it is "a moving target" (Holling, Berkes and Folke, 1998).

For Holling and others writing as part of the Resilience Alliance (Berkes, Folke, Gunderson) the necessary response to working with uncertain systems and "surprise" is adaptive management (Holling, 1978). In adaptive management, uncertainties are identified upfront, and then methodologies are developed to test hypotheses related to the uncertainties. Ecological systems management is the tool used to manage to alter or manage the system, and more importantly, to gather data to learn about the system. The learning is then applied to future management approaches in an on-going feedback loop of adaptive cycles in a nested hierarchy, which is further developed by Gunderson and Holling (2002) as the concept of "Panarchy". In essence, "panarchy" is an elaborate resource management approach to deal with uncertainty in complex, evolving ecosystems where there are unknown, unknowns. Figure 4.7 illustrates how a non-linear "reflexive adaptive" or "adaptive precautionary" approach to the science-policy interface appears, based on the "panarchy" model proposed by Holling.

Figure 4.7: Reflexive Adaptive Science-Policy Interface Loop



McEvoy (1987) describes adaptation with three evolving elements – ecology, production and cognition – noting the distinctiveness of humanity in causing change. McEvoy echoes Beck's reflexive modernity in his assessment of the ability of humans to: alter environments; respond and adapt to the alterations produced; and organize these adaptive behaviours along the lines of specific world views rooted in individual experience and understanding (McEvoy, 1987).

Adams (1973) undertook groundbreaking research on uncertainty and cognitive dissonance. According to Adams individuals are predisposed to maintaining a course of action even if new information indicates that their actions are contrary to their stated goals (Adams, 1973). This form of cognitive dissonance seems common in environmental policy whereby policymakers appear, in the words of Adams (1973) "to engage in perceptual distortion in order to justify their particular decisions."

Uncertainty is core to the integration of science in the policy process. When science becomes too close to policy or too close to the adoption of a position (e.g. Salter's mandated science), as is often the case in stakeholder-funded science, there is a tendency to under report or underestimate uncertainty within the research findings. This increases the likelihood of a false negative in risk terms. Scientists are now in the habit of minimizing the perception of uncertainty or understating uncertainty (Shackley and Wynne, 1996). Simplifying the degree and nature of uncertainty as well as omitting obvious aspects of uncertainty that scientists would intuitively consider, but policy-makers may not, contributes to the misunderstanding of uncertainty in policy making, compromising risk management decisions.

Conversely, reports funded by vested interests are often produced to create uncertainty where none may exist in the non-affiliated (i.e. to either industry or NGO interests) science community. Michaels and Monforton (2005) describe the growing phenomenon of industry attempts to undermine science certainty stating: "manufacturing uncertainty and creating doubt about scientific evidence is ubiquitous in the organized opposition to the government's attempts regulate health hazards." The anthropogenic versus natural mercury debate that took place in Canada through the 1990s is an excellent example and is highlighted in detail in Chapter 5.

One of the outcomes of uncertainty in risk management is that a decision outcome to do nothing or maintain the *status quo* is still considered to be a legitimate outcome, on par with a decision that may require significant investment on the part of government or industry. The bias in the "do nothing" outcome is not adequately addressed in risk management literature, nor is the idea that vested interests use uncertainty to encourage "no action" as a decision outcome.

Mechanisms are not in place within risk management frameworks to recognize or attempt to address the prevailing pressure to maintain the *status quo*. Moreover, there is a related reciprocal effect whereby preferred decisions and policies drive the science research agenda so that the science outputs lead to pre-determined policy options. Tickner (2002) describes in considerable detail the inherent bias to support the status quo in the context of Canada's toxic substances management under CEPA and even within Canada's interpretation of the application of precaution at the time.

Where public policy is involved scientists are obliged to describe the limits inherent in the model being used and policy-makers in turn are irresponsible when asking scientists to verify models or use models for anything more than heuristic endeavours, supportive investigation or scenario testing. "No general empirical proposition about the natural world can ever be certain" (Oreskes et al., 1994). Scientific uncertainty is inherent in most situations regarding risk management decisions to address chemicals management (Wahlström, 1999). Beck states that "anyone who insists on strict proof of causality [of pollution related illness] is maximizing the dismissal and minimizing the recognition" of industrial pollution (Beck, 1996).

According to Maler and Fisher (2005):

"The environmental field, in particular, is permeated by uncertainty. Besides the usual economic uncertainties, we have major uncertainties characterizing our knowledge of environmental processes. Often, we simply do not know the long run consequences of interventions in the environment. For example, for many new chemicals, we do not know whether they are carcinogenic or not. Our models of ecosystems dynamics are far from precise. Moreover, future preferences for environmental services are uncertain, which means that future benefits from nature preservation today are uncertain."

Scientific uncertainty has an important behavioural element related to the way in which scientists relay information to policy makers (Shackley and Wynne, 1996). When scientists are too close to policy-making there may be a tendency to under report and under estimate uncertainty in an effort to reduce policy uncertainty and maintain personal credibility as scientists (Shackley and Wynne, 1996). This phenomena is related to Beck's contention that science uncertainty creates a "legitimacy gap in the system" and policy makers no longer have legitimacy to be making decisions with incomplete understanding (Whiteside, 2006). Under reporting uncertainty is therefore a science response to closing or avoiding a legitimacy gap.

M’Gonigle et al. (1994) provide one of the most detailed and direct assessments of the role of scientific uncertainty in preventing environmental regulation in Canada. The authors cite numerous cases where:

“The regulatory framework for environmental protection in Canada has been widely noted as placing an onerous burden on those seeking to protect the environment, the effect which is a perhaps unintended, but nonetheless, de facto *bias in favour of industrial freedom of action.”*

This “bias” can be examined more closely in the context of uncertainty as it relates to Type I and Type II errors. Uncertainty may lead to decisions that turn out to be wrong. These errors can be described as Type I and Type II errors. Type I errors result from acting upon false information and Type II errors result from not acting upon true information. One of the primary observations in the environmental policy literature is that scientists and policy decision-makers have a bias toward Type II errors (Lee, 1973).

Statistical analysis also affects the balance between Type I and Type II errors. If a scientist is focused on minimizing the probability of a Type I error (by establishing stringent probability settings), which is generally the case, the probability of committing a Type II error increases (M’Gonigle et al., 1994). More importantly, M’Gonigle et al. (1994) note the “serious implications” that face lawmakers and regulators when “in many instances serious and irreversible” environmental damage occurs as a result of a lack of recognition of Type II error bias.

Figure 4.8 is a graphical representation of the relationship between Type I and Type II errors. For example, a Type I error occurs in the upper left quadrant where there is an intervention based on information that is subsequently determined to be false. The “neutral decision line” represents the theoretical continuum along which “trueness” and “intervention” intersect. A decisive intervention may be warranted where there is confidence in the accuracy of the science and this would be represented in the far upper-right quadrant. The assessment of Type I and Type II errors is retrospective. Uncertainty and certainty may also be represented as the prospective aspect of intervention. Where there is greater certainty there may be greater confidence in acting higher on the “no action – intervention” continuum.

Figures 4.8 and 4.9 have been developed to represent these ideas. The “risk decision sphere” indicates the area in which decisions tend to fall showing graphically the bias against Type I errors and in favour of Type II errors. It illustrates the idea that “no action” even where action may be warranted is a more common outcome then taking action where none is warranted. This bias is clearly stated in the draft WHO framework for guiding policy in areas of scientific uncertainty.

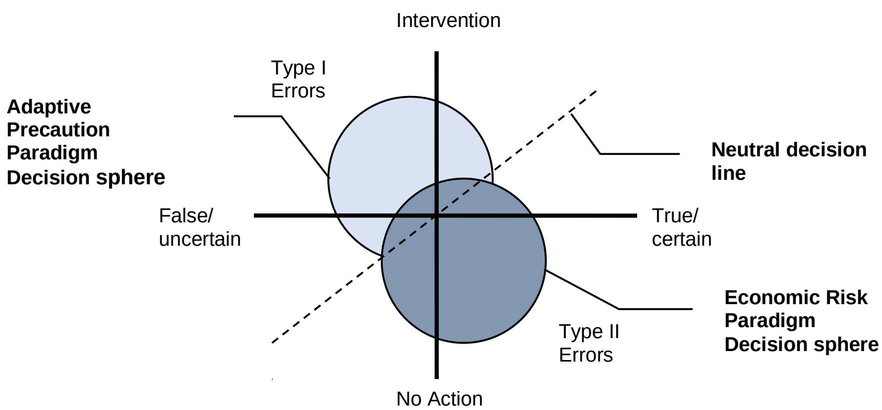
The document states that “a high level of proof is required to establish a risk, which tends to generate false negatives” or Type II errors, whereas “society as a whole is often more ready to accept a false positive” or Type I error, consistent with the idea that the public is generally more risk averse in cases where the risk is uncertain, the exposure involuntary and the consequences potentially harmful. The risk decision sphere is therefore where the risk paradigm is operationalized; precautionary decisions fall within the precautionary decision sphere; with attendant risk paradigm and precautionary paradigm characteristics associated with each.

In a study commissioned by Environment Canada, Joel Tickner addresses concerns that Environment Canada and Health Canada, under CEPA tend to over-emphasize the avoidance of Type I errors at the expense of committing Type II errors. Tickner observes that errors in risk assessment are different from errors in scientific research. Risk assessors focus on the integration of only those science studies that are highly quantitative and statistically significant to the assessment and that their objective is to achieve “high certainty that a risk is real before regulating” (Tickner, 2002).

The desire to achieve a high degree of certainty combined with the inherent lack of certainty in understanding complex ecosystems or the subtle effects of chronic low level exposure to neurotoxins pushes decisions into the risk decision sphere illustrated below. Challengers associated with the study of ecosystems increases the occurrence of Type II errors in an environmental regulatory setting due to the characteristics of ecosystems including resilience, time-lags, threshold responses, synergistic effects and issues related to study design (M’Gonigle et al., 1994).

The risk decision sphere is where Type I errors are avoided and Type II errors favoured and according to Tickner (2002) is the default decision pattern of Health Canada and Environment Canada.

Figure 4.8: Error Bias Decision Diagram



Preference for Type II errors aligns with protection of the status quo and eschewing government action or intervention. Galbraith (1992) notes that:

"…the overwhelming presumption as to the necessity for government action is negative. The case for any specific intervention must be strongly proved; the case against rests not on empirical demonstration, not alone on formal theory, but also on deeper theological grounds."

According to Galbraith in "the age of contentment" any efforts to challenge the status quo are most vigorously opposed because reform may threaten the contented. In fact Galbraith goes so far as to say that faith in "the [economic] system" is perhaps stronger than any other belief as a sustaining force. "The result is government that is accommodated not to reality or common need but the beliefs of the contented…" (Galbraith 1992). There is a relevant precautionary aspect in that Galbraith's ethos of contentment supports "a powerful commitment to the short run and to the rejection of longer-run concerns" mirroring the short-run aspects of the risk paradigm versus the longer-run perspective of the precautionary paradigm.

4.9 Risk, Error Bias and Bisphenol A: A Short Case Study

In 2008 the federal government decided to ban the sale of carbonate plastic baby bottles that contain the additive bisphenol A (BPA). This is an example where the political decision-makers acted based on public concerns and targeted media pressure created by a well-organized campaign to highlight the failure of Canada's toxic substances management framework. The Minister of Health invoked the precautionary principle stating it is "better to be safe than sorry" (Globe and Mail, 2008). Based on the author's direct involvement in the campaign to ban BPA it was clear that the science evidence alone was not the crucial factor in the government's decision to ban BPA baby bottles. Arguably there is far greater scientific evidence of the risk of harm caused by mercury in tuna. In fact Health Canada bureaucrats fought the BPA ban internally and on many occasions stated that BPA posed negligible public health risk.[9]

Kiss (2015) uses the regulation of bisphenol A and baby bottles in Canada as a reference point for examining the role of environmental organisations and the media in toxic chemicals management, referencing Smith and Lourie (2009) and highlighting the policy activities of Environmental Defence. Kiss is critical of the extent to which Environmental Defence was able to influence the regulatory outcome, however, he also notes that although it represented a shift from a technocratic to pluralistic decision structure, returning to the previous risk management regime is not the answer, given the extent to which special interests are able to dominate and manipulate outcomes (Kiss, 2015).

Udovyk (2014) uses the management of bisphenol A in the European Union to highlight the complexity of uncertainty within science-policy interactions. Udovyk concludes that uncertainty is a major challenge in chemicals management, highlighting limitations to the modern regulatory model in addressing uncertainty. She goes further in suggesting uncertainty "paralyses" science-policy interactions or enhances controversy, as Kiss (2015) describes.

[9] At the time of the bisphenol A campaign and government ban I was Chair of the Board of Environmental Defence Canada.

Bisphenol A is used by Edge and Eyles (2017) to better understand how risk, uncertainty and precaution interacted in Canada's decision to ban Bisphenol A baby bottles. They describe Canada's decision as controversial and precedent setting in the application of precaution and weight-of-evidence. The paper, oddly enough, does not reference Kiss (2015) which, from the perspective of this author as a participant in the policy process, is a far more accurate account of how the policy debate unfolded in Canada. Edge and Eyles (2017) touch on familiar themes of the policy interface dichotomy being normative versus objective, technical versus political and scientific versus precautionary.

Elliott (2002) offers a critique consistent with the research herein and my own policy experience stating; "his work does not appreciate the full significance of inter-personal, emotional and cultural factors as these influence and shape risk-monitoring in contemporary societies." McEvoy's (1987) critique of Garett Hardin's "tragedy of the commons thesis" similarly points to Hardin's depiction of individuals (in this case farmers) as "alienated, rational, utility-maximizing automatons" absent of interpersonal, emotional or cultural influences.

My experience in Canada's banning of BPA baby bottles would include a great many inter-personal, emotional and cultural factors that resulted in that specific regulatory action.[10] Maguire and Hardy (2012) provide an analysis of the federal government's RA/RM efforts under CEPA to categorize and manage the risks of vinyl acetate monomer (VAM) and Bisphenol A (BPA). They note that with respect to the subject matter, "empirical studies are rare." Their analysis effectively compares several things: the different ways that risk was characterized for VAM and BPA; the efforts of industry (in both cases) to undermine the risk characterization (in order to limit regulatory actions); and, subsequent responses from government either accommodating industry positions (as was the case for VAM) or rebuffing industry positions (as was the case for BPA). In the end, BPA was declared toxic under CEPA and several uses were banned whereas VAM was not declared toxic and no regulatory action was taken.

[10] At the time of the BPA baby bottle ban in Canada I was the Chair of the Board of Environmental Defence Canada, an environmental NGO that was the lead advocate for the BPA ban.

Missing from the Maguire and Hardy (2012) analysis is any assessment of why these two chemicals were treated so differently through the RA/RM policy process. There is no reference to the fact that banning BPA baby bottles was driven by a high profile environmental campaign achieving national media attention. BPA, moreover, fit the definition of a political chemical and in the case of the BPA ban, the power dynamic among policy actors shifted from industry to environmental NGOs reminiscent of Hajer's (1995) "discourse coalition". VAM on the other hand was an unknown, non-political chemical and did not have an environmental organization calling for it's elimination.

Sjostrom and Stenborg (2014) suggest that BPA restrictions originated from "the public's reaction" and that it was only later that "scientific evaluation proved the public right." While not an accurate portrayal of events (the science evaluation was used to provoke public action), at least Sjostrom and Stenborg appreciate the role that media played in the BPA policy debate. They did not, however, address the extent to which the media was used by Environmental Defence as a public provocation tool. Kiss (2015) provides a more accurate account of this dynamic.

Beck describes the tactics of environmental activists (Greenpeace) as "judo politics designed to mobilize the superior strength of environmental sinners against themselves" (Beck, 1996). In the case of the BPA campaign, the BPA plastic baby bottle was used effectively as a "discursive construction", "an emblem" and an "implicit critique of industrial society", using the language and ideas of Hajer (1995). The BPA campaign relied on two socio-cultural communication theories that appear to be largely undiagnosed in the academic assessments. First, the baby bottle is used as an icon or ideogram, what Umberto Eco (1998) may describe as "portraying the shapes of the things they represent". Smith and Lourie used the rubber duck to similar effect in Slow Death by Rubber Duck (2009). Second, the bisphenol A narrative plays into the mythology of good and evil, or David and Goliath, whereby big evil chemical companies are knowingly poisoning little babies, a classic activist tactic honed by Greenpeace (Beck, 1996). What Eco describes as "the social theory of conspiracy" which is "occupied by men and powerful sinister groups that can be blamed … for all of the evils we suffer" referring to Karl Popper's 1969 *Conjecture and Refutations* (Eco, 1998).

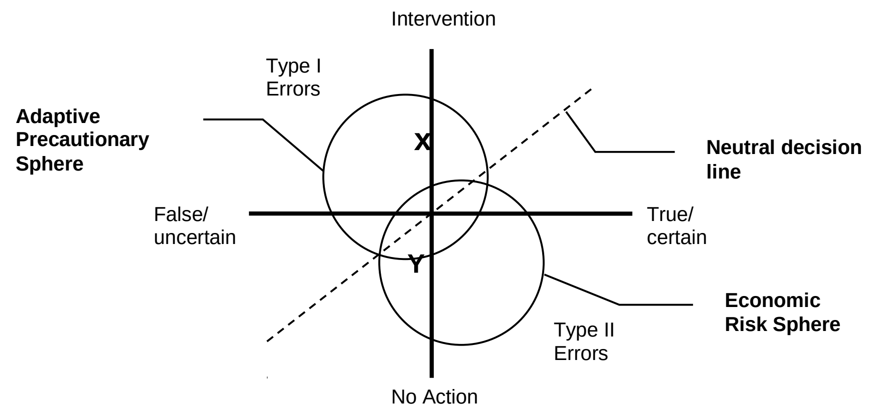
Beck, also, fails to recognize more fully, politics or the ability of environmental stakeholders as policy actors to influence environmental policies or laws in a positive fashion (Jarvis, 2007). Jarvis (2007) provides a detailed critique of Beck's work focusing to a large extent on the lack of "empirical realities" to support his thesis and relying instead on "a philosophy of fatalism." Bergkamp (2017) is also highly critical of the lack of Beck's use of empirical data to support the idea of risk society, "rather than merely relying on a hunch." Given that Bergkamp worries that Beck's ideas have entered the thinking of risk managers thereby impeding "rational, science-based risk regulatory decision-making" suggests that his perspectives may be more aligned with material society interests. As it turns out, Bergkamp is an employee of a private American law firm which in 2012 was awarded the distinction of "Belgium's Chemical Law Firm of the Year" erasing to considerable extent the independent scholarly validity of his opinions. Furthermore, it reinforces the primary thesis herein that corporate interests are highly vested in the status quo risk regulatory decision model, actively working to promote it while undermining pluralist, non-technical forms of risk decision-making, such as the precautionary approach.

Why then did the federal government act on BPA? It appears that there were at least four important elements. First, there was the use of compelling scientific research that may have passed the "weight-of-evidence" test, but most importantly was packaged for, and presented directly to, key political decision-makers. The material conformed to high standards of risk communication that Leiss notes is so often lacking. Second, there was a well-crafted earned media campaign that highlighted health risks to infants and played on the idea that one of the most fundamental activities to sustain life, feeding an infant, could be harmful.[11] Third, the federal government wanted to demonstrate that they were able to take action on environmental matters to allay public perception that they were unconcerned. Finally, specific retailers were

[11] Earned media refers to news coverage that is generated deliberately in mainstream media outlets and is not paid advertising. The BPA campaign attracted prominent, consistent high profile national media coverage in Canada. The decision by the Canadian government to ban BPA baby bottles received international news coverage.

targeted successfully to voluntarily remove BPA containing drinking bottles to demonstrate to the government that the solution was easily implemented.

Figure 4.9: BPA Case Error Bias Plot



X = Health Canada political decision
Y = Health Canada bureaucratic position

Decision-making regarding BPA is a contemporary example of toxic substance decision-making that demonstrates several elements of the thesis put forward herein. The formal risk-based decision framework within Health Canada put BPA squarely on track in the economic risk decision sphere (point Y) where avoidance of Type II errors is paramount. The policy outcome in this instance is that no intervention is made, and no policy action taken. This is the typical outcome for most toxic substance decision processes in Canada over the past fifteen years. The ultimate political decision in this case (point X) falls well within the adaptive precautionary decision sphere where there is an increased potential for a Type I error, but the nature of the health risk and the degree of public concern and the sophisticated “risk communications” framing seemed to be factors in pushing the decision into the precautionary sphere.

In Figure 4.9 it is assumed that an equal level of information regarding certainty is available and accepted by both the political and bureaucratic decision-makers. Points X and Y are plotted with the assumption that there is still some uncertainty regarding the evidence. It is possible that X and Y could each be plotted in the adjacent quadrants to the right where there is greater certainty, but it is not material to the ultimate decision.

The BPA case may also be indicative of the gradual transition taking place from the risk paradigm to the precautionary paradigm. It is one of the first examples in recent times of the federal government taking political action on a toxic substance where the political decision is more precautionary than the bureaucratic expert advice. This may be explained in part with reference to a report of the Assistant Deputy Minister Working Group on Risk Management which states:

"In a free and democratic society, where Ministers are accountable to Parliament, and thereby, to the public, societal values and the public's willingness to accept or tolerate risk are relevant and legitimate considerations for public decision making, whether or not they are consistent with a scientific assessment of the risk.
(Privy Council Office, 2000)

BPA also fits the contemporary nature of an environmental problem that suits both the characteristics of the adaptive precautionary paradigm and those of Beck's risk society in that it is a carcinogenic substance produced by industry, its use is pervasive, and it is largely unobservable by those using the products in which it is found. The risk therefore is unknown, involuntary and distributed across society. Government action to curtail the risk may therefore be described as "politically reflexive" in Beck's terminology.

4.10 Risk Assessment and Risk Management Conclusion

Kraft (2017) asks the question "Is the concept of environmental risk broad enough to permit evaluation of and action on third-generation environmental problems such as climate change, biodiversity loss, population and economic growth or the many inequities in the distribution of risks, costs, and benefits across society, generations and the world?" The answer is a resounding "no" especially in the narrow terms Kraft uses to define environmental risk. The industry of risk assessment and risk management is fraught with challenges so great relative to the problems we face that there is little value in tinkering with what has become an institutional governance mechanism captured by material society interests that prevents the advancement of ecological protection.

Scientists too are captured by the same institutional arrangements that lack any sense of societal reflexivity. Beck's concept of risk society remains an important contemporary frame to understand the failures of RA/RM as it has been and continues to be practiced. As ecological risks and economic interests continue to globalize, an absence of cultural and social reflection embedded in the scientific elements of environmental policy will perpetuate the failings of material society to grasp the magnitude of change needed.

CHAPTER 5:
MERCURY SCIENCE-POLICY, 1995 to 2005:
A CASE STUDY OF MATERIAL SOCIETY DEBATES

“And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away. Therefore the inhabitants of these regions ... find great difficulty in procuring the necessities of life ...”

(Georgius Agricola, De Re Metallica, Book I, 1556)

5.1 Introduction

Georgius Agricola, quoted above, was the founding father of modern mining and yet over four hundred years ago he recognized the ecological and human health impacts of resource extraction. His comments are both prophetic and a sad testament to the resource extraction history that began three hundred years later in Canada. Quoting a historical figure from the world of mineral extraction may seem counter-intuitive as an introduction to a case study of environmental policy and toxic substances however the appropriateness of this quote to this story is obvious in the context of Canada’s staples economy.

What began ostensibly as a case study into the challenges Canada faced with respect to the regulation of toxic substances evolved into a complex story of competing science, intergovernmental conflict, federal policy inconsistency, the appropriateness of science funding in the context of “client-focused” government priorities, and Canada’s role as global purveyor of toxic metals and minerals. It provides corollary insight into over a decade of mismanagement of the environmental science policy interface in Canada, with climate change the most obvious issue where the policy dynamics are remarkably similar. Finally, it is a story of “bureaucratic inertia” as described by Meadowcroft (2009), where the single-minded efforts of industry aligned bureaucrats put Canada’s economic and international trade priorities well ahead of domestic environmental protection.

Mercury is a substance or "political chemical", which illustrates well the considerable lag between science consensus and policy action in Canada in the period under investigation. The "natural versus anthropogenic mercury" debate highlights the deliberate abuse of science leading to a perverse application of public policy entrepreneurship designed to favour industrial interests over the public interest. A case study of the nature and extent to which Canada's pollution policies were trapped in Beck's "material society" and the institutions of "organized irresponsibility."

5.2 Context and Relevance: The On-going Poisoning of Grassy Narrows

Mercury was selected as the substance under investigation largely due to the extensive and long-lived body of research on the ecological and human health effects of mercury. It is possible that mercury has been studied as much, and for as long, as any other toxic element, with lead being the other obvious contender. Mercury was known and used in Roman times, with well-documented cases of toxic effects dating back 2,000 years. The affliction of the British "mad hatters" with serious neurological impairment from the mercury used in the beaver felt pressing process, was of course made famous by Lewis Carrol in the 19th century.

Contemporary poisoning events in Minamata Japan in the 1950's, Grassy Narrows (Ontario) in the 1960s and Iraq in the 1970's provided the basis for our modern understanding of acute mercury toxicity. In Japan, the quest for conclusive evidence of the source of the contamination led to the continued poisoning of hundreds of thousands of citizens despite the knowledge and evidence gathered by local physicians.

The case study focuses on policy debates and decision-making that took place between 1995 and 2005 in Canada regarding mercury risks and uncertainties. Mercury pollution and Canada's historic failure to clean-up legacy mercury contamination has re-entered policy debates with the re-emergence of the Grassy Narrows Wabaseemoong First Nations poisoning in scholarly research and high-profile media stories. Grassy Narrows connects the discourse of "material society" with that of "settler society". Ilyniak (2014), for example, explains the Grassy Narrows poisoning as part of Canada's history of "capitalism and colonialism", through which "racism [and] exclusion" expose First Nations to "industrial hazards".

A short description of the mercury released into Ontario's English-Wabigoon River system creating the Grassy Narrows incident was provided in Chapter 2. Following are some additional details. In 1970, Japanese scientists examined fish caught in the English-Wabigoon River system and found them to be contaminated with mercury from a nearby chlor-alkali plant. At the same time, they studied members of the Grassy Narrows First Nations community and found that they displayed symptoms of methylmercury poisoning or "Minamata disease" (paresthesia, visual field constriction, ataxia, impaired hearing and speech impairment) (Takaoka et al., 2013). Individuals examined in 2010 were found to have symptoms comparable to those in communities in Japan that suffered from methylmercury poisoning (Takaoka et al., 2013)

In 1985, the governments of Canada, Ontario, and the companies Reed Paper and Great Lakes Paper reached a legal settlement with Grassy Narrows and Wabaseemoong, providing both communities with $17 million for health-related damages stemming from mercury pollution. Simultaneously, Ontario granted Great Lakes wide-ranging indemnity and assumed all of the Dryden plant's environmental liabilities (McGrath, 2016). As a result of these agreements and formation of a Mercury Disability Board, Canada and Ontario began providing financial redress for area victims of Minamata disease and between 1986 and 2016, the two governments issued average payments of $400 a month to over 300 people (Beaumont, 2016). Still, there were ample signs that the region's mercury contamination had yet to subside. In 2003, Donna Mergler of the Université du Québec à Montréal found the community's average mercury intake to be nearly three times that of the limit considered to be safe (Poisson, 2016).

In 2009, after a series of sales and mergers, Weyerhaeuser, an American forest operator and investment trust, acquired Great Lakes Paper's operations and closed the Dryden mill. Several years later, following local reports of ongoing contamination, Ontario ordered Weyerhaeuser to begin monitoring mercury levels surrounding the Dryden mill in 2011 (McGrath, 2016). In July

2016, Weyerhaeuser successfully overturned this order in court, citing Ontario's assumption of the mill's environmental liabilities in 1985 (McGrath 2016). In the meantime, one of the mill's former employees contacted the Grassy Narrows community and admitted to burying approximately fifty drums of liquid mercury in the region in 1972 (Goldberg, 2017). Scientists from the Center for Minamata Studies in Japan – who had been studying the region since the mid-1970s – reported in September 2016 that more than 90% of the population of Grassy Narrows and Wabaseemoong showed signs of mercury poisoning.

They observed that one meal of Grassy Narrows fish represented mercury exposure equivalent to 150 times the recommended limit (Paul, 2016). Moreover, the scientists identified the area as "one of the most heavily contaminated in Canada" and predicted – in contrast to government reports – that its mercury contamination was still spreading to "new locations" (Paul, 2016). At the same time, reporters from the Toronto Star had collaborated with volunteers from EarthRoots, an environmental organization, to gather a dozen samples from the dumpsite identified by the mill's former employee. There, they discovered mercury levels up to eighty times the expected concentration for soil in the region (Goldberg, 2017).

In the face of growing public outrage, Ontario committed in February 2017 to "identifying potentially contaminated sites" and developing a "remediation action plan for the English-Wabigoon River system" in partnership with the people of Grassy Narrows and Wabaseemoong (Goldberg, 2017). In June 2017 the Ontario government announced that the province would spend $85 million to clean up the "industrial mercury contamination" responsible for poisoning the communities of the Grassy Narrows and Wabaseemoong First Nations (Porter, 2017), fifty years after the initial contamination.

Berkes (1980) documented problems related to scientific uncertainty and mercury pollution in Canada in the 1970's. At the time, the primary scientific uncertainty centred on "evidence" of Minamata disease; despite massive amounts of mercury entering numerous watercourses in Ontario (thousands of kilograms per year in some cases) and populations dependent on local fish for protein and livelihood, industry was unprepared to act without documented evidence of poisoning (Berkes, 1980; Iannen 1996). Governments of the day demonstrated behaviour consistent with chronic downplaying of environmental concerns and did little "to dispel these uncertainties and to educate the public" (Berkes, 1980).

The suffering and devastation caused by the contamination of English-Wabigoon River system provoked scholars to examine the recent history of the Grassy Narrows First Nations from the perspective of environmental justice. Willow (2014) contrasts the sociological impacts of environmental degradation in Grassy Narrows with rural Ohio, noting: "People who are already disadvantaged confront disproportionately degraded environments" and furthermore, "members of indigenous and minority groups cope with the detriments of industrial activity, but enjoy few of its benefits" (Willow, 2014). Ilyniak (2014) adds that Grassy Narrows is a textbook example of "environmental injustice" related to: i) the "distributional patterns of environmental hazards"; ii) the "historical processes [determining] hazard distributions"; iii) "patterns of non-recognition"; and iv) "unequal access" to levers of decision-making.

These four factors illustrate how the public and private sectors "produce and maintain Indigenous oppression" in service of their commercial interests where "industrialization disproportionately affects marginalized communities" and that government and industry justify pre-existing preferences with "illusory gains" (e.g. short-term employment opportunities in ecologically hazardous industries) (Ilyniak, 2014). Environmental injustice experienced by the people of Grassy Narrows is an important illustration of the interconnectedness of settler society to material society in Canada with a "deeply embedded colonial history" in staples theory.

Mitchell and D'Onofrio (2016) conclude that, "Ultimately, the first step in addressing issues of environmental injustice [in Canada] will be an open and honest examination of the links between race, socio-economic status and environmental risk." They add that, as a nation, Canada must strive to better understand "how communities belonging to historically disadvantaged groups are disproportionately exposed to and impacted by environmental hazards".

Mercury therefore is used in the case study as a bellwether or representation of toxic substances management and control in a material society; with the simple notion that if mercury use and exposure could not be managed under Canada's toxic pollution policy framework, given the relative abundance of scientific "certainty" or evidence of ecological and human health harm; it becomes hard to imagine whether any substance, notably carbon, can be adequately controlled to minimize human and environmental harm in Canada.

5.3 Mercury Policy Framework 1995 to 2005

The Canadian Environmental Protection Act, 1999 (CEPA) titled "An Act respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development" came into force on March 31, 2000, following an extensive Parliamentary review of the "original" CEPA 1988. CEPA was, and still is, Canada's primary environmental protection legislation focusing on the management of toxic substances, although it is limited to substances "not otherwise regulated by law."[12] CEPA was the legislation that authorized federal action to control mercury use and release.

CEPA provides legislative authority to:

- protect human health and the environment, including its biological diversity
- promote pollution prevention
- apply the precautionary principle
- effectively manage toxic substances within strict timeframes
- virtually eliminate releases of man-made substances determined to be persistent, bioaccumulative and toxic
- achieve the highest level of environmental quality while taking into consideration social, economic and technical concerns.

Substances are deemed "CEPA-toxic" if they:

[12] Supreme Court Decision *Canada v. Hydro-Québec.*

- have or may have an immediate or long-term harmful effect on the environment or its biological diversity; or
- constitute or may constitute a danger to the environment on which life depends; or
- constitute or may constitute a danger in Canada to human life or health.

The federal Ministers of the Environment and Health jointly administer CEPA. The Minister of Health administers human health issues related to toxic substances. The Minister of the Environment administers all other aspects of the Act.

Mercury is a designated CEPA toxic substance however CEPA has rarely been used to regulate mercury in Canada prior to 2005. Instead, the federal government relied on other mechanisms, notably the Canada Wide Standards process under the Canadian Council of Ministers of the Environment (CCME). The Canada-Wide Accord on Environmental Harmonization was signed in January 1998 by the CCME members (all provinces with the exception of Quebec). A sub-agreement to the Accord, the Canada-Wide Environmental Standards (CWS) is a framework to set priorities, develop non-regulatory standards in consultation with stakeholders, and implement work plans to address potentially toxic substances. The CCME endorses "the principles of sustainable development, pollution prevention and the precautionary principle" to manage toxic substances.

The CCME does not have the authority of the federal government to set national requirements for action, but rather provides for "regional flexibility" and allows jurisdictions to use a "variety of regulatory and voluntary measures" to achieve goals. In practice, each of the signatory provinces participates in consensus-building processes with stakeholders aimed at achieving consensus on common "Canada wide" targets.[13]

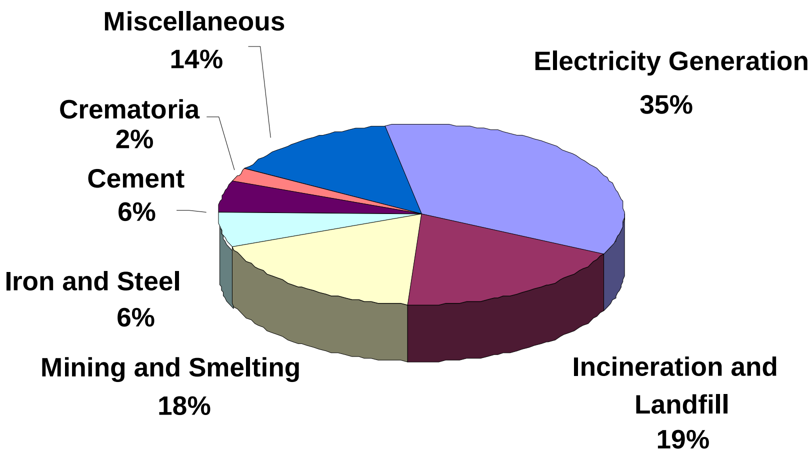
[13] The term "Canada wide" is used to differentiate from either "federal" which implies federal government authority or "national" which implies participation of all provinces.

5.4 The Science Policy Debate: Natural versus Anthropogenic

One of the most contentious issues at the science-policy interface regarding mercury was the debate regarding the relative contributions of anthropogenic versus natural mercury to the global cycle. Uncertainty regarding the total amounts, and more importantly relative amounts, of natural versus anthropogenic mercury released to the atmosphere led to considerable debate within science and policy circles in Canada and abroad. The debate in Canada was largely between the federal departments of Natural Resources Canada (NRCan) and Environment Canada. NRCan and its agents promoted the idea that mercury in the environment was largely a result of natural sources whereas Environment Canada (along with the global mercury research community) supported evidence that suggested human sources contributed to more than half of the global mercury pool. This case study illustrates science-policy interface issues and toxic pollution policy discourse in Canada, within the material society framework.

Natural sources of mercury include volcanoes, forest fires, evaporation from soil and water, among others (UNEP, 2002). Anthropogenic sources include coal-fired electric power plants (the largest globally), metal smelters (the largest in Canada), incinerators, landfill sites and the re-emission of historical anthropogenic releases from water and soil. Figure 5.1 below illustrates the primary anthropogenic sources of mercury in Canada at the time of the policy debates. Four of the top five sources were related directly or indirectly to industrial activities, namely mining and mineral processing and/or combustion.

Figure 5.1: Canadian Mercury Emissions (% by Sector, 2003)



Source: Environment Canada, 2007.

Scientists were undertaking considerable research on global mercury cycling with attempts to estimate the relative anthropogenic contributions of mercury. This research included measuring natural mercury flux, deposition rates, global transport and anthropogenic emission sources. Understanding the mercury cycle was fundamental to understanding mercury behaviour in the environment, including regional and global aspects of mercury pollution (Schuster et al., 2002).

At the core of this issue was an important policy consideration: the relative amount of anthropogenic mercury entering the global cycle had a bearing on the effectiveness of efforts to reduce mercury emissions. The greater the natural contribution, the less effective would be efforts to control anthropogenic sources. For example, if natural mercury sources were thought to exceed anthropogenic sources by a considerable margin, the argument used by large mercury emitters was that any efforts to control their emissions sources would offer negligible benefit to the environment due to the large natural component that continues to "pollute" the environment.

A common feature of mercury science symposia of the day (i.e the biennial "Mercury as a Global Pollutant" conference) was the presentation of various estimates of the total mercury pool with estimates of the natural versus anthropogenic contributions. At the time, the uncertainty regarding mercury contributions from natural sources became less of an issue with the convergence of data that "points unequivocally" to the important contribution of anthropogenic mercury (Fizgerald et al., 1998).

Early estimates of the total and relative quantities of mercury in the global pool contained wide margins of error, representing the uncertainty within the data (Jackson, 1997). Weiss et al. (1971) estimated natural mercury emissions at between 25,000 and 150,000 tonnes/year and anthropogenic contributions at 6,700 tonnes/year. Lantzy and MacKenzie (1979) estimated natural emissions at 29,300 and anthropogenic at 11,500 tonnes/year. In 1991 Lindqvist et al. (1991) reduced the natural estimate to 3000 tonnes/year and the anthropogenic to 4500 tonnes per year. Notably, the relative anthropogenic emissions shift dramatically from averages of below 30 percent in the early estimates to 60 percent in Lindqvist et al.'s estimate.

Subsequent work by Robert Mason and his colleagues in 1994 and 1995 (including Hudson et al.) narrowed the estimates to natural emissions of 2200 tonnes and anthropogenic emissions of 2700 tonnes. With these revised estimates the contribution of anthropogenic mercury (including anthropogenic mercury reemitted from oceans) was estimated to be between 55 and 68 percent of total mercury emitted to the atmosphere. This was the beginning of the science discourse shift from recognizing the global mercury problem as being predominantly natural to predominantly anthropogenic. A critical shift that provoked a predictable response from the vested industrial interests tied to material society.

The debate regarding natural versus anthropogenic mercury was most prominent in the mid to late 1990's and Canada played an important role. In 1994 a Canadian government researcher working with the Geological Survey of Canada (GSC, a department of Natural Resources Canada) wrote a critical review of anthropogenic mercury flux research in the journal Environmental Science and Technology (Rasmussen, 1994). This paper helped focus much of the global controversy at the time. Rasmussen noted that when studies suggest that a significant portion of the mercury found in remote regions are of anthropogenic origin, "their validity needs careful examination." Ironically, it was careful examination of Rasmussen's research that became the subject of much academic investigation and ultimately undermined the validity of her research.

The GSC paper provides an excellent example of the challenges inherent in assuming that science and policy are distinct and separate. The nature and style of the research findings and conclusions illustrate well the emerging trend of scientific research used to promote a vested industrial society interest. The research paper reveals what is perhaps the primary intent of the work, which relates more to policy than science, by suggesting that the “conclusions hold serious implications to both government and industry” (Rasmussen, 1994).

Another colleague of Rasmussen, Coker (1995), cited Rasmussen’s work in an Ecological Monitoring and Assessment Network (EMAN) paper. EMAN is a creation of Environment Canada, and Coker was a colleague of Rasmussen’s in the Geological Survey of Canada. Coker supported one of Rasmussen’s primary arguments that using vertical core samples to estimate anthropogenic deposition was inaccurate due to surface enrichment (diagenesis) following deposition. Coker stated that due to surface enrichment, core samples do not identify anthropogenic mercury nor do they indicate atmospheric deposition.

As with much mission-driven material society research or “mandated science” as described by Salter (1998), the intended outcomes for NRCan were to produce research that minimized anthropogenic sources and specifically atmospheric deposition (e.g. from smelters) while asserting the need for “more careful examination.”

Coker cautioned that “knowledge of the processes by which a metal is mobilized, transported, precipitated, and possibly remobilized, is of prime concern in order to comprehend possible controls on that metal's dispersion…”. Although ostensibly a “science” paper, Coker too enters the realm of policy by introducing the idea of emission controls as a “prime concern.” It certainly was a prime concern to resource companies, specifically the mining and coal-fired electricity industry.

In 1995, R. G. Garrett (Rasmussen's supervisor) presented to the Canadian Mercury Network Workshop making the point that natural mercury emissions from geological faults and deep sea hydrothermal sources were significant and that certain rock types are "natural hazards" due to high levels of mercury. Garrett's presentation referenced Rasmussen's 1994 research paper several times. In addition to pointing out the erroneous and incorrect research on "large natural emissions", Garrett cited studies that suggested the long-range transport of mercury from major smelting point sources in Canada could not be detected, and that within a relatively short distance (120 km) of major smelting point sources mercury levels reach natural background levels. At the same time, Lucotte et al. (1995), among Canada's leading mercury research groups at the time, found anthropogenic mercury to be "ubiquitous" at sites up to 1400 km from industrial point sources.

Garrett concluded that "the distribution of Hg in the Canadian environment is regionally controlled by geological factors" noting that "clearly future research must be focused on this issue in order to assess the relative contribution of natural and anthropogenic processes in effecting the environment, and to assist in selecting appropriate effective risk management options." Here Garrett, a scientist with natural resources Canada is making a policy statement by invoking the concept of scientific uncertainty and invoking risk management, Canada's primary regulatory framework for toxic substances.

Reference to "appropriate" risk management options introduces the policy interface into this "science" paper and provides an early indication of the direction of future NRCan research efforts at that time. The focus on the significance of geological mercury together with the references to the modest regional impacts of smelters fits well with the mission of Natural Resources Canada "the government lead in promoting the responsible development and use of Canada's mineral and metal resources" (NRCan, 2006). This quote is a direct representation of Canada's long history as a staples economy.

The scholarly scientific evidence refuting NRCan's research was building. In 1995 Lucotte et al.'s study of mercury in sub-Arctic Québec concluded that "at sites situated 200 to 1400 km away from the closest industrial centers, we find the ubiquitous presence of anthropogenic mercury." Lucotte held the Research Chair in the Environment at Université du Québec a Montréal and was the lead researcher on a national mercury research effort supported by NSERC called COMERN (Community Mercury Research Network).

In 1997 Togwell Jackson, a research scientist with Environment Canada, produced a paper titled "Long-range atmospheric transport of mercury to ecosystems, and the importance of anthropogenic emissions – a critical review and evaluation of the published evidence." Jackson notes that the purpose of his review was "to resolve the controversy" regarding the role of natural emissions and specifically the GSC research by examining the considerable evidence available to determine the extent of anthropogenic atmospheric mercury releases in remote ecosystems and to determine how lake sediment cores should be interpreted.

The dispute between the scientists at Environment Canada and Natural Resources Canada was privately vitriolic; symbolic of the tensions and rivalries under the dysfunctional management of the environment file under the Chretien Liberal government. Moreover, it was representative of the binary conflict between the firmly entrenched material society epoch that Natural Resources Canada embodied, and the struggling, insufficient attempts of Environment Canada to transition to an adaptive precautionary approach in the epoch reflexive modernity.

The details of the scientific debate at the time are worth expanding upon since it was one of the most contentious elements of the GSC research and was a featured argument in much of the NRCan literature on natural mercury. Lake sediment core samples provide a historical record of atmospheric deposition. Substances that fall from the sky into lakes deposit themselves on the lake bottom where they become part of sediment layers, which are buried with successive years of detritus and lake sediment. After hundreds of years of this process, sediment layers provide a historical record of atmospheric deposition.

Lake sediment cores of a meter or more are commonly extracted to identify mercury concentrations at various depth intervals, which are correlated to specific time horizons

(Engstrom and Swain, 1997). A large body of literature produced over the period showed that mercury in the upper portion of the sediment cores (i.e most recent deposition layers) contained the greatest mercury concentrations, declining with depth until they leveled off in pre-industrial times (Jackson, 1997). Typical mercury deposition profiles are shown as bar or line graphs that equate mercury concentration with depth and/or date. Engstrom and Swain (1997) used this method to evaluate mercury deposition in Minnesota and Alaska.

Their data showed on average slight declines in mercury deposition after 1980, mercury deposition peaking in the 1960's and 1970's, sharp increases in deposition beginning in the 1940's, up to the peak period, and gradual increases from the mid-1800's until the 1940's. Prior to 1850 mercury deposition rates were relatively constant. This methodology was used to determine deposition rates in remote lakes around the world and the findings were strikingly similar globally. It was this method of scientific research that helped support the commonly cited figure that post-industrial mercury deposition rates were 1.5 to 3 times higher than pre-industrial deposition rates in remote regions and 2 to 10 times higher in industrial areas (UNEP, 2002).

Rasmussen argued that "post-depositional diagenetic processes" explained the higher mercury concentrations in the upper (more recent) portions of lake sediment cores. Diagenesis is a geological term that refers to chemical and physical changes in sediments prior to or as part of the transformation from sediment to sedimentary rock. The specific processes referred to by Rasmussen suppose chemical reactions that lead to physical processes whereby mercury migrates to the top of the sediment following deposition. These processes, according to Rasmussen, resulted in the higher concentrations seen in the upper levels of the core samples, versus post-industrial deposition as the cause.

Jackson states that "Rasmussen (1994) has questioned the quantitative significance of emissions due to human activities in the long-range atmospheric distribution of Hg, claiming that insufficient attention has been paid to the assessment of natural sources of Hg in the Earth's crust." He also noted Rasmussen's challenge to the evidence on mercury enrichment in the upper portion of core samples of lake sediments from remote regions but refers to the processes that Rasmussen described as “only negligible” in their effect.

Engstrom and Swain’s (1997) paper on atmospheric deposition using sediment cores provided important evidence of the mercury levels following industrial emissions and use patterns, including the decrease in Hg concentrations post-1980, matching well the proportionate decline in industrial mercury emissions in the same period. This evidence discounted the diagenesis theory of migration of mercury to the upper most levels of sediments as the primary cause of the mercury enrichment. More specifically, Engstrom and Swain reference Rasmussen’s work on diagenesis stating that “such mechanisms cannot explain” their findings.

In 1998, four of the world’s leading mercury researchers responded directly to Rasmussen’s (1994) paper. The paper, authored by Fitzgerald, Engstrom, Mason and Nater (1998) was supported by an additional seventeen mercury scientists from around the world, including several Canadian government researchers, all of whom “contributed materially and critically” to the paper. The paper was a fine example of the global science community rallying together to clarify and characterize the nature of uncertainty and identify areas of emerging consensus within the scientific community.

They noted that the purpose of the paper was to provide the “careful scrutiny” that Rasmussen calls for. The authors’ contention in the paper was that not only were the GSC researcher’s conclusions unsupportable, but the case for atmospheric mercury contamination was “stronger than ever.” Fitzgerald et al. pointed to erroneous and/or outdated information as the source of the GSC assumptions, leading to the misleading conclusions that were drawn. They specifically address “the weaknesses in interpretation and the choices of information used to support the contention that geological sources of mercury are the principal contributors of mercury in remote locations.” This was clearly demonstrated in the erroneous material presented by Garrett in the 1995 Mercury Research Network workshop described above.

They, like Jackson (1997), provided a detailed, point by point critique of Rasmussen's methodology, choice of data, inferences and conclusions. They affirmed, for example, the validity of lake sediment core sample data that showed post-industrial anthropogenic enrichment, dismissing Rasmussen's diagenetic process arguments.

Privately, scientists involved in the preparation of the Fitzgerald et al. paper pointed to their frustration at Natural Resources Canada's continued efforts to produce and promote scientifically misleading information regarding anthropogenic metals in the environment.[14] They felt the need to provide a collective global critique to end the controversy, a controversy that was created and promoted largely by Canadian government researchers, with Canadian government and resource industry funding. The non-government mercury scientists in this case recognized the critical link between science and policy. Clarifying the science to help resolve the policy controversy was the explicit motivation behind the Fitzgerald et al. paper.

From the perspective of the Canadian government it was clear that the controversy was not resolved and if anything, following the Fitzgerald et al. paper, the Canadian federal government increased resources and attention on natural mercury in the environment.

The same year as the Fitzgerald et al. paper (1998) the seminal U.S. Mercury Report to Congress (EPA, 1997) was released. At eight volumes and 2,000 pages it is almost certainly the most comprehensive report on mercury in the environment ever produced. In the report, the U.S. Environmental Protection Agency (EPA) identified anthropogenic mercury emissions at between 50 and 75 percent of the total annual atmospheric emissions, consistent with the summary of the literature prepared by Jackson (1997).

In a review of the Report to Congress, Hanisch (1998) captured the science-policy interface debate summarizing the Report to Congress that not all emissions are produced by human activity, and that uncertainties have resulted in controversy about how to control mercury

[14] I was an active mercury policy researcher at the time and interacted regularly with Jackson, Fitzgerald, Lucotte and others, and attended the 1995 Mercury Research Network meeting described here.

emissions. Hanisch concluded that regarding contributions of global and local mercury to the environment "most researchers agree with William Fitzgerald of the Department of Marine Sciences at the University of Connecticut."

With a global science consensus having emerged and with Canadian researchers, both inside and outside the federal government, playing an important role in the research and the consensus process, it was not obvious at the time why the anthropogenic versus natural mercury debate warranted a renewed research focus for the Canadian government.

In 1999 the Canadian government embarked on a three-year $600,000 study "to obtain better estimates of natural mercury emissions from major Canadian natural sources/geological features, such as soils water surfaces, vegetation, and fault zones." Rasmussen was one of the researchers assigned to the study, although at the time had moved to Health Canada.

The Metals in the Environment Research Network (MITE-RN) was established with Federal government funding, also in 1999, including a $3.5 million National Science and Engineering Research Council (NSERC) grant, to match $1.95 million from the Mining Association of Canada and Ontario Power Generation. Unspecified in-kind contributions were made by Environment Canada, Natural Resources Canada and the Department of Fisheries and Oceans Canada. Moreover, participation in the MITE-RN mercury research by University of Guelph, the MITE-RN host, was made possible in part by funding from the Canada Foundation for Innovation (innovation.ca, 2000), another Federal government funding source. The NSERC award was provided to "help answer critical research questions being asked by scientists and policy makers."

In fact, mercury scientists were no longer asking those questions and the only policy-makers asking questions were those responsible for mineral and metals development policy in Canada. The NSERC announcement, for example, notes that the outcome of this research is "to implement policies that support the sustainable use of metals in Canada". This language is consistent with "sustainability" discourse, embedded in material society framing, that was used throughout NRCan literature related to the continued exploitation and use of mercury and other metals and minerals, including, for example, lead and asbestos.

The NSERC grant for MITE-RN appears to be related to the federal government's competitiveness and innovation strategies. According to Lopreite (2006) NSERC's funding emphasis shifted to include a focus on partnerships between universities and industry, and specifically research networks; one of the objectives of the shift was to assist the global competitiveness of Canada's resource economy. By supporting research with the aim of casting doubt on the science of mercury in the environment, it may be argued that the MITE-RN grant abetted this objective.

MITE-RN was a joint government, industry, academic research venture and fell under the auspices of the Canadian Network of Toxicology Centres (supported by, among others, the Mining Association of Canada and the Canadian Chemical Producers Association) located at the University of Guelph under the direction of Dr. Len Ritter, one of Canada's leading authorities on industrial risk management. MITE-RN was established to provide policy advice to the government on the issue of metals in the environment. The focus of MITE-RN and the sponsors involved was therefore less on scientific research and more on the risk management aspects of metals in the environment as they related to metals control policy in Canada (i.e. regulatory aspects of toxic metals). It is through this lens that one better understands how the research priorities and research findings of MITE-RN appeared disconnected to, and inconsistent with, the global mercury research community; highly consistent, however, with the economic interests of Canada's resource sector.

MITE-RN was formed in 1998 and terminated in 2004, a Phase II of MITE was consecrated as the Metals in the Human Environment Research Network in 2005. The Board of Directors of MITE-RN included representatives of several of the largest metal (including mercury) emitters in Canada (Inco, Noranda and Ontario Power Generation) along with government officials, and academics involved in the research.

It appears that despite the global mercury research community having resolved the most contentious issues regarding relative anthropogenic contributions of mercury to the environment, the sponsors of MITE-RN were not content with the findings and used MITE-RN as a vehicle to continue to inject scientific uncertainty into the anthropogenic versus natural mercury debate.

In March 2001, MITE-RN organized a "science policy workshop" (attended by the author) with three plenary presentations, one from a senior Environment Canada official, one from the Mining Association of Canada, and one from an Ontario Power Generation (OPG) employee and MITE-RN board member.

The focus of the OPG presentation was on the question of natural versus anthropogenic emissions noting that "natural sources are believed to be large but are poorly understood." In one of the presentation slides emissions from coal plants were compared to releases from natural sources in Canada. The figure used for natural sources was from a twenty-year-old Environment Canada reference that suggested natural emissions in Canada were 3500 tonnes per year. Officials in attendance from Environment Canada were outraged and pointed out how preposterous and out-of-date the data were. The MITE-RN summary notes of the workshop refer to the knowledge gaps of natural sinks presented by OPG but excluded any reference to the discussion regarding the misleading presentation of obsolete and inaccurate data.

To place this into perspective, by 1995 the atmospheric mercury research community had arrived at a global natural flux figure of 2200 tonnes (Hudson et al., 1995). Given that Canada occupies 7 percent of the world's land mass and land occupies 29 percent of the Earth, a more accurate figure for natural flux for Canada would be 45 tonnes[15], significantly less than the 3500 tonnes identified, and even less than the 50 tonnes emitted by US coal plants (as juxtaposed in the OPG presentation). One of the researchers of the Hudson et al. (1995) paper (Don Porcella) was an employee of the Electric Power Research Institute (EPRI), an organization that OPG worked

[15] Differences between emissions from land and ocean evasion overly simplify this calculation but variations are such that the order of magnitude is not affected.

closely with on mercury research, making the MITE-RN/OPG presentation of outdated and misleading data even more inappropriate.

In December 2002, the United Nations Environment Program (UNEP, 2002) published the Global Mercury Assessment. This 250-page report documented all major aspects of mercury in the environment including a chapter on sources and cycling of mercury to the global environment. Both the Fitzgerald et al. (1998) and the Jackson (1997) papers are referenced in the global cycling chapter. No papers by Rasmussen, Garrett or any NRCan researchers are referenced. The UNEP study concluded that, “natural sources account for less than 50 percent of the total releases.”

In June 2004 MITE-RN prepared a “Science Brief” (as part of their final round of publications) titled “Separating Natural from Human-related Metals in the Environment.” The brief highlighted the significance of natural sources of metals in the environment noting that “elevated concentrations are not always the result of human activities.” The “science” brief also stated that “unnecessarily stringent environmental regulation of the industrial sector, based on incomplete knowledge of natural sources, may result in severe economic consequences with no measurable benefit to Canadians or the environment.”

As with much of the NRCan and MITE-RN work the “Science Brief” focused on policy, not science, highlighting the threat of environmental regulation to economic interests. Environmental regulations in Canada are not “unnecessarily stringent.” In fact, regulations specific to the use or emissions of metals, notably mercury, in Canada were almost entirely absent at the time. The assertions and accusatory language in the MITE-RN brief is consistent with the common tactics used by industrial interests to undermine policy processes as described by Rampton and Stauber (2001).

The brief claimed that “surprisingly, research on natural sources of metals and their impact and contribution to elevated concentrations at remote and background sites has been relatively scarce” ignoring the decades of extensive global research efforts to do precisely that. Jackson

(1997) based his paper on the “wide range of relevant published information” on the same subject. As opposed to “scarce” Jackson asserted that “an impressive amount of evidence comprising many different kinds of information supports the conclusion that the anthropogenic contribution to the long-range atmospheric flux of mercury rivals or exceeds the natural contribution in quantitative importance.”

Eight years before the MITE brief, Miller (1989) noted that “levels of mercury sufficient to justify governmental warnings are now found in fish taken from waters far from any known sources, and our new understanding of the atmospheric dynamics of the metal makes it perfectly understandable that this should be so.”

Fitzgerald et al. (1998) concluded “in summary, there is much published literature on the mercury cycle” and “much recent research on mercury.” They did also caution readers that inaccurate results “plague” mercury research misleading those unfamiliar with the field, a likely reference to the Canadian federal government’s various research efforts designed to create and promote scientific uncertainty.

The MITE-RN science brief ended with a section on “Additional Information” where four references were provided. Three of the four references provided were to papers written by either Garrett or Rasmussen, including Rasmussen’s 1994 paper that was so thoroughly discredited by Jackson (1997) and Fitzgerald et al., (along with the global mercury research community) in 1998. None of the broadly accepted, peer-reviewed research from acknowledged mercury researchers was cited in the MITE-RN materials.

With the natural versus anthropogenic debate settled within the scientific community (although still actively disputed at NRCan) Environment Canada launched the Canada Wide Standards process to set mercury content and emission control guidelines for a number of products and sectors. The standards applied to waste incinerators, base metal smelting, dental amalgam and fluorescent lamps. Progress was made by each of these sectors in voluntarily limiting the release of mercury to the environment leading up to 2005 (CCME, 2005). No regulatory actions were taken and in no instances did restrictions impinge on the economic activities of the resource sector in Canada.

Based on personal experience, the mercury standards developed under the CWS process are typically generated by the mercury using and emitting proponents in the process and represent the codification of business as usual practices. It is worth noting that CEPA, the federal government's primary toxic substance regulatory tool was not being used, consistent with the policy interests of NRCan. No regulatory requirements are established under the CWS process. The voluntary guidelines used are administered and monitored at the provincial level. The CWS process was, in effect, an abdication of federal responsibility to regulate the use and release of toxic substances.

5.5 Policy Analysis

The case study raises a number of important questions regarding the purpose, use, understanding, independence, rigour and funding of science in Canada. It highlights a case of what one would assume the federal government would not classify as "sound science". For example, what are the standards for independent science research in Canada? To what extent were government-funded organizations accountable for their understanding and representation of accepted, peer-reviewed science? Are federal funding agencies mandated to support the vested interests of federal departments and their "clients" even though the research is not supported by global academic consensus? What are the economic and political implications of science research in Canada and what bodies, if any, consider these? And what motives may explain Canada's departure from the prevailing worldview of anthropogenic metal emissions? And finally, what can we learn from the mercury case as it relates to contemporary science debates with notable parallels, such as climate change policy.

Related to some of these questions, the federal government initiated a government-wide exercise in 1998 to address the science-policy interface. This exercise led to the 1999 Science Advice for Government Effectiveness (SAGE) report. SAGE was the first initiative of the Council of

Science and Technology Advisors (CSTA), established by the federal government in 1998 (the year MITE-RN was formed) to provide external advice to the cabinet on the management of the federal science and technology enterprise.

The SAGE report outlined six principles for effective science advice: early issue identification; inclusiveness; sound science and science advice; uncertainty and risk; transparency and openness; and, review. The SAGE principles were developed recognizing that the federal government "requires an effective science advisory process that leads to better government decisions, minimizes crises and unnecessary controversies, and capitalizes on opportunities." It does not appear as though the SAGE principles were applied to the natural versus anthropogenic mercury research activities of the federal government; in fact, most of the SAGE principles appear to have been violated.

At the very least one might imagine the call for the establishment of federal guidelines to help ensure the procurement of valid, peer-reviewed science designed to aid, not undermine, environmental policy objectives in Canada. Much of the mercury research described herein, however, was funded and carried out by federal agencies after the introduction of Science Advice for Effective Government (SAGE), the document presumably designed to avoid the creation of poorly conducted, and clearly bias research programs, such as MITE-RN, created by NRCan. Despite considerable effort to improve guidance on science advice to government through the SAGE process, federal government departments and funding agencies continued to engage in scientific research that:

1. was not needed;
2. introduced confusion and uncertainty into otherwise well-established scientific understanding;
3. was highly aligned to the interests of industrial "clients" of resource departments; and,
4. did not conform to basic standards of academic research.

Each these four findings support the findings of Fahey and Pralle (2016) whereby contemporary research has identified an emerging pattern in policy analysis, that environmental policy is at the nexus of “two complex and evolving systems: natural environments and human policy-making and governance.” The four points are symptomatic of Canada’s political economy as described in detail by Hessing et al. (2005); notably “the continuing high profile of the resource sector” and “original dependence on staples export.” Moreover, the policy behaviour of the federal government during the mercury science debates was a strong representation of the epochal tensions between material society and risk society, still witnessed today.

Figure 5.2, following, illustrates the three phases of the science policy interface for mercury.

Figure 5.2: Three Phases of Mercury Science and Policy

Time Frame	Phase 1 Pre-1960 Direct Elemental Exposure Phase	Phase 2 1960-1990 Modern Industrial Phase	Phase 3 1990 – 2005 Post Modern Global Pervasive Phase
Science	Hg metal a well-known neuro-toxic	Hg methylation and bioaccumulation discovered	Chronic low-level health effects detected related to fetal and child development
Mercury Form	Exposure to metallic vapour	Methylmercury in fish, seafood, as preservative in grain	Methylmercury in fish and marine mammals
Mercury Release	Direct use or extraction of metallic mercury volatilizing in air	Direct release or use of methylmercury or inorganic compounds	Pervasive global mercury concentrations from multiple historical and present releases
Exposure Point	Occupational hazard, beaver felt hats, mercury miners, product manufacturing.	Ingestion of fish and seafood or accidental consumption of preserved food (grain) in specific contaminated areas.	Ingestion of fish and marine mammals with elevated mercury due to global mercury uptake. Specific populations and/or consumption patterns (First Nations, inland fisherman, tuna)
Concentration	High metallic vapour concentrations in air	Elevated methylmercury concentrations of up to 100,000 x above background	Very low, measured in ppm or ppb
Evidence of Hazard	Serious neurological and behavioural damage and disease leading to death	Modest to severe neurological damage with death in serious cases	Subtle developmental impairment in children
Temporal Exposure Profile	Acute and chronic exposure	Acute exposure	Chronic exposure
Spatial Profile	Site specific occupational setting	Facility-based or local ecosystem pollution event	Pervasive global presence with regional concentration anomalies
Uncertainty Profile	Little uncertainty regarding gross cause-effect relationship based on direct observation but lack of scientific research	Initial uncertainty regarding cause-effect and source contributions. No uncertainty remains regarding acute toxicity	Emerging medical consensus regarding evidence of problem, considerable uncertainty regarding extent of harm and benefits of action
Policy Response	Restrict worker hours, improve working conditions	Regulate chlor-alkali plant emissions and major sectoral uses (paint, batteries etc)	Regulate incidental emitters (incineration, smelters, coal) and expand global research efforts

5.6 Conclusions

The anthropogenic versus natural mercury debate, or material society conflict, highlights one of the fundamental problems regarding the science-policy interface in Canada as it relates to environmental policy decision-making; namely the manufacturing of scientific uncertainty. This issue is not unique to Canada or the environment, “manufacturing uncertainty and creating doubt about scientific evidence is ubiquitous in the organized opposition to the government’s attempts regulate health hazards” (Michaels and Monforton, 2005).

Two possibilities may have led to the federal government’s continued support and promotion of inaccurate and misleading research. In the first, one must suspend any reasonable expectation of the competence or integrity of the bureaucrats; which is that the research scientists and funding bodies involved were unaware of the global literature on mercury and the critical assessments of the GSC work. This is highly unlikely given the narrow subnetwork of policy actors connected to the mercury research community and global events, such as the “Mercury as a Global Pollutant” Biannual Conference, that provide opportunities for mercury researchers and bureaucrats from all disciplines to convene. In fact, representatives from NRCan and the GSC attended these events regularly. MITE-RN may have also served this networking function had it followed its mission, as stated, as opposed to acting as a promoter of discredited government science.

The second and more plausible conclusion is that the on-going research and research-funding decisions were manifestations of material society; influenced by those with a vested economic interest in promoting specific policy outcomes (avoiding the regulation of the resource sector) manufacturing scientific uncertainty through the promulgation of deliberately misleading research.

There are at least two factors that together may support a motive for the second explanation. First, NRCan and the GSC were “client-focused” agencies and their clients were primarily the extractive resource industries. This phenomenon was part of the federal government’s shift to a market-based mandate under the Chretien Liberal government. Similar issues, for example, have been raised in connection with drug approvals at Health Canada, where scientists were instructed to relax procedures in order to accommodate "corporate clients" in the pharmaceutical sector (Turner, 2001). Leiss (2000 and 2001) describes in detail many cases where political and corporate interests have interfered in environmental, health and resource science to promote decisions that favour the interests of departmental clients over public interest.

Former federal Environment Minister, David Anderson, was highly critical of his Liberal colleagues for lack of action on climate change stating that "there is no coherent leadership" in the Canadian government and moreover stating that half a dozen "departments of government … are notorious for being spokespersons for industrial sectors or being essentially lobbyists for industrial sectors" (Canadian Press, 2004). In John Kenneth Galbraith's "Culture of Contentment", Galbraith explains lack of motivation to alter the status quo as a sign of contentment and he attributes much of the general "bureaucratic syndrome" to the pursuit of contentment within bureaucratic organizations (Galbraith, 1992). As is no doubt the case with the GSC scientists, the issue is not about individual achievement or errant research, but conformity to the organizational mandate and to overall departmental policy. According to Galbraith individual contentment within bureaucratic institutions is "powerfully served by acceptance of this formally stated … purpose" (Galbraith, 1992).

In 1995 a Science and Technology Management Framework was developed for NRCan. One of the objectives listed in the framework was "to enhance client focus." In a 1999 evaluation report the evaluators concluded that "NRCan remained responsive to client needs." A similar issue faced the US Geological Survey (USGS) in the 1880s, when at the time a debate ensued over the tension between the USGS as a servant to economic interests, versus an independent, public-minded scientific research organization (Frodeman, 2003). Economic interests of the day (largely ranchers and farmers) were successful in convincing the US Congress to limit the USGS authority to narrow economic interests (Frodeman, 2003).

The debate returned over 100 years later when in 1994 the US Congress attempted to eliminate the USGS in favour of privately funded geological research (Frodeman, 2003). This was early in the days of the US government's on-going efforts to eliminate and/or manipulate publicly funded independent science research.

In Beck's *Risk Society* these are examples of risk management being linked to the "very fabric of industrial society" (Jarvis 2007). Having a temporal context within which to understand Beck is relevant in the mercury case study in that it conforms with Beck's focus on the failure of modern (as in late twentieth century) institutions to manage the consequences of modernization (Matten, 2004).

The second factor that may explain the MITE-RN research program is that government research funding had shifted from independent government research to jointly funded research whereby federal research dollars required matched funding. In most cases the funding match was with industry funds where the research is driven by an economic imperative related to industrial interests. Several researchers have commented that this approach can lead to situations where the industry funding partners with federal contributions fulfilling the match set the research agenda. The MITE-RN initiative is a good example of this. According to some scientists this is a serious impediment to independent research in Canada and can lead to questionable public spending (Zayed, 2005, personal communication)

Stringing the sequence of information found in the case study together it is not hard to imagine how a department that sees the mining industry as its client base, and is instructed to be more client focused, working within a framework that requires matched research funding from industry, leads to the funding and promotion of research that is consistent with industrial interests, but not the public interest. Public policy is generally biased toward promoting economically favourable outcomes for organized groups that lobby for their own narrowly defined self-interest, versus groups that lobby for widely dispersed public benefits (Laundry, 1990).

The fact that a quasi-independent research body such as MITE-RN would see fit to highlight scientific papers and ideas that were repeatedly dismissed by the global scientific community raises other more serious questions about the objectivity and credibility of the organization, and the ethical standards within Natural Resources Canada at the time.

If the case were unique, it may be excused as the work of overzealous government employees eager to fulfill the directives and mandate within their department. Sadly, lead, asbestos and climate change science all have similar stories in Canada in the same time-frame. Canada was increasingly criticized at international fora for the continued extraction and export of asbestos to impoverished countries without the capacity to ban or acquire alternatives. NRCan, until recently, was supporting research suggesting that Canada's asbestos is safe. Climate change research experienced similar issues although at a much more significant global scale with well-publicized cases of industry-sponsored organizations established with the sole purpose of casting scientific doubt on the cause, severity or even existence of global warming as a phenomenon (Rampton and Stauber, 2001).

The science-policy debate on natural versus anthropogenic mercury in the environment casts an unappealing pall on Canada's reputation for credible, independent science research. It also provides insight into the shifting science-policy interface in environmental policy-making and the role of government funded "client-based" policy research that emerged in the 1990s designed to meet the objectives of corporations as clients. Public interest and environmental protection became secondary in this model of public policy.

There is a fundamental flaw in Canada's procurement, oversight and use of science to aid environmental policy-making. Mercury science debates mimic, although in a much less public way, the competing science and internecine battles between Environment Canada and Natural Resources Canada, notably on climate change policy, which characterized the failed environmental policies of the Chretien years.

The analysis points to many serious failures in the federal policy system directly contravening efforts toward effective environmental policy entrepreneurship. First, was the inappropriateness of the federal government assigning NRCan with responsibility for leading the mercury research given the department's vested interest in their clients. This arrangement amounted to a direct conflict of interest on the part of NRCan. Second, it illustrates the power imbalance within the federal policy system and, at the time, Environment Canada's subordinate and largely ineffective role in regulating toxic substances. Third, it highlights the risks involved in sub-contracting government research to third-party quasi-academic institutions.

In this case the governance and funding model MITE-RN was so antithetical to the independence of the matter under investigation that it raises serious questions about adherence to even the most rudimentary conflict of interest rules. Fourth, federal government efforts to enhance policy relevant science advice (i.e. SAGE) clearly failed to have any bearing on the actual procurement and use of science to aid environmental policy decision-making.

The mercury debate sheds light on Canada as a global policy laggard at that time, where not only was there a lack of policy effectiveness, but Canada played an active role in undermining global policy efforts to control the use of toxic metals. Parallel efforts to promote global asbestos use, and Canada's general inability to provide rational policy leadership on a range of environmental issues point to the more fundamental assessment of staples theory and material society overwhelming the "science" side of the science-policy interface. Represented in the perverse entrepreneurial nature of Canada's environmental policy stance, of client-focused, manufactured science, and the deliberate fomenting of science uncertainty to cast doubt on the utility of regulating toxic substances.

The case highlights Marshall et al.'s. (2017) "political turmoil" between policies and regulations where sustainability goals restrict human economic endeavour, as well as Buckeley and Newell's (2015) science-policy paradox. Wesselink et al. (2012) comment that the science-policy interface is an "interweaving of interests and politics" exhorted the need for "reflexivity on the part of scientists working at the science-policy interface regarding the political choices implicit in the policy discourses they work within and help construct." Again, the science cannot be seen as "rational" or "objective" when the scientists are tied to proponents or opponents of specific policy outcomes.

The research is consistent with Beck's risk society theory in the extent to which uncertainty and risk of ecological collapse are not scientific or ecological issues themselves, but rather in this case constructed by material society interests. Canada's pollution policy regime is therefore trapped between the material society epoch (accentuated by staple economy institutions), and an emergent risk society attempting, without success, to introduce adaptive precautionary approaches.

Concluding on one of the few positive notes in this story; responsible efforts of independent scientists and government scientists at Environment Canada, such as Togwell Jackson and others that led and contributed to the Fitzgerald et al. paper, resulted in critical contributions to the betterment of science and policy, and need to be encouraged. Although millions of taxpayer dollars were wasted, and years of obfuscation and delay were endured, peer-reviewed science prevailed (at least in the science domain), no thanks to Canadian federal government science and policy funding directed by NRCan.

CHAPTER 6:
ORIGINAL RESEARCH FINDINGS AND DISCUSSION

6.1 Introduction and Methodology Review

Four primary research activities were undertaken to inform the understanding of the science-policy interface in pollution policy in Canada; and specifically, to investigate their relationship to risk, precaution and uncertainty in decision-making, using mercury policy between 1995 and 2005 as the primary period of investigation. Two of the four research activities were traditional primary data gathering; in the form of in-person expert interviews and an on-line expert survey. These research activities provide original primary data sets related to the thesis subject.

The research focuses on risk and uncertainty in the environmental policy sphere referencing pollution policy in the 1995 to 2005 period to highlight the intersection of three areas of increasing complexity: ecological complexity, governance systems complexity and stakeholder complexity. This is juxtaposed with a growing neo-liberal political environment bound in Canada's historic resource-based political economy described as material society.

This Chapter includes results and discussion of the quantitative survey research methods, augmenting the literature review and case study on mercury. The research methodology is designed to disprove the conventional policy understanding that Canadian environmental policy practices are "science-based" or "evidence-based". Specifically, the goal of Chapter 6 is to explore the economic risk and adaptive precautionary paradigms through expert interviews and an on-line survey of environmental representatives, experts and stakeholders in government, industry and non-government organizations and demonstrate with quantitative research the binary tension between the economic risk paradigm ("material society") and adaptive precautionary paradigm ("risk society") using pollution policy in Canada in the 1995 to 2005 period. The quantitative research contributes to the understanding of Beck's world risk society theory as a manifestation of material society and specifically addresses the empirical analytical shortcoming of Beck's work. This is combined with a response to Watkin's call for a contemporary ecological analysis of the role of staples theory in defining Canada's "bias towards resource exploitation."

Interviews were conducted with experts in the field of pollution policy in Canada, active in the 1995 to 2005 period. Thirty individuals were interviewed representing both the bureaucratic and political sides of government, as well as environmental non-government organizations, environmental lawyers, academics and representatives from industry.

Interviews were conducted in person where possible with all but two interviews being conducted in person. Interviewees each signed detailed research consent forms and indicated whether they wished to be quoted or remain anonymous. One interviewee wished to remain anonymous all others consented to be quoted. An ethics review was undertaken and approved. Interviewees were all professionals in the field discussing professional matters related to their expertise. No personal information was gathered aside from profession and title. Interviews took on average between 60 and 90 minutes to complete. Interviewees were selected based on research conducted by the author into leaders that have cross-cutting expertise, typically in one or more of the following areas: federal pollution policy, risk management, the precautionary principle, mercury policy, and or science-policy interface issues related to the environment.

The interviews provided direct relevant insight into the dissertation topic as well as providing a practical context to support the ideas developed based on academic literature. In person interviews were used to design the on-line expert survey.

Seven hundred individuals completed an on-line expert survey. The survey is the main body of original research and forms the basis for new thinking on the concept of precautionary versus risk-based paradigms in environmental decision-making.

The third research method comprised detailed case studies. The primary case study is an action research case study prepared by the author amid active mercury policy deliberations in Canada. A variation of the mercury case study was published in Canadian Environmental Policy and

Politics - Prospects for Leadership and Innovation, Third Edition (Van Nijnatten, Debora L. and Robert Boardman, Eds., 2009).

An additional case study written by the author is included in the Appendix as a participatory action research study involving direct mercury experimentation on the author, namely Action Research Case Study on mercury.

The fourth research method also contributes to the establishment of original primary data in the form of formal information requests to government. These include the results of an Access to Information request under the federal *Access to Information Act* and the results of three Environmental Petitions submitted to the federal Commissioner of Environment and Sustainable Development pursuant to the *Auditor General Act.*

6.2 Organization of Research and Findings

The purpose of the dissertation research, as described in the first Chapter, is to identify and analyse the concepts of risk, precaution, and sound science, in the context of the science-policy interface in pollution regulation in Canada, focusing on the period of 1995 to 2005. A specific goal of the research is to understand and comment upon the science-policy interface by exploring the idea of an “economic risk paradigm” representing material society interests and an “adaptive precautionary paradigm” representing risk society. The research was conducted through expert interviews and an on-line survey of environmental representatives, experts and stakeholders in government, industry and non-government organizations to demonstrate with quantitative research the binary tension between material society and risk society.

The quantitative research contributes to the understanding of Beck’s world risk society theory which in turn provides new research and thinking to better understand Canada’s environmental policy failures as a manifestation of material society interests.

The discussion is organized under two main headings each representing areas that constitute theoretical and practical challenges for the policy-interface in Canada. First, is the theoretical conceptualization and application of uncertainty and an attempt to situate the 1995 to 2005 period of “environmental policy disarray” within three temporal phases of environmental policy in Canada (Figure 6.8).

Second, is a discussion of the economic risk versus adaptive precautionary paradigms. This includes the comparison of the theoretical risk-precaution decision curves developed as part of the dissertation research, with the results of the expert survey plotted within the graphs corresponding analysis of the survey data and plotting of survey data within the risk-precaution decision graphs and the idea of two dominant and conflicting theoretical paradigms.

Precaution and pollution prevention in the context of Canada’s primary pollution regulatory mechanism, CEPA, and specifically the way in which mercury pollution policy has been addressed in Canada, is discussed. Results of Access to Information requests have been used to understand mercury pollution decision-making related to mercury. Fourth, is further discussion of the idea of competing policy paradigms including attempts to graphically illustrate policy paradigms and the science-policy interface.

6.3 Survey Results

The survey identified some trends that help explain the challenges faced by policy-makers in the face of scientific uncertainty. Well over half (59 percent) of corporate responders either agree or strongly agree that risk management systems demand greater scientific certainty than in the past when risk management was less common. Whereas 39 percent of NGOs support this statement. This suggests that industry has a better understanding of risk management systems. Government responses, at 54 percent, were closer to the views of industry and again government representatives may have a better understanding of the risk management process.

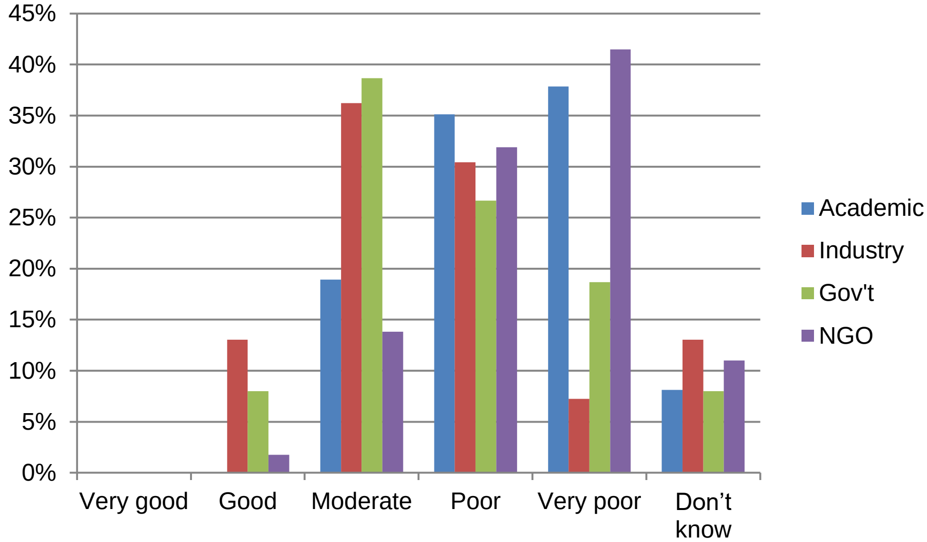
When asked whether research on global ecosystems introduces more uncertainty than certainty, industry and government respondents were most likely to agree (38 percent and 46 percent). Academics mostly disagreed (60 percent) and NGOs were split evenly with 50 percent disagreeing.

Taking the results of these two questions, industry respondents agree that RM requires more certainty and they are also the group agreeing most to the idea that research introduces more uncertainty. This is one demonstration of the impasse that RA/RM introduces into policy decision-making.

When asked whether environmental policy-making addresses uncertainty well, responses were consistent across all groups, with two-thirds of industry, academics and government disagreeing with the statement and 70 percent of NGOs disagreeing. The view across all groups is therefore that uncertainty is poorly addressed in environmental policy-making in Canada.

When asked to rate Canada's efforts at implementing risk assessment only 4 percent of total respondents considered Canada's efforts to be good or very good. Nearly three-quarters of academics and NGOs rated the efforts as poor or very poor. Over one-third (36 percent) of industry respondents rated Canada's RA efforts as moderate and approximately the same number rated them as poor.

Figure 6.1: Federal Government Efforts at Implementing Risk Assessment



There was a general sense that accountability in risk decision-making was lacking. Nearly half of government respondents, disagreed with the statement that risk management decisions are accountable.

Corporate and NGO views diverge dramatically with respect to the role of economics in decision-making, consistent with the idea that there is a significant divergence between material society interests as represented by industry, and risk society interests of non-industry experts. It is also consistent with Kraft (2017) remarking on how the perspectives of scientists varies with place of employment, with industry scientists being much more conservative relative to risk of harmful substances. Nearly three-quarters (72 percent) of NGOs believe risk management decisions are based mainly on economics whereas only 30 percent of corporate respondents share this view. Academics share the view of NGOs. And government respondents, at 60 percent agreeing that economics are the main factor, are more closely aligned to NGOs and academics.

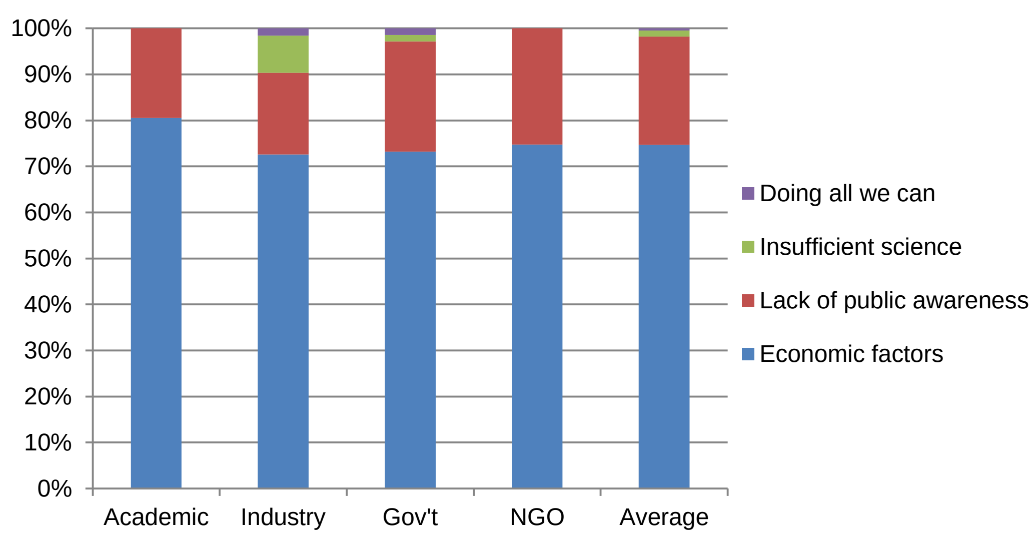
NGOs are also disinclined to believe that risk management decisions are based mainly on science or that risk management decisions are in the public interest with only 6 percent of respondents agreeing to either of these statements.

The following question is at the core of the issues under investigation in the dissertation:

Why, given the considerable scientific evidence of the potentially serious environmental harm being caused by humans, do societies not take more action to reduce the risk of harm?

The consistency across respondents from different sectors is remarkable with between 73 percent and 81 percent of all respondents citing economic factors as the main reason preventing action to reduce the risk of environmental harm caused by humans. *According to experts from both "sides" of the environmental pollution debates, Canada is therefore trapped in material society.* On average, three quarters of all respondents cited economic factors. Academia and NGOs were the two cohorts where "insufficient science" was never the primary reason for not acting. Approximately 10 percent of industry respondents attributed lack of action to "insufficient science." "Lack of public awareness", which may be a proxy for political motivation to act, was cited by between 20 and 25 percent of respondents.

Figure 6.2: Why Given Scientific Evidence of Harm We Do Not Act



Three main conclusions can be drawn from this set of expert interview questions. First, there is a widespread sense that government does not implement RA/RM processes effectively. Two, there are two dominant cohort groupings with the industry cohort representing one perspective, and

NGOs, academia and government cohorts roughly aligned with a different perspective. Industry respondents are much more inclined to view RA/RM processes favourably. Three, there is universal agreement across the cohorts that in answer to the question “why given scientific evidence of harm we do not act”, economic factors are the dominant reason.

6.4 Assessment of Risk-Precaution Decision Pathways

A central theoretical concept tested in this research is the idea that there are two dominant paradigms for understanding risk and uncertainty. These were described in Chapter 2 and specifically in Figure 2.1, Material Society Risk Society Epistemic Alignment Table, representing characteristics of the material society epoch versus the risk society epoch.
The two distinct paradigms are the “economic risk paradigm” also called risk-based and the “adaptive precautionary paradigm” also called precautionary.

The initial idea of two policy paradigms existing was based on interactions with individuals working in the risk management and pollution regulatory fields from NGOs, industry and governments, noting the very different kinds of responses to similar risk scenarios. A specific element of this research was to determine the extent to which, first, the concept of the two paradigms could be represented graphically, and second, whether there was a possibility that the theoretical graphical representation could be modeled using actual survey data.

As an initial step, based on anecdotal responses, two distinct paradigms were plotted to graphically represent them. Figure 6.3 is the resulting sample graph of risk-precaution decision curves based on anecdotal experience created to test the theory of two paradigms and help the design of the survey instrument. Figure 6.4 is the survey instrument used to produce the actual graph, found in Figure 6.7. Figures 6.5 and 6.6 are the theoretical risk precaution pathways against which the survey data is being tested.

Figure 6.3: Sample Graph of Decision Curves Based on Anecdotal Responses

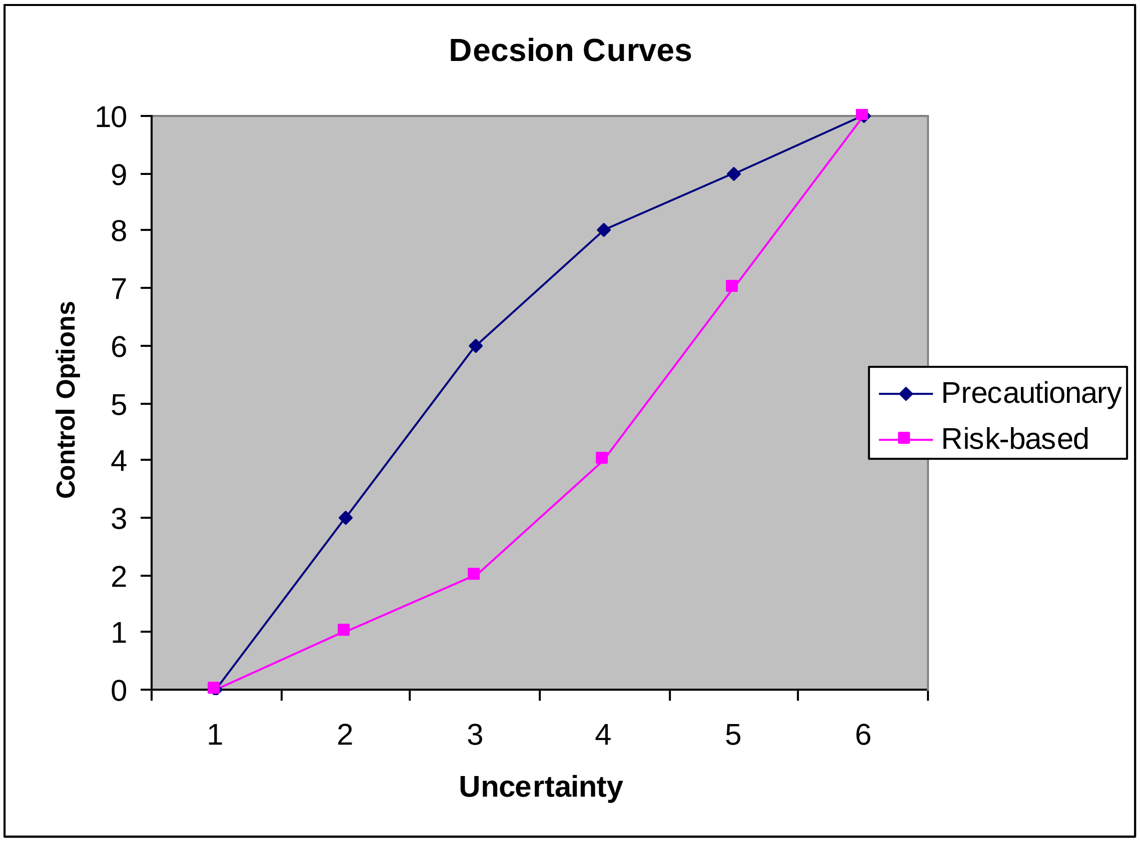


Figure 6.4: Risk-Precaution Paradigms Decision Graph Survey Instruments

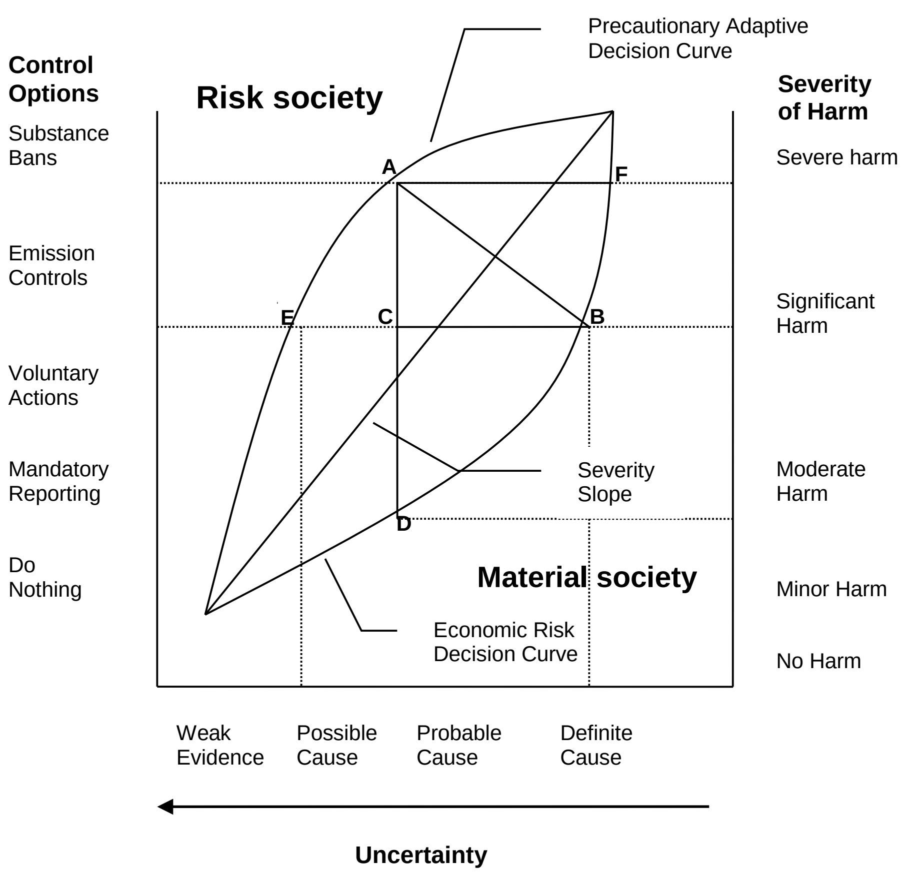
Please provide a numerical response of between 1 and 10 for the following ***five situations*** where the following hazardous substance/product control options are considered:

1 = doing nothing
2 = voluntary reporting
3 = voluntary labeling
4 = mandatory reporting
5 = mandatory labeling
6 = voluntary controls
7 = limited mandatory controls
8 = comprehensive mandatory controls
9 = limited substance/product bans
10 = comprehensive substance/product bans

You may choose any whole number between 1 and 10, inclusive. For each of the five situations a control decision is being considered regarding a substance identified as toxic. There are five differing degrees of uncertainty defining each situation, with decreasing uncertainty:

Situation 1 No evidence and high uncertainty regarding risk
Situation 2 Weak evidence regarding risk
Situation 3 Moderate evidence indicating strong possibility of risk
Situation 4 Considerable evidence indicating strong probability of risk
Situation 5 Conclusive evidence, little uncertainty regarding risk to human

Figure 6.5: Risk-Precaution Decision Pathways for Severe Harm



AB = Precautionary Gap – AB is measured at its widest point, generally in the Probable Cause range.
AC = Control Gap – Control Gap represents the difference in proposed control options for the same degree of uncertainty.
AD = Risk Perception Gap – the greater the severity slope the greater the Risk Perception Gap.
AF = Uncertainty Gap 1 – As information improves and uncertainty is reduced, the Uncertainty Gap becomes smaller.
EB = Uncertainty Gap 2 – In the probable cause range, the Uncertainty Gap is at its greatest

Figure 6.5 describes precautionary and risk-based decision path curves in relation to control options. The Precautionary Adaptive Decision Curve is characterized by a steeper slope as it moves through the higher uncertainty ranges, indicating a propensity to support more restrictive control options in the face of uncertainty. At point E on the precautionary curve, control options range between voluntary actions and emission controls where significant harm is present but cause of harm is in the possible range. At point A on the precautionary curve, substance bans are supported where severe harm exists and where there is probable cause.

The Economic Risk Curve is characterized by a more gradual slope in the higher uncertainty ranges with a steeper curve as information becomes more certain. At point B on the Economic Risk Curve, emission controls are warranted where harm is significant and where certainty exists. The line AB represents the Precautionary Gap and occurs at the greatest point between the Precautionary Adaptive Curve and the Economic Risk Curve, typically at a point directly above the Probable Cause range. The Precautionary Gap (AB) illustrates how the precautionary approach accepts a greater degree of control with greater uncertainty. The greater the distance AB the greater the degree of curvature in the Precautionary Adaptive and Economic Risk Curves, signifying greater disagreement between those with a precautionary perspective versus risk-based stakeholders.

Line EB represents the Uncertainty Gap, the difference in acceptable levels of uncertainty between the Precautionary Curve and the Risk-based Curve where the same control option is adopted. For stricter control measures a much higher degree of confidence is required on the risk-based curve. In general terms, uncertainty is described by policy experts as reliability and is related to the concept of confidence. The greater the uncertainty, the less reliable the information is, and therefore the less confidence in decision-making.

Scientific uncertainty is an important element of uncertainty and one that requires attention in pollution regulation, as noted in the survey results. There are many aspects of scientific uncertainty. For the purposes of this paper, scientific uncertainty includes the broad notion capturing the many sub-sets of uncertainty within science and may be defined generally as a lack of consensus among the science community regarding a particular phenomenon.

The Severity Slope represents the severity of harm; the greater the severity of the problem the greater the severity slope. The Risk Perception Gap (AD) generally increases as the Severity Slope increases. In this model the degree of severity may represent the perception of severity, since severity is to some extent related to values. GMO's represent an excellent example of where potential severity is seen as very high among those who typically favour precaution and very low among the proponents of the technology. The Severity Slope represents a point between the adaptive precautionary and economic risk-based views. In the case of GMO's both the Risk Perception Gap (AD) and the Precautionary Gap (AB) are much wider than for many less contentious environmental issues given heightened public concern and issue mismanagement with respect to biotechnology (Leiss, 1999).

There is also a temporal aspect to the relationship between the precautionary and risk-based curves. As issues mature over time, there is generally less uncertainty. The Precautionary Gap and Risk Perception Gap typically narrow as research proceeds and more information is made available to stakeholders. The two curves begin to converge with the Severity Slope finally intersecting when consensus regarding certainty is achieved.

Figure 6.6: Risk-Precaution Decision Pathways for Moderate Harm

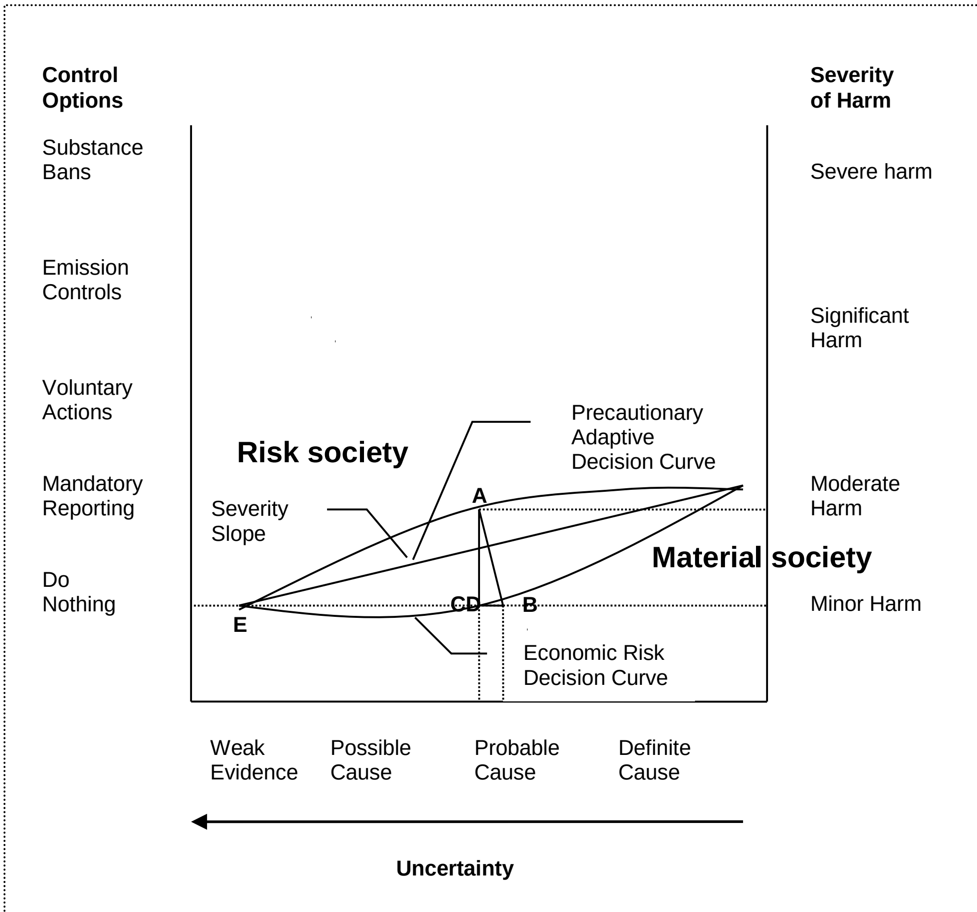


Figure 6.6 illustrates the relationship between the Precautionary Adaptive Decision Curve and the Economic Risk Decision Curve where the severity of harm is moderate. At point A on the Precautionary Curve, probable cause of moderate harm warrants mandatory reporting as a control option.

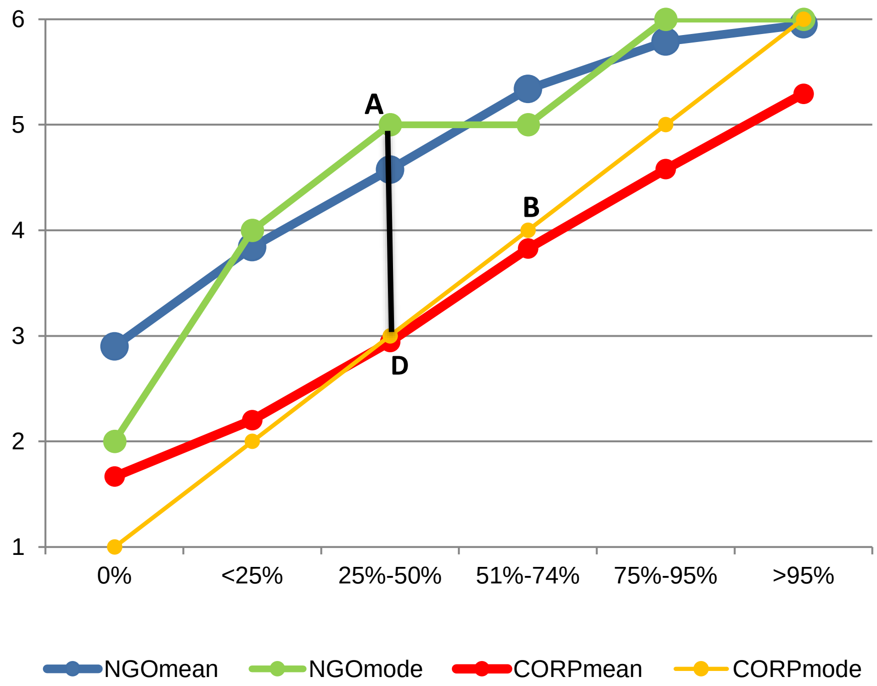
Several relationships emerge when the severity of harm slope is reduced. The Risk Perception Gap (AD) is reduced with decreased severity. With reduced harm there is less variation between the risk-based versus precautionary decision curves suggesting that the analysis may have the greatest value when applied to situations where there is a combination of available evidence, uncertainty and a higher severity of harm.

Figure 6.7 presents the results of one question (Question 4, Chapter 6 – End Note 1) in the on-line survey designed to test the hypothesis that there is an economic risk perspective and a precautionary perspective and moreover, that these two different perspectives are associated with specific sectors, namely the corporate and NGO sectors.

The “actual” lines plotted based on the survey data are a statistically relevant approximation of the theoretical risk-precaution decision pathways hypothesized in the dissertation. The central tendencies of statistical mean and mode were used to find single values to be plotted. Based on the actual survey data the NGO mean and NGO mode curves are close approximations to the theoretical precautionary decision curves represented in Figure 6.3 and Figure 6.5 with a distinctive concave downward curve. The corporate mean and corporate mode curves display less obviously the convex upward curve found in the theoretical curves of Figure 6.3 and Figure 6.5. They are, however, consistent with the theoretical model, in that in Figure 6.7 the precautionary gap, line AB, is evident as is the risk perception gap, line AD.

Figure 6.7 therefore demonstrates that given similar information on scientific uncertainty, individuals in NGOs expect more precautionary actions to be taken by government whereas those in corporations adopt the risk-based approach where more certainty is required before a control action is taken. Again, consistent with the risk society and material society epistemologies and epochs.

Figure 6.7: Actual Risk-Precaution Decision Pathways Based on Survey Results



Scientific uncertainty is often presented as a major source of conflict in environmental policy-making. Plotting the risk-precaution decision pathways with actual survey data provides a graphical illustration of this idea.

6.5 Uncertainty, Sound Science and Environmental Policy Failure

Uncertainty is a dynamic process with spatial, temporal and social elements that appear not to be well-considered in policy-making. As described in the previous chapters, uncertainty is a complex and variable issue with many dimensions and figures prominently in the science-policy interface in environmental decision-making. There are "gulfs and inaccuracies in what we know of ecological systems and human health" (Hessing et al. 2005) and an inability to manage "manufactured uncertainty". In the case of mercury in the 1990s, uncertainty manufactured by a federal department representing industrial interests is what many experts have concluded to be at the core of policy failures at Environment Canada.

The 1995 to 2005 period is a clear representation of Canada's environmental policy apparatus trapped between Beck's epochs of a relic material society in NRCan, and an optimistic but impotent adaptive precautionary, risk society, as attempted by Environment Canada.

Leiss (2001) describes numerous failures in environmental policy in Canada as "symptomatic" of "weaknesses in policy-making competence in environmental matters." He describes the late 1990s as "politically induced organizational chaos at environment Canada." What Beck would call "organized irresponsibility."

Hessing et al. (2005) describe Canada's environmental performance as a "record of unfulfilled expectations that has resulted in serious discontent with the policy status quo." Schrecker (2001) describes several environmental "policy disasters" in Canada, such as the collapse of the cod fishery, wondering whether they are "extraordinary and pathological malfunctions of the policy process" or simply routine dysfunction with impacts at a much greater scale.

Boyd (2003; 2015) reports on numerous independent evaluations of Canada's environmental performance that consistently place Canada among the poorest environmental performers of any wealthy nation. Based on these assessments, Boyd describes Canada's economy "as among the dirtiest and least efficient in the industrialized world." Further, he notes that Canada's performance declined on most environmental indicators through the late 1990s. These are assessments by the OECD, the University of Victoria and the World Economic Forum.

Year after year, through the late 1990s and early 2000s Canada's Commissioner of the Environment describes Canada's growing "sustainable development deficit" and "persistent problems with the federal government's management of key issues" in areas of air quality, biodiversity, climate change, water quality and toxic pollution. The Commissioner stated at the time of the mercury policy debates that; "cumulatively …these cracks in the foundation threaten the federal government's ability to detect, understand and prevent the harmful effects of toxic substances on the health of Canadians and their environment" (Canada, 2000). The 1995 to 2005, period under investigation in this paper, is where Canada's science-policy interface regarding the regulation of mercury providence clear evidence of policy disarray.

The thesis put forward in this paper is that environmental policy-making in Canada is hampered by the systemic weaknesses in the science-policy interface, and namely the way in which risk and uncertainty are used as deliberate tactics of industrial interests aided and abetted by a resource exploitation ethos within the federal bureaucracy. Moreover, the risk regulatory system is structured in such a way as to prevent the restriction or regulation of toxic substances, especially natural toxins as seen with mercury, asbestos and carbon.

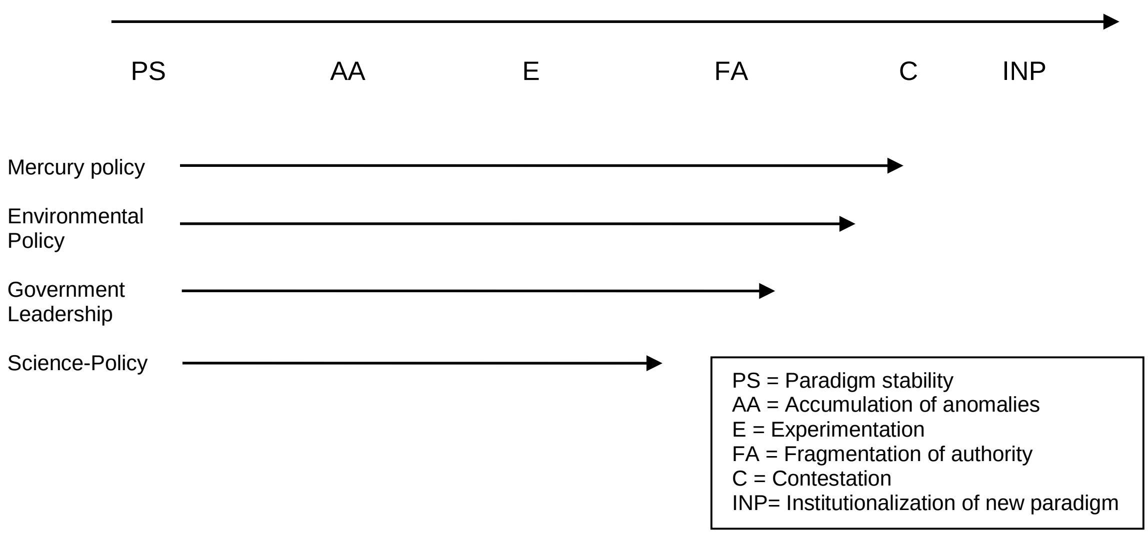
The federal government's failure to deliver on environmental policy commitments is confounded by risk management approaches that require a level of scientific certainty that is difficult, if not impossible, to achieve. The adoption and implementation of the risk assessment and risk management framework, as well as Canada's overarching approach under CEPA, is a clear representation of two theoretical underpinnings, which emerge in the survey research in this chapter.

First, Beck's material society frames the environmental science-policy debate as a contest between material industrial society and an emergent risk society. Second, material society can be further described as an example of staples theory, whereby Canada's especially poor environmental performance, relative to other industrial nations, can be explained by the dominance of resource exploitation in Canada's foundational history.

The science-policy interface may be more accurately described as a "science-society interface" where society in Canada, as represented in environmental policy decisions, is trapped between the competing epochs or paradigms. The material society epoch, characterized by resource dependency and described in this chapter as the "economic risk paradigm", dominates the political and bureaucratic decision processes. The uncertainty that undermines policy action is therefore not the technocratic scientific uncertainty within the regulatory risk framework but a systemic societal uncertainty, a manifestation of reflexive modernity, which can never be addressed adequately in material society's risk decision frame.

Applying the policy paradigm change model developed by Hall (1993) and adapted by Hessing et al. (2005) with reference to the mercury policy situation in Canada, the following emerges in Figure 6.8.

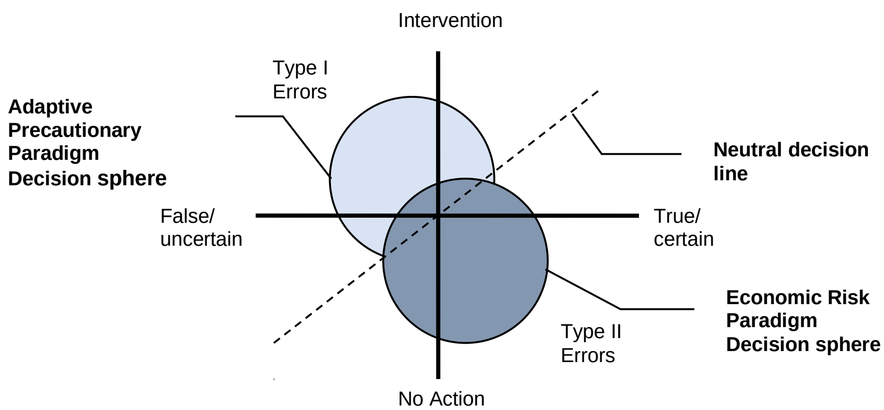
Figure 6.8: Policy Paradigm Shift



The state of Canada's policy paradigm has been plotted within the paradigm categories developed by Hall (1993) in Figure 6.8. In descending order of specificity, the mercury policy is plotted at the contestation stage, described by Hessing et al. (2005) where the debate spills into the public arena and involves the larger political process. Environmental policy more generally speaking has been positioned between the fragmentation of authority stage and contestation. At the fragmentation of authority stage, stakeholders and new participants challenge experts and government bureaucrats, and the status quo is discredited. The discrediting of the status quo has been demonstrated in numerous publications by academics as well as the government's own audit function.

The science-policy interface, it is argued is approaching the fragmentation of authority stage, as evidenced by the emergence of centralized efforts to contain the use of science advice in policy. This is undertaken specifically by defining the role of uncertainty in decisions in such a way that policy-making conforms to the risk paradigm decision sphere in Figure 6.9 whereby Type I errors are avoided and there is a bias in favour of Type II errors.

Figure 6.9: Error Bias Paradigm Decision Diagram



The result is that there is no solid foundation underpinning the federal policy system in Canada. There is no paradigm stability; the accumulation of anomalies is well documented. Climate change, as a policy discourse, more than anything demonstrates unequivocally the emergence of Beck's world risk society. Experimentation to "stretch the existing paradigm" (Hessing et al., 2005) appears to have failed. Fragmentation of authority is well-documented, including by government auditors. The material society epoch lives only in the bureaucratic and political institutions of Canada, not in the reality of global risk society.

A critical question is how long can a bureaucratic organization function at the contestation stage when the global risk society paradigm is in play? What are the conditions that push contestation to institutionalization of a new paradigm? Is there a role for adaptation, innovation, foresight and transformation? How are they applied and by whom? Or is Canada perpetually trapped in the material society epoch, unable to move into the adaptive precautionary paradigm of reflexive modernity.

Figure 6.10 is a table created to describe different periods and related characteristics of the science-policy interface. The periods represent three dominant phases in environmental policy over the forty odd years since the establishment of Environment Canada. The description of Phase 3 is theoretical, if not utopian, and not yet established.

Figure 6.10: Three Phases of Environmental Policy

	Phase 1 Science Paradigm: Government Leadership	Phase 2 Economic Risk Paradigm: Disarray and Paradigm Shift	Phase 3 Adaptive Precautionary Paradigm: Ecology and Culture
Time Frame	≈1970 – 1990	≈ 1990 – 2015	≈ 2015 -
Description	Technocratic model	Political-industrial model	Post-industrial model
Role of science	Science important and well-funded, generally held in high esteem in government and with public. Sociological critique of science emerges.	Science influence diminished, funding cut, some science discredited, science departments demoralized, public profile still generally high for independent science (non-government, non-industry).	Emergence of non-government science and new government science. Science becomes more socially relevant and acquires renewed importance in policy decision-making.
Science Discourse	Age of modern science and the technological fix	Age of sound science and mandated or manufactured science	New science, adaptive, ecologically-based, global systems context
Bureaucracy	Senior scientists play important role in government and environmental policy.	Scientists removed from senior policy making role and senior government positions. Industry policy actors dominate.	Scientists with policy sensibilities regain prominence in reflexive social and cultural systems.
Science-policy interface and uncertainty	Integrated policy decision-making, interface less clear or important. Uncertainty reasonably well accommodated.	Interface politicized, science uncertainty used to delay or influence policy	Critical new thinking to shift to a more explicit articulation of uncertainty in risk society
Spatial scale	Local and regional	Regional, national and global	Watershed, airshed, ecosystem, global cycles
Temporal scale	Short term	Short to medium term	Long term
Transparency	Very little	Variable	Increased
Independence	Reliance on independent science and relative independence of science within government.	Independent science bodies “de-funded” with limited role and limited influence. Vested third-party science bodies often tied to industry.	Recognition of distinction between independence of science and validity of research. Cross-disciplinary social and cultural integration.
Stakeholders	Public the prime stakeholder with close alignment with line departments (Environment, NRCan, Fisheries, Health etc) representing “public” interest.	Industry and NGO participation as stakeholders, but token influence with neither group clear of role or influence	Role of stakeholders at more stages in process and more meaningful in substance with clearer articulation of roles
Beck’s Risk Society	Modernity	Post-modernity – “organized irresponsibility”	Reflexive modernity
Paradigm Phases (Figure 6.8)	“Paradigm Stability”	Accumulation of Anomalies” to “Fragmentation of Authority”	“Contestation” to “Institutionalization of New Paradigm”
Effectiveness and environmental record	Generally strong ecological focus through this period. Canada a recognized leader in environmental science and policy	Lack of clarity, decision processes characterized by delay and inaction. Few environmental policies. Canada in environmental laggard status	To be determined. Early signs that credible science bodies re-emerging globally.

Canada is caught in a “paradigm shift” in environmental policy; trapped between material society policy frameworks and world risk society. Cohen (1997) offers the perspective on public sentiment in support of science describing instances where after periods of heightened scientific progress (the “Science Paradigm”) there is often a period of public mistrust or disinterest in science and a resurgence of interest arts, mythology and other non-scientific pursuits (“Economic Risk Paradigm”). This is a period which lacks stability, is fundamentally unworkable and therefore compromises decision-making. The period of 1995 to 2005 sits squarely within the period where the science-policy interface was seen to be trapped in “policy disarray” and “organized irresponsibility”.

6.6 Environmental Petition Research

One element of the dissertation is to explore direct action research methods. Using the environmental petition process in Canada is one such action research method. The purpose of the petitions was to determine the extent to which the federal government’s official responses on toxic substances management are consistent with their stated policies.

Canadian citizens are able to request information from the Government of Canada under Section 22 of the *Auditor General Act.* This provision was used to ask a series of questions regarding Canada’s approach to toxic substances management. Three petitions were submitted.

In response to the question “Which naturally occurring substances have been targeted for reduction to naturally occurring levels?” the Minister responded in part by saying “the federal government has not used the phrase *‘reduction to naturally occurring levels.’* The questions I asked were clearly presented in the context of the Toxic Substances Management Policy (TSMP), which I referred to in the background materials provided for my questions. The TSMP states that “a natural substance that is used or released as a result of human is activity may be targeted for *reduction to naturally occurring levels [my emphasis]* under Track 2.” Furthermore, not only does the federal government use the phrase *‘reduction to naturally occurring levels’* but in one of the other responses the Minister confirmed that the TSMP document, where the phrase is used, "remains the primary policy guiding the management of toxic substances in Canada."

In another Environment Canada policy document titled The Canada US Strategy for the Virtual Elimination of Toxic Substances from the Great Lakes, toxic chemicals "will be targeted for reduction …so as to achieve naturally occurring levels…" Moreover, in a response from Environment Minister Christine Stewart to a letter written at the time by the author states that "this statement is consistent with the federal TSMP and MMP (Metals and Minerals Policy of Natural Resources Canada).

The Minister is therefore making contradictory statements by, on the one hand, acknowledging the primacy of the Toxic Substances Management Policy while also stating that an important phrase in that policy "reduction to naturally occurring levels" is not used by the Federal government. This inconsistency is at the crux of the natural versus anthropogenic contributions debate regarding mercury (and other naturally occurring elements such as carbon) and may represent a sign of the "contestation" phase of the paradigm shift shown in Figure 6.8 and an example of the policy "disarray" characteristic of Phase 2 of the three phases of environmental policy as described in Figure 6.10.

With respect to Beck's "reflexive modernization" there are also strong parallels to the notion of being in between phases, trapped in "paradigm disarray" in Beck's "transition from the industrial to the risk epoch of modernity" (Beck, 1996).

6.7 Expert Interviews and the Science Policy Interface

According to experts interviewed as part of the dissertation research, when asked about science-policy issues in Canada, they noted a science-policy interface challenge whereby scientists have a poor understanding of policy and policy-makers are often unfamiliar with scientific methods. In fact, the experts interviewed were unanimous in their view that scientists do not understand policy and vice versa. Experts described scientists understanding of policy as “incredibly naïve,” remarkably naïve” and “hopeless.” Also noting that they do not receive training in policy.

Experts interviewed stated: “both sides [policy and science] need to listen to one another more” (Boyd). Also “scientists do not ask the right questions” or “understand questions needed for policy” (Elgie). Conversely, I. Smith noted that policy-makers need to be asking scientists the right questions. Krantzberg noted that “scientists and policy-makers work in different paradigms” and “scientists in government often fail because they assume logical connections will be followed and decisions made based on science.”

Leiss provided one of the most specific definitions of the science-policy interface, saying that from an institutional perspective it is “regulation.” Miller described it as “a persuasion process” where “lawyers ignore uncertain evidence and economists externalize uncertainty.” R. Smith said “policy makers pick and choose the science to fit the political agenda” and that “science is a pawn in the process.”

In describing the science-policy interface Granville stated that fisheries management in Canada was an interesting case where we knew “we are depleting the resource to death yet still carry on.” Miller uses aid rain as an example where the issue was “led by scientists as policy-makers” and today “none of the policy-makers are scientists” and scientists are “increasingly excluded from the policy process” s described in Phase II of Figure 6.10. An anonymous political staff member in the federal government and a former senior civil servant over-seeing toxic substances management (Vic Shantora) both cited PBDE (a chemical flame retardant banned in many jurisdictions but not in Canada) as an example where ample scientific evidence did not result in pollution control restrictions in Canada, placing the decision outcome squarely in the Economic Risk-paradigm decision sphere of Figure 6.9.

Specifically, they describe the level of certainty required by CEPA as a barrier to policy action. Described technically as the “Level of Quantification” required by CEPA being too stringent. Even though there is “sufficient science” the science becomes “hamstrung” because “industry has figured out the science process” and knows that they can inject questions that create scientific uncertainty causing the “political process bogs things down.” This was corroborated by another senior civil servant (John Moffett) who described science being “filtered through risk-assessment” where “science is double-edged” because even though science identifies a problem, if all the science is not clear, nothing may be done. Moreover, if the weight of scientific evidence suggests a problem, and senior government officials know they should “do something on a precautionary basis, there is no mechanism to do that.”

On the question of the general state of scientific understanding of ecosystems, expert views were largely consistent with Leiss’s description of “fairly primitive understanding” or Boyd’s “in kindergarten” comment. Leiss noted that “policy lags at least a decade behind science.” The anonymous political staff advisor noted the same saying “policy has not caught up with environmental science.”

There was a consistent theme among experts that scientists know a great deal about a small number of ecosystems, or aspects of ecology, but that for the most part ecology is “an immature science”, “we are emerging from the dark ages” and furthermore other science disciplines know very little about ecology and scientists do not communicate among the disciplines.

Experts noted the difficulty of understanding complexity in ecosystems; suggesting that the greater the degree of complexity the less likely scientists are to comment on the complexity, and that there is a need for this. Scientific understanding is “very poor with respect to complex ecosystems” and that “we suffer from an overly simplistic view of ecology” and that “it is very complex.”

The term “sound science” elicited strong views from the experts, who, apart from two civil servants and one other (former civil servant), described it as “Orwellian,” “industry crap,” “a public relations scam,” and “not useful,” among other things. Experts were largely of the view that it was a term created by industry.

When asked about the role of uncertainty and definitions of scientific uncertainty and policy uncertainty, I. Smith noted that scientific uncertainty is essentially a lack of confidence in information whereas policy uncertainty is a lack of knowing what the outcome of a policy choice may be. Granville and Miller noted that scientific uncertainty is “obvious” and “easily dealt with” within science. There was a general sense that when it comes to policy the notion of uncertainty becomes much more complex.

Shantora said that it is healthy to debate uncertainty, but it should not stop government from making policy decisions. Whereas it is clearly seen in that way, as several experts noted that uncertainty can be used to “either push or stall an initiative,” as “a mechanism used by industry to delay action,” and as “a pawn in the hands of some to forestall decisions.” At the same time policy-makers noted the prominence of uncertainty and that it is “a feature of almost every decision” despite being “not very well characterized within government.”

Precaution, particularly the Rio definition, was seen to be a “a good balance” between using uncertainty to demand action, and not preventing uncertainty from being an excuse for not acting. There was also a general sense that whereas precaution is a useful concept, particularly for addressing uncertainty as it considers the “weight of evidence” however according to several experts interviewed it is not well applied or widely used. Others saw it as being more useful to certain areas of policy, such as chemical regulation, but cautioning that it has several shortcomings, including that it has become politicized as a concept and therefore may carry political baggage, as well as being an abstract idea relative to RA/RM.

Regarding questions on addressing uncertainty and improving the science-policy interface a common set of suggestions emerge around the following concepts:

- Incorporating precaution and adaptive management
- Creating transparency and independence
- Containing and exposing secretive industry practices
- Improving communications, training and public dialogue

On the question of which comes first; effective decision systems that lead to environmental gains, or a desire to achieve environmental gains that leads to the creation of effective decision systems, the later was seen to be most true. There was near unanimity on the idea of goals and/or a vision being required which then leads to the adoption of policy processes that achieve the stated sustainability goals, with Sweden used as an example.

Expert comments on CEPA implementation and cause for lack of action under CEPA elicited strong and important insights. Two experts described CEPA implementation as “glacial”, others as “weak”, “burdensome”, “not a great success”, “underfunded, bureaucratic and plodding”, “fundamentally flawed” and “miserable.” It is safe to say that there is near consensus among the experts interviewed that CEPA is not working. With CEPA as Canada’s predominant legislation for managing toxic chemicals it points to a serious problem in Canada’s ability to protect human health and ecosystems.

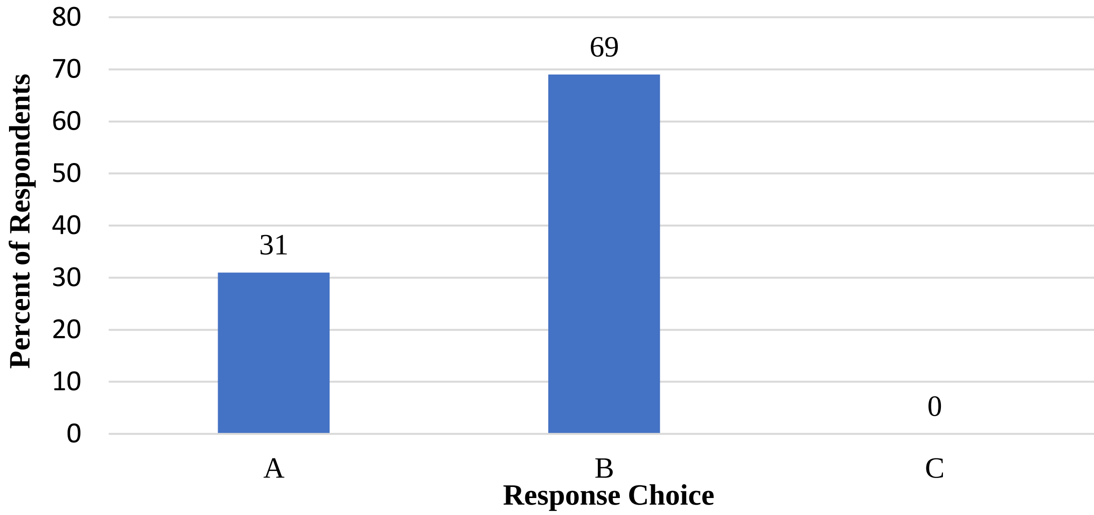
Experts commented on a number of specific weaknesses regarding lack of government action with respect to using CEPA to manage toxic substances. They can be categorized in three ways:

1. A constitutional barrier to implementing CEPA, referring to the fact that Canada’s weak central federalism makes it difficult for Environment Canada to impose regulatory burdens on the provinces.
2. Lack of science capacity.
3. Government being influenced by industry interests.

Together these explain the more generic remark that politicians are not motivated to implement CEPA. 6.11 includes five bar graphs illustrating the quantitative expert survey responses.

Figure 6.11: Expert Survey Quantitative Response Graphs (with Commentary)

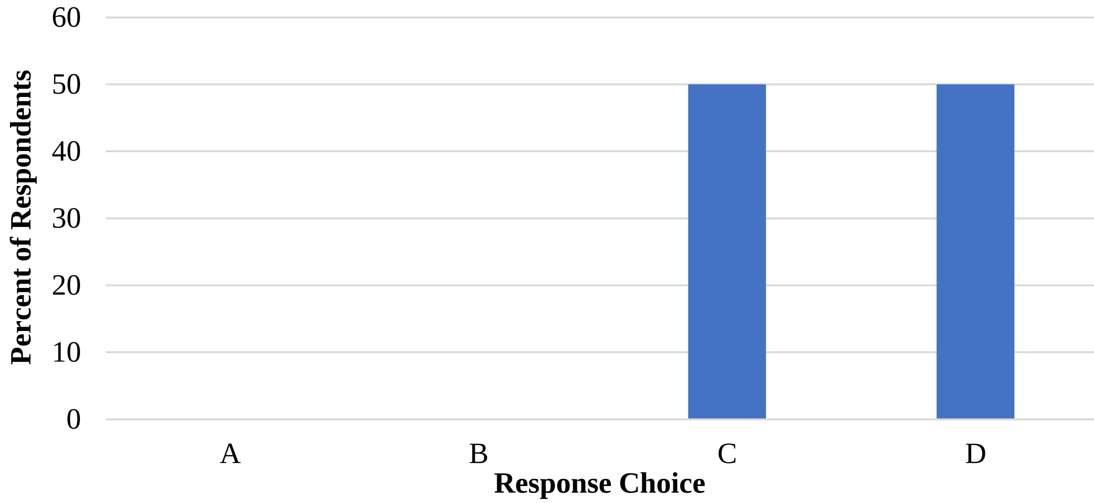
Which of the following statements best characterizes scientific understanding of ecosystem functions and global systems? Please review the full list before answering.



A. Science has led to a greater understanding of global ecological systems and human impacts, so that there is more certainty today in decisions to manage human interventions in global ecological systems than 10 years ago.
B. Science has found more questions than answers regarding the complexity of global ecological systems and human impacts, so that there is less certainty today in decisions to manage human interventions in global ecological systems than 10 years ago.
C. Scientists know so little about ecosystem complexity that there has always been a lack of certainty with respect to managing human interventions in global ecological systems.

A critical conclusion from this result is that despite the amount of ecological research underway nearly 70 percent of expert respondents chose the response indicating that there is “less certainty today in decisions to manage human interventions in global ecological systems.” This response reinforces the dissertation thesis that the sense of scientific uncertainty is increasing along with the increasing degree of complexity identified in research on ecological systems.

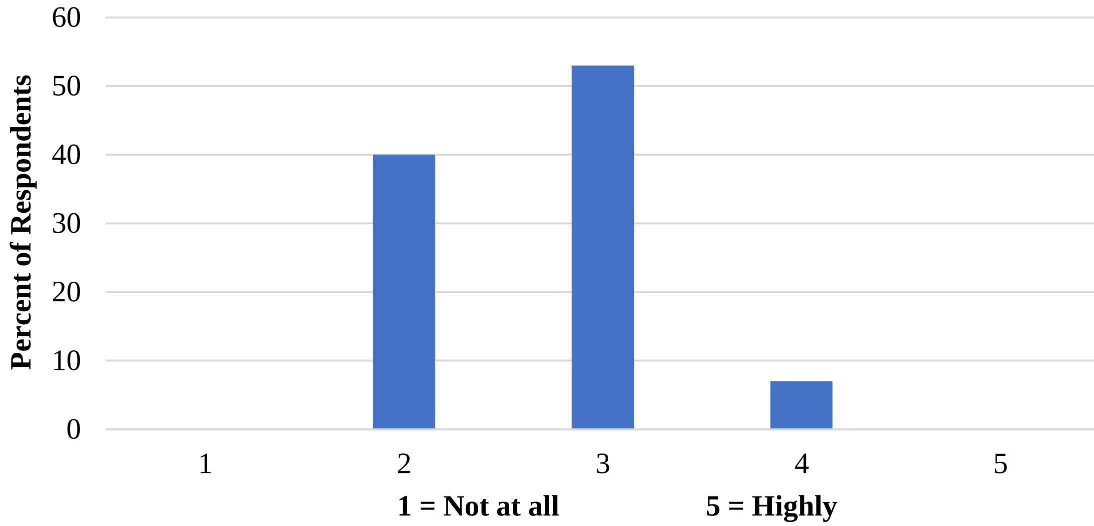
Is scientific information an important part of environmental policy making? Please choose from the following which *best describes the basis* for Canada's environmental policy approach:



A. Clear science regarding environmental impacts (science-based).
B. Societal or community concerns or needs (social-based).
C. Economic issues related to corporate cost considerations or job considerations (economic-based).
D. A balance of all three above.

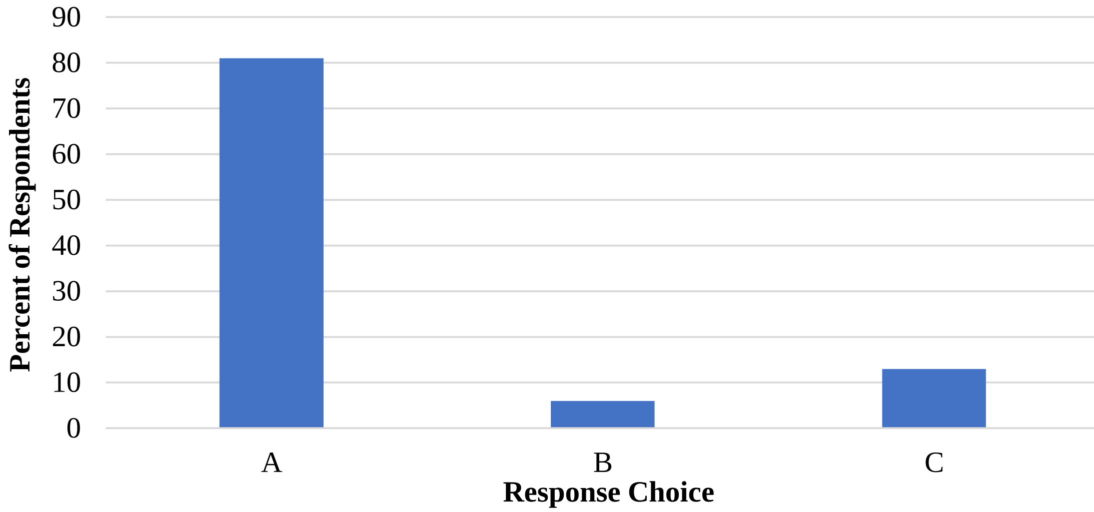
None of the expert respondents said that Canada's environmental policy approach could best be described as "science-based." Half of the respondents described it as "economic-based" and the other half as a balance of science, social and economic considerations. Again, reinforcing the extent to which Canada's environmental policies are trapped in material society.

Please choose a number that best reflects how effectively science is used in environmental policy decision-making in Canada, where 1 is not at all effective and 5 is highly effective.



With respect to the effectiveness of science used in environmental policy decision-making in Canada 40 percent of expert respondents ranked it not effective and just over 50 percent as neither effective or ineffective. Less than ten percent suggested it was effective and none said highly effective.

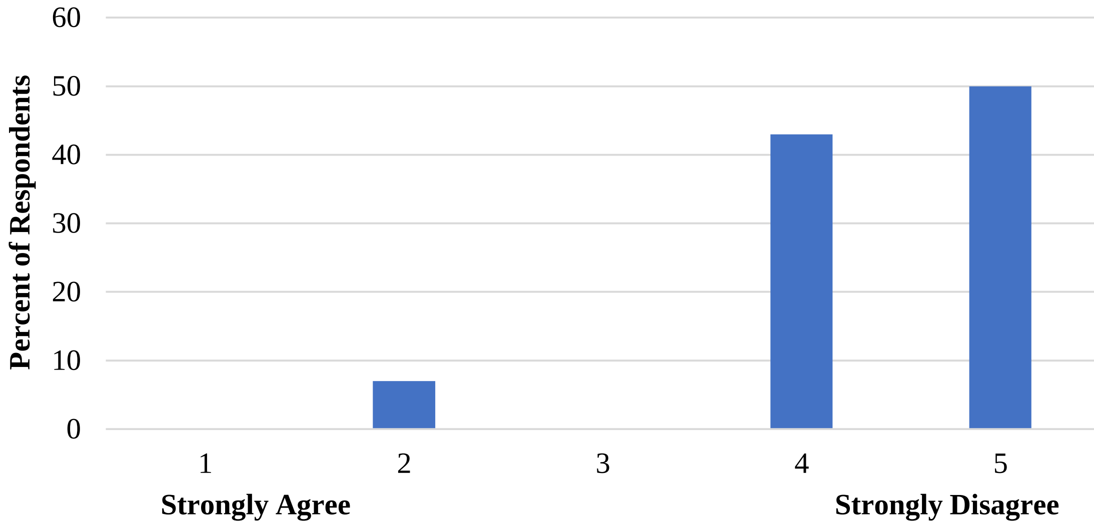
Which of the following statements best characterizes environmental policy processes in Canada?



A. Environmental decision-making processes have become more rigorous in recent years with increased demands for scientific certainty and/or cause-effect relationships in setting environmental or pollution control standards.
B. Environmental decision-making processes have become less rigorous in recent years with a decrease in demands for scientific certainty and/or cause-effect relationships in setting environmental or pollution control standards.
C. Environmental decision-making processes have not changed with respect to scientific uncertainty.

Over 80 percent of respondents selected "environmental decision-making processes have become more rigorous in recent years with increased demands for scientific certainty." This finding is significant with respect to the thesis question regarding the idea that there are ever increasing demands by policy-makers for the elusive notion of "scientific certainty" in environmental policy. Often disingenuous demands made in the context of industrial policy and the maintenance of Canada's resource extractive economy. *This finding reinforces the theoretical underpinning of this research; namely, Canadian environmental policy discourse must be viewed not in isolation but as subordinate to material society and staple theory discourse.*

Please indicate whether you agree or disagree with the following statement: *Canada's policy paradigm regarding pollution control has kept pace with the evolving discourse of uncertainty in ecological systems.*



In a related concept to several questions above, over 90 percent of respondents disagree or strongly disagree with the statement: "Canada's policy paradigm regarding pollution control has kept pace with the evolving discourse of uncertainty in ecological systems." This is consistent with the qualitative responses where several experts noted that with respect to the science-policy interface policy has not kept up with science. In a recent publication, Kraft (2017) notes that environmentalists claim "regulators have not been able to keep pace with the multiplicity of challenges they face." It is clear from the survey research that this is neither a new phenomenon nor is it limited to the views environmentalists.

Summarizing the expert responses there is strong confirmation of the combination of conditions describing the failure of environmental policy in Canada particularly as it relates to the science-policy interface and the management of toxic substances under CEPA. Namely:

1. Ecosystem research is raising more questions than it answers, enhancing a sense of scientific uncertainty.
2. More certainty is being demanded by policy processes.

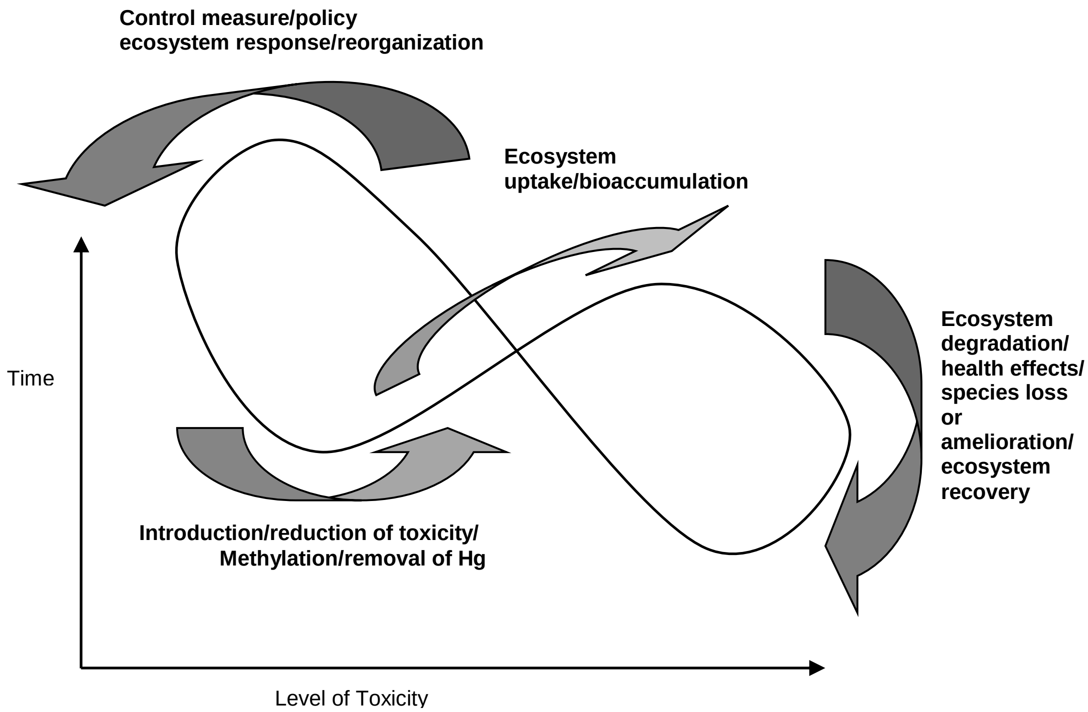
3. Science is not being used effectively and our policy system is seen to be economic-based not science-based, as governments claim.
4. Policy and policy institutions have not kept pace with the complexity of global ecological systems, particularly regarding the role of policy in the face of scientific uncertainty.

The larger conclusion to draw from the survey research, based on the theoretical framework of risk society, is that the science-policy interface itself is a construct with limited relevance in the realpolitik of Canada's staples economy. The social and cultural aspects of reflexive modernity as described by Beck's global risk society are critical elements to consider when interpreting failures of science and policy integration.

In terms of solutions to the challenges discussed, a number of ideas emerged from the experts. Leiss noted that one "useful mechanism" for dealing with the science-policy interface is when government asks the questions and a "panel makes authoritative statements that are difficult to ignore." Krantzberg described the Great Lakes Water Quality Agreement where Regional Action Plans brought together science and public process. The use of adaptive management and precaution were raised as examples of approaches that better integrate science and policy.

Transparency, accountability, public participation and communications are all related ideas raised by expert respondents as ways to improve the science-policy interface. These align with the conclusions in recent academic reviews of the science-policy interface (Layzer and Schulman, 2017; Marshall et al., 2017; Richards, 2017). Additional discussion and analysis of adaptive management is included in Chapter 7. Figure 6.12 is a graphical representation of what an adaptive management cycle applied to pollution policy may look like.

Figure 6.12: Mercury Adaptive Management Cycle



In response to the question: "Please rate the following as possible ways of improving the science-policy interface in environmental decision-making, rated from 1 to 5 where you consider 1 to be least effective and 5 to be most effective:

a. Independent science advisory bodies that do not include stakeholder representation: { 1 2 3 4 5 }
b. Greater transparency in science advice and the policy decisions based on the advice: { 1 2 3 4 5 }
c. Major structural change to the federal bureaucracy with respect to science research, analysis and advice: { 1 2 3 4 5 }
d. A more explicit recognition of inherent scientific uncertainty regarding environmental issues and reducing the demands for certainty: { 1 2 3 4 5 }
e. Others

Many of the experts ranked “a”, “b”, “c”, and/or “d” with a “4” or a “5” suggesting that there is strong support among experts for independent science advisory bodies, greater transparency in science advice and policy decisions, the need for major structural change within government around the science-policy interface, and more explicit recognition of scientific uncertainty while reducing the demands for certainty.

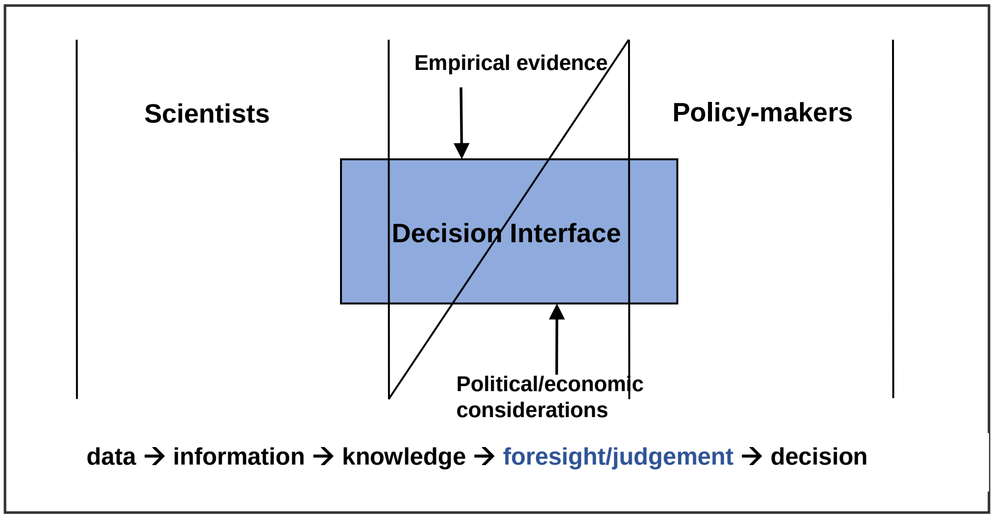
The expert interviews inform the primary thesis idea that scientists and policy makers are operating within two separate cultures or epochs. Furthermore, policy processes have not kept pace with science, and science capacity has been lost in Canada. Combining this reality with the overarching material society discourse explains in large measure the dysfunctional science-policy interface and consequent failure to implement effective environmental policy.

A fundamental point made by Boyd was that there is a basic understanding of ecosystems “but not enough to make decisions with confidence.” This hits at the core of the failure of the science-policy interface in Canada. Moffet noted that there is a temporal aspect to precaution in that policy decisions are made sooner (ie move into the Adaptive Precaution Paradigm Decision Sphere of Figure 6.9) where Type I errors are tolerated, and decisions err on the side of protecting public health versus economic interests.

6.8 Interpreting the Science-Policy Interface

The science-policy interface is often referred to, but rarely defined. Figure 6.13 is a graphical depiction of the science-policy interface. Science may be thought of as the methods and practices to acquire data, structure information and create knowledge. Decisions are the realm of policy. It is therefore “judgment” that is at the heart of the science-policy interface. There is also a sense that the right combination of empirical evidence and political will is required in order for governments to take action. The decision interface was described by one interviewee as “the invisible world” where science and politics come together to produce policy responses.
The “invisible world” is in fact the very visible material society.

Figure 6.13: Science – Policy Decision Interface



An analysis of the science policy interface together with results of expert survey research has led to the concept of foresight (as well as judgment) as "the interface." This finding reintroduces the idea of precaution. The precautionary principle is rooted in the concept of foresight. The policy basis for the precautionary principle comes from the German term "Vorsorgenprinzip" which means literally "foresight principle" (Raffensperger and Tickner, 1999).

Grunwald (2004) describes strategic knowledge for sustainable development falling into three fields of knowledge based on categorization by Weber and Whitelegg (2003). The three fields are "orientation knowledge," "system knowledge," and "knowledge for action." Knowledge for action is referred to as "foresighted knowledge of sustainably-efficient measures." Foresight is the action component of sustainability knowledge. Judgment is the action component of expert advice. Experts use judgment when providing an expert opinion (Loveridge, 2004). Hammond and Adelman (1976) viewed judgment as the critical connection between values and science (Loveridge, 2004).

Foresight and judgement are similar concepts. Both have predictive qualities, both are rooted in a preliminary activity of information gathering and assessment, and both contribute to decision-making. While foresight and judgement typically evoke a temporal or predictive scale, which for both can be highly variable, they do not imply Beck's reflexivity in the sense that the system illustrated in Figure 6.13 is still linear and lacks the interpretation and use of scientific knowledge created through social interactions to anticipate the future.

Marshall et al. (2017) describe research-policy partnerships as does Richards (2017), consistent with the findings herein regarding the need for more systematic, collaborative mechanisms between scientists and policy-makers. Moreover, the science-policy interface needs to be a dynamic interaction between multiple processes of knowledge production and decision-making (Wesselink et al., 2012).

Marshall et al. (2017) suggestions are in many ways obvious to policy practitioners, as discovered in the survey research, such as the need to commit adequate time to meet with policy-makers and attempting to understand the motivations of policy-makers. The authors usefully note the need for institutional innovation in academia to recognise the effort required to be effective in policy influence.

There are several possible ways to address the shortcomings in policy-making identified by the research findings herein.

1. Ecological constraints to human activity need to be considered.
2. The anthropogenic alterations of major biogeochemical cycles and ecological functions need to be considered in both science and policy research.
3. Uncertainty cannot be a rationale for inaction, and a decision not to act (i.e. maintain the status quo) cannot be on equal footing as a decision to make change - status quo bias must be overcome.
4. Greater independence in science is needed. There needs to be a clear separation between the undertaking of scientific research (science), the provision of science advice (judgement) and the decision-making (policy).

5. Explicit recognition of uncertainty in science and the creation of institutional mechanisms that incorporate the inherent uncertainty in complex ecological systems are needed.
6. Methods of reaching decisions on the nature and degree of uncertainty need to be established as part of the empirical evidence input into the decision interface, this is identified as the Process Gap in Figure 4.6.
7. The science-policy decision interface requires greater transparency.
8. Science capacity, independent and within government, needs to be enhanced in order to strengthen the generation and analysis of scientific evidence used for policy.
9. The Science-policy decision interface in Figure 6.13 is where specific decision mechanisms, such as deliberative collaboration, may contribute to improved process outcomes, identified in the Process Gap in Figure 4.6.
10. Recognition of systemic economic bias of material society in policy decisions related to environmental protection are needed and would take place in the Decision Gap of Figure 4.6.
11. Appreciating the role of judgement and seeking judgement skill sets in policy processes which would take place in both the Process Gap and the Decision Gap.
12. The reflexive nature of social and cultural interactions with science, including the interplay of ecological system response and human system response need to be better understood and recognized.
13. Decision processes would ideally move from linear to circular and follow the adaptive management model or a "precautionary adaptive approach" as depicted in Figure 4.7.

In conclusion, decision policy frameworks for managing toxic substances in Canada have not kept pace with the evolving discourse of uncertainty in ecological systems due to the lack of recognition of uncertainty; defined not merely as process or decision "gaps" but as a fundamental theoretical gap representing the chasm between material society and risk society.

CHAPTER 7: CONCLUSIONS

Inevitably, therefore, information and decisions are vulnerable to being manipulated by powerful interests. While scientists do not thereby need to become politicians, they do have to be sensitive to political and human realities, and to recognize how theories, different modes of inquiry, and different rules of evidence can facilitate, hinder, or destroy the development of constructive policy and action.

(C.S. Holling, 1998)

7.1 Overview

The question at hand is; why, when given what we know about society's seemingly perilous ecological direction, do we appear unable to take actions to protect ourselves – particularly where the scientific evidence of the need to act is relatively clear? This idea was reiterated throughout the research and may be paraphrased as "given what we know about environmental stresses and solutions, why is it that we do not act to protect our future?" This is not a new challenge, in 1989 Dr. David Peakall, Chief of the Toxicology Research Division of the National Wildlife Research Centre of Environment Canada, asked: "How much damage are we prepared to tolerate? How much proof is enough?"

These are still critically relevant questions in environmental policy in Canada today. They also mimic the original question under investigation and introduce the idea that there is a growing gap between the nature of scientific understanding of stresses on the environment, and the policy paradigms designed to mitigate these ecological stresses. Nearly thirty years after Peakall's questioning, the only conclusion that can be drawn based on the research gathered herein is that the fundamental forces of economic growth and industrialization, relics of material society, have overwhelmed the environmental policy-making process.

The thesis put forward in this paper is that the science-policy interface is a science-society interface. Canada is trapped between the competing epochs or paradigms of material society and risk society. The material society epoch defines Canada's resource dependent history and dominates political and bureaucratic decisions. The uncertainty that undermines policy action is therefore not the technocratic scientific uncertainty within the regulatory risk framework but a systemic societal uncertainty, a manifestation of reflexive modernity, that can never be addressed adequately in material society's risk decision frame. The discourse and *realpolitik* of climate change are a vivid demonstration of Beck's world risk society where the human construct is both the risk and the uncertainty.

Environmental policy-making in Canada is hampered by the systemic weaknesses in the science-policy interface, and namely the way in which risk and uncertainty are used as deliberate tactics of industrial interests aided and abetted by a resource exploitation ethos within the federal bureaucracy. Moreover, the risk regulatory system is structured in such a way as to prevent the restriction or regulation of toxic substances, especially natural toxins as seen with mercury, asbestos and carbon. The federal government's failure to deliver on environmental policy commitments has been confounded by risk management approaches that require a level of scientific certainty that is difficult, if not impossible, to achieve.

The adoption and implementation of the risk assessment and risk management framework, as well as Canada's overarching approach under CEPA, is a clear representation of two theoretical underpinnings, which emerge in the survey research in this chapter. First, Beck's material society frames the environmental science-policy debate as a contest between material industrial society and an emergent risk society. Second, material society can be further described as an example of staples theory, whereby Canada's especially poor environmental performance, relative to other industrial nations, can be explained by the dominance of resource exploitation in Canada's foundational history.

The research question that emerged from the problem statement asks: *"In what ways does Beck's risk society theory explain the failure of Canada's science-policy interface in pollution control decisions not keeping pace with the evolving discourse of risk and uncertainty?"*

The research herein identifies that decision-making mechanisms designed to protect the environment and human health are challenged when confronted with uncertainty. More specifically, uncertainty in the science-policy interface contributes to a stasis in environmental policy decisions in Canada regarding the regulation of toxic chemicals. This was evident in the case study research on mercury pollution policy in Canada in the 1995 to 2005 period.

The problem statement has both a scientific dimension and a policy dimension. The conclusions support the premise that: humans are dramatically altering global life systems; environmental science is increasingly complex and more uncertain; capacity to undertake science has been reduced; and industrial stakeholders are demanding greater certainty and clarity in science, as a tactic to avoid environmental policy outcomes that restrict extractive industrial activity. Collectively, these are manifestations of the material society - risk society conflict, that dominate Canada's pollution policy practices.

There is broad recognition among policy actors that Canadian decision models are not well-suited to address these conflicting and diverging factors of complex, uncertain science amid demands for regulatory and economic certainty. As a result, the concept of scientific certainty, often presented as the discourse of "sound science," has created a policy environment where pollution control decisions do not protect the environment and human health to the extent that academic and non-government expert actors consider to be necessary for human safety and ecological survival. The science-policy interface regarding standard-setting for mercury in Canada (Chapter 5) provides a vivid illustration of the material society forces in contestation with risk society.

In the reflexive modernity epoch, the notion of scientific uncertainty has little meaning given that the uncertainty is human-caused and iterative; the Anthropocene is the embodiment of world risk society. Reflexive modernity is concerned with itself. Ecosystems cannot be understood without understanding social interactions, discourse and the adaptive feedback loops of decisions and actions.

In Chapters 3, the research describes the historical Canadian political economy trapping environmental and resource policy decisions in material society. Canada's historical and on-going role as a resource exploitation and export centre, or staples economy, describes much of the political structure and motivation behind environmental policy. The federal government's role constitutionally and historically has been to promote and accelerate resource extraction. Environmental protection, as a relatively recent concept, has been "tacked on" with little success in mitigating fundamental ecological crises.

The predominance of economic priority in environmental policy introduces the idea of economic hegemony within the sustainability paradigm as a clear manifestation of material society and a staple economy. The fact that it appears to be increasingly hegemonic presents a fundamental challenge to achieving sustainability goals, noted below; where Section 7.4 explores the challenges within the sustainability paradigm and how it is being implemented in Canada.

7.2 Risk, Uncertainty and Environmental Policy

Canada's policy legacy regarding resource extraction together with the ideas highlighted through the primary research discussed in Chapter 6 raise several questions regarding the role of science in the science-policy interface. For example, is the lack of support for science capacity, notably the dramatic cuts to science in the 1995 to 2005 period, a deliberate effort to delay or prevent action regarding environmental protection? Scientific assessment and monitoring capacity has been chronically under resourced, with declining resources through the latter part of the 1990s and early 2000s under a Liberal government, and which continued through to 2015 under the federal Conservative Government.

According to the expert interviews summarized in Chapter 6, cumulative synergistic research is not a strong feature of modern science. Furthermore, a lack of cross-cutting and interdisciplinary research is a failure of the traditional science system to support environmental understanding and solutions. The result being that when science adds to complexity and uncertainty, as opposed to supporting clear, albeit simplistic policy decisions, policy-makers are inclined to avoid making decisions.

Yet there is consensus on increasing uncertainty, not only in the form of ecological complexity, but more critically, as outlined in this research, as reflexive modernity; where society creates the uncertainty, and humans are in fact the uncertainty in the system. An idea that surpasses the conceptual boundaries of traditional science-policy interface discourse. Uncertainty of all forms cause environmental policy processes to fail with respect to making timely decisions that are in-line with ecological and social values.

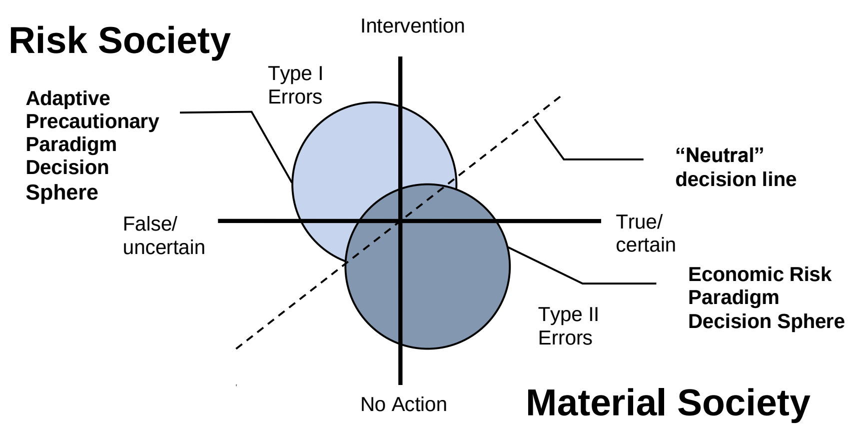
Chapter 4 focuses on the extent to which RA/RM is the dominant decision paradigm while also illustrating the extent to which it has failed to function in practice, versus how it is described in theory. Moreover, the theory of risk management too, is flawed as a mechanism. Risk management is a bureaucratic manifestation of material society. Risk management systems are antithetical to the need for flexible innovative responses to complex adaptive ecological systems dominated by the economic and social forces that define risk society. As a result, failures of the science-policy interface are chronic, systemic and well-documented.

According to one of Canada's Environmental Commissioners, science simply is not used in Canada. When asked how much science plays a role, the Commissioner suggested that science had "virtually no role" in environmental policy decisions in Canada (Jelinas, pers. comm., November, 2006). Material society is manifested in the discourse of "sound science" with the conclusion that: "It is clear environmental decisions are not sound, even though the science behind them might be. The problem lies not in the science but in how policy makers interpret the science" (Morrone and Lohner, 2002). There is a need for "reflexivity on the part of scientists working at the science-policy interface regarding the political choices implicit in the policy discourses they work within and help construct" (Wesselink et al. 2012).

Three main conclusions are drawn from the expert interview questions. First, the widespread sense that RA/RM processes are not implemented effectively by government. Second, there are two dominant cohort groupings, with the industry cohort representing the material society paradigm, and NGOs, academia and government cohorts roughly aligned with an adaptive precautionary paradigm, consistent with risk society and reflexive modernity. Industry respondents are much more inclined to view *status quo* RA/RM processes favourably. Third, there is universal agreement across the cohorts that in answer to the question "why given scientific evidence of harm do we not act", economic considerations, i.e. Canada's entrapment in the material society epoch, is the dominant reason.

Risk-based management systems are dysfunctional with respect to ecosystem integrity due to the chronic inability to meet requisite baseline confidence. The inherent material society bias in risk management exercises that result in a decision to maintain the status quo, is not well-documented in Canada with respect to pollution policy. The research in Chapter 4 sheds some light on the Type I and Type II errors with the creation of an error bias diagram that illuminates the binary conflict between material society or the economic risk paradigm and risk society or the adaptive precautionary paradigm (Figure 7.1).

Figure 7.1: Error Bias Paradigm Decision Diagram



According to experts when asked about science-policy issues within Environment Canada, there is unanimity regarding scientists' lack of understanding of policy and policy-makers unfamiliarity with scientific methods. These factors together with reduced science capacity and a lack of independent science advice are thought to be contributing to the low opinion held of Environment Canada's management of toxic substances and specifically CEPA implementation.

As part of the participatory action research used in the dissertation research, the author summarized some of the challenges facing CEPA in a presentation before the House Committee for Environment and Sustainable Development, as follows:

1. Federal Authority and Leadership

CEPA amendments must address Federal accountability in toxic substances management in Canada. The concept of "national coherence" appears to be a furthering of the Federal abdication of responsibility to manage toxic substances. Relying on voluntary fora, other governments, First Nations and other federal mechanisms has not worked in the past and there is no reason to expect they will work in the future. CEPA must incorporate mechanisms to assert Federal regulatory authority to manage toxic substances.

2. Pollution Prevention

Canada has not used the mechanisms under CEPA to implement pollution prevention, even in the most obvious, cost-effective and socially beneficial cases. CEPA needs to be strengthened in this regard with explicit direction and authority provided to Environment Canada to implement actual pollution prevention. One specific area that needs strengthening is the management of toxic substances in products. This major shortcoming must be addressed if CEPA is to have any contemporary relevance and if pollution prevention is to be implemented under CEPA.

2. Precaution and Risk

CEPA has not facilitated precautionary action with respect to toxic substances management in Canada. The CEPA review must address the inherent barriers to precaution, particularly the *rigid application of risk management and adherence to false concepts such as "sound science." The Federal Government should require Environment Canada and Health Canada to prepare an internal guideline on understanding and incorporating uncertainty in toxic substances assessment and management. The guiding principles of this document must be incorporated within decision-making frameworks that allow for, not restrict, precautionary action. Uncertainty must not be used as an excuse for inaction, as is the present paradigm.*

In the case of CEPA as illustrated through the case study on mercury policy in Chapter 5, there is no shortage of empirical scientific evidence of toxicity of mercury, but there was a clear shortage of policy action due to a weak sustainability model, embedded in material society, whereby economic interests are placed ahead of sustaining ecological integrity or social outcomes. The expert survey research confirmed, with a high degree of corroboration in the literature, the sense of serious science-policy weaknesses in Canada, as described in Chapter 6.

Summarizing the expert responses from Chapter 6, there is strong confirmation of the combination of conditions found in material society and staples theory that describe the failure of environmental policy implementation in Canada particularly as it relates to the management of toxic substances under CEPA. Namely:

1. Regulatory risk processes are a manifestation of material society interests and reinforce Canada's historic resource dependency.
2. Ecosystem research is raising more questions than it answers, enhancing a sense of scientific complexity and uncertainty, where humans are the uncertainty.
3. More certainty is being demanded by policy processes, in many cases "artificial" calls for certainty, driven by material society interests.
4. Science is not being used effectively and our policy system is seen by a broad range of policy practitioners to be "economic-based" rather than "science-based", consistent with material society.

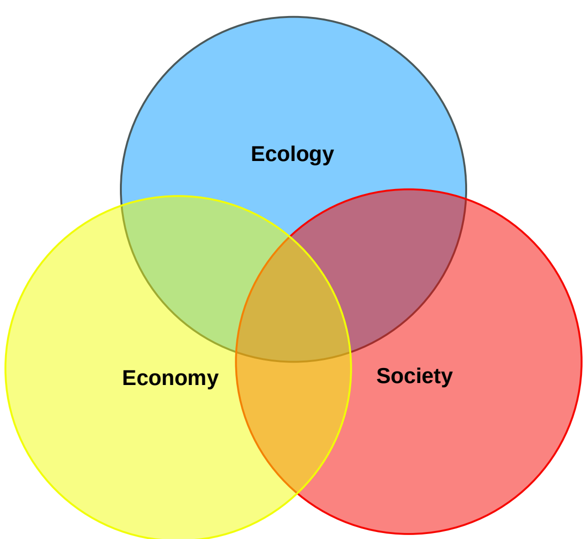
5. Policy has not kept pace with science and particularly scientific uncertainty in regulatory risk processes, which have proven to be incapable of bridging the material society-risk society gap.

The larger conclusion to draw from the survey research, based on the theoretical framework of risk society, is that the science-policy interface itself is a construct with limited relevance in the realpolitik of Canada's staple economy. The social and cultural aspects of reflexive modernity as described by Beck's global risk society are critical elements to consider when interpreting failures of science and policy integration.

7.3 Risk Society and the Sustainable Development Paradigm

"Sustainable development" according to Langhelle (2017) is "notoriously complex" yet "inescapable" as a framework for the "integration of the challenges of environment and development." As an analytical framework that is "disputed", "contested" and "celebrated", as well as having "permeated all academic disciplines" (Langhelle, 2017); it is worth a commentary as it relates to risk society theory. A conclusion drawn from the research herein is that the theoretical sustainable development paradigm (Figure 7.2) is "broken" because it, too, is a manifestation of material society. The idea of a balance between ecology, economy and society is not credible based on the evidence of the federal government's management of toxic substances, notably in the 1995 to 2005 time-period, and as seen in the contemporary climate debate.

Figure 7.2: Theoretical Sustainability



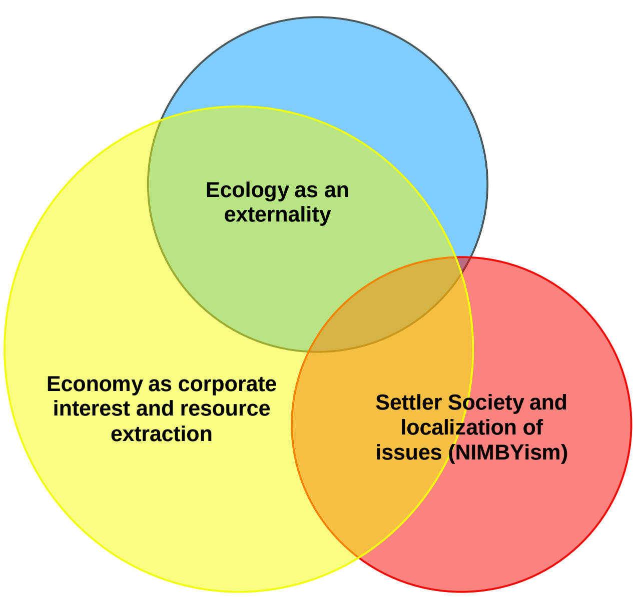
Canada's staples history, colonial resource exploitation, and the history of environmental bureaucracy explain Canada's failed approach regarding the science-policy interface in environmental decision-making. The political and bureaucratic challenges are so great and the successes so modest that they challenge the very concept of sustainable development as a workable framework for environmental policy.

The conceptual representation of sustainability from a theoretical perspective i.e. "text book" sustainability, is the model for Environment Canada.

This is consistent with Pierre Trudeau's vision for Environment Canada where "environmental issues would have to be fought out *among* ministers as well as *within* a single department" (Doern and Conway, 1994). In this sequence of graphical depictions, it is described as "theoretical sustainability".

Like the Trudeau government vision, Marshall et al. (2017) position the environmental policy impasse as a conflict and "political turmoil" of competing policies and regulations to achieve sustainability goals and the restriction of human economic endeavour. They do not go as far as challenging the fundamental flaw of sustainable development as it has been conceptualized, however their research supports the premise.

Figure 7.3: Sustainability in Material Society: Economic Risk Paradigm



Environment Canada will never be positioned to lead resource, health or economic issues within the federal system. When reviewing a traditional Venn diagram of the ecology, economy, society triad or trialectic that comprises sustainability, two of the three spheres are clearly outside of Environment Canada's mandate (economy and society) and much of the third sphere, ecology, has divided jurisdiction between Environment Canada and federal "material society" resource departments (e.g. Fisheries and Natural Resources). Moreover, the provinces with their strong material society structures have considerable environmental jurisdiction in Canada's weak federalist system.

Figure 7.3 represents material society sustainability, where social and ecological goals are dominated by economic interest. It illustrates "sustainable development as a latent policy paradigm" one without "operational relevance" as practiced by the federal government (Doern and Conway, 1994). It is based on statements made by experts, within and outside of government, that corporate economic and resource interests have disproportionate influence on environmental policy decisions and the approach to toxic substances management at Environment Canada in the 1995 to 2005 period.

Economics are driven by corporate interests, societal goals focus narrowly on local priorities, and ecological goals are treated as externalities. This describes the material society structure of resource and economic policy decision making in Canada. Rooted in the historical role of maximizing resource exploitation, this version of sustainability can be taken to represent the federal government approach to sustainability. This was identified specifically with respect to the implementation of CEPA and the widely held perception that Canada has done a very poor job of implementing CEPA. A viewpoint identified in the literature research as well as the survey and expert interview research. Representative of why Holling et al. (2000) suggest that with respect to the regulation of toxic substances in the United States (among other examples) sustainable development fits the description of an "oxymoron".

Figure 7.4 depicts an ecological representation of risk society, or the adaptive precautionary paradigm, where sustainability represents the idea that the economy is a human construct embedded within society, essentially a tool to serve society. Without a social purpose, economics, or even the concept of an economy, would not exist. Society can only exist within the context of a functioning ecological system, defined by access to air, water and resources. This conceptualization of sustainability is different from the traditional theoretical sustainability model (Figure 7.2) which represents a competition between economic, social and ecological interests, with a small area of overlapping interest.

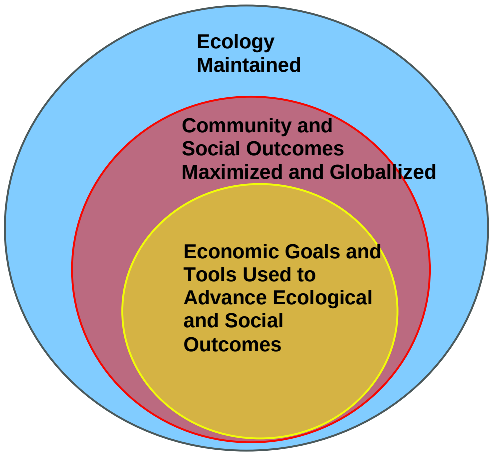
Sustainability in the "adaptive precautionary paradigm" model of sustainability may be likened to "ecological rationality" which is qualitatively different from economic or social rationality (Bartlett, 1990). In the adaptive precautionary paradigm of sustainability (Figure 7.4), ecological thinking takes precedence over social and economic rationality. In Beck's "risk society" there is a tension between social reflexivity and ecology. For Beck, everything falls within the domain of the social. Beck (1996) writes from the perspective of historical social theory and dismisses "nature itself as not nature" but rather "a norm, a recollection, a utopia, an alternative plan". Beck's sustainable development model may therefore place ecology and economy within the society circle. For Beck, natural science approaches to ecological questions "imply hidden cultural models of nature" and he does not separate society from the idea that there is a knowable and well-developed understanding of ecology and nature, beyond "recollections" or "an alternative plan".

Beck favours a discourse of "the social" with a diminished view of the legitimate scientific aspects of "nature", describing ecology as an "ecocracy" (Beck, 1996). Quoting the German poet Gottfried Benn, writing that "nature is empty and desolate; only petty-bourgeois minds see something in it" presupposes an anti-scientific bias in Beck; perhaps an extreme representation of the idea that "we", as in society and institutions, are the only uncertainty. Taken too far, this rationale is akin to suggesting that there is no physical difference between an imagined rainforest and an actual rainforest.

Beck asks the question: "how do we handle nature after it ends?" when based on ecological science it seems the more relevant question may be: what is nature after society ends? Given that nature is human construct, it is easier to imagine a natural planet without humans, than it is to imagine a human planet without nature. The former does not require interpretations of social norms or culture. His arguments often reinforce the critique of academia, similar to C.P. Snow's critique, reinforcing, rather than bridging, the scholarly chasm between the two cultures. A risk from a pragmatic policy development perspective is that this thinking does not contribute to an improved, sophisticated understanding of the society versus nature debate. A greater risk is that it feeds the anti-science sentiment so prevalent in right-wing material society politics.

Sustainability as a paradigm has not succeeded in delivering the systemic change needed. The material society *status quo* adopted (co-opted) sustainability rather than sustainability becoming a paradigm for change.

Figure 7.4: Sustainability in Risk Society:
Adaptive Precautionary Paradigm



Langhelle (2017) argues that the sustainable development framework, as an analytic, normative, and flexible concept has much to offer in evaluating and making policy choices. Questions, however, remain for those practicing in the field of environmental policy in Canada: Why given these specific historical barriers and limitations to Environment Canada's effectiveness, are these barriers not more explicitly referenced when Environment Canada participates in policy processes? Is the bureaucratic system aware of the extent to which material society barriers constrain Environment Canada's actions? The sustainability framework analysis leads to one idea for Environment Canada to overcome the barriers to increased policy effectiveness within the sustainable development paradigm. Given the stated prominence of science at Environment Canada and the purported importance of science in federal decision-making, Environment Canada must assert leadership in the ecological sciences, by using an adaptive precautionary frame that recognizes and confronts the conflict between material society and risk society. Well-structured, adaptive precautionary policy decision-making may help to overcome historical biases and bureaucratic systems that have left Environment Canada a second-tier Department with little clout; only to the extent that reflexive modernity is acknowledged.

7.4 Two Cultures: Science-Policy Interface and the Material-Risk Society Epochs

The original C.P. Snow lecture articulated the concept of two cultures, also to be thought of as paradigms or epochs, which clearly emerge throughout the research herein; in the literature, the survey results and the expert interviews. I have created Figure 7.5, to represent the extent to which the concept of two cultures is used as an epistemic dialectic across disciplines. It explains the research question I set-out to answer; namely, that Beck's material society-risk society dualism is a powerful theoretical lens through which to understand Canada's science-policy interface. Moreover, the research contributes to a theoretical understanding of the precautionary principle and risk management dialectic as being embedded in Beck's more expansive social theory of world risk society and reflexive modernity.

An expansion of the notion of two dominant paradigms contributes to a theoretical understanding of the alignment of a range of epistemologies. This insight leads to the introduction of a clearer ontology: two epochs, paradigm duality and the discourse of risk.

Using discourse analysis as a method of understanding policy development, the research identifies that the precautionary principle is a discourse in and of itself, whereas risk management is largely an engineering tool. Consequently, risk managers have a mechanistic tool, supporting material society, used to implement the risk paradigm, whereas the precautionary principle advocates are left with a discourse tool that fails to deliver outcomes when policy processes are trapped between material society and world risk society.

Figure 7.5: Material Society-Risk Society Epistemic Theory Alignment Table

Material Society **Economic Risk Paradigm**	***Risk Society*** **Adaptive Precautionary Paradigm**	**Dominant Discipline**
Conservatism	Liberalism	Political science
Objectivism	Subjectivism	Pervasive
Structuralism	Post-structuralism	Linguistics
Logical positivism	Post-positivism	Philosophy
Modernism	Post-modernism	Pervasive
Constructionism	Deconstructionism	Philosophy
Behvariorism	Cognition	Psychology
Rationalism	Mysticism	Religion
Technocratism	Pluralism	Political Science
Weberian	Longian	Philosophy
Rationalism	Incrementalism	Decision Theory
Normal	Post-normal	Philosophy
Yin	Yang	Taoism
Humanism	Naturalism	Conservation Biology
Empiricism	Phenomenalism	Philosophy
Industrialism	Post-industrialism	Political science
Valuation attitude	Recognition attitude	Decision theory
Atomism	Holism	Ethics
Scientific method	Heuristics	Research methods
Modernity or material society	Reflexive modernity or risk society	Ulrich Beck
Analytical ecology	Integrative ecology	C.S. Holling, Resilience alliance

The contemporary literature on science-policy interface issues associated with environmental policy highlights several points identified in the dissertation research. First, that risk and uncertainty are indeed critical confounding elements in environmental policy. Second, anthropogenic contributions to natural systems are adding to complexity and uncertainty. Third, existing policy and regulatory regimes are incapable of managing increasingly complex formulations of uncertainty and risk. Fourth, regulatory regimes are susceptible to political influence regardless of the empirical understanding of the level of risk. Fifth, a persistent theme of two paradigms, although characterized in different ways, emerges from the literature. In general terms the binary themes align with the dissertation proposition of a risk-based paradigm and a precautionary paradigm, and more specifically, there is consistency with the Risk-precaution Epistemic Alignment Table (Figure 7.5) whereby risk and uncertainty can be described as a tension between technocratic objectivism versus pluralistic subjectivism. Sixth, the precautionary principle, while being advocated by contemporary scholars as an important element for addressing uncertainty in anticipatory policy, remains difficult in practice.

Ironically, the main failure of the precautionary principle is in addressing what is variously referred to as “deep uncertainty”, “extreme uncertainty”, “ambiguity” or “Knightian uncertainty” in complex systems, which is where policy innovation is most needed.

Four barriers to effective environmental policy-making in Canada have been identified in the research as:

1. The primacy of resources (staples) in Canada’s economy, represented within the federal government as core client groupings, of which environment is not one.
2. The dominance of material society policy practices trapped in the social reality of world risk society.
3. The limited national jurisdictional scope for Environment Canada whereby provinces have primary responsibility for resource management (except fisheries), air and water quality, and pollution control.
4. The limited stature of Environment Canada within the federal political system, exacerbated by the joint administration of environmental legislation, policies and programming, where Environment Canada, as the weaker link in material society, has difficulty asserting authority.

These historical factors provide a critical context for reviewing the science-policy interface in Canada and provide additional motivation for exploring the role of an effective science-policy interface as a means of improving environmental policy making. Toxic pollution, and specifically the case of mercury, foretell many of the contemporary challenges Canada and the world face regarding the difficulty in managing environmental stress, particularly in cases where uncertainty is manufactured by strong material society interests which resist policies that may harm economic performance.

It is an example that contributes to a broader understanding of the complex systemic challenges in world risk society that translate into environmental policy stasis in Canada. Characteristics of mercury policy history in Canada have strong similarities to climate change debates and greenhouse gas restrictions (others include lead, and toxic substances) with protracted policy exercises and political discourses, fueled by industry efforts to inject uncertainty, trapped between epochs.

The research confirms that we are living in a world risk society and this explains the failure of environmental regulatory risk processes and the breakdown of the science-policy interface in Canada, with specific challenges at Environment Canada, as summarized below:

1. We are living in world risk society. Humans have irreparably altered the Earth's ecosystems to the point where materially significant contributions of most of the basic life forces and "death forces" are anthropogenic. A primary element of the research was to build support for the idea that ecological research and global natural systems research are pointing to ever increasing complexity. Uncertainty is a dominant discourse in science-policy and an increasing reality in environmental and ecosystem sciences. This was borne out in the literature as well as through the expert survey data. Confidence regarding scientific understanding of ecosystems has not been established.

2. The pace and extent of human intervention in natural biogeochemical cycles has injected an increased level of complexity and uncertainty in ecosystem science beyond natural factors, consistent with risk society discourse articulated by Beck and others. Predictability of ecosystem responses to anthropogenic interventions is not keeping pace with the nature and extent of anthropogenic inputs. Whereas ecological systems are inherently complex, and many are increasingly seen to be more complex, there is the additional complexity of human intervention as the single largest input parameter in fundamental global material cycles (carbon, nitrogen, phosphorous etc) contributing to increasing scientific uncertainty. The Earth is a complex, evolving human construct; the

Anthropocene or risk society, with human activity as the cause of uncertainty Nature is no longer a natural phenomenon.

3. Institutional systems (political, policy and economic) are designed with the assumption that ecosystems are fundamentally unchanging natural systems and that science can be used to establish a reasonable degree of certainty with respect to how ecosystems function and how they respond to anthropogenic interventions. Environmental policy systems, particularly risk assessment and risk management frameworks are mirrors or material society and therefore inadequate for understanding and responding to environmental threats in increasingly complex, dynamic and uncertain ecosystems.

4. Two cultures, “material society” and “risk society”, each with distinct and competing world views, overshadow the field of environmental policy. The dominant industrial and political world view is one of “material society” described herein as the “economic risk paradigm” which supports environmental action as a measured response to firmly established scientific evidence within a linear, objectivist, empiricist risk model. The ecological and social reality is that we live in a “risk society” where “reflexive modernity” or the “adaptive precautionary paradigm” describe an emerging world view which supports environmental action as a necessary, adaptive and iterative response to uncertainty. Concepts of weight of evidence based on accepted uncertainties within a complex non-linear, subjectivist, holistic, ecological model are lacking.

5. The distinction between Beck’s material society and risk society emerge as unique and critical to Canada’s environmental and resource policy, where Canada’s material society interests align with neoliberal epistemology. Beck’s emergence of “world risk society” as a sequential, temporal extension of material society fails in Canada. Rather than exhibiting legitimate, democratic, reflexive elements characteristic of risk society, Canada is trapped in a rationalist, neoliberal epoch where tight policy networks of economic interest dominate environmental policy-making. In this respect, Canada differs from Beck’s European experience in that the science-policy interface in Canada exhibits

contemporary neoliberal cynicism toward science combined with material society economic realities that make for a dysfunctional policy system.

6. Canada's colonial history as raw resource export colony continues to be a relevant context for understanding environmental policy responses in the resource sector. Several theoretical frames provide important insights into science-policy failures in Canada, as well as broader failures to advance ecological and social goals within the sustainable development framework. In addition to Beck's "risk society", three important discourses are connected through this research that explain much of contemporary Canada's approach to the environment writ large: staples theory, resource dependency theory and settler society theory. Each provides a critical historical context for Canada and are essential to understanding contemporary policy conflicts, most notably climate change policy.

7. The Government of Canada, and specifically Environment Canada, have adopted a risk-based decision framework for environmental decision-making that requires a level of scientific certainty that is incompatible with how scientists understand uncertainty in ecological systems. This is especially problematic given the extent of human intervention in biogeochemical cycles. Consequently, policy decisions at Environment Canada are trapped in material society and the "economic risk paradigm" decision sphere (Figure 7.1) and favour maintaining the status quo over making decisions that threaten the economics of industrial activity. The result is a failure to restrict or regulate the use of known toxic chemicals or other pollutants such as greenhouse gases.

8. Science is used as "a pawn" in environmental policy decision-making, as opposed to helping understand and/or facilitate the management of toxic chemicals. Material society strategies create an impediment to taking actions that result in restrictions to toxic chemical use. Industrial interests have been successful at creating the discourse of "sound science", a "public relations scam" designed to slow down environmental policy processes. Two elements of the "sound science" strategy developed by industrial

stakeholders have worked in concert to successfully impede Canada's progress in managing toxic chemicals. First, is the establishment of the risk management model as the primary policy decision tool. Second, is injecting uncertainty (scientific uncertainty, policy uncertainty and economic uncertainty) into the risk assessment process causing delayed action or no action, consistent with maintaining the material society status quo.

9. Environment Canada has a weak political position in the federal system, specifically the department's subservience to economic and resource policy priorities of other government departments and the government overall. This is a result of the historic development of the federal government's primary function as a resource exploitation division of Great Britain, described by staples theory. Unlike material society departments of the federal government (e.g. Fisheries, Natural Resources, Transportation, Industry, Health, Agriculture), Environment Canada does not have an economic, corporate "client base" to which it is accountable. The theoretical idea that "the environment" is the client becomes meaningless when actual clients (corporate interests) are able to exert political influence through client-oriented departments representing their sectors' material society interests.

10. Environment Canada's policies are internally inconsistent regarding concepts of pollution prevention, precaution and science-based policy. Despite the references in numerous policy publications to being "science-based" and using a "precautionary approach" the government did not act in a precautionary fashion to restrict toxic products and toxic pollution, notably mercury. This conclusion is corroborated in academic papers, reports of the Auditor General's Office, and expert interviews.

7.5 Embracing Reflexive Modernity: Risk Governance in Risk Society

It has been shown herein that Beck's risk society theory explains in large measure Canada's failure to manage environmental policy decisions. A corollary question is, how risk society informs risk governance. Beck's work does not provide a clear answer to this question. In fact, one of the dominant critiques of Beck's work is in his inability to move from a theoretical construct to practical applications of risk society theory based on empirical evidence (Elliott, 2002; Jarvis, 2007; Bergkamp, 2017).

In response to some of the critique of Beck's lack of empiricism, the research undertaken herein contributes to the understanding of Beck's central thesis that empirical evidence of ecosystem decline and related human suffering has outweighed policy responses to mitigate the decline. Beck's risk society theory supports the thesis whereby uncertainty and risk of ecological collapse are not scientific or ecological issues themselves but rather constructed by a risk society and produced by discourse politics and institutions, creating new reflexive realities not measurable in ecological terms.

Beck's concepts of "reflexivity" and "reflexive modernity" have parallels with the concepts of adaptive management whereby there is a circularity with aspects of reflection, dissolution and renewal in both adaptation and reflexivity. Both are also responses to uncertainty in the face complex risk. A critical distinction is that whereas adaptive management is based on intentional action, analysis, reflection, adaptation and re-creation; reflexive modernity is an "unintended self-modification of forms" to the point where risk society itself creates the reflexivity (Elliot 2002). Adaptive management can be thought of as an intentional reflection on complex uncertainty to mitigate the failings of rationalist risk regulatory systems; and reflexive modernity as the unintentional consequence of rationalist institutions ("organized irresponsibility") creating a forced reflection.

The research herein contributes to the understanding of science-policy organizational theory and risk governance in terms of adaptation and reflexivity. To be more effective, risk governance systems and science-policy organisations, must focus on the growing conceptualization of organizations as dynamic, co-produced, unbounded "entities in-the-making" versus the conventional management view of organizations as solitary, stable structures (Pallett and Chilvers, 2015). Uncertainty and complexity in climate policy is a reference point for this organizational shift, noting that adaptive management and reflexivity are necessary elements of addressing uncertainty in science-policy debates. Describing global climate risk, Beck (2015) introduces the idea of “emancipatory catastrophism” meaning that whereas climate change produces “bads” as in destruction of the climate and much more, the bads that it causes, forces positive side effects, or common goods. An example of the common goods would be the closure of Chinese coal plants and the global adoption of renewable energy sources, making the Chinese healthier and providing electricity to parts of the world that have never had access to it.

Reflection and reflexivity are needed if policy models are to address chemical management, suggesting further that participatory and/or precautionary approaches need to be incorporated into reflexive models (Udovyk, 2014). “Under conditions of significant uncertainty, the basis of risk evaluation needs to include the results of collective reflection”, as Udovyk (2014) notes.

There are differences between reflexivity and adaptive management in that adaptive management, as the name suggests, is about adapting and managing future risk in complex and uncertain ecosystems; it is a policy and resource management tool, perhaps too rationalist for Beck. Reflexive modernity, on the other hand is a theoretical construct that is reactive, not proactive; abstract not practical. Furthermore, there is an element of “hopelessness” in Beck’s thesis, compounded by his lack of analysis of practical policy mechanisms to overcome the systemic challenges he points to. In risk society bad things are being done to “us” and our response is involuntary, uncontrollable and future altering. Humans are passive recipients of the bad and mostly making it worse through negative feedback loops of reflective behaviour. Adaptive management is the opposite in as much as it is a forward-looking management practice designed to cope with, overcome, adapt to, or move beyond the unintended consequences of risk society.

Beck’s idea of “reflexive regulation”, while somewhat more forward looking, relies heavily on voluntary arrangements between government and industry or “enforced self-regulation” (Matten, 2014) which in Canada embody the environmental failures highlighted herein. Voluntary arrangements in Canada were, for the most part, the manifestation of material society’s interests to avoid regulatory actions, and moreover the successful manipulation of the design and outcomes of the risk assessment and management process.

In Fahey and Pralle's (2016) review of complexity in environmental policy they concluded that it is at the nexus of "two complex and evolving systems: natural environments and human policy-making and governance." Consistent with Beck's tension between modernity and reflexive modernity, as well as reinforcing the idea of two paradigms or two cultures. Importantly, they note the absence of policy feedback analysis, a critical component in both adaptive management and reflexivity. Lack of adaptive or conscious reflexive feedback leaves major gaps in how we understand policy complexity. Both Adaptive management and reflexivity necessitate policy feedback and need to be considered in any science-policy governance model that attempts to integrate complexity and uncertainty in world risk society. For adaptive management to succeed "governance systems must be reconfigured or transformed" and "exhibit resilience, defined as the ability of a desired social ecological system to reorganize and renew itself following disturbance" (Layzer and Schulman, 2017).

Small et al. (2014) echo the view of other researchers in calling for the need to evolve existing institutions and establish new institutions to strengthen risk governance. They too use hydraulic fracturing in U.S. shale to evaluate risk governance. Sidortsov (2014) concludes his analysis noting the need for innovation and new approaches to governing risk where theoretical knowledge is "hardly enough" and that a "deep understanding" of the "practical effect" of laws and policies is required.

In their research synthesizing organizational theory as it applies to science-policy organizations, Pallett and Chilvers (2015) focus on the growing conceptualization of organizations as dynamic, co-produced, unbounded "entities in-the-making" versus the conventional management view of organizations as solitary, stable structures. Uncertainty and complexity in climate policy is a reference point for this organizational shift, noting that adaptive management and reflexivity are necessary elements of addressing uncertainty in science-policy debates. Udovyk (2014) also recommends reflection and reflexivity in policy models for addressing chemical management suggesting further that participatory and/or precautionary approaches need to be incorporated into reflexive models. According to Udovyk (2014) "under conditions of significant uncertainty, the basis of risk evaluation needs to include the results of collective reflection."

Perez and Snir (2013), as with many others, raise the need for new risk governance models and point out the need for research into the linkages between the "scientific" and the "political" again resembling the binary science-policy paradox described by Bulkeley and Newell (2015) and Marshall et al. (2017). Klinke and Renn (2014) describe post-normal risk governance as a necessary response to uncertainty noting specifically the challenge of anthropogenic risk within existing risk regulation systems. This is a similar idea to regulatory systems not keeping pace with increasing uncertainty related to human intervention in ecosystems.

The authors focus on expert advice and more specifically the idea that a division of labour between experts, stakeholders and the state will lead to superior policy outcomes. The suggestion in the dissertation research that the traditional risk model, including risk assessment and risk management, is inadequate for addressing uncertainty is stated (Klinke and Renn, 2014). Instead research-policy partnerships are needed with systematic, collaborative mechanisms between scientists and policy-makers (Marshall et al., 2017; Richards, 2017) and as described in the expert interviews.

The science-policy interface is a dynamic interaction between multiple processes of knowledge production and decision-making (Wesselink et al., 2012). The authors usefully note the need for institutional innovation in academia to recognise the effort required to be effective in policy influence. Suggestions in Marshall et al. (2017) are in many ways obvious to policy practitioners, as discovered in the survey research, such as the need to commit adequate time to meet with policy-makers and attempting to understand the motivations of policy-makers.

Finally, the call for new forms of risk governance is repeated throughout the contemporary literature as well as being a central theme in Beck's risk society. Whereas many scholars point to the need for "new", "evolved", "innovative", "reflective" risk governance, there is an absence of concrete analysis of what this may look like, and moreover, a repeated call for additional research into the optimal design of risk governance structures. A common element of proposed new governance design is a move toward dynamic, interactive and adaptive governance structures, away from traditional linear "science advice" models.

The connection often missing in academic research on science-policy debates is the idea that the policy actors are not operating with a view to advance good risk governance or improve the adoption of evidence-based policy making, but rather are working within a governance structure that is not trusted, to achieve a specific aim that is typically either to advance or prevent an economic activity. Risk governance systems as they stand are largely incapable of producing widely accepted policy responses where there is uncertainty combined with complexity.

Furthermore, there is a connection between material society and neo-liberalism. The anti-science stance of neo-liberals is a representation of material society reconstituted as neo-liberalism in resource-based economies like Canada, Australia and many in the Global South. There is an element of Beck's work that implies a temporal connection between material society and risk society, that one succeeds the other. This may be the case in EU countries that are not resource-based, otherwise it may be a phantasm. More specifically, risk society may be a normative goal, like sustainability; there to promote change but not necessarily a sequential relationship between the two ideas.

Wessellink et al. (2012) offer coherent insights into the *realpolitik* of science-policy interactions introducing hegemony and politics at the science-policy interface as was raised in Chapter 2 of the dissertation to describe the conventional risk paradigm. Several examples of local and/or indigenous knowledge being discredited in favour of supposed neutral scientific expertise have been described as examples of technocratic hegemony (Wessellink et al., 2012).

Policy actors use science as a political technique to advance a cause. Policy discourse and framing become critical elements of policy decision-making and in many ways outweigh science in policy making. The path forward is almost certainly defined by the need for wider recognition of the integrative, non-linear nature of the science-policy interface and an acceptance of the many elements of a precautionary paradigm that include heuristics, pluralism and subjectivity. More to the point, the main take-away from Hessing et al. is that resource policy in Canada has never been democratic but instead has been controlled by tight networks of regulators and interests. Economic interests defined the policy discourse and the regulatory infrastructure. This was made clear in the mercury policy case study. Risk society is, by definition, democratic. A policy chasm has been created in Canada between the narrow policy network structure of material society and the democratic imperative of risk society.

Two of the “alternatives” to traditional regulatory risk approaches to managing the environment: the precautionary principle and adaptive management were found lacking. Application of the precautionary principle has shown limited success and behaves as a theoretical concept not a practical policy-making tool leaving it open to criticism and difficult to implement. Adaptive management was found (Layzer and Schulman, 2017) to be difficult to implement in practice. A new form of hybrid environmental management may be needed that combines and updates the valuable contributions of both the precautionary approach and adaptive management; hence the adaptive precautionary paradigm.

Most importantly as part of this effort there needs to be further research on how to craft an overt and explicit recognition of the extent to which discourse, framing and political motivation drive risk governance policy processes and outcomes. Environmental policy would benefit from new governance approaches that value and embed transparency, diversity and iteration at the science-policy interface; effectively making them more democratic, consistent with risk society.

Reflexive modernization and adaptive management seek to enable more sophisticated actions (policy, societal, or in the case of adaptive management, the actions of resource managers) in response to uncertainty in complex systems. The critical aspect being reflection and adaptation to the alterations and responses following a deliberate human intervention in a system; for risk society, the response is largely societal in scale, whereas in adaptive management, the response to a human management intervention is seen through an ecosystem adaptation. The concept of “*status quoism*” is relevant across the various theoretical dimensions of “material society”, staples economy” and “settler society” whereby a lack of willingness or ignorance or deliberate and intentional efforts.

A risk society frame places settler society and the future rights of Indigenous people within a broader understanding of global risk, versus an isolated and marginalized understanding of Indigenous communities as “out there” and “disconnected”. With this in mind, “the suppression of Indigenous input” has potentially “detrimental consequences” for “all human settlements" (Borrows, 1997). Being trapped in material society, as Canada’s political economy clearly is, perpetuates settler society environmental racism, along with environmental policies that place industrial resource interests ahead of ecological protection. Staples theory, seen by some as a historical relic, is rather a fundamental political-economy framework for understanding modern environmental policy in Canada; most notably when combined with the work of Howlett et al. on the resource-dependency in environmental policy together with settler society discourse.

Beck’s risk society thesis, now twenty-five years old, retains a critical relevance today, that in some respects is even more important to understanding contemporary environmental science-policy discourse, especially in Canada. Beck’s central themes of uncertainty, complex risk, globalization, institutional failure, “organized irresponsibility,” and reflexive modernity presage climate risk in the Anthropocene. The trends Beck identified twenty-five years ago have mostly accelerated, as has the power of global corporations relative to governments and public interest groups, reinforcing the power of material society. Canada, as a staple economy, is still trapped n material society while the sustainability issues we attempt to address are firmly rooted in global risk society. The science-policy interface is therefore recast through this research as an adaptive precautionary model where social reflexivity frames the decision sphere.

CHAPTER 6 END NOTES

Pollution Control Survey Results

1. Professional Affiliation

1. Please indicate your professional affiliation (choose one). Note: if you are a consultant to mainly one sector please choose that sector.	Response Percent	Response Count
Corporate/private sector	11.3%	66
Government	11.3%	66
Non-government (ENGO)	**58.2%**	**341**
Academic	6.1%	36
Other (please specify)	13.1%	77
answered question		**586**
skipped question		**2**

2. Academic Training

2. Please indicate your principal academic training (choose one).	Response Percent	Response Count
Natural Sciences	**35.2%**	**206**
Law	4.6%	27
Engineering	3.8%	22
Management/Economics	8.0%	47
Social/Political Sciences	25.3%	148
Other (please specify)	23.2%	136
answered question		**586**
skipped question		**2**

3. Primary Responsibility

3. Please indicate your primary professional responsibility (choose one)	Response Percent	Response Count
Senior executive	23.2%	135
Risk manager	0.5%	3
Scientific researcher	4.3%	25
Environmental expert	22.0%	128
Government relations/policy	10.8%	63
Other (please specify)	**39.2%**	**228**
answered question		**582**
skipped question		**6**

4. Risk Management Option According to Certainty Level

Please indicate for each of the certainty levels in the far-left column, which risk management option you would advise governments to implement. (Percent refers to peer-reviewed studies suggesting significant harm to the environment.)

	Do nothing	Voluntary reporting	Voluntary pollution prevention planning	Voluntary standard with national target	Regulated emission reductions of 75-95%	Substance/ product ban
No certainty (0%)	13.9% (66)	**29.3% (139)**	24.0% (114)	17.1% (81)	8.8% (42)	6.9% (33)
Limited or conflicting (<25%)	3.2% (15)	10.1% (48)	**30.4% (144)**	28.5% (135)	20.5% (97)	7.4% (35)
Potential or emerging (25% - 50%)	0.8% (4)	2.5% (12)	8.9% (42)	36.9% (175)	**39.5% (187)**	11.4% (54)
Weight of evidence established (51% - 74%)	0.8% (4)	0.6% (3)	0.4% (2)	9.7% (46)	**54.3% (258)**	34.1% (162)
Probable cause of harm (75% - 95%)	0.8% (4)	0.6% (3)	0.4% (2)	1.1% (5)	25.3% (120)	**71.7% (340)**
"Total" certainty (>95%)	0.8% (4)	0.2% (1)	0.0% (0)	0.6% (3)	5.5% (26)	**92.8% (441)**
answered question						
skipped question						

5. Perspectives on Scientific Uncertainty

5. Please indicate whether you agree or disagree with the following statements:							
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Rating Average	Response Count
The risk assessment/risk management approach demands greater scientific certainty for setting regulations, than in the past when risk management was less common	8.4% (38)	27.4% (124)	22.1% (100)	**33.6% (152)**	8.6% (39)	3.07	453
Research on global ecological systems often introduces more uncertainty than certainty	10.7% (49)	**36.8% (168)**	21.9% (100)	26.8% (122)	3.7% (17)	2.76	456
Environmental policy-making addresses scientific uncertainty well	22.1% (101)	**46.5% (212)**	18.9% (86)	11.4% (52)	1.1% (5)	2.23	456
						answered question	**457**
						skipped question	**131**

6. Factors Preventing Action to Prevent Harm

6. Please choose the answer that in your opinion BEST responds to the following question:					
	We are doing all we can	Not enough scientific evidence	Economic factors prevent action	Lack of public awareness	Response Count
Why, given the considerable scientific evidence of the potentially serious environmental harm being caused by humans, do societies not take more action to reduce the risk of harm?	0.4% (2)	0.7% (3)	**73.6% (334)**	25.3% (115)	454
				answered question	**454**
				skipped question	**134**

7. Canadian Government Efforts on Toxic Substance Management Efforts

7. Please choose which answer you think best describes the Canadian government's toxic substance management efforts in implementing the following:

	Very poor	Poor	Moderate	Good	Very good	Rating Average	Response Count
Canadian Environmental Protection Act	10.2% (44)	35.8% (154)	**43.5% (187)**	10.2% (44)	0.2% (1)	2.54	430
Pollution prevention	22.1% (95)	**45.2% (194)**	28.9% (124)	3.5% (15)	0.2% (1)	2.14	429
Precautionary principle	**40.4% (172)**	36.4% (155)	20.9% (89)	2.3% (10)	0.0% (0)	1.85	426
Risk Assessment	13.3% (56)	**41.1% (173)**	38.0% (160)	7.6% (32)	0.0% (0)	2.40	421
Risk Management	16.7% (71)	**46.5% (198)**	33.3% (142)	3.5% (15)	0.0% (0)	2.24	426
						answered question	**434**
						skipped question	**154**

8. Canada's Approach to Toxic Substances Management

8. Please choose whether you agree or disagree with the following statements regarding Canada's approach to toxic substances management and pollution control decisions.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Rating Average	Response Count
Decisions are transparent	18.7% (81)	**47.2% (205)**	26.5% (115)	6.9% (30)	0.7% (3)	2.24	434
Decisions are accountable	20.8% (90)	**46.5% (201)**	25.7% (111)	6.3% (27)	0.7% (3)	2.19	432
Decisions are mainly based on economics	0.5% (2)	5.1% (22)	19.1% (83)	**56.7% (246)**	18.7% (81)	3.88	434
Decisions are mainly based on science	9.9% (43)	**46.3% (201)**	32.9% (143)	10.4% (45)	0.5% (2)	2.45	434
Decisions are mainly in the public interest	20.9% (91)	**45.5% (198)**	22.5% (98)	10.6% (46)	0.5% (2)	2.24	435
						answered question	**435**
						skipped question	**153**

Environmental Risk Management Survey Results

1. Professional Affiliation

1. Please indicate your professional affiliation (choose one). Note: if you are a consultant mainly to one sector, please choose that sector.	Response Percent	Response Count
Corporate/private sector	**81.0%**	**81**
Government	15.0%	15
Non-government (ENGO)	0.0%	0
Academic	0.0%	0
Other (please specify)	4.0%	4
answered question		**100**
skipped question		**5**

2. Academic Training

2. Please indicate your principal academic training (choose one).	Response Percent	Response Count
Natural Sciences	34.3%	34
Law	1.0%	1
Engineering	**39.4%**	**39**
Management/Economics	15.2%	15
Social/Political Sciences	2.0%	2
Other (please specify)	8.1%	8
answered question		**99**
skipped question		**6**

3. Primary Responsibility

3. Please indicate your primary professional responsibility (choose one)	Response Percent	Response Count
Senior executive	27.6%	27
Risk manager	8.2%	8
Scientific researcher	2.0%	2
Environmental expert	**30.6%**	**30**
Government relations/policy	1.0%	1
Other (please specify)	**30.6%**	**30**
	answered question	**98**
	skipped question	**7**

4. Risk Management Option According to Certainty Level

Please indicate for each of the certainty levels in the far left column, which risk management option you would advise governments to implement. (Percent refers to peer-reviewed studies suggesting significant harm to the environment.)

	Do nothing	Voluntary reporting	Voluntary pollution prevention planning	Voluntary standard with national target	Regulated emission reductions of 75-95%	Substance/ product ban
No certainty (0%)	**44.7% (34)**	32.9% (25)	11.8% (9)	10.5% (8)	0.0% (0)	0.0% (0)
Limited or conflicting data (<25%)	11.8% (9)	**44.7% (34)**	25.0% (19)	15.8% (12)	2.6% (2)	0.0% (0)
Potential or emerging (25% - 50%)	3.9% (3)	15.8% (12)	27.6% (21)	**40.8% (31)**	11.8% (9)	0.0% (0)
Weight of evidence established (51% - 74%)	3.9% (3)	2.6% (2)	11.8% (9)	**39.5% (30)**	36.8% (28)	5.3% (4)
Probable cause of harm (75% - 95%)	3.9% (3)	1.3% (1)	3.9% (3)	10.5% (8)	**63.2% (48)**	17.1% (13)
"Total" certainty (>95%)	3.9% (3)	1.3% (1)	0.0% (0)	3.9% (3)	31.6% (24)	**59.2% (45)**
					answered question	
					skipped question	

5. Perspectives on Scientific Certainty

5. Please indicate whether you agree or disagree with the following statements:							
	Strongly disagree	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**	**Rating Average**	**Response Count**
The risk assessment/risk management approach demands greater scientific certainty for setting regulations, than in the past when risk management was less common	1.4% (1)	12.7% (9)	18.3% (13)	**53.5% (38)**	14.1% (10)	3.66	71
Research on global ecological systems often introduces more uncertainty than certainty	4.2% (3)	25.4% (18)	28.2% (20)	**38.0% (27)**	4.2% (3)	3.13	71
Environmental policy-making addresses scientific uncertainty well	7.1% (5)	**51.4% (36)**	31.4% (22)	10.0% (7)	0.0% (0)	2.44	70
						answered question	**71**
						skipped question	**34**

6. Given Scientific Evidence Why Do We Not Take Action

6. Please choose the answer that BEST responds to the following question:					
	We are doing all we can	**Not enough scientific evidence**	**Economic factors prevent action**	**Lack of public awareness**	**Response Count**
Why, given the considerable scientific evidence of the potentially serious environmental harm being caused by humans, do societies not take more action to reduce the risk of harm?	0.0% (0)	11.4% (8)	**67.1% (47)**	21.4% (15)	70
				answered question	**70**
				skipped question	**35**

7. Canadian Government Efforts on Toxic Substances Management

7. Please choose which answer you think best describes the Canadian government's toxic substance management efforts in implementing the following:

	Very poor	Poor	Moderate	Good	Very good	Rating Average	Response Count
Pollution Prevention	6.0% (4)	23.9% (16)	**49.3% (33)**	19.4% (13)	1.5% (1)	2.87	67
Precautionary Principle	6.0% (4)	25.4% (17)	**52.2% (35)**	16.4% (11)	0.0% (0)	2.79	67
Risk Assessment	3.0% (2)	20.9% (14)	**52.2% (35)**	23.9% (16)	0.0% (0)	2.97	67
Risk Management	4.5% (3)	17.9% (12)	**53.7% (36)**	23.9% (16)	0.0% (0)	2.97	67
Canadian Environmental Protection Act	1.5% (1)	13.4% (9)	**47.8% (32)**	37.3% (25)	0.0% (0)	3.21	67
						answered question	**67**
						skipped question	**38**

8. Canada's Approach to Toxic Substances Management

8. Please choose whether you agree or disagree with the following statements regarding Canada's approach to toxic substances management and pollution control decisions.							
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Rating Average	Response Count
Decisions are transparent	3.0% (2)	25.4% (17)	**43.3% (29)**	28.4% (19)	0.0% (0)	2.97	67
Decisions are accountable	3.0% (2)	35.8% (24)	**43.3% (29)**	17.9% (12)	0.0% (0)	2.76	67
Decisions are mainly based on economics	1.5% (1)	**35.8% (24)**	32.8% (22)	28.4% (19)	1.5% (1)	2.93	67
Decisions are mainly based on science	1.5% (1)	20.9% (14)	**49.3% (33)**	28.4% (19)	0.0% (0)	3.04	67
Decisions are mainly in the public interest	1.5% (1)	17.9% (12)	**44.8% (30)**	34.3% (23)	1.5% (1)	3.16	67
						answered question	**67**
						skipped question	**38**

REFERENCES

Chapter 1: Introduction and Problem Statement

Aarhus Protocol on Persistent Organic Pollutants (1998), accessed at: http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1998.POPs.e.pdf.

Boardman, R. (1992), Canadian Environmental Policy: Ecosystems, Politics and Process. Oxford: Oxford University Press.

Boardman, R. and Van Nijnatten, D. (2009), Canadian Environmental Policy and Politics: Prospects for Leadership and Innovation. Oxford: Oxford University Press, 296.

Borrows, J. (1997), "Living between Water and Rocks: First Nations, Environmental Planning and Democracy", *The University of Toronto Law Journal*, 47 (4): 417-468.

Boyd, D. R. (2003), Unnatural Law: Rethinking Canadian Environmental Law and Policy. Vancouver: University of British Columbia Press, p. 469.

Bradshaw, G. A. and J. G. Borchers (2000), "Uncertainty as Information: Narrowing the Science-Policy Gap", *Conservation Ecology*, 4 (1): 7.

Colborn, T., D. Dumanoski and J. P. Myers (1997), Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? A Scientific Detective Story. Dutton, NY: Plume, 306.

Commissioner of the Environment and Sustainable Development (1999), May 1999 Report of the Commissioner of the Environment and Sustainable Development. Accessed at: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_199905_e_1141.html.

Darwin, C. (1859), On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. London: J. Murray.

Doern, G. B. and T. Reed (2000), Chapter 1: Canada's Changing Science-Based Policy and Regulatory Regime: Issues and Framework in Risky Business: Canada's Changing Science-Based Policy and Regulatory Regime, G. B. Doern and T. Reed (Eds.). Toronto: University of Toronto Press, 3-28.

Environment and Climate Change Canada (2011), Environment Canada and Health Canada's Response to Comments Following Consultations on the Proposed Regulations Respecting Products Containing Certain Substances Listed in Schedule 1 to the Canadian Environmental Protection Act, 1999. Accessed at: www.ec.gc.ca/mercure-mercury/default.asp?lang=Enandn=E4070F21-1#X-2011091517001519.

Fahey, B. K. and S. B. Pralle (2016), “Governing Complexity: Recent Developments in Environmental Politics and Policy”, *Policy Studies Journal*, April. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/psj.12159/full.

Grandjean, P. (1999), Mercury Risks: Controversy or Just Uncertainty. *Public Health Reports*, 114: 512-15.

Hessing, M. (2005), Canadian Natural Resource and Environmental Policy: Political Economy and Public Policy. Vancouver: University of British Columbia Press, 338.

Ilyniak, N. (2014), “Mercury Poisoning in Grassy Narrows: Environmental Injustice, Colonialism and Capitalist Expansion in Canada”, *McGill Sociological Review*, 4: 43-66.

Kriebel, D., J. Tickner, P. Epstein, J. Lemons, R. Levins, E. L. Loechler, M. Quinn, R. Rudel, T. Schettler and M. Stoto (2001), “The Precautionary Principle in Environmental Science”, *Environmental Health Perspectives*, 109 (9): 871-76.

Lourie, B. (2009), “Mercury Science-Policy Debates” in Canadian Environmental Policy and Politics: Prospects For Leadership Fourth Edition, D. Van NijNatten and R. Boardman (Eds.). Oxford: Oxford University Press.

Ludwig, D., B. Walker and C. S. Holling (1997), “Sustainability, Stability, and Resilience”, *Conservation Ecology*, 1 (7). Accessed at: http://www.consecol.org/vol1/iss1/art7/.

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), “Empirically Derived Guidance for Social Scientists to Influence Environmental Policy”, *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

Mason, R. P., W. F. Fitzgerald and F. M. M. Morel (1994), “The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences”, *Geochimica et Cosmochimica Acta*, 58 (15): 3191-98.

McKenzie, J. (2002), Environmental Politics in Canada. Accessed at: http://www.oupcanada.com/catalog/9780195415087.html.

Millenial Ecosystem Assessment (2005), Current State and Trends Assessment. Accessed at: www.millenniumassessment.org/en/Condition.html.

Morrone, M. and T. W. Lohner (2002), Sound Science, Junk Policy: Environmental Health Policy and the Decision-Making Process. Dover, MA: Auburn House.

Organisation for Economic Co-operation and Development (2008), Report on Applications of Complexity Science for Public Policy: New Tools for Finding Unanticipated Consequences and Unrealized Opportunities. Accessed at: www.oecd.org/science/sci-tech/43891980.pdf.

Preston, J. (2013), "Neoliberal Settler Colonialism, Canada and the Tar Sands", *Race and Class*, 55 (2): 42-59.

Salter, L. (1988), Mandated Science: Science and Scientists in the Making of Standards. Dordt: Kluwer Academic Publishers.

Schlosberg, D. and D. Carruthers (2010), "Indigenous Struggles, Environmental Justice, and Community Capabilities", *Global Environmental Politics*, 10 (4): 4-35

Smith, R. and B. Lourie (2009) Slow Death by Rubber Duck: How the Toxic Chemistry of Everyday Life Affects Our Health, Toronto: Knopf Canada.

Udovyk, O. (2014), "Models of Science–Policy Interaction: Exploring Approaches to Bisphenol A Management in the EU", *Science of the Total Environment*, July. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0048969714003763.

Union of Concerned Scientists (2004), Scientific Integrity in Policy Making: Further Investigation of the Bush Administration's Abuse of Science. Accessed at: http://www.ucsusa.org/scientific_integrity/abuses_of_science/reports-scientific-integrity.html.

Vitousek, P., H. A. Mooney, J. Lubchenco and J. M. Melillo (1997), "Human Domination of Earth's Ecosystems", *Science*, 277 (5325): 494-99.

Wesselink, A., K. S. Buchanan, Y. Georgiadou and E. Turnhout (2013), "Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface", *Environmental Science and Policy*, January. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S1462901112002365.

Chapter 2: Theoretical Framework and Methodology

Adams, R. L. A. (1973), "Uncertainty in Nature, Cognitive Dissonance and the Perceptual Distortion of Environmental Information: Weather Forecasts and New England Beach Trip Decisions", *Economic Geography*, 49 (4): 287-97.

Adkin, L. (2009), Environmental Conflict and Democracy in Canada. Vancouver: University of British Columbia Press.

Barry, D. and M. Oelschlaeger (1996), "A Science for Survival: Values and Conservation Biology", *Conservation Biology*, 10: 905-11.

Bolin, B. and R. B. Cook (1983), "The Major Biogeochemical Cycles and their Interactions", *SCOPE,* 21. Chichester: John Wiley and Sons.

Boyd, D. (2015), Cleaner, Greener, Healthier: A Prescription for Stronger Canadian Environmental Laws and Policies. Vancouver: University of British Columbia Press.

Boyd, D. (2003), Unnatural Law: Rethinking Canadian Environmental Law and Policy. Vancouver: University of British Columbia Press.

Bradshaw, G. A. and J. G. Borchers (2000), "Uncertainty as Information: Narrowing the Science-Policy Gap", *Conservation Ecology, 4* (1): 7

Bulkeley, H. and P. Newell (2017). Governing Climate Change. Abingdon, UK: Routledge Press.

Bushe, G. (1995), "Advances in Appreciative Inquiry as an Organization Development Intervention", *Organization Development Journal*, 13 (3): 14-22.

Cordner, A. (2015), "Strategic Science Translation and Environmental Controversies", *Science, Technology and Human Values*, May, 40 (6): 915-38.

Government of Canada (2001), Report of the Commissioner of Environment and Sustainable Development, Auditor Generals' Office 2001. Accessed at: http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c101sec8e.html.

Capra, F. (1975), The Tao of Physics. Boulder, CO: Shambhala.

Colborn, T., D. Dumanoski and J. P. Myers (1997), Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? A Scientific Detective Story. Dutton, NY: Plume, 306.

Commissioner of the Environment and Sustainable Development (1999), *May 1999 Report of the Commissioner of the Environment and Sustainable Development*. Accessed at: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_199905_e_1141.html.

Cooperrider, D. L. and S. Srivastva (1987), Appreciative Inquiry in Organizational Life in Research in Organizational Change and Development, R. Woodman and W. Pasmore (Eds.). Greenwich, CT: JAI Press, 129-69.

Cranor, C. F. (1995), The Use of Comparative Risk Judgments in Risk Management in Toxicology and Risk Assessment: Principles, Methods and Applications, A. M. Fan and L. W. Chang (Eds.). New York: Marcel Dekker, 817-33.

Edge, S. and J. Eyles (2013), "Message in a Bottle: Claims Disputes and the Reconciliation of Precaution and Weight-of-Evidence in the Regulation of Risks from Bisphenol A in Canada", *Health, Risk and Society*, April. Accessed at: http://www.tandfonline.com.myaccess.library.utoronto.ca/doi/abs/10.1080/13698575.2013.802293.

Ehrlich, P.R., A. H. Ehrlich and G. C. Daily (1993), "Food Security, Population, and Environment", *Population and Development Review*, 19: 1-32.

Environics (2003), Global Issues Monitor, Report. Toronto: Environics.

Fahey, B. K. and S. B. Pralle (2016), "Governing Complexity: Recent Developments in Environmental Politics and Policy", *Policy Studies Journal*, April. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/psj.12159/full.

Giddens, A. (1999), "Risk and Responsibility", *Modern Law Review*, 62 (1): 1-10.

Giddens, A. (1999), Runaway World: How Globalization Is Reshaping Our Lives. London: Profile.

Gunderson, L. H. and C. S. Holling (2002), Panarchy: Understanding Transformations in Human and Natural Systems. Washington D.C.: Island Press.

Hoey, J. (1997), "Human Rights, Ethics and the Krever Inquiry", *Canadian Medical Association Journal*, 1 (9): 1231.

Homer-Dixon, T. (2001). The Ingenuity Gap. Toronto: Random House.

Jackson, T.A. (1997), "Long-Range Atmospheric Transport of Mercury to Ecosystems and the Importance of Anthropogenic Emissions – A Critical Review and Evaluation of the Published Evidence", *Environmental Review*, 5: 99-120.

Kiss, S. (2014), “Where Did All The Baby Bottles Go? Risk Perception, Interest Groups, Media Coverage and Institutional Imperatives in Canada's Regulation of Bisphenol A”, *Canadian Journal of Political Science*, December.

Klinke, A. and O. Renn (2014), “Expertise and Experience: A Deliberative System of a Functional Division of Labor for Post-Normal Risk Governance”, *Innovation: The European Journal of Social Science Research*, August. Accessed at: http://www.tandfonline.com.myaccess.library.utoronto.ca/doi/abs/10.1080/13511610.2014.943160.

Layzer, J. A. and A. Schulman. (2017), Adaptive Management: Popular but Difficult to Implement in Conceptual Innovation in Environmental Policy, J. Meadowcroft and D. J. Fiorino (Eds.). Cambridge, MA: Massachusetts Institute of Technology Press.

Lee, K. N. (1993), Compass and Gyroscope: Integrating Science and Politics for the Environment. Washington, D.C.: Island Press.

Leiss, W. (2001), In the Chamber of Risks: Understanding Risk Controversies. Montreal, QC and Kingston, ON: McGill-Queen’s University Press.

Lele, S. and Norgaard, R. B. (1996), “Sustainability and the Scientist’s Burden”, *Conservation Biology*, 10 (2): 354-65.

Lourie, B. (2009), Mercury Science-Policy Debates in Canadian Environmental Policy and Politics: Prospects For Leadership Fourth Edition, D. Van NijNatten and R. Boardman (Eds.). Oxford: Oxford University Press.

Lucotte, M. R. et al. (1999), Mercury in the Biogeochemical Cycle. Berlin: Springer, 334.

Ludwig, D., R. Hilborn and C. Walters (1993). Uncertainty, Resource Exploitation and Conservation: Lessons from History, *Science*, 260 (17): 36.

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), “Empirically Derived Guidance for Social Scientists to Influence Environmental Policy”, *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

McEvoy, A. (1990), The Fisherman's Problem: Ecology and Law in the California Fisheries, 1850–1980; Evanston, IL: Northwestern University Press.

McKibben, B. (1989), The End of Nature. New York: Random House.

Milich, L. (1999), “Resource Mismanagement Versus Sustainable Livelihoods: The Collapse of the Newfoundland Cod Fishery”, *Society and Natural Resources*, 12 (7).

Millenial Ecosystem Assessment (2005), Current State and Trends Assessment. Accessed at: www.millenniumassessment.org/en/Condition.html.

Mitchell, B. (2002), Resource and Environmental Management. Abingdon, UK: Routledge.

M'Gonigle, M. (1999), "Ecological Economics and Political Ecology: Towards a Necessary Synthesis", *Ecological Economics*, 28 (1): 11-26.

Montague, P. (1999), "The Uses of Scientific Uncertainty", *Rachel's Environment and Health Weekly*, 657.

Morrone, M. and T. W. Lohner (2002), Sound Science, Junk Policy: Environmental Health Policy and the Decision-Making Process. Dover, MA: Auburn House.

Munthe, J., I. Wängberg, N. Pirrone, A. Iverfeldt, R. Ferrara, R. Ebinghaus, X. Feng, K. Gårdfeldt, G. Keeler, E. Lanzillotta, S. E. Lindberg, J. Lu, Y. Mamane, E. Prestbo, S. Schmolke, W. Schroeder, J. Sommar, F. Sprovieri, R. K. Stevens, W. Stratton, G. Tuncel and A. Urba (2001), "Intercomparison of Methods for Sampling and Analysis of Atmospheric Mercury Species", *Atmospheric Environment*, 35 (17): 3007-17.

Neville, K. J. and E. Weinthal (2016), "Mitigating Mistrust? Participation and Expertise in Hydraulic Fracturing Governance", *Review of Policy Research*, September. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/ropr.12201/full.

New Directions Group (2004), Applying Precaution in Environmental Decision Making in Canada. Accessed at: http://www.newdirectionsgroup.org/projects/precaution.php.

Oreskes, N., K. Belitz and K. Schrader-Frechette (1994), "Verification, Validation and Confirmation of Numerical Models in the Earth Sciences", *Science*, 263 (4): 641-46.

Pallett, H. and J. Chilvers (2015). "Organizations in the Making: Learning and Intervening at the Science-Policy Interface", *Progress in Human Geography*, April. Accessed at: https://search-proquest-com.myaccess.library.utoronto.ca/docview/1663507743/D0006BD0CA1B4325PQ/2?accountid=14771.

Policansky, D. (1993), Fishing as a Cause of Evolution in Fishes in The Exploitation of Evolving Resources, T. K. Stokes, J. M. McGlade and R. Law (Eds.). Berlin: Springer-Verlag, 2–18.

Pollution Probe (2001), Applying the Precautionary Principle to Standard Setting. Accessed at: http://www.pollutionprobe.org/old_files/Publications/datepublished.html.

Pritchard, L. and S. E. Sanderson (2002), The Dynamics of Political Discourse in Seeking Sustainability in Panarchy: Understanding Transformations in Human and Natural Systems, L. H. Gunderson and C. S. Holling (Eds.). Washington, D.C.: Island Press, 147-72.

Raffensperger, C. and J. A. Tickner (1999), Protecting Public Health and the Environment: Implementing the Precautionary Principle. Washington, D.C.: Island Press.

Rampton, S. and J. Stauber (2001), Trust Us, We’re Experts! How Industry Manipulates Science and Gambles with Your Future. New York: Penguin Putnam.

Salter, L. (1988), Mandated Science: Science and Scientists in the Making of Standards. Dordt: Kluwer Academic Publishers.

Salzman, J. (2007), A Field of Green? The Past and Future of Ecosystem Services. Durham, NC: Duke Law School Legal Studies, Research Paper Series, Research Paper, no. 159.

Santillo, D., R. L. Stringer, P. A. Johnston and J. Tickner (1998), The Precautionary Principle: Protecting against Failures of Scientific Method and Risk Assessment, *Marine Pollution Bulletin*, 36 (12): 939-50.

Shackley, S. and B. Wynne (1996), “Representing Uncertainty in Global Climate Change Science and Policy: Boundary Ordering Devices and Authority”, *Science, Technology and Human Values*, 21 (3): 275-302.

Simon, H. (1996), Research Briefings 1986: Report of the Research Briefing Panel on Decision Making and Problem Solving by the National Academy of Sciences. Washington, D.C.: National Academy Press.

Smil, V. (1997), Cycles of Life Civilization and the Biosphere. New York: Scientific American Library, 221.

Snow, C. P. (1990), “The Two Cultures”, *Leonardo*, 23, (2/3): 169-73.

Vitousek, P., H. A. Mooney, J. Lubchenco and J. M. Melillo (1997), “Human Domination of Earth's Ecosystems”, *Science*, *277* (5325): 494-99.

Szwarc, S. (2004), Fishy Advice: The Politics of Methylmercury in Fish and Mercury Emissions. Washington, D.C.: Competitive Enterprise Institute.

Steffen, W., A. Sanderson, P. D. Tyson, J. Jager, P. M. Matson, B. Moore, F. Oldfield, K. Richardson, H. J. Schnellnhuber, B. L. Turner and R. J. Wasson (2004), Global Change and the Earth System: A Planet Under Pressure. New York: Springer-Verlag, 336.

Susman, G. I. and R. D. Evered (1978), “An Assessment of the Scientific Merits of Action Research”, *Administrative Science Quarterly*, 23, 582-603.

Wahlstrom, B. (1999), A Precautionary Approach to Chemicals Management in Protecting Public Health and the Environment: Implementing the Precautionary Principle, C. Raffensperger, and J. A. Tickner (Eds.). Washington, D.C.: Island Press.

Watkins, M. (2007), Staples Redux, Studies in Political Economy, Vol. 79.

Wesselink, A., K. S. Buchanan, Y. Georgiadou and E. Turnhout (2013), "Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface", *Environmental Science and Policy*, January. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S1462901112002365.

Westley, F., M. Scheffer and W. Brock (2003). "Slow Response of Societies to New Problems: Causes and Costs", *Ecosystems*, 6: 493-502.

World Wide Fund (2010), Living Plant Report 2010. Accessed at: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/2010_lpr/.

Yorque, R., B. Walker, C. S. Holling, L. H. Gunderson, C. Folke, S. R. Carpenter W. A. Brock (2002), Toward an Integrative Synthesis in Panarchy; Understanding Transformation of Human and Natural System, L. H. Gunderson and C. S. Holling (Eds.). Washington, D.C.: Island Press, 419-38.

Chapter 3: Canada's Resource Economy and the Environmental Policy Context

Baehler, K. (2017), Environmental Justice in Conceptual Innovation in Environmental Policy, J. Meadowcroft and D. J. Fiorino (Eds.). Cambridge, MA: Massachusetts Institute of Technology Press.

Borrows, J. (1997), “Living between Water and Rocks: First Nations, Environmental Planning and Democracy”, *The University of Toronto Law Journal*, 47 (4): 417-68.

Cavanagh, E. and L. Veracini (2016), The Routledge Handbook of the History of Settler Colonialism. Abingdon, UK: Routledge Press.

Cotton, R. and J. Zimmer (1992), Canadian Environmental Law: An Overview in Canada – United States Law Journal, 18: 63-84.

Doern, B. and T. Conway (1994), The Greening of Canada: Federal Institutions and Decisions. Toronto: University of Toronto Press.

Dryzek, J. (2005), The Politics of the Earth: Environmental Discourses. Oxford: Oxford University Press.

Dwivedi, O. P. (1980), Resources and the Environment: Policy Perspectives for Canada. Toronto: McClelland and Stewart.

Galbraith, J. K. (1992), The Culture of Contentment. Boston: Houghton Mifflin Harcourt.

Government of Alberta (2006), Department of Energy.

Government of Canada (2003), Departmental Case Studies: Environment Canada, Treasury Board of Canada Secretariat. Accessed at: http://www.tbs-sct.gc.ca/rma/account/studies/ec-ec_e.asp?printable=True#S2.

Government of Canada (2001), Report of the Commissioner of Environment and Sustainable Development, Auditor Generals’ Office. Accessed at: http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c101sec8e.html.

Hanrahan, M. (2017), “Water Insecurity in Canada: National Identity and the Exclusion of Indigenous Peoples”, *British Journal of Canadian Studies*, 30 (1): 69-89.

Hessing, M., M. Howlett and T. Summerville (2005), Canadian Natural Resource and Environmental Policy – Political Economy and Public Policy. Vancouver: University of British Columbia Press.

International Joint Commission (1997), *Focus*, 22 (3).

Innis, H. A. (1956), The Lumber Trade in Canada, Essays in Canadian Economy History.

Laxer, J. (2006), How Harper Wants Washington to See Us. Accessed at: http://www.jameslaxer.com/2006_08_01_archive.html.

Lindblom, C. (1959), The Science of Muddling Through, *Public Administration Review*, 19 (2): 79-88.

Macdonald, Sir. J. A. (1856), Referenced in a speech made by J. W. Pickersgill, 1953. Accessed at: http://empireclubfoundation.com/details.asp?SpeechID=2790andFT=yes.

Murdocca, C. (2010), "'There Is Something in That Water': Race Nationalism and Legal Violence", *Law and Social Inquiry*, 35 (2): 369-402.

Nesbitt, D. (2006), The Origins of Canadian Capitalism in Marxism: A Socialist Annual.

Preston, J. (2013), "Neoliberal Settler Colonialism, Canada and the Tar Sands", *Race and Class*, 55 (2): 42-59.

Thompson, S. (2015), "Flooding of First Nations and Environmental Justice in Manitoba: Case Studies of the Impacts of the 2011 Flood and Hydro Development in Manitoba", *Manitoba Law Journal*.

Torgerson, D. and R. Paehike (1990), Managing Leviathan: Environmental Politics and the Administrative State. Peterborough, ON: Broadview Press.

Razack, S. (2002), Race, Space and the Law: Unmapping a White Settler Society. Toronto: University of Toronto Press.

Schrecker, T. (1990), Resisting Environmental Regulation in Managing Leviathan: Environmental Politics and the Administrative State. Peterborough, ON: Broadview Press.

Stanford, J. (2014), The Staple Theory at 50 Reflections on the Lasting Significance of Mel Watkins' 'A Staple Theory of Economic Growth'. Canadian Center for Policy Alternatives.

Statistics Canada (2006), CANSIM, Tables 379-0017 and 379-0020 and Catalogue no. 15-001-XIE, accessed at: http://www40.statcan.ca/l01/cst01/econ41.htm?sdi=gross%20domestic%20product.

Uddin, S. (2006), The Impact of Higher Commodity Prices on Canada's Trade Balance, Office of the Chief Economist, Foreign Affairs and International Trade, Government of Canada.

United States Energy Information Administration, (2006), accessed at: http://www.eia.doe.gov/emeu/cabs/Canada/Background.html.

Watkins, M. H. (1963), "A Staple Theory of Economic Growth". *Canadian Journal of Economics and Political Science*, 29 (2): 141-58.

Webb, K. (1990), Pollution Control in Canada: The Regulatory Approach in the 1980s. Administrative Law Series, A Study Paper prepared for the Law Reform Commission of Canada. Minister of Supply and Services, Government of Canada.

Woodrow, B. R. (1980), Resources and Environmental Policy-making at the National Level: The Search for a Focus Resources and the Environment: Policy Perspectives for Canada, O.P. Dwivedi (Ed.). Toronto: McClelland and Stewart.

Chapter 4: Risk, Uncertainty and the Regulatory Risk Framework in Material Society

Adams, R. L. A. (1973), “Uncertainty in Nature, Cognitive Dissonance and the Perceptual Distortion of Environmental Information: Weather Forecasts and New England Beach Trip Decisions”, *Economic Geography*, 49 (4): 287-97.

Arthur, W. B. (1994), “Inductive Reasoning and Bounded Rationality”, *American Economic Review*, 84: 406-11.

Ashford, N. A. (1999) A Conceptual Framework for the Use of the Precautionary Principle in Law in Protecting Public Health and the Environment: Implementing the Precautionary Principle, C. Raffensperger and J. A. Tickner (Eds.). Washington, DC: Island Press.

Beck, U. (2015), “Emancipatory Catastrophism: What Does It Mean to Climate Change and Risk Society?”, *Current Sociology*, 63 (1): 75-88.

Beck, U. (1992), Risk Society: Towards a New Modernity. London: SAGE Publications.

Beck, U. (1996), “World Risk Society as Cosmopolitan Society? Ecological Questions in a Framework of Manufactured Uncertainties”, *Theory, Culture and Society*, 13 (4): 1-32.

Berland, N. and M.-C. Loison (2008), “Fabricating Management Practices: Responsible Care and Corporate Social Responsibility”, *Society and Business Review*, 3 (1): 41-56.

Bocking, S. (2006), Nature's Experts: Science, Politics and the Environment. New Brunswick, NJ: Rutgers University Press.

Boehmer-Christiansen, S. (1994), “Global Climate Protection Policy: The Limits of Scientific Advice”, *Global Environmental Change*, 4 (2-3): 140-159 and 185-200.

Bradshaw, G. A. and J. G. Borchers (2000), “Uncertainty as Information: Narrowing the Science-Policy Gap”, *Conservation Ecology*, 4 (1): 7.

British Health and Safety Executive (1999), Reducing Risks, HSE’s Decision-Making Process Protecting People, accessed at: www.hse.gov.uk/risk/theory/r2p2.pdf.

Buege, D. J. (1997), “An Ecologically-Informed Ontology for Environmental Ethics”, *Biology and Philosophy*, 12: 1-20.

Canadian Standards Association (1997), Risk Management: Guidelines for Decision-Makers. CAN/CSA-Q850-97.

Chandrasekaran, B., J. R. Josephson and V. R. Benjamins (1999), "What Are Ontologies and Why Do We Need Them?", *IEEE Intelligent Systems*, 14 (1): 20-26.

Charnley, G. (1999), accessed at: http://65.54.113.26/Author/23820539/gail-charnley.

Congressional Research Service (1998), Environmental Risk Analysis: A Review of Public Policy Issues, 40, Hereinafter: CRS Report 98-618, Part VIII, 3-4.

Cordner, A. (2015), "Strategic Science Translation and Environmental Controversies", *Science, Technology and Human Values*, 40 (6): 915-38.

Edge, S. and J. Eyles (2013), "Message in a Bottle: Claims Disputes and the Reconciliation of Precaution and Weight-of-Evidence in the Regulation of Risks from Bisphenol A in Canada", *Health, Risk and Society*, April. Accessed at: http://www.tandfonline.com.myaccess.library.utoronto.ca/doi/abs/10.1080/13698575.2013.802293.

Ehrlich, P. R. and G. C. Daily (1993), "Population Extinction and Saving Biodiversity", *AMBIO, 22* (2/3): 64-68.

Environmental Protection Agency (1991), Environmental Risk: Your Guide to Analyzing And Reducing Risk, Region 5, Publication Number: 905/9-91/017.

Galbraith, J. K. (1992), The Culture of Contentment. Boston: Houghton Mifflin Company.

Gardner, D. (2008), Risk: The Science and Politics of Fear. Toronto: McClelland and Stewart.

Government of Canada (2001), Report of the Commissioner of Environment and Sustainable Development, Auditor Generals' Office. Accessed at: http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c101sec8e.html.

Government of Canada (2002-2016), Commissioner of the Environment and Sustainable Development Reports, Office of the Auditor General of Canada. Accessed at: www.oag-bvg.gc.ca/internet/English/parl_lp_e_901.html.

Grunwald, A. (2004), "Strategic Knowledge for Sustainable Development: The Need for Reflexivity and Learning at the Interface between Science and Policy", *International Journal on Foresight and Innovation Policy*, 1 (1/2).

Hajer, M. A. (1995), The Politics of Environmental Discourse: Ecological Modernization and the Policy Process. Oxford: Clarendon Press.

Harvard Center for Risk Analysis (1999), The Precautionary Principle: Refine It or Replace It in Making Sense of the Precautionary Principle, *Risk in Perspective*, 7 (6).

Health Canada (2006), Blueprint for Renewal: Transforming Canada's Approach to Regulating Health Products and Food. Accessed at: www.hc-sc.gc.ca/ahc-asc/branch-dirgen/hpfb-dgpsa/blueprint-plan/blueprint-plan_gloss_e.html.

Health Canada (2004), Canadian Handbook on Health Impact Assessment, Volume 2: Approaches and Decision-Making. Accessed at: http://www.hc-sc.gc.ca/ewh-semt/pubs/eval/handbook-guide/vol_2/risk-risque_e.html.

Health Canada (2000), Decision-Making Framework for Identifying, Assessing, and Managing Health Risks. Accessed at: http://www.hc-sc.gc.ca/ahc-asc/alt_formats/hpfb-dgpsa/pdf/pubs/risk-risques_e.pdf.

Health Canada (2010), Prepared by Dr. Marc Saner: A Primer on Scientific Risk Assessment at Health Canada. Accessed at: http://www.hc-sc.gc.ca/sr-sr/pubs/about-apropos/2010-scientif-ris/index-eng.php.

Health Canada (1990), Risk Determination: A Model for Risk Assessment and Risk Management, Health Protection Branch.

Health Canada (1998), Risk Management and Regulation Proposed Decision-Making Framework Presentation to the Decision-Making Challenge Team on Regulatory Reform.

Hester, D. and Pierce, J. (1968), "Cross Section Analysis and Bank Dynamics", *Journal of Political Economy*, 76 (4): 755-76.

Holling, C. S., F. Berkes and C. Folke (1998), Science, Sustainability and Resource Management in Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. New York: Cambridge University Press.

Hurlbert, M. and J. Gupta (2015), "Adaptive Governance, Uncertainty and Risk: Policy Framing and Responses to Climate Change, Drought, and Flood". Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/risa.12510/full.

Iverson, T. and C. Perrings (2012), "Precaution and Proportionality in the Management of Global Environmental Change", *Global Environmental Change*, February. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S09593780110014
.

Jasanoff, S. (1993), "Bridging the Two Cultures of Risk Analysis", *Risk Analysis*, 13 (2).

Jordan, A. and T. O'Riodan (1999), The Precautionary Principle in Contemporary Environmental Policy and Politics in Protecting Public Health and the Environment, Implementing the Precautionary Principle. Washington, D.C.: Island Press.

Keeney, R. (2001), “Appraising the Precautionary Principle – A Decision Analysis Perspective”, *Journal of Risk Research*, 4: 191-202.

Kinzig, A. and D. Starrett (2002), “Coping With Uncertainty: A Call for a New Science-Policy Forum”, *Ambio*, 32 (5): 330-35.

Kiss, S. (2014), “Where Did All The Baby Bottles Go? Risk Perception, Interest Groups, Media Coverage and Institutional Imperatives in Canada's Regulation of Bisphenol A”, *Canadian Journal of Political Science*, December.

Klinke, A. and O. Renn (2014), “Expertise and Experience: A Deliberative System of a Functional Division of Labor for Post-Normal Risk Governance”, *Innovation: The European Journal of Social Science Research*, August. Accessed at: http://www.tandfonline.com.myaccess.library.utoronto.ca/doi/abs/10.1080/13511610.2014.943160.

Knight, F. H. (1921), Risk, Uncertainty and Profit. Hart, Schaffner and Marx. Accessed at: http://www.econlib.org/library/Knight/knRUP1.html.

Layzer, J. A. and A. Schulman. (2017), Adaptive Management: Popular but Difficult to Implement in Conceptual Innovation in Environmental Policy, J. Meadowcroft and D. J. Fiorino (Eds.). Cambridge, MA: Massachusetts Institute of Technology Press.

Leiss, W. (1999), Between Expertise and Bureaucracy – Risk Management Trapped at the Science-policy Interface in Risk Issue Management: A New Approach to Risk Controversies. Accessed at: www.ucalgary.ca/~wleiss/publications/vagaries_body.htm.

Leiss, W. (1999), Inaugural Lecture at the University of Alberta.

Leiss, W. (2001), In the Chamber of Risks: Understanding Risk Controversies. Montreal, QC and Kingston, ON: McGill-Queen’s University Press.

Lele, S. and R. B. Norgaard (1996), “Sustainability and the Scientist’s Burden”, *Conservation Biology*, 10 (2): 354-65.

Lourie, B. (2009), Mercury Science-Policy Debates in Canadian Environmental Policy and Politics: Prospects For Leadership Fourth Edition, D. Van NijNatten and R. Boardman (Eds.). Oxford: Oxford University Press.

Ludwig, D., B. Walker and C. S. Holling (1997), “Sustainability, Stability, and Resilience”, *Conservation Ecology*, 1 (7). Accessed at: http://www.consecol.org/vol1/iss1/art7/.

Maler, K.-G. and A. Fischer (2005), Environment, Uncertainty and Option Values in Handbook of Environmental Economics, K. G. Mäler and J. R. Vincent (Eds.).

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), "Empirically Derived Guidance for Social Scientists to Influence Environmental Policy", *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

Matten, D. (2004), "The Impact of The Risk Society Thesis on Environmental Politics and Management in a Globalizing Economy – Principles, Proficiency and Perspectives", *Journal of Risk Research*, 7 (4): 377-98.

McEvoy, A. (1987), Toward an Interactive Theory of Nature and Culture: Ecology, Production, and Cognition in the California Fishing Industry Environmental Review, 11 (4): 289-305.

Menges, G. (1968).

M'Gonigle, R. M., T. L. Jamieson, M. K. McAllister and R. M. Peterman (1994), "Taking Uncertainty Seriously: From Permissive Regulation to Preventative Design in Environmental Decision Making", *Osgoode Hall Law Journal*, 32 (1): 99-169.

Micheals, D. and C. Monforton. (2005), "Manufacturing Uncertainty: Contested Science and the Protection of the Public's Health and Environment", *American Journal of Public Health*, 95 (1).

Miller, C. A. (2001), Challenges in the Application of Science to Global Affairs in Changing the Atmosphere: Expert Knowledge and Environmental Governance, C. A. Miller and P. N. Edwards (Eds.). Cambridge, MA: Massachusetts Institute of Technology Press.

Mitchell, B. (2002), Resource and Environmental Management. Abingdon, UK: Routledge Press.

National Research Council (1993), Risk Assessment in the Federal Government: Managing the Process. Washington, D.C.: National Academy Press.

National Research Council (1994), Science and Judgment in Risk Assessment. Washington, D.C.: National Academy Press.

Network for Environmental Risk Assessment and Management (2000), Environmental Health Risk Management: A Primer for Canadians. Accessed at: www.irr-neram.ca/pdf_files/primer/full_primer.pdf.

Neville, K. J. and E. Weinthal (2016), "Mitigating Mistrust? Participation and Expertise in Hydraulic Fracturing Governance", *Review of Policy Research*, September. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/ropr.12201/full.

Oreskes, N., Shrader-Frechette, K. and K. Belitz. (1994), "Verification, Validation and Confirmation of Numerical Models in the Earth Sciences", *Science*, 263 (5147): 641-46.

O'Riordan, T. (1995), Risk Management Approaches in Industry. UNEP Industry and Environment, 45-47.

Policansky, D. (1993), Fishing as a Cause of Evolution in Fishes in The Evolution of Evolving Resources, T. K. Stokes, J. M. McGlade and R. Law (Eds.). Berlin: Springer-Verlag, 2-18.

Privy Council Office (2000), Risk Management for Canada and Canadians: Report of the ADM Working Group on Risk Management. Accessed at: http://www.pco-bcp.gc.ca/index.asp?lang=engandpage=informationandsub=publicationsanddoc=aarchives/social-dev/cover-eng.htm#toc.

Raffensperger C. and J. A. Tickner (1999), Protecting Public Health and the Environment, Implementing the Precautionary Principle. Washington, D.C.: Island Press, 385.

Richards, G. W. (2017), "How Research-Policy Partnerships Can Benefit Government: A Win-Win for Evidence-Based Policy-Making", *Canadian Public Policy*, June. Accessed at: http://muse.jhu.edu.myaccess.library.utoronto.ca/article/663225.

Robinson, W. S. (1950), "Ecological Correlations and the Behavior of Individuals", *American Sociological Review*, 15: 351-57.

Rosenhead, J. (2007), Complexity Theory and Management Practice. Accessed at: http://human-nature.com/science-as-culture/rosenhead.html.

Saner, M. (2001), "Real and Metaphorical Moral Limits in the Biotechnology Debate", *Nature Biotechnology*, 19 (609).

Santillo, D., R. Stringer, P. Johnston and J. Tickner (1998), "The Precautionary Principle: Protecting Against Failures of Scientific Method and Risk Assessment", *Marine Pollution Bulletin*, 36 (12): 939-50.

Shackley, S. and B. Wynne. (1996), "Representing Uncertainty in Global Climate Change Science and Policy: Boundary Ordering Devices and Authority", *Science, Technology and Human Values*, 21 (3): 275-302.

Shere, M. E. (1995), "The Myth of Meaningful Environmental Risk Assessment", *Harvard Environmental Law Review*, 19 (409).

Shortreed, J. H., L. Craig and S. McColl (2001), Benchmark Framework for Risk Management, Report 6.

Shrader-Frechette, K. S. (1995), Evaluating the Expertise of Experts. Accessed at: http://www.piercelaw.edu/risk/vol6/spring/shrafrec.htm.

Simpson, J., M. Jaccard and N. Rivers (2007), Hot Air: Meeting Canada's Climate Change Challenge. Toronto: McClelland and Stewart.

Tickner, J. (2002), Operationalizing the Focus on Alternatives and Prevention Opportunities during the Risk Assessment Process.

Udovyk, O. (2014), "Models of Science–Policy Interaction: Exploring Approaches to Bisphenol A Management in the EU", *Science of the Total Environment*, July. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0048969714003763.

Vanderzwaag, D. (1999), The Precautionary Principle. Environmental Law and Policy: Elusive Rhetoric and First Embraces, 8 (355).

Vogel, D. (2012), The Politics of Precaution: Regulating Health, Safety and Environmental Risks in Europe and the United States. Princeton, NJ: Princeton University Press.

von Moltke, K. (1988), The Vorsorgeprinzip in West German Environmental Policy in Twelfth Report: Best Practical Control Options, Royal Commisssion on Environmental Pollution, 3-31.

Wahlström, B. (1999), The Precautionary Approach to Chemicals in Protecting Public Health and the Environment: Implementing the Precautionary Principle, C. Raffensperger and J. J. Tickner (Eds.). Washington, D.C.: Island Press, 51-69.

Watson, B. (1968), The Complete Works of Chuang Tzu. New York: Columbia University Press.

Weale, A. (1992), The New Politics of Pollution. Manchester, UK: Manchester University Press.

Whiteside, K. (2006), Precautionary Politics, Principle and Practice in Confronting Environmental Risk. Cambridge, MA: Massachusetts Institute of Technology Press.

Chapter 5: Mercury-Science Policy, 1995 to 2005: A Case Study of Material Society Debates

Agricola, G. (1950), *De Re Metallica*, H. C. Hoover and L. H. Hoover (Trans.). New York: Dover.

Basdeo, M. and L. Bharadwaj (2013), "Beyond Physical: Social Dimensions of the Water Crisis on Canada's First Nations and Considerations for Governance", *Indigenous Policy Journal*, 23. Accessed at: http://indigenouspolicy.org/index.php/ipj/article/view/142/130.

Beaumont, H. (2016), "Most of First Nation Tests Positive for Mercury Poisoning Decades After Toxic Dumping Into River", *VICE*. Accessed at: https://www.vice.com/en_ca/article/wdbyx4/most-of-first-nation-tests-positive-for-mercury-poisoning-decades-after-toxic-dumping-into-river.

Berkes, F. (1980), The Mercury Problem: An Examination of the Scientific Basis for Policy-Making in Resources and the Environment, O.P. Dwivedi (Ed.). Toronto: McClelland and Stewart, 269-87.

Canadian Press (2004), "Anderson Slams Climate Change Efforts," *Halifax Herald*, October 21.

Canadian Council of Ministers of the Environment (2005), Canada Wide Standards for Mercury: A Report on Progress. Accessed at: http://www.ccme.ca/assets/pdf/joint_hg_progress_rpt_e.pdf.

Coker, W. B. (1995), Processes Effecting Mercury and Associated Metals in Lake Sediment Columns, Ecological Monitoring and Assessment Network, Environment Canada. Accessed at: http://www.eman-rese.ca/eman/reports/publications/mercury95/part15.html.

Engstrom, D.R. and E.B. Swain (1997), "Recent Declines in Atmospheric Mercury Deposition in the Upper Midwest", *Environmental Science and Technology*, 31, 960-67.

Environment Canada (2007), Risk Management Strategy for Mercury Containing Products. Accessed at: www.ec.gc.ca/ceparegistry/documents/part/Merc_RMS/Merc_RMS.cfm.

Fahey, B. K. and S. B. Pralle (2016), "Governing Complexity: Recent Developments in Environmental Politics and Policy", *Policy Studies Journal*, April. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/psj.12159/full.

Fizgerald, W. F., D. R. Engstrom, R. P. Mason and E. A. Nater (1998), "The Case for Atmospheric Mercury Concentration in Remote Regions", *Environmental Science and Technology*, 32, 1-7.

Frodeman, R. (2003), Geologic: Breaking Ground Between Philosophy and the Earth Sciences, New York: State University of New York Press.

Garrett, R. G. (1995), Regional And Large Scale Patterns Of Mercury Distribution: Influential Factors, Proceedings, Mercury Research Network.

Goldberg, S. (2017), "The Town Where Mercury Still Rises", *New York Times*. Accessed at: https://www.nytimes.com/2017/04/19/opinion/the-town-where-mercury-still-rises.html.

Hanisch, C. (1998), "Where is Mercury Deposition Coming From?", *Environmental Science and Technology*, 32, 176-79.

Hudson, R. J. M, S. A. Gherni, W. F Fitzgerald and D. B. Porcella (1995), "Anthropogenic Influences on the Global Mercury Cycle: A Model Based Analysis", *Water, Air and Soil Pollution*, 80, 265-72.

Ilyniak, N. (2014), "Mercury Poisoning in Grassy Narrows: Environmental Injustice, Colonialism and Capitalist Expansion in Canada", *McGill Sociological Review*, 4: 43-66.

Industry Canada (1999), Science Advice for Government Effectiveness (SAGE): A Report of the Council of Science and Technology Advisors. Accessed at: http://publications.gc.ca/site/eng/256539/publication.html.

Innovation.ca (2000), accessed at: http://www.innovation.ca/evaluation/Guelph.pdf.

Jackson, T. A. (1997), "Long-Range Atmospheric Transport of Mercury to Ecosystems and the Importance of Anthropogenic Emissions – A Critical Review and Evaluation of the Published Evidence", *Environmental* Review, 5, 99-120.

Lantzy, R. and F. MacKenzie (1979), *Geochim. Cosmochim. Acta*, 43, 511.

Laundry, R. (1990), Biases in the Supply of Public Policies in Policy Communities and Public Policy in Canada, William Coleman and Grace Skogstad (Eds.). Missisaauga, ON: Copp Clark Pitman.

Leiss, W. (2000), Between Expertise and Bureaucracy: Risk Management Trapped at the Science-policy Interface. Accessed at: http://www.leiss.ca/articles/62

Lindqvist, O., K. Johansson, M. Aastrup and A. Anderson (1991), *Water, Air and Soil Pollution*, 55, 7.

Lopriete, D. C. (2006), The Natural Science and Engineering Research Council as a Granting and Competitiveness Granting Body in Innovation, Science, Environment, B. Doern (Ed.). Montreal, QC and Kingston, ON: McGill-Queen's University Press.

Lucotte, M., A. Mucci, C. Hillaire-Marcel, P. Pichet and A. Grondin (1995), “Anthropogenic Mercury Enrichment in Remote Lakes of Northern Québec”, *Water, Air and Soil Pollution*, 80, 467-76.

Meadowcroft, J. (2009), “Climate Change Governance”, Policy Research Working Paper 4941, World Bank, Washington, DC.

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), “Empirically Derived Guidance for Social Scientists to Influence Environmental Policy”, *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

Mason, R. P., W. F. Fitzgerald and F. M. M. Morel (1994), *Geochim. Cosmochim. Acta*, 58 (15), 3191.

McGrath, J. M. (2016), “How the Waters of Grassy Narrows Were Poisoned”, TVO. Accessed at: https://tvo.org/article/current-affairs/shared-values/how-the-waters-of-grassy-narrows-were-poisoned.

Micheals, D. and C. Monforton (2005), American Journal of Public Health; Supplement 1, Vol. 95 (S1).

Miller, D. R. (1989), Mercury in Canadian Rivers in Ecotoxicology and Climate, P. Bourdeau, J. A. Haines, W. Klein and C. R. Krishna Murti (Eds.). Etobicoke, ON: John Wiley and Sons.

Mitchell, K. and Z. D’Onofrio (2016), “Environmental Injustice and Racism in Canada: The First Step is Admitting We Have a Problem”, *Journal of Environmental Law and Practice*, 29, 305-47.

Natural Resources Canada (2006), accessed at: http://www.nrcan.gc.ca/ms/au_e.htm.

Paul, A. (2016), “First Nation Urges Ontario to Heed Report of Mercury Dump”, *Winnipeg Free Press*. Accessed at: https://www.winnipegfreepress.com/local/first-nation-urges-ottawa-to-heed-report-of-mercury-dump-383820881.html.

Poisson, J. and D. Bruser (2016), “Mercury Levels Enough to Impact Children’s Brain Development: Report”, *Toronto Star*. Accessed at: https://www.thestar.com/news/canada/2016/07/18/mercury-levels-enough-to-impact-childrens-brain-development-report.html.

Poisson, J. and D. Bruser (2016), “Province Ignored Minister’s 1984 Recommendation to Clean Up Mercury in River Near Grassy Narrows: Star Investigation”, *Toronto Star*. Accessed at:

https://www.thestar.com/news/canada/2016/07/04/province-ignored-ministers-1984-recommendation-to-clean-up-mercury-in-river-near-grassy-narrows-star-investigation.html.

Porter, J. (2017), "Mercury Contamination at Grassy Narrows First Nation Can Be Cleaned Up, Scientists Tell Government, Again", *CBC News*. Accessed at: http://www.cbc.ca/news/canada/thunder-bay/grassy-narrows-mercury-report-1.3604183.

Porter, J. (2017), "Ontario Announces $85M to Clean Up Mercury Near Grassy Narrows, Wabaseemoong First Nations", *CBC News*. Accessed at: http://www.cbc.ca/news/canada/thunder-bay/ontario-mercury-cleanup-1.4180631.

Porter, J. (2017), "Ontario Commits to Cleanup of Mercury Contamination Near Grassy Narrows First Nation", *CBC News*. Accessed at: http://www.cbc.ca/news/canada/thunder-bay/ontario-mercury-clean-up-1.3979912.

Rasmussen, P. E. (1994), "Current Methods of Estimating Atmospheric Mercury Fluxes in Remote Areas", *Environmental Science and Technology*, 28, 2233-41.

Salter, L. (1998), Mandated Science: Science and Scientists in the Making of Standards. Dordrecht: Kluwer Academic Press.

Schuster, P. F., D. P. Krabbenhoft, D. L. Naftz, L. D. Cecil, M. L. Olson, J. F. Dewild, D. D. Susong, J. R. Green and M. L. Abbott (2002), "Atmospheric Mercury Deposition During the Last 270 Years: A Glacial Ice Core Record of Natural and Anthropogenic Sources", *Environmental Science and Technology*, 36, 2303-10.

Takaoka, S., T. Fujino, N. Hotta, K. Ueda, M. Hanada, M. Tajiri and Y. Inoue (2013), "Signs and Symptoms of Methylmercury Contamination in a First Nations Community in Northwestern Ontario, Canada", *Science of the Total Environment*, October. Accessed at: https://www.sciencedirect.com/science/article/pii/S0048969713010437.

Turner, S. (2001), "Of Milk and Mandarins: rSBT, Mandated Science and the Canadian Regulatory Style", *Journal of Canadian Studies*, 36 (3).

United Nations Environmental Programme (2002), Global Mercury Assessment, Chemicals, Geneva.

U.S. Environmental Protection Agency (1997), Mercury Study Report to Congress (Volumes I - VIII), Office of Air Quality Planning and Standards and Office of Research and Development, EPA-452/R-97-003 through EPA-452/R-97-010, December. Accessed at: http://www.epa.gov/oar/mercury.html.

Vecsey, C. (1987), "Grassy Narrows Reserve: Mercury Pollution, Social Disruption, and Natural Resources: A Question of Autonomy", *American Indian Quarterly*, 11 (4): 287-314.

Weiss, H. V., M. Koide and E. D. Goldberg (1971), *Science*, 174, 692.

Wesselink, A., K. S. Buchanan, Y. Georgiadou and E. Turnhout (2013), “Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface”, *Environmental Science and Policy*, January. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S1462901112002365.

Willow, A. J. (2014), “The New Politics of Environmental Degradation: Un/expected Landscapes of Disempowerment and Vulnerability”, *Journal of Political Ecology*, 21, 237-58.

Zayed, J. (2005), Interview conducted: August, 2005.

Chapter 6: Original Research Findings and Discussion

Auditor General of Canada (2003), Managing the Safety and Accessibility of Pesticides in Report of the Commissioner of the Environment and Sustainable Development. Ottawa: Office of the Auditor General of Canada.

Boyd, D. (2015), Cleaner, Greener, Healthier: A Prescription for Stronger Canadian Environmental Laws and Policies. Vancouver: University of British Columbia Press.

Boyd, D. (2003), Unnatural Law: Rethinking Canadian Environmental Law and Policy. Vancouver: University of British Columbia Press.

Elgie, S. (2003), Personal communication.

Hall, P. A. (1993), "Policy Paradigms, Social Learning and the State: The Case of Economic Policymaking in Britain", *Comparative Politics*, 25 (3): 275-96.

Hessing, M. and T. Summerville (2005), Canadian Natural Resource and Environmental Policy – Political Economy and Public Policy. Vancouver: University of British Columbia Press.

Kraft, M. E. (2017), Environmental Policy and Politics. New York: Routledge Press.

Leiss, W. (2001), In the Chamber of Risks: Understanding Risk Controversies. Montreal, QC and Kingston, ON: McGill-Queen's University Press.

Leiss, W. (1999), The Censorship of Commercial Speech with special reference to Tobacco Product Advertising in Chapter 6 in Interpreting Censorship in Canada, K. Petersen and A. C. Hutchinson (Eds.). Toronto: University of Toronto Press.

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), "Empirically Derived Guidance for Social Scientists to Influence Environmental Policy", *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

Richards, G. W. (2017), "How Research-Policy Partnerships Can Benefit Government: A Win-Win for Evidence-Based Policy-Making", *Canadian Public Policy*, June. Accessed at: http://muse.jhu.edu.myaccess.library.utoronto.ca/article/663225.

Schrecker, T. (1990), Resisting Environmental Regulation in Managing Leviathan: Environmental Politics and the Administrative State. Calgary: Broadview Press.

VanNijnatten, D. L. and R. Boardman (2009), Canadian Environmental Policy and Politics: Prospects for Leadership and Innovation. Oxford: Oxford University Press.

Wesselink, A., K. S. Buchanan, Y. Georgiadou and E. Turnhout (2013), "Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface", *Environmental Science and Policy*, January. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S1462901112002365.

Chapter 7: Conclusion

Bartlett, A.A. (1990), “The Future of Fusion”, *Physics and Society*, 19, 2.

Cross, P. (2015), “Unearthing the Full Economic Impact of Canada’s Natural Resources”, *McDonald-Laurier Institute*. Accessed at: https://www.macdonaldlaurier.ca/files/pdf/MLI-CrossNaturalResourcesPaper05-15-WebReady.pdf.

Bulkeley, H. and P. Newell (2017), Governing Climate Change. Abingdon, UK: Routledge Press.

Doern, B. and T. Conway (1994), The Greening of Canada: Federal Institutions and Decisions. Toronto: University of Toronto Press.

Fahey, B. K. and S. B. Pralle (2016), “Governing Complexity: Recent Developments in Environmental Politics and Policy”, *Policy Studies Journal*, April. Accessed at: http://onlinelibrary.wiley.com.myaccess.library.utoronto.ca/doi/10.1111/psj.12159/full.

Gelinas, J. (2006), Personal communication.

Grunwald, A. (2004), “Strategic Knowledge for Sustainable Development: The Need for Reflexivity and Learning at the Interface between Science and Policy”, *International Journal on Foresight and Innovation Policy*, 1 (1/2).

Hammond, K. R. and L. Adelman (1976), “Science, Values and Human Judgement”, *Science*, 194, 389-96.

Klinke, A. and O. Renn (2014), “Expertise and Experience: A Deliberative System of a Functional Division of Labor for Post-Normal Risk Governance”, *Innovation: The European Journal of Social Science Research*, August. Accessed at: http://www.tandfonline.com.myaccess.library.utoronto.ca/doi/abs/10.1080/13511610.2014.943160.

Loveridge, S. (2004), “A Typology and Assessment of Multi-Sector Regional Impact Models”, *Regional Studies*, 38 (3): 305-17.

Ludwig, D., B. Walker and C. S. Holling (1997), Sustainability, Stability, and Resilience. Conservation Ecology, 1 (7). Accessed at: http://www.consecol.org/vol1/iss1/art7/.

Marshall, N., N. Adger, S. Attwood, K. Brown, C. Crissman et al. (2017), “Empirically Derived Guidance for Social Scientists to Influence Environmental Policy”, *PLOS One*, March. Accessed at: https://search-proquest.com.myaccess.library.utoronto.ca/docview/1875828564/40BDCC31FA724A49PQ/5?accountid=14771.

Morrone, M. and T. W. Lohner (2002), Sound Science, Junk Policy: Environmental Health Policy and the Decision-Making Process. Dover, MA: Auburn House.

Pallett, H. and J. Chilvers (2015), "Organizations in the Making: Learning and Intervening at the Science-Policy Interface", *Progress in Human Geography*, April. Accessed at: https://search-proquest-com.myaccess.library.utoronto.ca/docview/1663507743/D0006BD0CA1B4325PQ/2?accountid=14771.

Raffensperger C. and J. A. Tickner (1999), Protecting Public Health and the Environment, Implementing the Precautionary Principle. Washington, D.C.: Island Press, 385.

Richards, G. W. (2017), "How Research-Policy Partnerships Can Benefit Government: A Win-Win for Evidence-Based Policy-Making", *Canadian Public Policy*, June. Accessed at: http://muse.jhu.edu.myaccess.library.utoronto.ca/article/663225.

Sidortsov, R. (2014), "Reinventing Rules for Environmental Risk Governance in the Energy Sector", *Energy Research and Social Science*, March. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S2214629614000279.

Small, M., P. Stern, E. Bomberg, S. Christopherson, B. D. Goldstein, A. L. Israel, R. B. Jackson, A. Krupnick, M. S. Mauter, J. Nash, D. W. North, S. M. Olmstead, A. Prakash, B. Rabe, N. Richardson, S. Tierney, T. Webler, G. Wong-Parodi and B. Zielinska (2014), "Risks and Risk Governance in Unconventional Shale Development", *Environmental Science and Technology*, 48 (15): 8289-97.

Udovyk, O. (2014). "Models of Science–Policy Interaction: Exploring Approaches to Bisphenol A Management in the EU", *Science of the Total Environment*, July. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S0048969714003763.

Wesselink, A., K. S. Buchanan, Y. Georgiadou and E. Turnhout (2013), "Technical Knowledge, Discursive Spaces and Politics at the Science-Policy Interface", *Environmental Science and Policy*, January. Accessed at: http://www.sciencedirect.com.myaccess.library.utoronto.ca/science/article/pii/S1462901112002365.

Whitelegg, J. and G. Haq, G. (2003), The Earthscan Reader in World Transport Policy and Practice. London: Earthscan.

APPENDIX I
QUICKSILVER, SLOW DEATH: MERCURY ACTION RESEARCH CASE STUDY

I was eating tuna four times a week. I had crying spells, low-grade depression, loss of memory, and brain fog, which is where I would be talking to you and I would get disoriented.
Daphne Zuniga, Actress

All she was doing was eating "your average Hollywood stay-in-shape diet, a ton of fish and low carbs," actress Daphne Zuniga told *ABC News* in 2005. Perhaps best known for her starring role in the 1990s TV series *Melrose Place*, Zuniga recollected that she "would go out for sushi and think, 'Oh, great, at least we're not going for Italian, with all the oil and carbs." (Bordo Wright, 2005) Over time, however, she noticed unusual symptoms, including an itchy rash all over her body that landed her in the emergency room. She saw plenty of doctors, but nobody seemed to have a clue. It was only after reading a commonly quoted statistic from a U.S. Environmental Protection Agency study to the effect that one in six women of childbearing age has elevated mercury levels that she thought she should go for tests. Sure enough, her blood mercury levels were significantly over the safe level. She changed her diet, and the symptoms largely disappeared within six months.

In addition to potentially addressing the question of why so many of the stars interviewed in *People* magazine seem so distracted (Answer: They're mercury-addled), Zuniga's cautionary tale also underlines mercury's credentials as one of the most potent neurotoxins known. It specializes in attacking the brain. That mercury poisoning of movie stars is making headlines is somewhat of a breakthrough for a toxin that has been haunting humans for thousands of years with little profile. In fact, it might just take a Hollywood star to motivate us to get around to protecting the public properly and taking mercury in our fish and water seriously.

The mercury story is one of human tragedy, industrial malfeasance, government collusion and the shocking inability of humans to act prudently when presented with the facts. There are powerful lessons to be drawn from mercury that help shed light on some of the other substances

Rick and I tested. Why, for example, does it take so long for a toxic chemical to be banned from use in products humans consume when we know it causes harm? And how is it that we continue to believe the corporations that profit from toxic pollution when time after time, substance after substance, they are proven to be wrong and the public pays the price? By asking these questions I am hopeful that we are starting to make some progress on the solutions.

Bruce's Tuna Feast

Speaking of losing brain cells, I'm not sure whether deliberately setting out to elevate my mercury levels was a sign of too few brain cells to start with or simply evidence of a healthy scientific curiosity. I'd like to think it was the latter. As a long-time mercury policy advocate, I have a special connection to this experiment. It's one thing to spend ten years telling people mercury is bad news. It's quite another to try to elevate my own mercury levels and actually test whether or not mercury in fish is as great a problem as the scientific studies suggest.

It's Saturday and the tuna eating experiment is about to begin. I have to start by saying I love tuna. I love tuna sandwiches, I love tuna sushi, I love grilled tuna steaks. Because of my love of this fish, and frankly all seafood, I tend to eat more of it than the average North American or European; my diet is perhaps somewhat Japanese. It's not unusual for me to eat about eight fish meals in a week. I've been know to have about four or five dinners that include mussels, crab, shrimp or scallops—with perhaps a smoked fish appetizer one night. For lunch I might have a tuna sandwich and a salmon sandwich in the middle of the week, or maybe sushi or shrimp pad thai, and one morning a week I might have smoked salmon for breakfast. So with the task of figuring out who was going to expose themselves to which toxic chemicals, I, of course, jumped at the chance to be the tuna guinea pig. How difficult could it be to eat a little tuna? And surely eating a few tuna meals over the course of 48 hours is hardly going to affect *my* mercury levels, I thought to myself.

To be clear, given my high level of fish consumption, the first thing I needed to do before testing was to try to bring my levels down to background levels more like those of a typical North American. We did no pretesting at this stage, but to be safe I avoided tuna and most other sources of fish for about six weeks prior to our formal testing. Given the half-life of mercury in our bodies, this probably had a modest impact on my actual mercury levels.

Colleagues of mine at the University of Quebec in Montreal are among the leading mercury researchers in the world. Whenever they do field research, they test their mercury levels in advance of their travels and upon their return. Invariably, their mercury levels increase noticeably as a result of eating the local fish at the places they visit.

I therefore knew that it was theoretically possible to measure the mercury increasing in my blood by eating fish that presumably contained mercury. What I did not know was whether eating a few meals over the course of 48 hours would show any measurable increase in my blood. I was worried that given the large amounts of fish I eat regularly, a few extra tuna meals would not have much effect.

After my first blood test to determine my pre-tuna mercury levels, I got to the task of gobbling down a tuna sandwich. We purchased many varieties of canned tuna, but I chose my favourite, solid white tuna. Solid white also happens to have the highest levels of mercury. Flaked or chunk light tuna has lower amounts of mercury because the fish used in flaked tuna tend to be smaller. Smaller fish have lower concentrations because they are younger and eat smaller fish themselves, so the effects of “biomagnification” tend to be less pronounced. (“Biomagnification” is the term used to describe how levels of toxins increase, the larger and higher in the food chain a predator is—because it keeps not only its own toxins, but also the accumulated toxins of the prey it eats, the prey its prey eats and so on.) The larger fish are also usually older and have had more time to bioaccumulate mercury in their diet over many years. Tuna can live for 20 years and reach weights of up to 1,500 pounds.

Most readers will be familiar with the classic tuna sandwich or tuna salad, but we all have our favourite variations. My tuna sandwiches are usually made with a can of tuna, a tablespoon or two of real mayonnaise, a chopped celery stalk and a big squeeze of lemon. Unfortunately, on Day 1 we were out of celery, so the tuna salad was a little bland. I spread the filling on commercial whole wheat bread.

Without celery as filler the tuna seemed to disappear easily into the bread, and before I knew it I had managed to get an entire 7.5-ounce can of tuna into my sandwich. Six minutes later I'd downed it. Rick stared at me with an evil glint in his eyes and then turned to the other tuna cans on the counter.

"Surely," he remarked, "that little tuna sandwich didn't fill you up. How about another?"

The steps above were repeated, and I managed to put back a second sandwich with another entire 7.5-ounce can of tuna in it. Now I do appreciate that this may not have imitated the diet of an average person. But at the same time, it's not completely out of the ordinary. The second one took more than 6 minutes to eat, perhaps 15 or so. That's the only tuna I ate on Day 1.

It was Day 2, another 24 hours had passed before I ate more tuna, and once again I had a tuna sandwich for lunch (and a blood test at 5:15 pm to measure my mercury). Rick and I were in the middle of breathing perfluorinated stain-resistant chemicals at the time, so the chance to get out to the kitchen was a welcome break from the nasty fumes. This time I ate only one sandwich filled with an entire 7.5-ounce can of solid white albacore tuna. It took a little longer to eat than the previous day's, but I have a hunch it was because I was prolonging my time in the relatively poison-free atmosphere of the kitchen. I also had a cup of tea, but not in polycarbonate plastic; deliberate exposure to two or three nasty chemicals at a time is enough for me. Tea, according to a recent study by my mercury-studying colleagues in Montreal, increases the metabolization of the metal (Canuel et al, 2006). That means it gets into your blood more quickly, which seemed to be a useful thing, given the short-term nature of our little experiment.

After a few hours of sitting and breathing PFOA, Sarah, our intrepid project coordinator, decided to pop out and get some tuna sushi take-out. At 5:45 p.m. I downed a healthy trayful of tuna sushi and sashimi. For non-aficionados of this delicacy, sushi is raw fish on a little bed of cold, sticky rice, and sashimi is just a piece of raw fish on its own. I ate them with wasabi (Japanese horseradish) and soy sauce. Unbeknownst to me this was Sarah's idea of an appetizer. Soon after happily gobbling down the contents of my tuna sushi tray, Sarah presented me with another tray of (much nicer looking, I must admit) tuna sashimi, sushi roll and nigiri sushi—for dinner. It took me a good 40 minutes to polish off this batch, and I was forced to consume a beer or two with it. I happen to love sushi—and tuna sushi, in particular—but I must admit that eating a large quantity of the dish in one sitting was a little tough.

Day 3 looked remarkably like Day 2, with another tuna sandwich for lunch. It was not a very memorable sandwich, to be honest, or perhaps that was the mercury kicking in, since I don't remember much of Day 3; frankly, it was a hellish day. I am generally very relaxed, easygoing and almost unflappable, but by Day 3 in our apartment, I was miserable. It suddenly occurred to me that perhaps this feeling of intense and uncontrollable irritability was the mercury building up in my body. I was also in no mood for casual conversation. Was it just a coincidence that irritability and shyness are early indications of mercury poisoning? Was I exhibiting signs of elevated mercury in my blood or was it basic hypochondria? Was I experiencing a Daphne Zuniga "brain fog"? At this point I had no idea whether or not my mercury levels were, in fact, any higher, but I was definitely experiencing an unpleasant anxiety.

Amazingly, despite the perceived health woes, I was looking forward to another tuna dinner. Sarah went out and picked up a couple of big, thick tuna steaks from the fish market. We decided we'd all have seared tuna steaks together, and I was more than happy to cook them. By now—and after reading Chapter 3—you may have guessed that they would be cooked in a frying pan with a non-stick coating. This was not to keep the tuna from sticking, of course, but to make sure we were not missing any opportunities to add to the perfluorinated chemicals Rick and I were inhaling in the other room.

I rubbed the tuna steaks in a combination of white and black sesame seeds and seared them in the hot frying pan with a little olive oil. We had a small salad and a little wasabi mayonnaise and, of course, an icy beer or two. Despite this being my seventh tuna meal or snack in three days, I thought dinner was absolutely delicious. I had no trouble consuming a hunk of tuna that weighed in at just over a pound (500 grams). Actually, fresh tuna is so expensive that only rich people can poison themselves in this way. At close to $20 a pound, it is definitely not a poor man's toxic dinner.

There are, of course, cheaper ways of elevating your mercury blood levels, especially if you enjoy sport fishing. Most lakes in North America have fish advisories warning against eating certain fish, and 80 per cent of fish advisories are due to mercury contamination (United States Environmental Protection Agency, 2008). If you are an excellent angler and can catch good-sized fish, like pickerel or walleye, on a regular basis, you'll have no trouble poisoning yourself. In fact, this happened to a fellow living in Minnesota, who became seriously ill, to the point where he was hospitalized and unable to walk (Oceana, 2008). After numerous tests and medical consultations, one doctor finally asked the man's wife if she could think of anything unusual about what he was doing or eating. She thought for a moment and mentioned that he loved to fish and that he ate much of the fish he caught. In fact, she said, he ate fish virtually every day of the week. The doctor immediately tested his blood for mercury, and sure enough, he had levels high enough to qualify him as having Minamata disease, so named after a town in Japan where mercury poisoning was rampant. More on that infamous incident later in this chapter.

Although I suspected my mercury levels would have increased, only the blood tests would determine whether, in fact, there was enough of the chemical in my seven meals and snacks to make a noticeable difference in the concentration of mercury in my own blood. Usually, waiting for blood test results leads to anxious anticipation or perhaps grave concern. But I was in a state of hopeful excitement that my blood levels would have above-normal levels of mercury. As with all of our blood samples, these were taken according to standard medical research protocols and the blood was centrifuged on site. My mercury blood samples were sent to Brooks Rand Laboratory in Seattle and tested using EPA Method 1631 protocols.

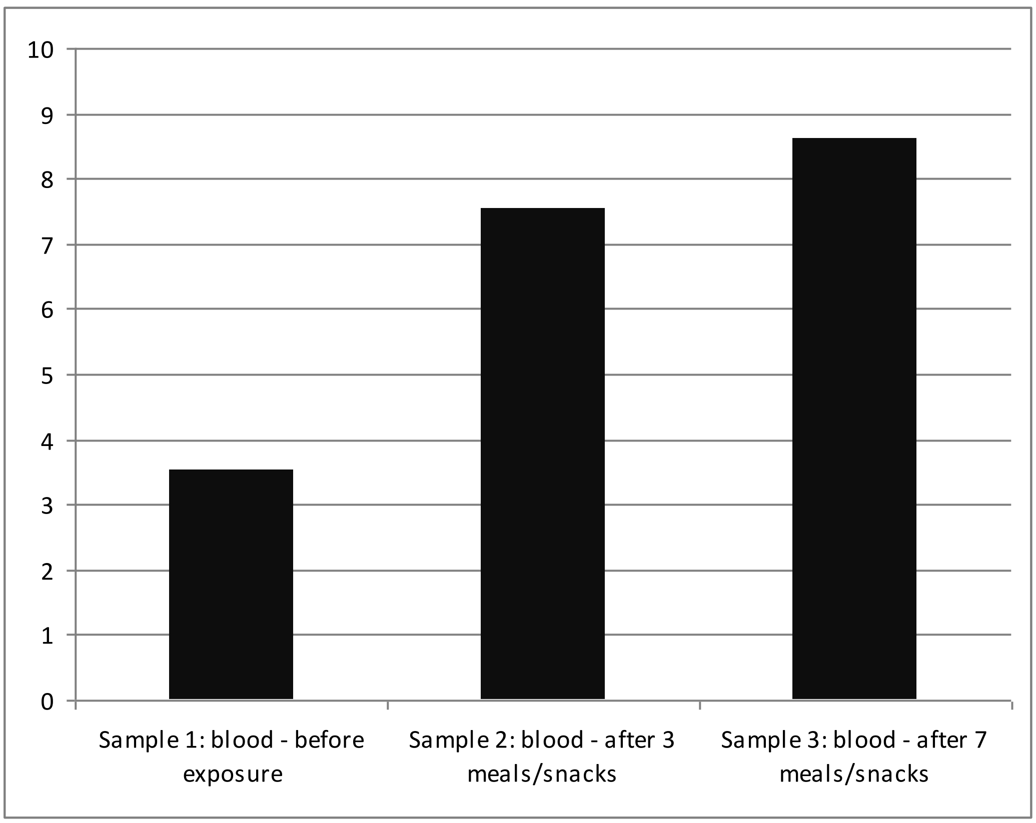
I was familiar enough with the literature to know that it was possible to elevate mercury levels in blood, and I certainly knew my colleagues in Montreal had demonstrated this. But I was still not convinced that seven meals and snacks would do the trick. What would a substantial increase look like anyway? If I increased my mercury levels by 10 per cent, was that really a big deal? What about 50 per cent? Or imagine if my levels doubled! Now that would be impressive, but it seemed impossible, given my ongoing higher-than-average fish consumption before doing the experiment. It's also important to keep in mind that with mercury, there is no safe level. Medical researchers have determined that any amount greater than zero increases the risk of harm to humans (Clarkson, 1996).

After five weeks of waiting, my results arrived. My first blood test (taken on Day 1 before I ate my two large tuna sandwiches for lunch), showed that the mercury concentration in my blood was 3.75 μg/L (micrograms per litre). The North American average is less than 1 μg/L, so I had more than four times the average mercury levels in my blood before my tuna eating even began. And this was after not eating fish for six weeks. I figured my levels would be a little higher than average but not quite that high.

After three mercury meals/snacks, the mercury in my blood shot up to 8.01 μg/L, more than doubling in less than 48 hours. This also sent my mercury levels above the U.S. Environmental Protection Agency reference dose level of 5.8 μg/L. The reference dose is the "safe" level set by the U.S. government, and anything above 5.8 μg/L is definitely cause for concern, primarily for women of childbearing age (US Food and Drug Administration, 2008). This number is based on extensive research in populations that consume large amounts of fish and marine mammals, such as the people of the Faroe Islands in the North Atlantic (Teasande et al, 2005).

In my final blood test, the morning after my tuna steak dinner on Day 3, my mercury blood levels reached 9.15 μg/L. After seven meals/snacks in three days, I had managed to *more than double* the mercury levels in my blood! Two and a half times, in fact. The experiment had worked. Not only did it reveal high levels of mercury in several sources of tuna, but it also demonstrated how easy it is to spike mercury levels by eating a few sandwiches and a couple of tuna dinners. After reading these results, I got a first-hand understanding of how communities that depend on fish in their diets can quietly poison themselves.

Figure 1. Bruce's mercury blood levels increase as a result of eating fish



Mercury and Me

Mercury is cool stuff. For over a decade I've been researching its uses, its effects on health and sources of mercury pollution, as well as supporting government efforts to reduce mercury levels in the environment.

I started working on mercury issues with a Canadian environmental group called Pollution Probe about 15 years ago. At the time most of my environmental colleagues were focused on a major global effort to ban chlorinated compounds. The thinking was that lots of nasty chemicals are based on chlorine. So rather than trying to ban deadly chemicals one at a time, a prospect that could take centuries, the idea was to look at "classes" of chemicals—like chlorinated substances—and seek restrictions on all chemicals in the group that shared certain fundamental toxic properties. In retrospect, it's apparent that this was an intellectually and scientifically sound concept, but at the time politically impossible.

After three years we were making virtually no progress on addressing the problem of complex chlorinated chemicals. The health data were controversial, industry opposition was vigorous and the regulatory systems of Canada and the U.S. could not handle our groundbreaking approach.

This is when it occurred to us that we were trying to take on dozens of complex chemicals for which health effects research was scarce or contentious, while mercury, one of the oldest and most studied toxic materials, was still being used freely in hundreds of consumer products. How is it, we asked ourselves, that given all we know about mercury, we are still putting it in skinny glass tubes and sticking those tubes in people's mouths—and other places, for that matter? Surely, we thought, if we can't restrict mercury use, we're hopelessly doomed in our efforts to rein in any of the newer and more complex synthetic toxins.

I worked with colleagues in Environment Canada and the Ontario Ministry of the Environment to investigate and advocate the restriction of mercury use in Canada. Three of us virtually carried the Canadian mercury file for most of this period. In fact, I recall one day when Ian, my provincial government counterpart, said that if it were not for each of us playing our respective roles—me pushing for policy action and Ian and his colleagues trying their hardest from the inside to move their behemoth bureaucracies—nothing would be happening on mercury in Canada.

We started our research by examining all the sources of mercury entering the environment. It turned out that much of the mercury contaminating our water and fish came simply from the use and disposal of everyday consumer products. Over the next ten years, it became my quest to figure out how and why, after thousands of years of clear evidence of harm, we still allow our bodies to be poisoned with mercury.

Mercury is one of the oldest poisons known to humans. It is one of the most toxic substances to which humans are regularly exposed, it has thousands of uses and it is also one of the best-studied toxins on the face of the earth. For these reasons mercury can help us understand pollution issues more broadly—particularly how it is that something so toxic is still used widely to this day.

Earlier, we described how toxic pollution has gone, more or less, through the following phases. The death by direct exposure phase, the belching and spewing industrial phase, the workplace exposure phase and finally the more subtle poisoning of the entire population with tiny, invisible amounts of toxins in our food and water. Unlike most toxins we tested, mercury has gone through all these stages during its long history.

Magical Mercury Tour

Anyone who has broken a thermometer knows how strange and fascinating it is to watch the mercury inside turned into tiny, silver-coloured balls that split apart and scatter. Even more bizarre is pushing the tiny balls back together, taking ten or so separate little blobs and watching them recombine into one perfect, larger sphere. It's an amateur alchemist's dream, the human equivalent of crows being drawn to shiny objects.

Given these alluring properties, it's no wonder that many cultures believed mercury had mystical properties, including the power to prolong life. In certain Latin cultures it is used to this day in attempts to ward off evil spirits. Mercury amulets can still be purchased at street markets throughout Mexico and parts of Central America. Perhaps one of the more dangerous practices was sprinkling liquid mercury in infants' beds to protect them from evil spirits and keep them healthy. This practice was also carried out in Latin communities in New York City until very recently, causing public health workers to initiate special education programs warning parents of the serious danger this poses (Johnson, 1999).

Mercury has been used for many other purposes over the centuries.[16] A Danish researcher has recently discovered that six medieval monks appear to have died of mercury poisoning from using mercury-based inks to transcribe religious documents (Rasmussen et al, 2008). The monks probably licked their brushes to make the beautiful fine lines with mercury-laden red pigments that are still so vibrant in their illuminated manuscripts.

The Ancient Romans discovered that mercury combines with gold and other precious metals and took advantage of this property to recover gold and silver in the early days of mining. During the Renaissance the physicians of the day used its healing properties. Throughout the American Civil War, mercury was considered to be a "cure-all" for everything from skin lesions to constipation. Abraham Lincoln was prescribed mercury tablets, called "calomel," but being the smart fellow he was, he soon recognized the telltale signs of mercury poisoning and stopped taking them[17].

[16] There are only a few examples of mercury being used for murder, because the slow death and telltale signs that mark its use made it less desirable than arsenic as a poison.
[17] Mercury Was Once Seen as a Cure-all. *Free Lance Star.* August 7, 2006.

Research was conducted on Spanish mercury miners in the 1960s that included memorable images of the miners' attempts to trace a curved line on paper (Putman, 1972). The miners were unable to follow the curve at all and instead produced a jagged, squiggly line resembling a child's attempt to draw lightning. Uncontrollable trembling is one of early signs of serious mercury poisoning.

We are all familiar with stories of Spanish galleons carrying tonnes of gold and silver looted from the Native people of Central and South America. Much less well known is the fact that many tonnes of mercury were transported in those same ships from Spain to the "New World." After murdering many of the locals and melting the golden riches of the Aztec and Mayan cultures into gold bars and coins, the Spanish conquistadors used mercury to mine even more gold, and silver. Thousands of tonnes of mercury were shipped from Spain during the four-hundred-year period of Spanish rule. My colleague, Luke Trip from Environment Canada, visited Zacatecas, Mexico, where up to thirty-four thousand tonnes of discarded Spanish mercury may be present (Ogura, 2003). Luke said it's possible to scoop a handful of dirt and squeeze liquid mercury from it. To put this in context, one tonne equals 1 million grams, and remember that one gram can contaminate the fish in a 20-acre lake. It's almost impossible to imagine the suffering associated with the billions of grams of mercury the Spanish brought with them to Latin America.

The height of 18th-century European fashion was the beaver felt hat, or what we think of as a typical black top hat. Owing to its fungicidal properties, mercury was used in the manufacture of these hats to ensure that the fur would not "go off." Unfortunately, the workers in the beaver felt factories of the day did not fare quite so well. In fact, the hatters would often go mad as a result of breathing the toxic mercury fumes—hence the phrase "mad as a hatter." The fact that irritability is one of the early symptoms of mercury poisoning may also account for the "mad" moniker. The most famous "Hatter," often referred to incorrectly as "the mad hatter," is most certainly the crazy, riddle-filled character in Lewis Carroll's *Alice in Wonderland*.

Mercury pollution these days is more complex. We now worry less about direct exposure causing disease and potential death and more about long-term exposure to tiny amounts in our food that can cause insidious neurodevelopmental problems, especially in children.

Mercury a naturally occurring element, not a manufactured chemical. It's been around forever: literally. Elements are the building blocks of natural and human-engineered chemistry. All the other substances that Rick and I tested were synthetic chemicals—products typically created in laboratories by chemists working for chemical companies. Mercury is very different in that it cannot be created—or destroyed, for that matter. It simply exists as a natural element found in rocks, plants, water and most living things. So volcanoes, forest fires and oceans all release mercury into the atmosphere. This is called "natural" mercury, because the source of the release into the environment is natural. There is also "anthropogenic" mercury, which results from human activity. All mercury generated by human-made sources (such as waste incinerators, coal-fired power plants, mercury thermometers and fluorescent lights) is called anthropogenic. Where it comes from may not seem to matter all that much, but it actually does, and I'll explain why a bit later.

Is Mercury Really Dangerous?

Whenever I mention mercury in casual conversation, which happens quite frequently, the first thing people often ask is: "I used to play with mercury as a kid whenever a thermometer broke. Was that dangerous?"

"Well, probably not really, as long as you didn't play with it for hours on end, day after day," I'd reply, knowing that lots of people, like me, did.

Then I tell the story of the dentist in British Columbia who decided to heat mercury on his stove (Pollution Probe, 2003). It seems he had a great fascination with mercury, and for some unknown reason decided to boil some up. Mercury vapour is highly toxic and the vapours killed him. Not only that, his apartment building was condemned due to the mercury levels, forcing all the residents into a local motel.

Then there was the boy from Ohio who was hospitalized with a mysterious, debilitating illness, later discovered to be mercury poisoning (Clarkson et al, 2003). It turns out there had been an accidental mercury spill in their apartment, and the mercury vapours caused the 15-year-old to become very ill. His symptoms included a rash, sweating, cold intolerance, tremors, irritability, insomnia and anorexia. He was diagnosed with measles, sent for psychiatric treatment and even accused of having psychosomatic symptoms before mercury poisoning was identified as the cause.

In another case a nine-year-old boy was being treated for neurological and kidney problems after a blood pressure device broke, spilling mercury in his house (Rennie et al, 1999). Unfortunately, the boy's mother vacuumed up the spilled mercury, thus inadvertently turning the vacuum cleaner into a mercury vapour distribution device. Each time the vacuum was operated, the warm air from the vacuum sprayed highly toxic mercury vapour throughout the apartment.

And consider the terrible tale of a chemistry professor at Dartmouth College[18]. Karen Wetterhahn was very concerned about the toxic effects of mercury on humans and the ecosystem and was working with a particularly toxic form of the metal called dimethylmercury. This is not a common form, but it is used in research because it produces the effects of mercury very rapidly, allowing studies to take place over short time periods of time. Special precautions are required when handling it, and Wetterhahn was wearing latex gloves and working under a fume hood to protect herself. It is believed that one or more drops of the lethal liquid spilled onto her latex gloves. The mercury leaked through the latex and reached her skin. The tiny amount of mercury was quickly absorbed by her body and led to devastatingly high mercury levels in her blood. Wetterhahn knew the effects of mercury poisoning and witnessed firsthand some of the classic symptoms of mercury poisoning: shaking, slurred speech and tunnel vision.

[18] Colleagues Vow to Learn from Chemist's Death. *New York Times.* October 3, 1997.

Less than a year after this exposure, Wetterhahn was dead. Her brief exposure to mercury represented nearly one hundred times the lethal dose. This young woman, who had devoted her life to preventing mercury from harming humans and the environment, died as a direct result of her concerns. The most tragic part of the story is that if governments and industry had acted responsibly over the past 50 years and banned mercury uses when it was obvious they were causing harm, she probably would not have needed to be doing this research in 1996.

Exposure to high levels of everyday mercury (let alone dimethylmercury) has serious consequences. It can cause permanent brain damage, central nervous system disorders, memory loss, heart disease, kidney failure, liver damage, cancer, loss of vision, loss of sensation and tremors. It is also among the suspected "endocrine disruptors," which do damage to the reproductive and hormonal development of fetuses and infants. Some studies also suggest that mercury may be linked to neurological diseases, such as multiple sclerosis, attention deficit disorder and Parkinson's, but the evidence here remains somewhat inconclusive (Clarkson et al., 2003).

Medical researchers at the University of Calgary have identified the exact cause of mercury damage to the brain (Vimy & Lorscheider, 1993). Mercury actually concentrates in major organs like the brain and kidneys, dissolving the neurons in certain parts of the brain and leading to various nervous system disorders. The Calgary researchers created a video (now on You Tube) that shows the mercury molecules literally destroying brain neurons as though they were little Pac-Mans munching away on brain cells. Alzheimer's and autism are associated with brain neuron damage.

So in case there is any doubt, mercury is a seriously potent neurotoxin that will kill you if you breathe, eat or otherwise expose yourself to high enough levels. Even moderately high levels over an extended period of time will cause serious physical and mental impairment.

Cool Liquid Metal

Mercury has an unbelievable array of unique and fascinating properties. Perhaps its coolest property is that it is the only metal that is a liquid at room temperature. Think about that for a minute: liquid metal. Most other metals need to be heated to hundreds or thousands of degrees Celsius before they melt. Most of our images of liquid metal are of refinery workers in protective suits and helmets holding long tongs to pour blazing liquid metal into ingot casts. Liquid mercury, on the other hand, can be stored safely in a plastic bottle.

As with other metals, mercury conducts electricity, but the unusual combination of its being liquid *and* an electrical conductor has led to its use in electrical switches. Remember the round household thermostats that first came into use in the 1950s? Or how about the silent wall switches popular in the 1970s? Just one of either of these devices contains enough mercury to contaminate a 20-acre lake to the point where the fish in the lake should not be eaten.

So why is there mercury in switches? It's quite simple: the little blob of liquid mercury slides back and forth each time the switch is flicked, resulting in an electrical contact forming or being cut off and the light turning on or off. Check to see if you still have a silent light switch at home. It's easy to tell because rather than clicking on or off, they're very smooth and quiet, and they give almost no resistance to being flicked. They can be quite easily and safely taken apart to reveal one or two silver metal disks about the size of a dime, which contain about one gram of mercury each. When you pop out the disks, you can shake them and feel the weight of the mercury sloshing around inside. If you do find mercury switches in your home, make sure they are returned to a hazardous waste depot, not discarded in the garbage.

You might think that mercury switches are a pretty limited application until you realize that so-called "tilt switches" are everywhere. Anyone for ice cream? When you open up the freezer lid, a little blob of mercury slides down the switch and, presto, the light comes on. How about trying to find the tire iron in the trunk of your car? Luckily, a little light goes on when you open the trunk, all thanks to tilt switches and the mercury they contain.

If you are (un)lucky enough still to have a classic round thermostat on your wall, you can actually watch this firsthand. Simply grab the sides of the thermostat and gently pull off the curved, circular cover, which is usually gold-coloured plastic with a large hole in the centre where the temperature disk is. It looks something like a doughnut. Once the cover is off, you will see a glass tube under some wires at the top of the thermostat. When you turn the temperature gauge up or down, you'll see the glass tube tilt back and forth and you'll also see the shiny liquid mercury sloshing from one side of the tube to the other. When you turn the heat up, the switch tilts, the mercury slides down and makes electrical contact, and the furnace turns on. This is a tilt switch in action.

Mercury has other uses as well. Because it's a highly volatile substance and evaporates to form vapour easily, it is used in virtually all fluorescent and neon lights. The metal vapour conducts electricity inside the glass tube, causing various gases to fluoresce when an electrical current is introduced. Mercury also has the unique property of expanding evenly with pressure and temperature, and this makes it perfect for thermometers, barometers and manometers.

Mercury can be used with other metals, creating combinations called amalgams. (The other metals dissolve in mercury like salt in water.) The best-known mercury amalgams are made with silver and are used to fill cavities in teeth. The average "silver" mercury filling is one-half mercury by weight. Some dentists continue to use mercury, but it is largely being replaced with white composite resins (Canadian Council of Ministers of the Environment, 2001). Controversy and active debate surround the health effects of mercury fillings. A segment of the population appears to have hypersensitivity to mercury, and these people often have their mercury fillings replaced (although removing a large number of mercury fillings at one time is not advisable, since that can result in very high temporary mercury exposure).

Sticking mercury in our mouths really does strike me as one of the crazier things we decided to do with it. I spoke with Dr. Peter Erickson, who specializes in treating patients with environmental sensitivities, including mercury, and he told me the story of how it became the most popular dental filling material in the North America. Mercury's toxicity was well known at the time and it was considered too toxic for dental fillings. But it was easy to use, much cheaper than gold and had the added benefit that its toxicity killed any bacterial infections.

In 1833 the French dentist who had perfected mercury amalgam use was banned from practising in France, so he moved to New York, where he opened a highly successful dental practice (Ozuah, 2000). In the mid-1800s dentists in the United States belonged to the American Society of Dental Surgeons. The society, following European standards of the day, banned mercury use by dentists. According to Dr. Erickson, the French dentist and his brother, together with a number of other mercury-using colleagues, decided that the only way they could continue to use mercury was to leave the Society of Dental Surgeons and create their own new organization, called the American Dental Association. The American Dental Association (and its Canadian counterpart, the Canadian Dental Association) became the *de facto* proponents of this practice in dentistry, ignoring the health concerns first expressed over 150 years ago. To this day the American and Canadian Dental Associations remain among the staunchest defenders of mercury.[19] They have vigorously opposed any efforts to restrict mercury use, and they have even fought proposals to make information about mercury available to patients. But despite the opposition and foot dragging, the tide has now turned, and the use of mercury amalgam is finally decreasing.[20]

Perhaps mercury's most obvious property is that it kills living things, including mould and fungus. These properties were well known in the 15th and 16th centuries, and ailments ranging from constipation to ringworm fungus to syphilis were treated with mercury into the early 20th

---

[19] "Are Your Teeth Toxic?" ***Chicago Tribune,*** **December 11, 2005. Accessed on August 10, 2008:** http://www.toxicteeth.org/pressroom_articles_tribune_122005.cfm**.**
[20] "Mercury Dental Fillings Not as Safe as Once Thought," MedHeadlines. Accessed on June 5, 2008: http://medheadlines.com/2008/06/05/mercury-dental-fillings-not-as-safe-as-once-thought/.

century. This has led to speculation that some of the crazy antics of famous emperors and leaders of the past may have been caused by mercury poisoning from their syphilis treatments.

Throughout the 20th century mercury was used widely in bathroom, kitchen and hospital paints to prevent the growth of mould and mildew, and mercury emissions from drying paint were significant. Most Western countries have now banned this practice. In countries like Canada, where the regulation of toxic substances has been virtually unknown until recently, manufacturers follow international standards. (The Canadian market is relatively small—compared to markets in the U.S., Europe or Japan—so Canada rarely sets industry standards that exceed those of other nations. We have not technically banned mercury from paint, but companies operating in Canada agreed voluntarily not to sell paint containing mercury.) Mercury has also been used as an agricultural fungicide, notably on potatoes. The high frequency of unusual cancers among potato farmers in Prince Edward Island may be linked to specialized potato fungicides and pesticides (Martin & Guernsey, 2008).

Given the well-known toxicity of mercury, it is surprising that it still has so many applications. We put it in children's vaccines and nasal spray and even in contact-lens solutions. Happily, in the past few years, most of these uses have either ceased or become severely restricted. The only one that still remains is—you guessed it—injecting it into babies, in the form of vaccines. Fortunately, however, this practice has come under examination of late (U.S. Center for Disease Control, 2008).

Dancing Cats and Human Tragedy

The devastating effects of mercury poisoning burst onto the international stage in 1956 when residents of Minamata, Japan, started to become very, very ill. Strange behaviour in cats was the first sign that something was awry in this fishing town on Japan's southernmost island, Kyushu. Throughout the town cats were literally jumping, twisting and doing back flips, which led to the term "dancing cat disease" in reference to the uncontrollable muscle spasms and tremors seen in the poisoned felines (Ui, 1992). Further research on the cats led local health scientists to the conclusion that mercury contamination in fish and shellfish was the cause of this strange and lethal disease. In addition to dancing cats, seabirds were dropping from the sky, unable to fly.

Seafood was, and still is, the primary protein in Japan and the most important part of the diet of any fishing village. Along with the cats people in Minamata started to show the telltale signs of mercury poisoning, including trembling, numbness, irritability and tunnel vision, but at the time mercury poisoning was not commonly known in the medical community.

The Minamata poisoning episode provided local medical researchers with the hard evidence that first linked mercury pollution in water to mercury contamination in fish and ultimately mercury poisoning in humans (Shigeto, 2000). The tragedy in Japan happened ten years before the modern environmental movement began and in the very early days of even the most rudimentary understanding of ecosystems. But local medical specialists were still reasonably quick to identify the cause of the poisoning as methylmercury, based on studies of the deceased, no-longer-dancing cats. It is important to point out that methylmercury is the organic form of mercury, making it much more dangerous in food. This is because organic chemicals ("organic" used here in the sense of substances composed of carbon and hydrogen atoms, not food produced on environmentally friendly farms) can be most easily incorporated into human blood and tissue.

Once the methylmercury link was made, it was not long before the source was discovered to be a chemical plant in Minamata that manufactured polyvinyl plastic. The mercury-laced industrial waste was being dumped directly into Minamata Bay. The same bay where local fishers placed their nets and traps.

Tragically for people in Japan's fishing industry, methylmercury bioaccumulates and biomagnifies more powerfully than almost any other substance known. Even at very low rates of bioaccumulation or with relatively low concentrations of mercury in the water, biomagnification can result in toxic mercury levels in fish. Top predator fish can have mercury concentrations that are hundreds or thousands of times, possibly even a million times, greater than concentrations in the water in which they swim. This is why large ocean predators such as shark, tuna, swordfish and marlin have the highest mercury levels. And this was why eating large fish out of Minamata Bay was deadly.

Eating poison fish, sadly enough, is not the greatest tragedy at Minamata. The most despicable part of this episode was the response of the Japanese government and of the chemical company responsible for the mercury dumping. Government officials ignored the well-established evidence of the local medical researchers for more than *10 years*. Without any government action and absent the concept of corporate responsibility, the chemical company continued to poison the people of Minamata for all those additional years. The Japanese government refused to acknowledge a connection between the mercury poisoning and the deaths and suffering of thousands of Japanese citizens, even when the medical evidence was clear. Stillbirths, serious deformities and the poisoning of tens of thousands of people may have been largely avoided had the government and the chemical company not acted with such blatant disregard for human suffering.

Today, the symptoms of severe mercury poisoning are still referred to as “Minamata disease.” In Japan court battles continue even now between the citizens of Minamata and the Japanese government over compensation for the poisoned families. Despite the devastation and gross negligence on the part of the government and the chemical company, the Japanese government is still fighting to minimize the official estimate of those affected, thereby limiting the compensation it might pay. The official government line is that 2,265 people were poisoned by methylmercury. Kumamoto University researchers put the number at 35,000. Many severely debilitated survivors are still living in Minamata today, but many, many more are no longer with us.

Paper, Rock, Fish

Soon after the tragic mercury poisonings in Japan, a number of serious incidents occurred in North America. In 1969 a pulp and paper mill polluted the English-Wabigoon River in northern Ontario, contaminating the water so severely that the fish were no longer safe to eat. Not only did this destroy the primary food source for the local people; it destroyed their traditional way of life.

Mercury is used in what are called chlor-alkali plants as part of the pulp and paper manufacturing process. It was common practice to have a mercury cell chlor-alkali plant connected to a paper mill. It was also common practice for tonnes of mercury to be dumped into local rivers from these plants.

Testing showed that the White Dog and Grassy Narrows First Nations people exhibited high levels of mercury in their blood and hair, but there is some dispute as to whether any of them exhibited levels high enough to suggest symptoms of Minamata disease (National Institute for Minamata Disease, 2008). Federal and provincial governments claim the mercury levels were only modestly elevated, since the people were warned in time not to eat the fish. Some independent studies suggest otherwise, although there is no conclusive evidence. The bigger issue is, again, the negligence that led to enormous quantities of mercury being dumped into the river system at a time when mercury poisoning in Japan was making international headlines. Similar incidents were occurring across North America, causing the closure of commercial fisheries and destroying the food supply for dozens of local communities.[21]

The mercury from chlor-alkali plants is elemental mercury, meaning it is pure, metallic mercury, as opposed to the much more toxic organic form, methylmercury, which was being dumped directly into the ocean at Minamata. The English-Wabigoon River fish were, however, contaminated with organic methylmercury similar to that found at Minamata. How could this be so? you may ask. The answer requires a final chemistry lesson. To make a long story short, mercury undergoes a process called "methylation, " and methylation is critical to understanding how mercury ends up in fish—and cats and birds and humans, for that matter.

[21] Mercury Rising: The Poisoning of Grassy Narrows. *CBC News*, February 18, 2004. Accessed on August 9, 2008: http://archives.cbc.ca/environment/pollution/topics/1178/.

Methylation is the process through which mercury is converted from “inorganic” to “organic” mercury. “Organic” mercury contains carbon atoms, making this form of the metal much more absorbable by living things. Methylation occurs naturally and to a significant extent in lakes and rivers around the world if the conditions are right. In fact, most lakes, especially northern lakes in North America, contain methylmercury. Places like Minnesota, Ontario, Quebec and Wisconsin seem to be particularly well suited to methylmercury formation, and this has to do with a number of factors, including the type of rock, the acidity of the water and the presence of organic matter in lakes where mercury is found.

To explain the rest of the process, let’s look at the reservoirs of hydroelectric dams, where elevated levels of mercury were found in fish in the late 1970s. This type of pollution still exists in dam reservoirs today and is of special to concern to Canada, where so many hydroelectric dams are in operation. Unlike the mercury from chemical plants in Japan or pulp and paper mills in North America, the mercury in hydropower reservoirs is not dumped directly into the water. It comes from rock. Mercury levels in lakes are also affected by additional mercury that is deposited with the rain, mainly blowing across the North Pole from coal-fired electric plants in China and Eastern Europe.

Mercury is a naturally occurring element found in rock and soil, and it is affected when a river is dammed. First, the dam causes a large area of land to be flooded. Next, when dams flood large areas of forest, the trees die and decompose in the reservoir. This is a critical step, because the rotting trees produce perfect conditions for methylating micro-organisms. The mercury found in the rock underlying a hydro reservoir is released by methylation caused by the increased bacterial activity associated with the decomposition of plant life in flooded areas. And with increased methylation come elevated levels of methylmercury. In northern Quebec, where some of the world’s largest hydro dams are found, the mercury levels in fish in the dam reservoirs are far too high to be consumed by the local Cree population (McKeown-Eyssen & Ruedy, 1983).

As mentioned before, methylmercury is the form of mercury that most easily enters our bodies. From a health risk perspective, a toxic substance is only as dangerous as its ability to get inside your body and harm critical bodily organs and functions. Methylmercury has these characteristics in spades, including two of the most serious toxicity traits: it crosses the blood-brain barrier and it crosses the placental barrier. So despite our bodies' best efforts to keep nasty things from getting into our brains and our unborn babies, methylmercury slips through with ease. In fact, not only is it able to get into our brains, but mercury seems to prefer hanging out in our grey matter—hence the term "neurotoxic." Mercury also binds to proteins. (This is different from "lipophilic" chlorinated chemicals such as pesticides or PCBs that are stored in our fat.) So in addition to collecting in brains, mercury tends to concentrate in major organs such as the heart, liver and kidney, and kidney failure is one of the major causes of death from mercury poisoning.

In case it is not now obvious, the mercury in the English-Wabigoon River was converted to methylmercury by the micro-organisms in the river. Then the fish (the ones that survived, that is) soon became too contaminated to be eaten, and the locals lost their food supply and a large part of their livelihood. Meanwhile, we got nice, white paper.

Getting Polluted Is Easy

Even when not eating massive amounts of tuna for purposes of experimentation, I participate directly in mercury pollution; we all do. Some more than others.

The Inuit people of the Canadian Arctic live in what is considered to be the most pristine and fragile ecosystem on earth. Sadly, it is also the world's toxic tailpipe. Poisonous chemicals of all kinds, including mercury, end up concentrating in the Arctic because of global weather patterns and the nasty emission sources located in the northern hemisphere. In some Arctic communities in Canada, nearly one-third of the women have mercury blood levels higher than the World Health Organization's increased risk levels (Wheatley &Paradis, 1995). This is in addition to their toxic levels of PCBs, dioxins and fluorinated chemicals. Governments have largely abandoned the Inuit cause, and the alternative of eating frozen chicken dinners and other substitutes instead of local wildlife is neither appealing nor healthy.

The major sources of mercury pollution today are atmospheric, and the two largest atmospheric sources are coal burning, to produce electricity, and waste incineration. In the case of incineration, most of the mercury comes from the products that are discarded, including fluorescent lights, old batteries, drywall with mercury paint and electronics. The mercury in coal occurs naturally, and it is released to the atmosphere up the smokestacks of coal-fired electrical plants when the coal is burned. Once in the atmosphere mercury can travel thousands of kilometres and can be deposited far from the original source.

The atmosphere is not a great place to practise the “dilution is the solution to pollution” motto (which was popular in the 1980s). It’s that kind of thinking that has led to the mercury pollution problems we face today. Once in the atmosphere mercury can also circle the globe, depositing itself in rain and snow, but areas downwind of major pollution sources are hardest hit. In general, mercury levels increase from west to east across Canada, following the paths of prevailing winds and deposited downwind from coal-fired electrical plants and waste incinerators.

Medical researchers discovered that mercury poses a health risk even at very low, continuous doses at about the same time that scientists studying atmospheric mercury shifted focus from direct local emissions to pervasive global pollution. Teams of medical researchers studied children who live in the Faroe Islands (in the North Sea) and the Seychelles Islands (in the Indian Ocean) (Grandjean et al, 1997). They chose these places because they’re far away from any direct sources of mercury and because fish is a major part of the local diet in both locales. After years of study they determined that there is no safe level of mercury. The old way of thinking (that there is a “safe threshold” and that we can pollute up to that level with no effect) was finally dismissed. Studies, the most famous of which were carried out by Dr. Philippe Grandjean and his team of researchers, found “cognitive deficit” and “impaired motor skills” in children with very low levels of mercury in their blood (Grandjean et al, 1997). The mercury the children were consuming did not come from a local factory dumping waste into or near fishing grounds; it was simply the background mercury found in the ocean today.

These studies led to a major revamping of mercury health standards and the issuing of special bulletins around the world, warning pregnant women to not eat *any* high-mercury fish while pregnant. The studies indicated that fetuses and infants are susceptible to even the tiniest amounts of mercury in their developing brains (Rasmussen et al, 2005). The Catch-22 is that for many women around the world, local fish is one of the most important sources of protein and omega-3 fatty acids, so not eating fish during pregnancy may be more harmful to an unborn baby than eating mercury-contaminated fish. Not a great choice. And in spite of the risks, Aboriginal peoples of both genders in Canada have been advised to continue eating contaminated fish because of its importance as a protein source.

So where do all these observations and edicts leave us today? There is good news and bad news. The good news is that after thousands of years of direct experience with one of the most toxic substances known, we are finally starting to act intelligently. My concern 15 years ago was that if we couldn’t start restricting mercury use, I wasn’t hopeful for the success of any reduction in the use of toxins. But thanks to government regulations (mainly in Europe and the United States), mercury use in consumer products has dropped dramatically over the past two decades. Most batteries, paints and switches are now mercury free. Mercury thermometers and thermostats are being phased out. Even dentists seem to be catching on.

Fluorescent lights still contain mercury, although much less now than they did ten years ago. The main challenge is the recent popularity of compact fluorescent lightbulbs (literally billions will be sold). They save energy (and if your electricity comes from coal, they lower mercury emissions), but they all have small amounts of mercury inside them. Proper recycling programs can recover most of the mercury when the lights are discarded, but to date programs like this are not widespread.

The bad news is that coal burning continues to increase at a fierce pace, particularly in China, but the location of the pollution does not really matter, because mercury is a global pollutant. So despite dramatic decreases in mercury use in many consumer products, global mercury levels continue to rise. Without regulations on mercury emissions from coal plants, we will continue to poison important food sources for vulnerable populations around the world.

Tuna lovers, sushi eaters, pregnant women and children should seriously limit the fish they eat. Unfortunately, governments are offering no help in this regard. In Canada fish with mercury levels that exceed the government's own health guidelines can be purchased at any fish market. My tuna steaks almost certainly exceeded health guidelines. How is this possible? It would be a good idea to ask the government regulators who exempt high-mercury fish from health guidelines. But as it turns out, the fish that are most likely to exceed levels in Canadian federal government health guidelines aren't included in the guidelines.

I asked Canadian federal government officials to explain how this was possible and how they could rationalize exempting tuna. I was told tuna are considered by the Government of Canada to be "exotic specialty fish." The Ferraris of the piscine world, I suppose. The thinking behind the exemption seems to be that fresh tuna is so expensive that the average person cannot afford to eat enough to poison themselves.

I think I proved that theory wrong.

Appendix I References

Bordo Wright, Liz (2005), "Actress Describes Mercury Poisoning Ordeal: Daphne Zuniga Was Eating a High Seafood Diet," *ABC News*, October 21, 2005.

Canadian Council of Ministers of the Environment, *Canada Wide Standard on Mercury for Dental Amalgam Waste,* September 2001.

Canuel, Marc., Boucher de Grosbois, Sylvie., Lucotte, Marc., Atikessé, Laura., Larose, Catherine, and Rheault, Isabelle. (2006) "New Evidence on the Effects of Tea on Mercury Metabolism in Humans," *Archives of Environmental and Occupational Health* 61, no. 5 (2006): 232–38.

Clarkson, Thomas. (1996) University of Rochester (presentation at "Mercury in the Environment" conference, University of Miami, Coral Gables, Florida, February 24, 1996).

Clarkson, Thomas., Magos, Laszlo, and Myers**,** Gary J. (2003) **"**The Toxicology of Mercury: Current Exposures and Clinical Manifestations," *New England Journal of Medicine* 349, no. 18 (October 30, 2003): 1731–37.

Grandjean,P., Weihe, P., & White, R. et al. (1997) "Cognitive Deficit in 7-year-old Children with Prenatal Exposure to Methylmercury," *Neurotoxicology Teratology* 19, no. 6 (1997): 417–28.

Johnson, Clyde (1999) "Elemental Mercury Use in Religious and Ethnic Practices in Latin American and Caribbean Communities in New York City," *Population and Environment* 20, no. 5 (May 1999).

Martin, Jillian Ashley and Guernsey, Judy Read. (2008) "A Comprehensive Review of the Health Effects of Fungicides," poster presentation, Department of Community Health and Epidemiology, Dalhousie University, Halifax, Nova Scotia, 2008 (http://www.theruralcentre.com/doc/JAM-phareposter(9_29).pdf) (accessed November 30, 2008).

McKeown-Eyssen, G.E. & Ruedy, J. (1983) "Methyl Mercury Exposure in Northern Quebec: 1. Neurologic Findings in Adults," *American Journal of Epidemiology* 118, no. 4 (1983): 461–69.

National Institute for Minamata Disease, 2008 (http://www.nimd.go.jp/archives/english/index.html) (accessed November 30, 2008).

Oceana, 2008. "Mercury Health Effects" (http://www.oceana.org/north-america/what-we-do/stop-seafood-contamination/the-problem/mercurys-health-effects/) (accessed November 30, 2008

Ogura, Tetsuya et al., (2003) "Zacatecas (Mexico) Companies Extract Hg from Surface Soil Contaminated by Ancient Mining Industries," *Water, Air, and Soil Pollution* (http://www.springerlink.com/content/100344/?p=7ba0175c831e474f98c0bd2d3b32dab4&pi=0).

Ozuah, Philip O. (2000) “Mercury Poisoning,” *Current Problems in Pediatrics* 30, no. 3 (March 2000): 91–99.

Pollution Probe (2003). '*Mercury in the Environment: A Primer'* (Toronto: Pollution Probe, 2003).

Putman, J.J. (1972) “Quicksilver and Slow Death,” *National Geographic*, October 1972, 506–27.

Rasmussen, Kaare Lund., Boldsen, Jesper Lier., Kristensen, Hans Krongaard., Skytte, LIlian., Hansen, Katrine Lykke., Mølholm, Louise., Grootes, Pieter M., Nadeau, Marie-Josée. and Eriksen, Karen Marie Flöche. “Mercury Levels in Danish Medieval Human Bones,” *Journal of Archaeological Science* 35, no. 8 (August 2008): 2295–96.

Rasmussen, R.S., Nettleton, J. and Morrissey, M.T. (2005) “A Review of Mercury in Seafood: Special Focus on Tuna,” *Journal of Aquatic Food Product Technology* 14, no. 1 (2005): 1–3.

Rennie, A.C., McGregor-Schuerman, M., Dale, I.M., Robinson, C. and McWilliam, R. (1999) “Mercury Poisoning after Spillage at Home from a Sphygmomanometer on Loan from Hospital,” *British Medical Journal* 319, August 7, 1999, 366–67.

Shigeto, Tsuru (2000). *The Political Economy of the Environment: The Case of Japan* (Vancouver: University of British Columbia Press, 2000).

Trasande, Leonardo., Landrigan, Philip J., and Schechter, Clyde. (2005) “Public Health and Economic Consequences of Methyl Mercury Toxicity to the Developing Brain,” *Environmental Health Perspectives* 113, no. 5 (May 2005): 590–96.

United States Environmental Protection Agency (2008) “National Listing of Fish Advisories” (http://www.epa.gov/waterscience/fish/advisories/2006/tech.html) (accessed August 5, 2008).

United States Food and Drug Administration, (2008) “An Important Message for Pregnant Women and Women of Childbearing Age Who May Become Pregnant about the Risks of Mercury in Fish,” consumer advisory (http://www.cfsan.fda.gov/~dms/admehg.html) (accessed August 5, 2008).

U.S. Center for Disease Control, (2008) “Mercury and Vaccines (Thimerosal)” (http://www.cdc.gov/vaccinesafety/concerns/thimerosal.htm) (accessed November 30, 2008).

Ui, Jun ed., (1992) *Industrial Pollution in Japan* (Tokyo: United Nations University Press, 1992).

Vimy, M.J. & Lorscheider, F.L. (1993) “Dental Amalgam Mercury: Background,” a summary of research results on dental amalgam mercury to date, Faculty of Medicine and Medical Physiology, University of Calgary, Calgary, May 1993.

Wheatley, B and Paradis, S. (1995) "Exposure of Canadian Aboriginal Peoples to Methylmercury," *Water, Air, and Soil Pollution,* 1995 (http://www.springerlink.com/content/x317026557217813/fulltext.pdf).