

University of Stirling

Occupational and Environmental Health Research Group

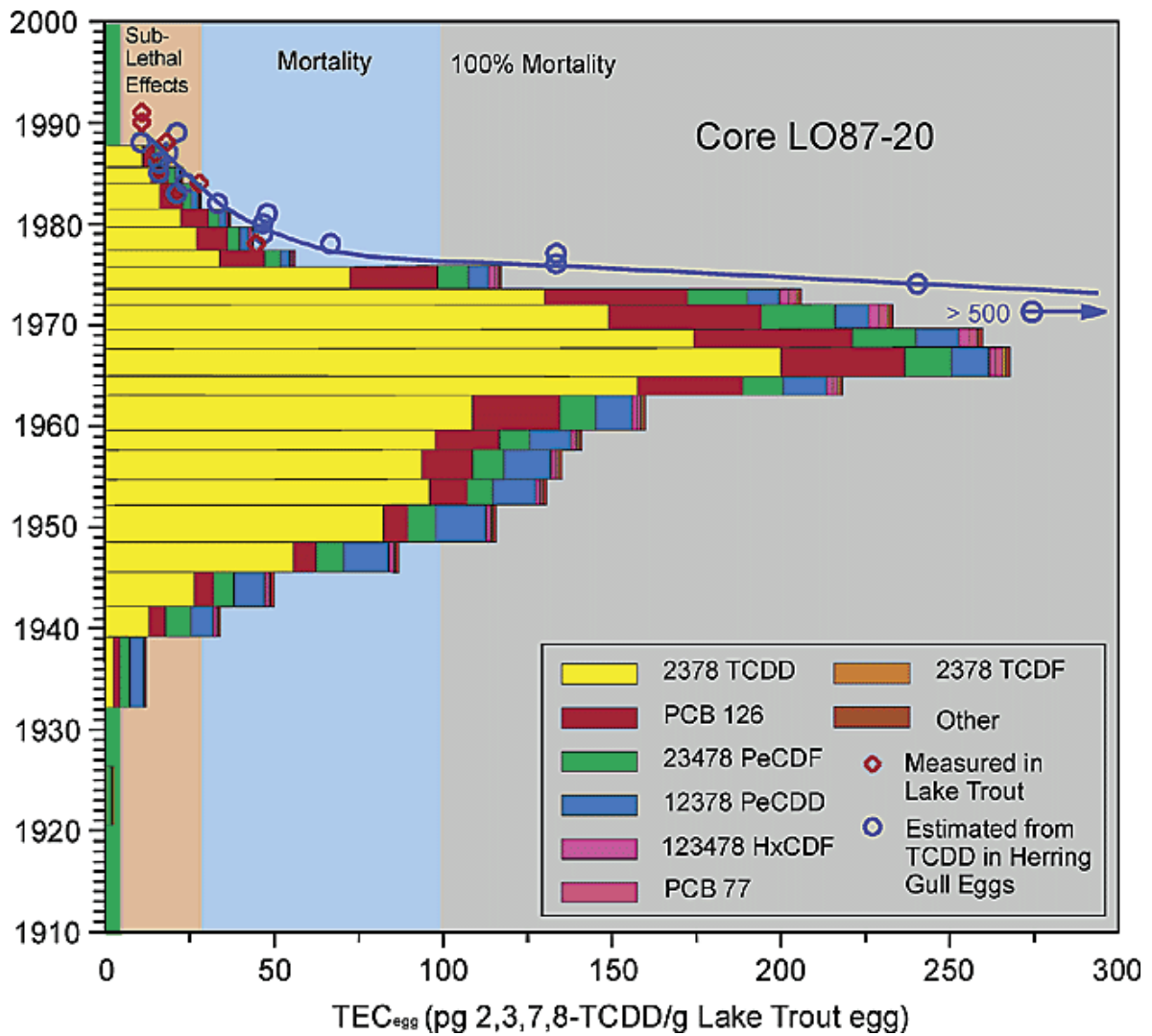
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**Injury to health: A forensic audit of the Great Lakes Water Quality
Agreement (1972-2005), with special reference to
congenital Minamata disease**

Submitted for the Degree of Doctor of Philosophy

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Frontispiece: Historical Reconstruction of Lake Trout 2,3,7,8 TCDD Equivalents in Radio-dated Lake Ontario Sediment Cores

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ABSTRACT

The objective of this research was to examine whether the United States and Canada have successfully implemented their Great Lakes Water Quality Agreement and to identify the factors determining the continuation of any injury to human health from pollution of the boundary waters. The Agreement was first negotiated in 1972 as part of the legitimization of the social unrest of the 1960s and gave special responsibilities to the International Joint Commission to advise the Parties of problems of water quality. It has been subject to periodic review and occasional renegotiation and amendment. Specifically, the Agreement was renegotiated in 1978 to address the health effects from the imperceptible exposures to persistent toxic substances. Though extensive scientific evidence of continuing injury to health from persistent toxic substances has been available, there has been a consistent pattern of deliberate failure by the authorities to report the injury and to implement many of the remedial provisions contained in the Agreement. The thesis claims that the failure of the International Joint Commission to advise the Parties of the new information about the injury to health and the failure of the Parties to act upon the information when it was obtained from other sources constituted dereliction of duty. While synthesis of the science linking the pollutant-induced injury to specific causal agents was necessary to provide an empirical measure of the failure to implement the Agreement, consideration of the social, economic and political aspects was needed to provide a sufficient explanation for the failure of the International Joint Commission to inform and of the authorities to act. There have been active attempts to use diversionary reframing of the Agreement, based on a multi-causal ecosystem theory proposed by fisheries ecologists, to attenuate the risk message and transform the Great Lakes Water Quality Agreement into a more inclusive and less focused agreement on restoring ecosystem

integrity. This has been welcomed by industry and governments as a means to remove the focus from addressing the unresolved dangers of persistent toxic substances through costly remedial actions. The International Joint Commission undermined its credibility when it recommended ‘sunsetting’ the use of chlorine in chemical manufacturing. The Parties failed to use a precautionary approach to prevent the commercial introduction of new persistent toxic substances, such as the brominated flame retardants. Since the 1980s, the economic politics of the two nations have been profoundly influenced by neo-liberalism and one of the consequences has been the removal of environmental health as a priority from the respective political agenda. Advisory bodies seem to have been captured not only by the prevailing neo-liberalism but also by corporate interests and these factors seem to underlie the reluctance to report the injury to health from exposures to persistent toxic substances. Though there were many different health endpoints affected by exposures to water pollutants in the Great Lakes, the thesis concentrated on the evidence of neuro-teratogenic effects. The adequacy of the implementation of the Agreement during the past thirty-three years was tested by using Health Canada data on cerebral palsy hospitalisation to evaluate whether there were indications of previously undetected outbreaks of congenital Minamata disease in human populations in Canadian Great Lakes communities potentially exposed to methyl mercury from natural sources or from historic industrial uses of mercury. The uncertainties in the apparent association that was found were reduced by the application of Hill’s guidelines. While these findings indicated both the need for further multi-disciplinary research to locate and diagnose the victims and for a precautionary approach to the consumption of Great Lakes fish, they also indicated that, for more than three decades, health authorities have not diligently implemented the Agreement. The

inclusion of the social, economic and political considerations in the forensic audit has revealed the dangers inherent in any renegotiation of the Great Lakes Water Quality Agreement.

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CHAPTER 1: INTRODUCTION

The purpose of this chapter is to describe the context for the development of the following three research questions related to the implementation of the Great Lakes Water Quality Agreement:-

Research question # 1: After 35 years of the operation of the Great Lakes Water Quality Agreement, is there continuing injury to health from pollution of the boundary waters with persistent toxic substances?

Research question # 2: To what extent has the Great Lakes Water Quality Agreement addressed the problems of human health and the possible reproductive hazard of pollution in relation to cerebral palsy?

Research question # 3: In addition to the scientific and technical aspects, does consideration of the social, economic and political contexts significantly contribute to the evaluation of the effectiveness of the implementation of the Great Lakes Water Quality Agreement?

In the 20th century, networks of scientists around the world have been researching the imperceptible effects of modern pollutants such as radionuclides and pesticides (1.1). In the previous century, trans-boundary pollution from sources located in the United States and Canada caused injury to the health of populations in the Great Lakes basin and was among the reasons that lead to the development of the 1909 Boundary Waters Treaty and establishment of the International Joint Commission to prevent potential disputes (1.2). Initial concerns about microbiological diseases were superseded by

issues of eutrophication resulting in the negotiation of the 1972 Great Lakes Water Quality Agreement, but this priority in turn was overtaken by the new knowledge of the effects of persistent toxic substances on reproduction and development in wildlife and humans resulting in a new focus during the 1978 renegotiation of the Great Lakes Water Quality Agreement (1.3). Conflicting methodologies between wildlife and fisheries researchers have resulted in divergent causal stories and contending interpretations of the purpose of the Great Lakes Water Quality Agreement that jeopardise its implementation (1.4.1) and indicate the need for a measure of whether pollution by persistent toxic substances is still causing effects on health (1.4.2) and whether social, economic and political considerations are needed to understand the proximate and ultimate causes of any continuing effects (1.4.3). The roles, responsibilities, ethics and boundaries of scientists within civil society are examined (1.5). Finally, the structure of the thesis is outlined (1.6).

1.1 Global Consciousness of the Risks of Modernity

The 1960s was a period of profound changes in humankind's perception of itself and its relationship with the world (Thomas 1962, Toynbee 1976). In the previous two decades, nuclear weapons had been devised and exploded, killing tens of thousands of people, and further testing had released massive quantities of radio-active particles into the atmosphere. Similarly, after World War II, persistent organochlorine pesticides and other products were being used in increasing quantities, and effects were being found in fish and wildlife. A few scientists were aware of the extent of the nuclear and pesticide contamination and determined to document the trends and effects. In the United States, parents were requested to send samples of their children's baby teeth to be analysed for radioactive compounds and the publicised

results contributed to a new and radical environmental consciousness (Commoner 1971). Similarly, the publication of *Silent Spring*, on the releases, exposures and effects of pesticides, brought about a revolution in thinking about the relationship of humans to the biosphere (Carson 1962). In Britain, chemical analyses of wildlife documented widespread contamination of food chains and declines of certain birds of prey, notably the peregrine falcon (Ratcliffe 1963), and lead, in the early 1960s, to controls on certain pesticide uses (Advisory Committee on Pesticides and Other Toxic Chemicals 1969). Networks of scientists started to form to respond to this global contamination. The Great Lakes basin became one of the important loci for the development of the science to document the sources, fate and distribution, pathways of exposures and the reproductive and developmental effects of persistent toxic substances that contaminated the environment.

1.2 Great Lakes as a shared resource and boundary

Throughout the world, clean water is becoming a scarce resource and a potential source of conflict between regions and nations. The Great Lakes contain about 20% of the world's freshwater and are politically divided between Canada and the United States. The boundary through the Great Lakes was decided at the 1783 Definitive Treaty of Peace and was demilitarised after the 1814 Treaty of Ghent. But throughout the 19th century there continued to be "irritants" at the boundary, not only because of obstructions, diversions and extractions of the shared waters, but also because of water pollution. With the development of municipalities and industrialisation in the Great Lakes basin, water quality deteriorated, and with the development of shipping and power generation, issues of water quantity and the allocation of water resources presented areas of potential bilateral disputes. In 1909, Great Britain, on behalf of

the Dominion of Canada, and the United States signed the Boundary Waters Treaty which contained provisions for the establishment of the International Joint Commission with powers to examine and adjudicate certain matters. Article IV of the Treaty was an agreement between the two Parties that they would not pollute their side of the boundary waters to the injury of health and property on the other side.

In 1918, the International Joint Commission responded to a reference from the two governments concerning the conditions of water quality at the boundary. The International Joint Commission spoke plainly when it described to the two governments:-

“The selfishness of vested interests, familiarity with evil conditions, which has begotten an indifference to both the doing and the suffering of wrong, an ill-directed spirit of economy averse to the assumption of financial burdens to remedy what was only regarded as an existing or potential evil to other communities, and the disinclination to change ingrained in humanity, have resulted in a situation along the frontier which is generally chaotic, everywhere perilous, and in some cases disgraceful” (International Joint Commission 1918).

1.3 Environmental Health Issues in the Great Lakes Basin and Institutional Responses

Of particular concern at the turn of the century were the epidemics of cholera and typhoid. But, during the first part of the century, with the treatment of drinking water with chlorine and improvements in public health engineering, these were largely

brought under control. Further references to the International Joint Commission, on water pollution at the boundary were not effective in bringing about improved water quality. Of particular concern were the visibly increasing quantities of algae caused by discharges of nutrients to the Great Lakes basin. In 1964, the two governments sent another reference, pursuant to the Boundary Waters Treaty, to the International Joint Commission to examine whether there was injury to health and property from pollution of the boundary waters in the lower Great Lakes (Lake Erie and Lake Ontario) and the interconnecting channels (Detroit River, Niagara River and the international section of the St Lawrence River). The International Joint Commission reported to the two governments in 1970 and advised that there was injury to health and property from pollution of the boundary waters (International Joint Commission 1970). The two governments used the report as the basis for negotiating the Great Lakes Water Quality Agreement which was signed in 1972 (International Joint Commission 1974). Much of the focus was on bringing the highly visible effects of eutrophication under control through negotiated restrictions on discharges of phosphorus into the Great Lakes and its tributaries. Though there were references to organochlorine pesticides, PCBs and mercury, these compounds were such newly discovered environmental phenomena and the effects of these risks of modernity were so imperceptible that their significance was largely overshadowed by the information on eutrophication and control of phosphorus. The ‘tortuous paths of their deleterious effects’ were ‘*erratic and unpredictable*’ and required ‘the ‘sensory organs’ of science - *theories, experiments, measuring instruments - in order to become visible and interpretable as hazards at all*’ (emphases in original) (Beck 1992 p. 27). The possibility of changing the priority was afforded through Article IX of the 1972 Great Lakes Water Quality Agreement which contained provisions for the Parties to conduct

“a comprehensive review of the operation and effectiveness of this Agreement during the fifth year after its coming into force.”

In 1969, I started my employment as a Great Lakes biologist with the Canadian Government. Before emigrating to Canada and as a student at Queen's University, Belfast, I had undertaken six years (1964-1969) of extramural surveys of peregrine falcons in Northern Ireland to document the effects of pesticides (Gilbertson 1969), following the pioneer work on British peregrine populations undertaken by Ratcliffe (1963). I was employed at the newly established Canada Centre for Inland Waters located at Burlington at the western end of Lake Ontario. Previous research had shown the widespread decline in peregrine falcons (Hickey 1969) and bald eagles (Sprunt et al 1973) in much of North America including the Great Lakes basin, and high chick mortality and reproductive failure in herring gulls nesting on a colony in Green Bay (Lake Michigan), Wisconsin (Keith 1966). Preliminary observations of reproductive failure and mortality in ranch mink fed Great Lakes fish were being investigated from a toxicological perspective (Aulerich et al 1973). Since my interest was in the effects of pesticides on bird reproduction, I soon devised a research programme to undertake a forensic investigation of reproduction in colonial fish-eating birds and documented high levels of organochlorine pollutants in Hamilton Harbour (Gilbertson and Reynolds 1972, Gilbertson 1974a). Of greater significance were the observations of severe chick mortality around the hatching period (Gilbertson 1974b), and of chicks with a variety of deformities (Gilbertson et al 1976). The novel implications of this research were that there were teratogenic compounds in the Great Lakes. Previously, pharmaceutical products such as thalidomide, had been found to be teratogenic, but the observations of deformities in

chicks of Great Lakes fish-eating birds was one of the first indicating the presence of teratogenic activity in the environment.

This finding, together with preliminary results of a survey of the levels of organochlorine pollutants in Lake Michigan sport fishermen (Humphrey 1976), influenced the review of the operation and effectiveness of the Great Lakes Water Quality Agreement and in 1978 it was renegotiated to focus on research, monitoring and controls on persistent toxic substances (International Joint Commission 1978a, Botts and Muldoon 2007). The renegotiation resulted in several significant changes including:- the introduction of an ambiguous 'ecosystem approach', a new statement of the purpose of the Agreement, and an important new precautionary policy that stated that 'the discharge of any or all persistent toxic substances be virtually eliminated.' The initial focus of the thesis is on the injuries caused by exposures to persistent toxic substances in populations of fish, wildlife and humans.

A 'forensic' approach has been taken to the audit of the operation and effectiveness of the Great Lakes Water Quality Agreement not only because there is continuing injury to health of fish, wildlife and human populations, and increasing concentrations of new persistent toxic substances, but also because the authorities have wilfully and knowingly denied the evidence in preparing reports and planning documents and have refused to implement remedial actions which they agreed to undertake by signing the renegotiated Agreement in 1978.

In recent months, Canadian politicians gave samples of blood and learned with surprise the results of the chemical analyses. Most were unaware of the presence of

persistent toxic substances in their bodies - 'hazards which are neither visible nor perceptible to the victims' (Beck 1992 p. 27). From the perspective of the early 21st century, scientists have been able to reconstruct the history of contamination of the Great Lakes particularly from chemical analyses of radiodated sediment cores (see frontispiece). Typically, levels of persistent toxic substances were low at the turn of the 19th century and exponentially increased to a maximum in the late 1960s with a precipitous decline in the 1970s and 1980s to the present. The challenge for researchers has been in attempting to understand the toxicological implications of the chronic episodes of contamination in each of the Great Lakes. Much of the focus of environmental toxicology since the 1940s has been on cancer (Hueper 1948, Hueper and Conway 1964), but the wildlife research in the Great Lakes basin indicated that reproduction and development were the health endpoints most relevant to understand the implications of the exposures to persistent toxic substances. In 1980, the first cohort of infants was established to investigate the developmental effects of prenatal exposures to persistent toxic substances, particularly associated with maternal consumption of fish (Jacobson et al 1984a). The results of the study not only showed gross effects on size at birth and subtle effects on neurological development, but also stimulated extensive further research (see literature review in chapter 3).

It is important to keep the reproductive and developmental effects caused by pollution of the Great Lakes with persistent toxic substances in perspective relative to other environmental controversies. As an heuristic device, comparisons are made in the thesis with the 2003 outbreaks of SARS and with climate change, as two other serious environmental issues. First, in terms of the specific agents, sources and modes of exposure, SARS was associated with person-to-person transmission of a previously

unidentified coronavirus (Centre for Disease Control and Prevention 2005), while climate change is largely associated with anthropogenic releases of carbon dioxide and methane to the atmosphere. These specific agents contrast with the organochlorine compounds and mercury that have caused the reproductive and developmental effects in exposed populations in the Great Lakes basin, particularly from maternal consumption of contaminated fish. Second, the three cases can be compared on the basis of geographic scale. While the SARS outbreak originated in February, 2003 in Guangdong Province, China and was spread globally to new outbreak nodes by travellers using airlines, the teratogens in the Great Lakes and the agents of climate change were released from local sources but were redistributed globally through atmospheric processes. A third comparison can be made on the basis of temporal scales. Whereas the SARS outbreaks were characterised by acute onset of symptoms and, with suitable quarantine and medical care were contained within weeks, and the persistence of the teratogenic toxic substances in the Great Lakes last for decades, the positive feedback mechanisms associated with climate change indicate effects over millennia or even tens and hundreds of millenia.

1.4 Development of Research Questions

Contrasting methodologies between fisheries scientists on the one hand and toxicologists working on wildlife and human populations have lead to contrasting interpretations of the Great Lakes Water Quality Agreement. Recently, the multi-causal interpretation of the fisheries scientists has become privileged posing the question of whether injury caused by persistent toxic substances is still occurring (1.4.1). There is a need for development of a specific empirical measure of whether

injury continues to occur (1.4.2) and of the ultimate, as well as proximate causes of the continuing injury (1.4.3).

1.4.1 Contrasting Methodologies and Interpretations

In addition to the findings of persistent toxic substances in wildlife and humans, fish were the other vertebrates that were highly exposed. However, following the development of multi-variate statistical techniques in the 1960s, fisheries scientists, like the epidemiologists (Krieger 1994 p 887) developed multi-causal methodologies with assumptions, values and biases that contrasted with those of the wildlife toxicologists and that have resulted in few statements relating fisheries declines and extirpations, during the 20th century, with exposures to persistent toxic substances (Regier and Cowell 1972, Selgeby et al 1995). Differences in causal stories can have profound effects on the formulation of policy (Stone 1989). The methodologies of the fisheries researchers have not only resulted in divergent causal explanations for the declines and extirpations of Great Lakes fish stocks but also have had profound effects on the interpretation of the purpose and the implementation of the Great Lakes Water Quality Agreement. Governments and industrial interests, wishing to avoid the costly commitments for remedial action, have endorsed the methodology as part of a process of diversionary reframing (Gilbertson and Watterson 2007) (see sections 4.4.2.3, and 6.2.5). The resulting debate concerns whether to transform the purpose of the Great Lakes Water Quality Agreement into an agreement on ecosystem management to address the multi-causal ‘stressors’ assumed to be causing changes in the ecology of the entire Great Lakes basin ecosystem. But this transformation would remove the present focus from the control of persistent toxic substances that caused the injury to health. The debate therefore poses the first research question as follows:-

Research question # 1: After 35 years of the operation of the Great Lakes Water Quality Agreement, is there continuing injury to health from pollution of the boundary waters with persistent toxic substances?

There is some urgency to responding to the research question not only because the proposal for the transformation of the Agreement has gained momentum, but also because the Agreement is undergoing an extensive periodic review that affords the opportunity for the proposed transformation to be adopted. The current review process started in 2004 and is not expected to be completed until 2008. In preparation for the process, an extensive history of the development and operation of the Great Lakes Water Quality Agreement was written and published by a policy analyst from the United States and by a Canadian environmental lawyer (Botts and Muldoon 2005) and has been used as a resource for preparing chapter 4. There has been extensive public consultation by the Parties and by the International Joint Commission, using teleconference and video technology to link people from throughout the Great Lakes, as well as holding traditional public meetings around the basin (International Joint Commission 2005). The review and consultation process became an opportunity for those seeking to transform the Great Lakes Water Quality Agreement and was marked by a polarization of views on what the Agreement is about and what is its purpose. I have been extensively involved in this process and my own representations have been informed by a literal reading of the Agreement. My assumptions have been that the Great Lakes Water Quality Agreement is a minimalist agreement between two sovereign nations which shared mutual concerns about protecting health and property

from injury by pollutants that crossed their shared boundary in the Great Lakes basin (Gilbertson and Watterson 2007).

1.4.2 Empirical measure of injury

Within the context of the general research question, there is a need for an empirical investigation of injury to health from pollution of the Great Lakes boundary waters as a test of whether the parties have successfully implemented the Agreement. Previous epidemiological research has shown the susceptibility of the brain to the developmental effects of exposures to persistent toxic substances (Chapter 3), and neuro-teratology data on the effects of pollutants on brain development was selected as a potentially useful measure of the status of implementation of the Great Lakes Water Quality Agreement. Health Canada (1998) developed epidemiological data on the rates of mortality, morbidity and congenital abnormalities in the 17 Canadian Areas of Concern around the Great Lakes (Figure 1). Among the extensive database, a specific measure of neuro-teratogenic activity is represented by the rate of mortality and morbidity as hospitalisation for cerebral palsy based on the assumption of an association with exposures to methyl mercury as occurred first in the population in Minamata, Japan in the 1950s. The results indicate that there are outbreaks of congenital Minamata disease in several locations on the Canadian side of the Great Lakes associated with elevated levels of mercury (Gilbertson 2004) and these form the main empirical part of the thesis. The results not only raise important questions about the extent to which the Great Lakes Water Quality Agreement has failed, but also the wisdom of transforming the purpose of the Agreement to address ecosystem management of the entire Great Lakes basin. In that these data were developed by Health Canada, their use as the test overcomes any criticism of my personal bias in

their generation (see methods in section 2.3), though not in the interpretation that I have placed upon them (see chapter 5).

Research question # 2: To what extent has the Great Lakes Water Quality Agreement addressed the problems of human health and the possible reproductive hazard of pollution in relation to cerebral palsy.

1.4.3 Social, economic and political considerations

While epidemiology data is central to providing the empirical analysis of the status of implementation of the Great Lakes Water Quality Agreement, there has recently been extensive debate about the limitations of epidemiology in improving health (Kreiger 1994, Susser and Susser 1996 a, b). From a technical standpoint there has been the recognition of the need to link the science to public health and to molecular epidemiology. But there have also been suggestions of the need to understand the causes of disease not only in terms of the specific risk factors that operate at the individual level, but also in terms of the ‘wide range of political, economic and social factors’ (Pearce 1996 p 680). Thus there may be a need to formulate a third research question to broaden the analysis to understand the social, economic and political contexts that influence the implementation of the Great Lakes Water Quality Agreement.

Research question # 3: In addition to the scientific and technical aspects, does consideration of the social, economic and political contexts significantly contribute to the evaluation of the effectiveness of the implementation of the Great Lakes Water Quality Agreement?

Based on the concerns about the limitations of epidemiology in improving health, some epidemiologists have proposed the development of a new ‘eco-epidemiological era’ (Susser and Susser 1996b) and an ‘ecosocial framework’ (Krieger 1994 p 896). They believed that there was a need to reconnect with public health and to undertake epidemiology at greater ‘depth’ through integrating several levels of analysis ranging from the ecosystem and the population levels, as well as the study of individuals, through to the molecular level (Susser and Susser 1996b p 674, Pearce 1996 p 680). This has immediate relevance to the development of a forensic methodology for examining whether the Parties have implemented their Great Lakes Water Quality Agreement. Any claims about the occurrence of outbreaks of congenital Minamata disease in any of the Canadian Areas of Concern, need to be made using all these levels of analysis (see section 2.4.3 Causation and the reduction of uncertainty).

Others have stressed the importance of adding ‘breadth’ to the science by redeveloping the debates about the relationship between disease and its social determinants that had been abandoned when the germ theory eclipsed the miasma paradigm more than 100 years ago. The era of the Sanitary Movement had been characterised by consideration of the prevailing social conditions and the political economy of the time (Susser and Susser 1996a). The third research question needs to be concerned with whether significant new insights can be gained in evaluating the effectiveness of the implementation of the Great Lakes Water Quality Agreement by considering the social, economic and political contexts in addition to the scientific and technical. It would seem that part of the development of the methodology for the forensic audit needs to be complemented by consideration of the social, economic and political contexts. Such complementary analyses have been developed by sociologists

in understanding disasters such as the increased mortality in Chicago in 1995 during the heat wave (Klinenberg 1999). This, however, opens up methodological possibilities that are far ranging and there is a need to be selective. Brief notes are made of the following particularly relevant categories:- risk communication and diversionary reframing (1.4.3.1); neo-liberalism and theoretical aspects of ‘struggle’, ‘resistance’ and ‘capture’ models (1.4.3.2); and the role of advisory committees (1.4.3.3); and the social production of science (1.4.3.4).

1.4.3.1 Risk communication and diversionary reframing

Since the 1970s, there has been significant debate about the scientific aspects of risk assessment (National Research Council 1983) and about the practice of the risk assessment process (Silbergeld 1993, Graham 1995). The Great Lakes application of these techniques were examined at a workshop of the Great Lakes Water Quality Board in February 1993 in relation to: - risk characterisation (Farland 1993); priority setting (Huggett 1993); fish advisories (Horn 1993, Hayton 1993); discharge limits (Clark 1993, Spry 1993); and wildlife (Sullivan 1993). The methods, particularly, have found application through the Great Lakes Initiative for the development of water quality objectives to protect wildlife as the most sensitive indicator organisms.

At the same workshop, there were two presentations on risk communication (Leiss and Walker 1993, Fessendon MacDonald 1993) and these may provide concepts that may be more directly useful complement to the forensic audit of the Great Lakes Water Quality Agreement. The social processing of risk, through amplification and attenuation of the information, has been a significant area of research in the past two decades and this has been an important analytical tool for the thesis (Kasperson et al

2003, Pidgeon et al 2003, Egilman and Bohm 2005). For example, the claim is made that the International Joint Commission and the Parties have purposely omitted evidence of the injury to health from documents. Similarly, one of the methods of risk attenuation is through diversionary reframing (Freudenburg 2003) and the claim is made that the International Joint Commission and the Parties are actively involved in processes of diversionary reframing to transform the purpose of the Great Lakes Water Quality Agreement into an agreement on ecosystem integrity rather than remaining focused on maintaining and restoring water quality (Gilbertson and Watterson 2007).

1.4.3.2 Neo-liberalism, 'struggle', 'resistance' and 'capture' models

During the era of the Great Lakes Water Quality Agreement (1972 – present), throughout the world, governments have undergone a 'global revolution' in management of their public administrations. 'The neoliberal orthodoxy can be represented as a generalised belief that the state and its interventions are obstacles to economic and social development' (Clark 2002 p 771). Canada is no exception and changes in Canadian public administration have been influenced not only by applying the ideological tenets of neoliberalism, including small government, deregulation, privatisation of facilities and services, laissez-faire economics, tax breaks, free trade agreements and development of global markets, but also by instituting managerial techniques from the private sector (Clark 2002). In turn, neo-liberalism has produced a 'struggle' within society as the disadvantaged mount 'resistance' to the social conditions and hegemonic forces attempt to further decrease the power of the state through the 'capture' and dismantling of regulatory agencies (Snider 2003, 2004, Glasbeek 2002 p 153).

The global recognition of the Environmental Crisis in the late 1960s and early 1970s was shortly followed by a similar recognition of an Energy Crisis after the Organisation of Petroleum Exporting Countries increased prices in 1973 (Reese 1983). The subsequent economic stagnation and inflation severely challenged economies throughout the world resulting in high interest rates, deficit financing and widespread unemployment and seriously challenged the ability of governments everywhere to underwrite the social welfare programs that had developed since the end of the Second World War based on Keynesian economics. Shortly after the Great Lakes Water Quality Agreement was renegotiated in 1978, a second oil pricing crisis occurred in 1979 as a result of the Iranian Revolution (OPEC 2007) and further exacerbated the global economic crisis.

Neoliberalism has been embraced by or imposed on nations through a great variety of methods and circumstances and has displaced Keynesian economics at the international institutions established through the Bretton Woods agreement, including the World Bank and the International Monetary Fund, and at the World Trade Organisation. 'Neoliberalism has, in short, become hegemonic as a mode of discourse' (Harvey 2005 p 3). In Britain, Prime Minister Margaret Thatcher abandoned Keynesianism and valorised the monetarist writings of Friedrich Hayek by instituting tax cuts (1981 budget), privatising industries (British Telecom), selling council houses to tenants, and developing and enforcing new legislation on trade union activities (Harvey 2005, Prasad 2006). Similarly, in the United States, Ronald Reagan espoused neoliberal values by instituting tax cuts (in 1981), deregulating the airline industry, and unsuccessfully attempting to roll back welfare (Prasad 2006). In

West Germany, Helmut Kohl, after his election in 1982, announced his intention of 'reducing the state to the core of its tasks' and advocated tax cuts, deregulation and cuts to welfare spending (Prasad 2006 p 162). After the death of Mao Tse-tung in 1976, Deng Xiaoping, while maintaining 'authoritarian centralised control', reformed China's economy by applying many neoliberal concepts and produced an economy that will soon rival that of the United States (Harvey 2005 p 120). These examples contrast with the neo-statist responses of some governments, including Sweden and France, which have involved greater involvement of their respective governments in direct management of their economies.

In Canada, the incorporation of neoliberal ideas has been described as ambiguous as successive governments attempted to respond to the increasing federal debt and deficits caused by the economic recession of the early 1980s (Clark 2002 p 782). In the 1980s, the Conservative Government of Prime Minister Brian Mulroney undertook 'managerialist' reforms to attempt to bring the deficit under control. But with the election of Prime Minister Jean Chretien's Liberals in the early 1990s, a serious retrenchment of government involvement was carried out with 'downsizing' of the public service, privatisation of facilities and services and devolution of programmes to the provinces (Clark 2002 p 782). The most far-reaching neoliberal reform was the negotiation of the Free Trade Agreement with the United States (1988) and the subsequent negotiation of the North American Free Trade Agreement with the United States and Mexico (1993). The Canadian provinces have similarly espoused neoliberal characteristics, particularly with the election of Ralph Klein in Alberta in the 1980s and the implementation of the 'Common Sense Revolution' of the Conservative Premier Mike Harris in Ontario in the 1990s. In contrast, the

Province of Quebec, which has traditionally been more social democratic, responded with more of a neo-statist approach resembling that which had occurred in France (Gow 2004).

Canada has been described as a 'liberal-capitalist-democracy' in which there is a need to 'balance' the encouragement of private investment while protecting the public, labour and the environment from harm (Glasbeek 2002 p. 154). After fifteen years of applying neoliberalism to Canadian public administration, this issue of balance is now reflected in the training of civil servants at the Canada School of Public Service which 'seeks a balance between the virtues of traditional bureaucracy on the one hand, and entrepreneurship and innovation on the other' (Cochrane preface to Gow 2004). For the purpose of the thesis, it is important to trace the effect of neoliberalism, and particularly trends towards small government and deregulation, on where the balance has lain and where it now lies. Whereas deregulation originally seems to have been a benign alternative based on a tax for the use of the 'assimilative capacity' of the environment for disposing of wastes (Reese 1983), it has become a weapon for politicians who are antagonistic towards environmental protection.

In the United States, various regulated industries had successfully 'captured' the agencies set up to oversee their operations and this had resulted in higher prices for consumers from a lack of competition. In the 1970s, Ralph Nader, as a consumer advocate, campaigned against these monopolistic practices and advocated industrial deregulation. President Ronald Reagan, however, extended the meaning to include deregulation of social programmes such as environmental protection and occupational health and safety (Prasad 2006 p 74-76). He used the following three methods to

undermine the Environmental Protection Agency:- instituted executive orders for the agency to perform cost-benefit analysis of all proposed regulations; promoted an agenda that was against the protection of the environment, through delays in the regulatory process and through budget cuts; and appointed heads of agencies that shared his agenda against the environment (Anne Gorsuch as Administrator of the Environmental Protection Agency and James Watt as Secretary of the Department of Interior) (Prasad 2006 p 78-79). Since 2000, President George W. Bush has used these techniques to re-enact an agenda against protection of the environment (Natural Resources Defence Council 2005).

In Canada, curbing of regulatory approaches was initiated in 1978 through the institution of the requirement for the preparation a Socio-Economic Impact Analysis of new regulations for health, safety and fairness (Treasury Board of Canada 2000). By the mid-1980s, with the election of the Conservative Government that ideologically believed in small government (Kelly 2000), there was a general sentiment that “Canadians were overregulated” (Government of Canada 2002). In particular, based on the 1985 Nielson Task Force on Regulatory Programmes, a recommendation was made for a study of the overlap between federal and provincial regulations for environmental protection (Government of Canada 2002). Neoliberal values seem to have been at play in 1986 when the Prime Minister appointed a Minister of State and an Office for Privatisation and Regulatory Affairs (Government of Canada 2002). The responsibility was moved to Treasury Board in 1991 and through a departmental and parliamentary review of regulations resulted in the revocation or revision of 835 regulations in five years (Treasury Board of Canada 2000).

The election of the Liberal Government under Jean Chretien in 1993 coincided with a serious crisis of increasing debt and annual deficits and, in 1994, after the first Liberal budget failed to impress industry and Moody's had lowered the credit rating of the Government of Canada, the new government instituted a Programme Review to reduce expenditures by all departments (Kelly 2000, Treasury Board of Canada 2002). Using conservative methods for estimating the budget, the federal government, by 1998, started to produce large surpluses, but not before about 40% of the annual programme expenditures had been cut (Kelly 2000). Canadian programmes for implementing the Great Lakes Water Quality Agreement were directly affected with cuts to the budgets of Environment Canada, the Department of Fisheries and Oceans and cancellation of the Great Lakes Health Effects Programme of Health Canada. The ability of the Government of Canada to fulfil its commitment under the Great Lakes Water Quality Agreement was seriously compromised.

Before the International Joint Commission (2002) exercised self censorship and aligned its comments with the retrenchment practices of the Parties, these concerns were reflected in the Eighth and Ninth Biennial Reports of the International Joint Commission (1996, 1998). It noted that 'governments appear to be less receptive and responsive to advice and to the wishes of their citizens regarding the environment' and it referred to the '3D's' of deregulation, devolution and downsizing as affecting the ability of governments in 'their approach to environmental restoration and protection' (International Joint Commission 1998 pp 13 & 17). The capacity to sustain the progress that had been made in the 1980s and early 1990s was placed in question by:-

Proposals to weaken regulatory frameworks that underpin pollution control and other effective programs, including reporting and compliance requirements; and

Erosion of funding and expertise for research, monitoring and enforcement, and transferred responsibilities to other levels of government without the requisite resources (International Joint Commission 1996 p 3).

1.4.3.3 Precautionary principle

Even before the neo-liberal era, the growing power of industry and increasing corporatism of governments undermined decision-making to protect society from risks posed by chemicals. This can be contrasted with the elaborate planning and preparation work to prevent and respond to outbreaks of SARS including guidance documents, information to travellers, surveillance of returning travellers, laboratory testing and establishing a Health Alert Network, quarantine procedures and infection control (Centre for Disease Control and Prevention 2005). The societal response to the undermining of decisions on protection of populations from exposures to chemicals has been to examine ways in which decisions can be made in a precautionary manner. The Precautionary Principle was first formulated in the early 1970s in relation to water protection laws in Germany (Raffensperger and Tickner 1999 p. 4). In contrast to the forensic approach, the 'Vorsorgeprinzip' was aimed at planning processes to avoid damage to the environment rather than relying on detection of damage and subsequent attempts to prove the cause of damage after the fact.

If there is a potential for harm from an activity and if there is uncertainty about the magnitude of impacts or causality, then anticipatory action should be taken to avoid harm (Raffensperger and Tickner 1999 p. 1).

After the social unrest of the 1960s and early 1970s, the United States Congress made progress in regulating chemicals and in protecting health and the environment. During the 1978 renegotiation of the Great Lakes Water Quality Agreement, precautionary policies were incorporated into the new statement of purpose in Article 2. The purpose was not only to ‘restore’, but also to ‘maintain’ water quality. Similarly, though toxic substances could be released in concentrations below those that were toxic, for persistent toxic substances there was a recognition that there was neither an assimilative capacity nor safe levels and a new precautionary policy was included for their ‘virtual elimination’ from discharges. Despite the institution of neo-liberal policies and the erosion of many of the advances in environmental protection during Reagan’s Presidency in the 1980s (Geiser 1999b p. xxi, Raffensperger and Tickner 1999 p. 5, 6), these precautionary policies have remained. In undertaking the forensic audit, it is necessary to examine whether the International Joint Commission and the Parties have successfully implemented these precautionary policies.

1.4.3.4 Role of advisory committees

Much of the process of implementing the Great Lakes Water Quality Agreement involves the production of advice through committees. The International Joint Commission has an advisory role to the Parties which it fulfils largely through its Biennial Reports. In turn, the International Joint Commission is dependent on its own

committees to advise it. Thus, there may be a need to consider the variety of advisory committees, including ‘expert’, ‘democratic’ and ‘pragmatic’ approaches (Irwin 1995) and the ‘curiously sheltered position’ that scientific advisory committees have held ‘in the landscape of American regulatory politics’ (Jasanoff 1990 p 1). Consideration may need to be given to the role of corporate interests that have become effective in the corruption of scientific processes (Egilman and Bohme 2005) including representation on advisory bodies. There may be a need for consideration of the quality of advice that has been produced by the advisory committees and by the International Joint Commission.

1.4.3.5 Social production of science

The debate about the purpose of the Great Lakes Water Quality Agreement reflects the differing biases, values and methodologies of different networks of scientists and therefore the forensic audit needs to consider not only the social production of disease, but also the social production of science (Krieger 1994 p 898). There may be a need for consideration of aspects of the sociology of science, such as the rewarding of grants and awards, and social processes for choosing between hypotheses (Merton 1973). One of the central claims involves the process of diversionary reframing of the Great Lakes Water Quality Agreement (Gilbertson and Watterson 2007). The opportunity for diversionary reframing was afforded not only by the ambiguity of Article 2 but also by the alternative causal stories of the Great Lakes fisheries ecologists. There is, thus, a need for the following detailed review of the concepts from the sociology of scientific knowledge, particularly concerning the methodologies for choosing between hypotheses (Chalmers 1982).

During the 20th century, the historians and philosophers of science explored a continuum of approaches and beliefs, spanning positivism at one extreme and relativism at the other (Popper 1965, Lakatos 1974, Kuhn 1962, Feyerabend 1991). The immediate relevance for Great Lakes scientists undertaking research on the injury to fish, wildlife and human health was to pose the question concerning the means for 'proving' how the injury to populations was caused. Popper (1965 p.vii) proposed that the way that scientific knowledge progresses is through a process of criticism to try to refute conjectures and thereby demonstrate a theory to be false. He maintained that theories that are falsified after ruthless criticism must be abandoned and new falsifiable theories proposed for testing. The relative merits of competing theories can be compared not only on whether it is more falsifiable but also on whether it predicts a new kind of phenomenon that is unaccountable by a rival theory.

Kuhn regarded scientific endeavours as more of a social process (Kuhn 1962). He described 'paradigms' that were established bodies of knowledge that were being researched by a network of scientists with agreed methodologies. This 'normal science' elaborates existing knowledge with new experiments and observations. However, persistent anomalous results from these experiments and observations could challenge existing theory and the paradigm, throwing the science into 'crisis'. He described in detail not only the sociological and psychological aspects of crisis and its resolution through the development of a new paradigm, but also the reluctance of a few practitioners to embrace the new paradigm (Kuhn 1970 p. 151).

In practice, hypotheses that have been falsified may persist and lead to useful new scientific insights. Lakatos (1974) took this objection to Popper's falsification

proposal and put forward the idea of ‘research programmes’ comprising a ‘hard core’ with basic assumptions that were not to be modified or rejected. This hard core was to be ‘protected from falsification by a protective belt of auxiliary hypotheses, initial conditions, etc’ (Chalmers 1982 p.80). Lakatos proposed that each research programme have rough guidelines for its development, either bolstering the hard core with new assumptions or by predicting new phenomena. In this proposal, the relative merits of competing research programmes can usually only be judged retrospectively in terms of whether they progressed or degenerated.

Chalmers has offered a useful comparison of whether the views of Popper and Lakatos can be described as ‘rationalist’ and those of Kuhn as ‘relativist’ (Chalmers 1982 p. 101). He noted the ‘debate is over the issues of theory appraisal and theory choice, and over ways of demarcating science from non-science.’ This is directly relevant in relation to the Great Lakes Water Quality Agreement in choosing between the causal hypotheses of the forensic toxicologists and the multi-causal statements of the fisheries ecologists. Chalmers (1982 p. 101,102) has described the rationalist as believing that ‘there is a single, timeless, universal criterion’ for assessing the relative merits of rival theories. He has contrasted this with the relativist position that denies such a criterion for judging between theories and instead assesses the relative merits based on what is of value to individuals or to scientific communities in terms of seeking knowledge.

In 1974, Feyerabend mapped out the extreme end of the relativist position on the continuum of theories of scientific knowledge. Feyerabend asserted that ‘anything goes’ and that, ‘*all methodologies, even the most obvious ones have their limits*’

(Italics in the original) (Feyerabend 1991 p.vii, 23). This scientific relativism has immediate implications for forensic environmental science:

If it is impossible anyway to determine causal relationships finally and unambiguously, if science is only a disguised mistake in abeyance, if ‘anything goes’, then where does anyone derive the right to believe only in certain risks? It is this very crisis of scientific authority which can favour a general obfuscation of risks (Beck 1992 p.71).

These contending viewpoints about scientific method have had their adherents and detractors within the Great Lakes scientific community. The immediate challenge for forensic toxicologists working in the Great Lakes basin was how to find agreed guidelines through which to make truth statements about the causal relationship between the injury and the exposures to certain persistent toxic substances. The discovery of Hill’s guidelines and their application to Great Lakes forensic science was a successful positivist response to the challenge (Hill 1965, Fox 1991, Gilbertson and Schneider 1991, 1993, Gilbertson 1996). Similarly, the challenge for the Great Lakes fisheries scientists was to supply environmental managers with truth statements about the causes of the ‘declines and extirpations’ of stocks of fish. In contrast to the forensic toxicologists, their relativistic response was to work at the ‘highest appropriate organisational level’ (Dunbar 1980 p. 127) which was the ecosystem level and to include all putative ‘stress’ factors in formulating their multi-causal statements (Regier and Cowell 1972). The immediate challenge for environmental managers is how to choose between ‘positivist’ and ‘relativist’ versions, how to choose between theories and how to demarcate between science and non-science (Chalmers 1982 p.

101 L). With the ambiguity of the purpose of the Great Lakes Water Quality Agreement, there are immediate difficulties with the different causal stories that can give rise to the formulation of divergent policy options (Stone 1989) as well as affording the opportunity for diversionary reframing of the purpose (Gilbertson and Watterson 2007 also see section 4.4.2.3).

1.4.3.6 Discussion and conclusions

By opening epidemiology to new eco-social considerations, epidemiologists may assist public health professionals in intervening in novel ways to prevent chronic diseases, including those suspected to be induced by exposures to persistent toxic substances from trans-boundary pollution. The thesis uses these various frames as a means to make several claims concerning:- the continuing injury to health (detailed in chapters 3, 4 & 5); risk message attenuation (section 3.3.3); the quality of advice (section 4.4.2.1); failure to implement the precautionary principle (section 4.4.2.2); and diversionary reframing as a means to avoid implementing the Great Lakes Water Quality Agreement (section 4.4.2.3);.

Since the 9/11 attacks, bilateral relations on border issues between Canada and the United States have been dominated by secret consultations on Deep Integration (Saul 2005, Barlow 2005, Dobbin 2007). The United States wants improved security, whereas Canada wants improved trade access to United States markets. In that the Great Lakes Water Quality Agreement is one of the diplomatic instruments for decreasing potential border irritants, its value in the bilateral context needs to be evaluated as part of the thesis.

The Great Lakes Water Quality Agreement was a remarkably successful diplomatic achievement when it was negotiated in 1972 and renegotiated in 1978, but there is a growing concern that in recent years it has failed in several domains including science, administration and diplomacy (see chapter 4). Details of the development and failure of the Great Lakes Water Quality Agreement have been the subject of a recent publication based on interviews with 128 people involved in its negotiation or implementation, and parts of the social, economic and political contexts of the thesis, as well as the chronology of events have been informed by the publication (Botts and Muldoon 2005).

The authors have provided an in-depth history of the successes and failures inherent in dealing with a complex ecosystem shared by two countries (Beeton in Botts and Muldoon 2005. Promotion on back cover).

While the forensic audit can provide an empirical measure of the alleged failure of the Parties to implement the Great Lakes Water Quality Agreement, manifested by continuing injury to health, it seems that consideration of the social, economic and political contexts will be required in understanding the ultimate causes of any failure.

1.5 Civil society: Ethics and boundaries

Canadians and Americans have slowly become aware that civil society within the United States of America is undergoing three simultaneous ideological revolutions (Barlow 2005, Saul 2005, Gore 2007). A neo-liberal economic revolution has aligned itself with neo-conservative ideals and these have been placed within a religious apocalyptic context of End Times (Bokaer 2004, Hedges 2006). These three

right-wing revolutions have profound ethical implications for both nations, and individuals and institutions involved in maintaining and restoring water quality within the Great Lakes basin are not unaffected. The information that there are subtle effects on foetal development from maternal exposure to persistent toxic substances from consumption of Great Lakes fish poses ethical dilemmas for government scientists in terms of their role in contributing to civil society. These dilemmas are particularly burdensome in societies that have become secretive, corporatist and neo-liberal, such as present day Canada and the United States.

I am convinced that it is the duty of those scientists who have a gift for writing to make their subject intelligible to the ordinary man and woman. Without a much broader knowledge of science, democracy cannot be effective in an age when science affects all our lives continually (Haldane quoted in Irwin 1995 p. 11).

Haldane's comments were made in 1939, some time before the atomic and hydrogen bombs were dropped on Japan, or atmospheric testing of nuclear devices spread radioactive particles around the earth. They were made some time before organochlorine compounds were released into the environment and ubiquitously redistributed. But he understood the linkage between public knowledge of science and the effective functioning of a democratic society. The Association of Scientific Workers 'was highly critical of those scientists who simply stood on the sidelines of social change' (Irwin 1995 p. 12). The Association felt that this 'new world would require scientists to adopt an explicitly *political* role in society' (emphasis in original).

On the other hand, sixty-five years after Haldane wrote his preface, there are now diverse mechanisms for ensuring that scientists, particularly civil servants, do not speak directly to inform the public about matters that might be interpreted to be political. For example, ‘boundary work’ is the strategy that scientists use in ‘building professional communities, defining and excluding non-members, competing for resources, or asserting their autonomy against external control’ (Jasanoff 1990 p. 14). Various strategies are used to define ‘who is in and who is out of relevant peer groups and networks of prestige and authority.’ Scientists who speak out and inform the public about the risks or actual injury to health from a particular activity or chemical substance may find that they are excluded from their network. This can have serious effects upon their employment, research funding and their ability to travel professionally and speak at conferences and meetings. These threats are implicitly known by the scientists who have received funding to undertake epidemiological research on fish and wildlife populations and on cohorts of infants and adults exposed directly or indirectly to persistent toxic substances from the Great Lakes. These threats are also implicitly known by scientists who have become managers within the bureaucracies. The implicit knowledge becomes operational through processes of self censorship and, where necessary, through silencing. In a sense, the thesis is a protest ‘driven by moral outrage’, ‘to counter the misuse of science by major social institutions’ (Nelkin 1992 p. xii, xiii).

1.6 Structure of the dissertation

Chapter 1 has briefly outlined:- origins of the Great Lakes Water Quality Agreement within the context of a growing global awareness of damage to the environment; the nature of the continuing injury to health from exposures to persistent toxic substances;

the reluctance of the authorities to report the injury; the use of the review process as a forum to transform the Agreement into an agreement on ecosystem management rather than remaining focused on water quality to protect human health. An audit based on the empirical data on the incidence of a disease might explain the proximate cause but likely would be deficient in understanding the ultimate causes of the continuing injury and a methodological framework is needed for consideration of the social, economic and political contexts. Finally, the role of the scientist in civil society is briefly examined.

Chapter 2 addresses the several methodological aspects of undertaking a forensic audit of the Great Lakes Water Quality Agreement. First, as a former employee of the International Joint Commission and of the Canadian Government, my role in undertaking a forensic audit can be thought of as a participant observer and, in undertaking such an audit, it is essential to address my own assumptions, values and biases. Second, there is a need for an empirical method for establishing whether the health authorities have implemented the Great Lakes Water Quality Agreement and this has been undertaken through analysis of Health Canada data on the rate of hospitalisation for cerebral palsy in 17 Canadian Areas of Concern as an index of congenital Minamata disease. Third, there is a need for a method of reducing uncertainty in evaluating whether or not an epidemiological association is causal. Finally, the limitations of the research are detailed.

Chapter 3 explores the pertinent literature on the neuro-toxicological effects that have been documented in Great Lakes populations and that contribute to the later empirical analysis. It includes consideration of the limits of the existing knowledge that has

been accumulating over the past thirty years. The uncertainties that remain frame the present research in terms of whether there might be previously undetected outbreaks of congenital Minamata disease. Finally, there is a brief synopsis of the institutional responses to the neurological findings.

Chapter 4 is a detailed review of the development and failure of the Great Lakes Water Quality Agreement partly based on an analysis of the book by Botts and Muldoon (2005).

Chapter 5 utilises the methodological framework to report the results of the Health Canada health data and statistics used to test whether there are indications of congenital Minamata disease within the Great Lakes basin. The locations with the significantly elevated rates are identified. The limitations and uncertainties of the findings are reviewed and where possible reduced through the application of Hill's epidemiological 'viewpoints'. The scientific relevance of the findings of preliminary indications of previously undetected outbreaks of congenital Minamata disease is assessed and the political significance in relation to the review of the Great Lakes Water Quality Agreement is discussed.

Chapter 6 details the conclusions including: - the continuing injury to health as a result of pollution of the boundary waters by exposures to persistent toxic substances; failure of the Parties to implement a precautionary approach indicated by increasing concentrations of new persistent toxic substances; attenuation of the risk messages by the International Joint Commission and the Parties through omission of evidence of injury to health from reports and planning documents; and attempting to transform the

purpose of the Great Lakes Water Quality Agreement through a process of diversionary reframing. The failure of the Parties to effectively implement the Great Lakes Water Quality Agreement is placed in the context of other failures, particularly of the United States, to prevent global crises that threaten civilisation

Future research needs are detailed in chapter 7 including:- prospective and retrospective identification of congenital Minamata disease victims in the Great Lakes basin; and a need to deconstruct all of 20th century Great Lakes fisheries science.

CHAPTER 2: METHODOLOGIES FOR A FORENSIC AUDIT

2.1 Introduction

The purpose of this chapter is to detail the methods and theories needed to undertake a forensic audit of the Great Lakes Water Quality Agreement and of the ongoing review of the Agreement. Both the General Accounting Office of the United States and the Auditor General of Canada have undertaken environmental audits of the Great Lakes Water Quality Agreement using standard accounting techniques and they have critically examined many aspects of the management and implementation and made extensive recommendations to the respective federal governments. The techniques include a review of the mandate and objectives, interviews with managers and other staff and comparisons with the actual programmes, budgets and results. However, the techniques do not include an examination of or comments on the government policies themselves and these would seem to be important in undertaking a forensic audit to understand why injury to health is still occurring after 35 years of the United States and Canadian governments ostensibly implementing the Great Lakes Water Quality Agreement.

The process of preparing a forensic audit into the operation and effectiveness of the Great Lakes Water Quality Agreement necessarily requires a mixture of many methods from many disciplines. As a former member of staff of the Great Lakes Regional Office of the International Joint Commission, in a sense I am writing an ethnography using the methodologies of a participant observer. One of the challenges in undertaking the forensic audit is to explain the assumptions, values and biases that I bring to this exercise, based upon my training and experiences (section 2.2.). Secondly, there is a need for an empirical measure of whether the Parties have been

successful in implementing the Great Lakes Water Quality Agreement. Epidemiological data on the rate of cerebral palsy hospitalisation in the 17 Canadian Areas of Concern have been used as an index of outbreaks of congenital Minamata disease (Gilbertson 2004) and the methods are detailed (2.3). Thirdly, the Agreement has been in existence (1972-present) during a period of profound changes, not only in the beliefs about the nature of science and the associated uncertainties but also in the social, economic and political contexts of the two nations, and the forensic audit needs to include consideration of how these have influenced the effectiveness and operation of the Agreement. Finally, the limitations of the research are briefly described (2.4).

2.2 Participant observer

The thesis is written from an ‘insider’ perspective in that I was a member of staff with the International Joint Commission (January 1988 - January 2004) and was thus a participant observer. Berreman et al (1971 p. 342) have reviewed the processes involved in participant observation and this has been used as a template to describe the context and methods. In undertaking the forensic audit, I bring a series of assumptions, values and biases accumulated from a variety of life experiences and these need to be made explicit.

2.2.1 Assumptions, values and biases

While the Commission offered me a unique locus in which to undertake a variety of different projects and functions related to Great Lakes water quality, it tended to be a fractious organisation. Only part of the fractiousness could be attributable to the

relations between the United States and Canadian Sections of the IJC, respectively located in Washington and Ottawa. Of more concern was the long-standing friction between the Section Offices and the Great Lakes Regional Office, located in Windsor, Ontario, and comprised of more staff than both Section Offices put together.

The Great Lakes Regional Office is located on the 8th floor of 100 Ouellette Avenue in Windsor, Ontario, with a panoramic view overlooking the Detroit River from as far as Lake St Clair to the north to beyond the Ambassador Bridge, carrying the largest volume of trade in the world, to the south. In 1988, there were about 35 staff members with continual interaction and opportunity to meet and know each other. The directorship alternated every four years between Canada and the United States leading not only to a sense of discontinuity, but also to the prospect that the next appointment would remedy the perceived failings of the then incumbent. There were about eight professionals who were United States employees and a similar number from Canada and the rest of the support staff was comprised of local Canadians.

I established rapport fairly quickly, because I had published several papers on a variety of aspects of Great Lakes science while working with the Canada Centre for Inland Waters (1969-1971), the Canadian Wildlife Service (1971-1975), the Environmental Protection Service (1975-1981), and the Department of Fisheries and Oceans (1981-1987). The experiences from each of these parts of my career influenced the assumptions, values and biases that I took with me to the International Joint Commission. But before emigrating to Canada and joining the staff of the Canada Centre for Inland Waters, my assumptions, values and biases had already been formed about how I believed environmental toxicology should be undertaken.

As a student, I had undertaken six years (1964-1969) of extramural research on the status of the population of peregrine falcons in Northern Ireland (Gilbertson 1969). In the late 1950s and early 1960s, nation-wide surveys had shown that the population of British peregrines had been decimated through adult mortality and reproductive failure (Ratcliffe 1963). Implicit in Ratcliffe's research is the belief that causes are knowable. Consideration was given to all possible putative factors that might have caused the declines and extirpations and each was systematically rejected on rational grounds until only the widespread introduction and use of organochlorine pesticides remained as a rational hypothesis. Analysis of chemical residues in samples from the field and results of toxicology experiments using captive birds confirmed the hypothesis. The accurate diagnosis of these specific causes and the subsequent voluntary ban on many agricultural uses of organochlorine pesticides rapidly resulted in the reestablishment of populations of peregrine falcons to most parts of Britain (Ratcliffe 1972). In retrospect, the experiences provided a strong methodological bias to my career in research and in the regulatory field and have been acknowledged in the ongoing debate about the interpretation of the Great Lakes Water Quality Agreement (Gilbertson 2000b p 28).

For example, I brought these experiences and methodological assumptions to the Canada Centre for Inland Waters, Burlington, in 1969 when I started the research on the effects of persistent toxic substances on the reproduction of common terns in Hamilton Harbour. I believed the following: that if there were chemicals in the harbour, this would be manifest as reproductive failure in the two colonies of fish-eating birds; that other possible putative factors could be excluded; and that the information could be used to bring about scientifically-defensible controls on the

substances causing the effects. The pilot surveys not only revealed severe reproductive failure in the two colonies and high levels of organochlorine compounds (Gilbertson and Reynolds 1972, Gilbertson 1974a), but also deformities in some of the few chicks that hatched (Gilbertson et al 1976). In turn, the findings suggested that other colonial fish-eating birds might be affected and should be surveyed and this was initiated (Gilbertson 1974b) while I was employed at the Canadian Wildlife Service, in Ottawa (1971-1975). Subsequent research over the past 35 years has produced some of the most detailed documentation of the status of fish-eating birds and of the role of persistent toxic substances (Gilbertson et al 1991, Fox et al 1998, Grasman et al 1998). The publication of the research on the reproductive failures and my discovery of deformed chicks of colonial fish-eating birds inform my assumptions about the interpretation and purview of the Agreement.

Other assumptions, values and biases that are important in my undertaking a forensic audit of the Great Lakes Water Quality Agreement can be briefly listed. I worked on the Environmental Contaminants Act with the Environmental Protection Service, in Ottawa from 1975-1981. The experiences reinforced not only a value system about the effectiveness of regulatory action on control of persistent toxic substances based on correct scientific diagnosis, but they also provided ample examples of the expansive ambitions of bureaucracies and creative reinterpretations of mandates to justify programmes. Similarly, my employment at the Department of Fisheries and Oceans, in the Fish Habitat Management Branch, in Ottawa from 1981-1987, contributed several experiences that reinforced or challenged my values. For example, the department saw its role as primarily economic. Because information about the presence of persistent toxic substances in fish might jeopardise the sale of fisheries

products, there was an underlying value of ‘buyer beware’ and an ongoing tension between those charged with contaminants research and those implementing the Fish Inspection Act. Further, I only slowly became aware, through a debate in the literature, of the cognitive dissonances between the methodologies of the fisheries researchers and those of the wildlife toxicologists (Gilbertson 1984, Hodson 1985, Gilbertson 1985). Whereas fisheries researchers undertook controlled experiments and made statements about “potential effects”, the wildlife toxicologists undertook forensic research in the field and made statements about the actual effects and specific causes.

In 1987, while compiling a review of the literature on the effects in wild vertebrates caused by exposures to PCBs and dioxins (Gilbertson 1989), I became aware of a growing crisis of epistemology that was partially solved by finding Hill’s guidelines (Hill 1965). The same year, Dr Theo Colborn in preparing a report on the state of the Great Lakes (Colborn 1990), formulated her hypothesis on the role of chemicals in disrupting the endocrine systems and provided a mechanistic interpretation of the observed teratogenic activity. The possession of Hill’s rational framework for making truth statements about causes and effects and Colborn’s mechanistic explanatory hypothesis reinforced my bias in favour of narrowly interpreting the Great Lakes Water Quality Agreement. My assumption is that the Agreement is about demonstrating causal relations between the various observed injuries to fish, wildlife and human populations and exposures to specific agents, particularly persistent toxic substances.

During my sixteen years at the International Joint Commission, unlike most other scientists, I was given a variety of assignments in different parts of the organisation which gave me a diverse daily perspective on many of the aspects of the responsibilities under the Agreement. It also provided an opportunity to interact with other Canadian and United States scientists and civil servants from research and regulatory agencies from the eight Great Lakes states and from Ontario and latterly, from Quebec. I arrived in January 1988 at a time when the Great Lakes Regional Office was in turmoil because many of the former roles and responsibilities of the International Joint Commission were being removed by the Parties following the 1987 review that resulted in a Protocol amending the Agreement. The elaborate committee structures within the International Joint Commission that had been at the core, for more than a decade, of the implementation of the Great Lakes Water Quality Agreement were being disassembled. As a consequence, many of the staff at the Great Lakes Regional Office were disoriented since their functions and identities had essentially been removed.

It took time to learn and understand the special language that the International Joint Commission and the associated advisory boards used to communicate on the Agreement. It took even longer to comprehend the unexamined variety of meanings and ambiguities of the special language. In addition, there were cultural differences. I was born in northern England, brought up in the south, had been to university in Belfast, Northern Ireland and as a student visited Scandinavia and East Africa. I had worked in Ottawa and Hull, Quebec from 1971 until 1988 where the culture is dominated by the border between French and English Canada. However, nothing prepared me for the cultural change of working in a binational office with Canadians

and Americans. Within months of my arrival, the office had fractured into two camps, known by the secretaries as the 'Inlaws' and the 'Outlaws'. This was important because, in sociology and anthropology, the examination of conflict can provide useful insights into cultures, and part of the thesis addresses the basis of the fracture within the office to understand the respective belief systems of the protagonists, including my own assumptions, values and biases outlined above, in interpreting the purpose of the Great Lakes Water Quality Agreement (Gilbertson 1997, 2000 a,b).

Unlike most anthropologists entering the field, I arrived at the Great Lakes Regional Office, in 1988, with an agenda. I was determined to implement work on 'causality' because of the widespread scepticism about the published research linking observed teratogenic effects on fish, wildlife and humans with exposures to persistent toxic substances. I was successful in this endeavour and organised three workshops of the International Joint Commission on 'Cause-Effect Linkages' (Gilbertson and Schneider 1991, 1993, Gilbertson 1996). Unbeknownst to myself, this positivist agenda, would be contrary to the relativistic assumptions of the 'Outlaws'. Further, the successes of the workshops, in retrospect, seem to have been a threat to the Outlaws many of whom had lost their identities with the 1987 changes in administration of the Great Lakes Water Quality Agreement. It took a long time to realise that the Outlaws were part of a network of Great Lakes fisheries ecologists aligned with the Dirk Gently Gang, an eclectic international group of intellectuals interested in applications of complexity and chaos theory to world problems (Waltner-Toews et al 2004). Implicit in its work seems to be the concept that specific causes of some complex phenomena are unknowable. These assumptions and their implications

are examined in detail in chapter 4 as part of the failure of the Great Lakes Water Quality Agreement. The success of the workshops, in retrospect, also seems to have been a threat to environmental managers, since the statements were about ‘injury to health’ rather than about ‘potential effects’ and thereby implied that, as managers, they needed to take action against the specific chemical causes; something they appeared inexplicably unable and unwilling to do.

The motives and ethics of participant observers have themselves become topics of study. There was a generally acknowledged sense within the ‘IJC family’ that the organisation had become ‘dysfunctional’. It seems appropriate to apply anthropological techniques to gain an understanding of the roots of the dysfunctionality. The ethical concerns in anthropological studies particularly concern the uses to which the information and insights are put (Berreman et al 1971 p. 351). The most difficult aspect of the research, from an ethical perspective, derives from the moral responsibilities of the participant researcher to civil society, that follow from the observations and the critical inferences drawn from the study.

2.3 Empirical test of the implementation of the Great Lakes Water Quality Agreement

In formulating the research question, the need for an empirical measure of whether the Parties had been effective in implementing the Great Lakes Water Quality Agreement was identified. Health data and statistics for 17 Canadian Areas of Concern (see figure 1) for diseases that “might be related to exposures to pollution” were made available by Health Canada (1998). One of these diseases was cerebral palsy because of its known association with exposures to methyl mercury. This section describes

the epidemiological methods and materials that have been used and the methodological limitations of the approach in using the data as the empirical measure of the operation and effectiveness of the Parties' implementation of the Great Lakes Water Quality Agreement.

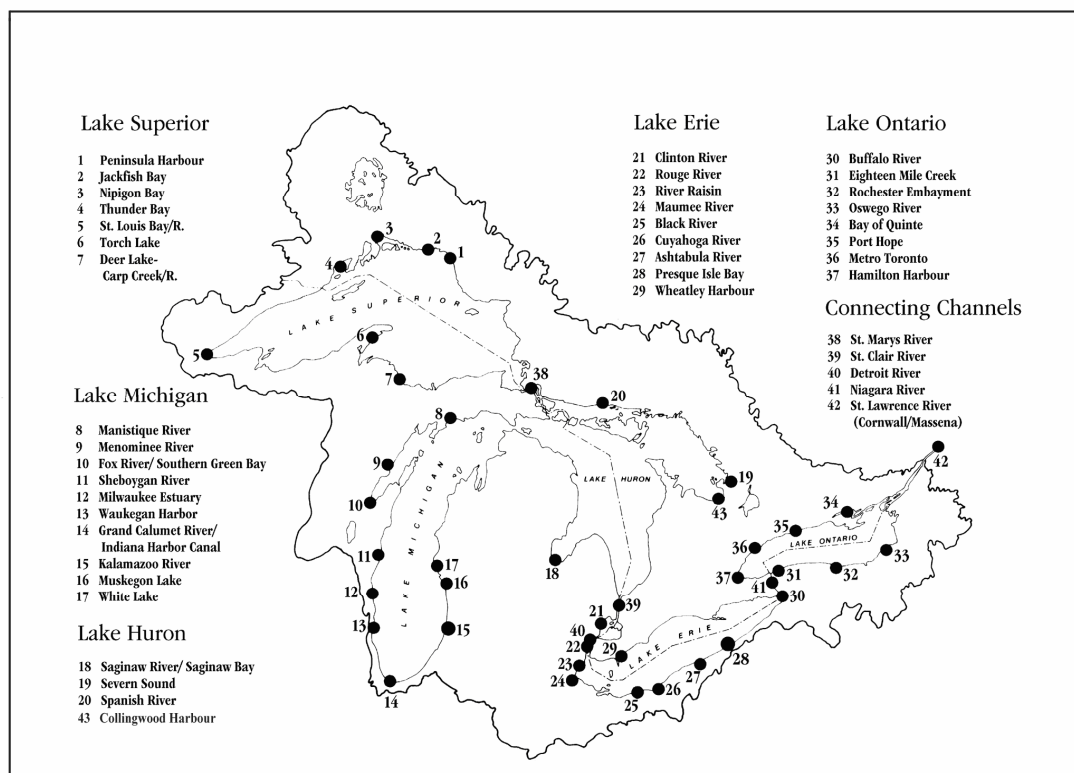


Figure 1. Areas of Concern in the Great Lakes Basin

2.3.1 Framing the scientific analysis: Limitations of toxicology and epidemiology in detecting effects

Many different scientific disciplines have been used in undertaking the investigations into the injury to health from exposures to persistent toxic substances in the Great Lakes basin. Foremost have been epizootiological field studies of the status and reproductive success of wildlife populations and correlation of the results with residues determined from chemical analyses of specimens. Similarly,

epidemiological investigations of cohorts of infants have detected irreversible developmental and neurological deficits from maternal consumption of Great Lakes fish and these findings have been correlated with specific compounds (see Chapter 3 for details). Experimental toxicology has provided corroboration of causal hypotheses, supplied mechanistic explanations and new health endpoints for further surveys.

There are, however, serious scientific limitations to both epidemiology and toxicology as a basis for health protection. The limitations of toxicology include: the identification of health endpoints; relevance of animal testing for extrapolation between species and particularly to humans; and uncertainties about the synergistic effects of exposures to mixtures of chemicals. Some of the limitations of epidemiology include: selection of relevant health endpoints; the subtlety of some significant effects that are difficult to diagnose clinically; long latency periods; measurements of exposures to the putative agent(s); interactions between toxicants; and alternative etiological agents. 'Epidemiology is a very insensitive measure' (Ozanoff cited in Fleckenstein 2001). Despite these limitations, a coherent picture of the effects of releases of persistent toxic substances into the Great Lakes on wildlife and human populations has begun to emerge. Given the imperceptibility of risks of modernity, including exposures to persistent toxic substances (Beck 1990), one of the primary challenges, as with occupational health, has been to detect that effects are occurring.

How in the first place do we detect these relationships between sickness, injury and conditions at work? How do we determine what are the physical,

chemical and psychological hazards of occupation, and in particular those that are rare and not easily recognised? [M]ore often than not we are dependent upon our observation and enumeration of defined events for which we seek antecedents (Hill 1965 p 295).

2.3.2 Materials and methods

Health Canada has responsibilities under the Great Lakes Water Quality Agreement and under the Canada – Ontario Agreement for surveillance of the effects of pollution on human health. As part of these responsibilities, Health Canada (1998) published a series of health data and statistics for the 17 Areas of Concern on the Canadian side of the Great Lakes. The forward to the series of reports stated:-

Individuals and communities are becoming aware of the relationship between their health and the environment. In Areas of Concern, Remedial Action Plans look to include human health considerations into the assessment, planning and implementation of their programmes. Professionals working in the area of environment and health are often called upon to provide assistance and advice to aid in understanding of this relationship and the impact it may have on communities. This report is a resource for these professionals and the communities they serve (Health Canada 1998).

The reports are the main materials used in the empirical part of the analysis and comprise cross sectional data for the seven-year period 1986-1992. Health Canada (1998) detailed the methods used in the study under the following headings:- Assigning Standard Geographic Codes; Selecting Health Outcomes; Gathering and

Analyzing Data. These methods have been detailed in a publication on community health for the Detroit River Area of Concern which mainly comprised mortality, morbidity as hospitalisation and congenital anomalies data for Windsor, Ontario (Gilbertson and Brophy 2001; see Appendix A).

Briefly, community health within each of the 17 Canadian Areas of Concern was compiled using standard geographic codes, which not only contain provincial, census division, and census subdivision information, but also coincide with the Canadian process for collection of human health data. Each of the 17 reports contained detailed background information on the study area and its population, methods used in the study for assigning standard geographic codes, and gathering associated health data. Data for the rates for diseases and disorders for the populations for all the Areas of Concern were age standardised by gender, and comparisons were made with the rates for the rest of Ontario. Health Canada did not include detailed consideration of demographic and socioeconomic risk factors, though these have been shown to be important, together with other risk factors, in relation to the geographic distribution of certain diseases.

2.3.2.1 Selection of health endpoints and calculation of rates

Health Canada selected about 70 health end points in about 11 disease categories using the International Classification of Diseases, Ninth Edition (ICD-9) (1992). Because the project was undertaken by the former Great Lakes Health Effects Programme under the mandate of the Great Lakes Water Quality Agreement, there was an orientation toward selecting diseases and disorders, based on references in the published literature that might plausibly be linked to environmental contaminants.

The process is similar to that recently used by the Collaborative for Environmental Health to compile a list of diseases and the association with chemicals in the environment (Janssen et al 2004).

Population census data for the 7-year period, 1986 and 1992, were accessed from the Demography Division of Statistics Canada to calculate mortality and morbidity rates on an age-specific and gender-specific basis. Mortality data were provided by Statistics Canada to Health Canada's Laboratory Centre for Disease Control (LCDC) and included information on the cause of death, reported by ICD code, the last location of residence based on the census subdivision, and the sex and age of the deceased. Hospital separations data were supplied by the Canadian Institutes for Health Information, and included data on sex, age, and residence, and the ICD code for the diagnosis for the main cause in cases of hospitalisation. The age-standardised rates were calculated based on 19 age groups, and the reports presented the rates for the following five age ranges: all ages, 0-24 years, 25-44 years, 45-74 years, and over 75 years.

2.3.2.2 Selection of cerebral palsy

The availability of mortality and morbidity as hospitalisation data for 70 health endpoints represents a significant opportunity to begin to understand the possible relationships between exposures to chemicals and health in the 17 Canadian Areas of Concern. The International Joint Commission held a Workshop on Community Health based largely on the database (Gilbertson et al 2001) and many anomalous rates of disease were noted compared with the rest of Ontario. There are, however, probably many more relationships still to be discovered from the dataset.

One of the 70 health endpoints selected by Health Canada was cerebral palsy (ICD-9:343). Health Canada (1998) provided a rationale for selecting cerebral palsy because of the historic association with exposures to methyl mercury based on the following four citations:- Woods et al. 1991; Marsh et al. 1987a; Choi 1989; and World Health Organisation 1990. The implicit hypothesis was that in Areas of Concern with higher exposures to methyl mercury, the rate of hospitalisation for cerebral palsy would be higher.

The cerebral palsy dataset has been selected for the dissertation for several reasons. The presence of mercury in the environment in the late 1960s and early 1970s was an emergency (United States Senate 1970) and was part of the context for negotiation of the Great Lakes Water Quality Agreement in 1972. Thus it is important to test whether there are indications of effects attributable to mercury occurring in the Great Lakes environment after more than thirty years of implementation of the Agreement. Though there is an extensive international literature that has developed since the 1970s on the toxicology and environmental chemistry of methylmercury, epidemiological studies of infants whose mothers consumed Great Lakes fish prior to or during pregnancy have not shown associations with exposures to methyl mercury. With neo-liberal proposals for slowing improvements in mercury releases from power plants in the United States, exposures to methyl mercury have become politically important as annual costs, in terms of lost productivity over a lifetime among the population, have been estimated at \$8.7 billion in US dollars, of which \$1.3 billion is attributable to the power plants (Trasande et al 2005). Finally, the initial identification, from the Health Canada health data and statistics, of the anomalous

rates of male cerebral palsy hospitalisation occurring at Sarnia, Ontario suggested that some major disease outbreak might be occurring (Gilbertson 2004).

Only the data for “all years” have been used since these were comprised of sufficient numbers of cases to provide the statistical power to identify locations where cerebral palsy data might be reliably used to indicate communities exposed to methyl mercury. The age-adjusted mortality and morbidity rates were compared with the rates for the rest of the Province of Ontario, and ratios were calculated comparing the local rates with the provincial rates using a z-test. For cerebral palsy in each of the Areas of Concern, the number of mortalities attributed to cerebral palsy was very small and yielded no statistically significant results. In the analysis, therefore, only the data for morbidity as hospitalisation are used (see chapters 5).

2.3.3 Limitations of the approach

Health Canada cautioned that the project had been undertaken to generate hypotheses for further investigation and noted that significantly higher rates could not be directly linked to exposures to environmental contaminants. No attempt was made to explain causal relationships between the levels of contaminants in the Areas of Concern and any elevated rates of specific health outcomes. In addition, Health Canada warned about some of the limitations of the approach under the following headings:- Data issues; Statistical issues; and Etiological factors.

2.3.3.1 Data issues

Under the category of data can be listed the following issues. First, these are not incidence data for cerebral palsy within the community and in using the hospital separations data, Health Canada referred to morbidity as hospitalisation rates rather than incidence rates. In addition, there is an implicit assumption that the patient was born in the Area of Concern and without further research no correction can be made for this. Similarly, there may have been difficulties in transforming residence information based on a postal code or an Ontario residence code into a census subdivision. Variations in population age distribution between the Area of Concern and the rest of the province may have been a confounding factor which was eliminated through age standardisation. The possible influence of gender as a potential confounding factor was removed as a variable by comparing data for males and females separately.

There are other limitations with using hospital separations data because they may include multiple visits or transfers between or within hospitals, but exclude visits to clinics, doctors' offices, and outpatient departments. A special algorithm, needed to separate cases of patients who are readmitted, was not used in compiling these Health Canada data. These data for Ontario Province do not include Ontario residents who were hospitalised in another province. Health Canada noted that local policies and practices may influence the data and these may be influenced by the size of the community. For example, in small communities, medical practitioners may tend to hospitalise patients who would normally have been sent to other specialised health facilities if they had resided in large metropolitan areas. Similarly, in rural areas, because of the unavailability of expensive diagnostic equipment, there may be a

higher rate of misdiagnosis which could affect the reported rates, though this seems unlikely for cerebral palsy.

2.3.3.2 *Statistical issues*

Health Canada noted several statistical issues associated with the approach. The cases of cerebral palsy reported represent numbers of acute care inpatient admissions (with the possibility of multiple admissions for a person). From the age standardised rate of morbidity as hospitalisation per 100,000 population within the community, Health Canada compared the statistical significance with the rate in the rest of Ontario using a z-test. Similarly, Health Canada compared the ratio of the observed number of cases within the community with the expected number of cases from the number of cases in Ontario, again using a z-test. Because of the possibility of multiple admissions, Health Canada did not calculate confidence intervals around these rates or ratios (Robert Semenciw, pers. comm., Laboratory Centre for Disease Control, Ottawa). Health Canada noted the limitations of interpretations that can be placed on data from small sample sizes, even though they pooled results from a seven-year period. Table 1 shows the rank ordering of the size of the various populations included in the 17 Canadian Areas of Concern. These range from nearly 35% of the Ontario population for the former Metro Toronto down to 0.02% of the Ontario population in the community at Jackfish Bay.

Table 1. Rank Order of Population Sizes and Percentages of the Ontario Population in the 17 Canadian Areas of Concern and Percent of the Ontario Population, 1986-1992.

Area of Concern (Fig.1 Map Number)	Population Size	Percentage of Ontario Population
Metro Toronto (36)	3,534,465	34.98%
Hamilton Harbour (37)	613,315	6.07%
Niagara River (41)	375,430	3.72%
Detroit River (40)	274,145	2.71%
Bay of Quinte (34)	256,600	2.54%
Thunder Bay (4)	124,435	1.23%
St Clair River (39)	93,420	0.92%
St Mary's River (38)	86,580	0.86%
St Lawrence River (42)	68,690	0.68%
Severn Sound (19)	53,770	0.53%
Collingwood (43)	25,665	0.25%
Wheatley (29)	18,900	0.19%
Port Hope (35)	15,565	0.15%
Spanish River (20)	8,940	0.09%
Peninsular Harbour (1)	5,065	0.05%
Nipigon Bay (3)	3,755	0.04%
Jackfish Bay (2)	2,475	0.02%

These limitations in the sizes of communities are reflected in the number of cases even when the data are aggregated for the seven-year period 1986-1992. Table 2 shows the number of hospitalisation cases for cerebral palsy for Ontario and in each of the 17 Canadian Areas of Concern. The data have been arranged in geographic shoreline sequence from Thunder Bay in the north-west to Cornwall on the St. Lawrence River in the south-east. For small study areas, with pooled sample sizes that are relatively small, there is a large probability of assigning insignificance when a significant difference was present. Health Canada did not make comparisons of elevated or lowered age-standardised morbidity rates when there were fewer than 4 hospitalisations recorded in the study-area population, and these rates were marked in the original morbidity tables with a # flag. Even in a small community, a finding of a

statistically significant difference in the rates and ratios compared with the rest of the province can be reliable, but the precision of the difference may be less certain. Statistical differences in rates and ratios within a large population compared to the rest of the province are likely to be both reliable and precise.

Table 2. Number of Hospitalisation Cases for Cerebral Palsy, by Gender, in all Ontario and in the 17 Canadian Areas of Concern: All Ages, 1986-1992

Location (Figure 1 Map #)	Males	Females
All Ontario	884	723
Thunder Bay (4)	20	4
Nipigon Bay (3)	0	0
Jackfish Bay (2)	1	0
Peninsular Harbour (1)	0	0
St Mary's River (38)	17	20
Spanish River (20)	2	2
Severn Sound (19)	8	1
Collingwood Harbour (43)	9	1
St Clair River (39)	44	3
Detroit River (40)	24	18
Wheatley (29)	2	3
Niagara River (41)	25	30
Hamilton Harbour (37)	60	58
Metro Toronto (36)	180	173
Port Hope (35)	1	1
Bay of Quinte (34)	33	44
St Lawrence River (42)	15	9

2.3.3.3 Other etiological factors

The final series of limitations noted by Health Canada related to the alternate etiological factors associated with cerebral palsy and the possibility of other potential confounding factors such as ethnicity, marital status, occupation, socio-economic

status, smoking, diet, and other unknown agents. Prenatal exposures to methyl mercury are known to cause outbreaks of neuro-pathologies in infants including mental retardation and seizures in addition to cerebral palsy. Cerebral palsy, however, is associated with many other etiological factors (American College of Obstetricians and Gynaecologists and American Academy of Paediatricians 2003). For full term infants, cerebral palsy is associated with:- congenital viral infections such as rubella and possibly cytomegalovirus; intrauterine strokes; previously undiagnosed congenital anomalies; and metabolic disorders such as hypoglycemia, hyperbilirubinemia and aminoacidurias (Mandelbaum and Paneth 2000). In the past two decades, there has been an increased rate of cerebral palsy in pre-term infants associated with:- very low birth weight; chorioamnionitis; low levels of thyroid hormone; and patterns of ventilatory management. The wide range of risk factors that has been associated with cerebral palsy would seem to undermine the reliability of cerebral palsy hospitalisation as a potential indicator of prenatal exposures to methyl mercury and this is addressed in more detail in 5.4.2.2. below.

2.3.3.4 Limitations of the Health Canada case

Finally, there is a methodological limitation in the four references that Health Canada used to justify the inclusion of cerebral palsy as a disease that might be linked to pollution and specifically to prenatal exposures to methyl mercury (Woods et al. 1991, Marsh et al. 1987a, Choi 1989, World Health Organization 1990). The World Health Organisation (1990) published a comprehensive criteria document that reviewed the properties, environmental chemistry and toxicology of methyl mercury as these were known at the end of the 1980s. This includes references to the epidemiological and experimental determination of an association between prenatal

exposure to methyl mercury and effects on developing tissues, and particularly the finding of cerebral palsy. Woods et al. (1991) discussed the use of patterns of urinary excretion of porphyrins as a biomarker of prolonged mercury exposure, however the document makes no reference to cerebral palsy or its aetiology. Choi (1989) reviewed the literature on the clinical and neuro-pathological findings, including cerebral palsy, of prenatal methyl mercury poisonings in humans and on the experimental studies that had been undertaken on mechanisms of action and on methyl mercury pharmacodynamics. Marsh et al. (1987a) reported severe psychomotor retardation in infants of Iraqi women who had consumed bread made from methyl mercury treated seed grain. The methodological limitation in the Health Canada reports was the omission of references to the differential susceptibility of foetal and infant males to exposures to methyl mercury.

The observation of increased susceptibility in developing males was first made in the evaluation of the effects of methyl mercury on the development of Cree children in northern Quebec (McKeown-Eyssen, 1983). This led to re-evaluations of the data on the outbreaks in Iraq and Japan. Marsh et al. (1987b), not only found a dose-response relationship between mercury levels in maternal hair and foetal effects in the Iraqi outbreak, but also that separation of the dose-responses for males and females indicated the greater susceptibility of males to prenatal exposure than females. Similarly, re-evaluation of the Japanese data for the most highly contaminated area at Minamata, indicated that during the period of very high exposures in the mid-1950s, there was a smaller number of male patients than females indicating elevated mortality among male cases (Harada 1994). Subsequently, with a decline in the levels of contamination, the number of male patients increased and the number of female

patients decreased. Toxicological experiments with mice have replicated the gender difference in susceptibility to the neurological effects of prenatal exposures (Sager et al. 1984, cited in Clarkson 1993). In the absence of prenatal exposures to methyl mercury, the rate of cerebral palsy incidence in males and females is regarded as being the same in the general population (Mandelbaum and Paneth 2000). The differential susceptibility of males would seem to be an important diagnostic tool and potentially might form the rationale for using hospitalisation data for cerebral palsy as a reliable indicator of community exposures to methyl mercury and for identifying previously undetected outbreaks of congenital Minamata disease.

Health Canada included cerebral palsy among the health endpoints of diseases and conditions that might be linked to pollution, based on the association with the outbreaks at Minamata, Japan and in Iraq. The observation of differential susceptibility of males was important in formulating the hypothesis (Gilbertson 2004) (see section 3.4.5).

2.4 Debates in epidemiology as guides to development of a forensic methodology

The Health Canada epidemiological data on cerebral palsy hospitalisation may serve as a reliable test of whether the Parties have been successful in implementing their Great Lakes Water Quality Agreement. For more than a decade, however, epidemiologists have been debating the future of epidemiology and these debates may be important in formulating methodologies for undertaking a forensic audit (Rose 1985, Kreiger 1994, Susser and Susser 1996 a,b, Pearce 1996, Pekkanen and Pearce 2001).

2.4.1 Paradigms and eras

The debates about the future of epidemiology were comprised of several threads. There was a recognition that epidemiology had undergone changes in paradigms during different eras and that epidemiology was on the threshold of a new paradigm shift (Susser and Susser 1996a). During the late 19th century, the germ theory of disease ushered in an era of epidemiology concerned with infectious diseases. This paradigm eclipsed the previous ‘miasma’ paradigm that had been at the centre of the Sanitary Movement from the beginning of the 19th century. In the 1950s, with the widespread introduction of antibiotics and vaccinations to control infectious diseases, a new era of epidemiology started that addressed chronic diseases, with notable success in understanding the aetiology of lung cancer and the relationship to tobacco smoking (Susser and Susser 1996a p 670). The release of persistent toxic substances into the Great Lakes can be regarded as producing risks of chronic diseases, rather than infectious diseases, in exposed populations. Thus the development of the Great Lakes Water Quality Agreement in the 1970s and the subsequent development of epidemiological data by Health Canada on chronic diseases in the 17 Canadian Areas of Concern were not inconsistent with the prevailing epidemiological paradigm of this era.

2.4.2 The ‘black box’ debate

With the transition from the infectious disease era to the chronic disease era, the focus of research was on the identification of risk factors in individuals, resulting in a neglect of research on populations (Rose 1985). Multivariate analysis, using case

control and cohort studies became the prevailing method (Krieger 1904 p 889, Pearce 1996 p 678) and with it came a new metaphor: the 'web of causation' (Krieger 1994, Susser and Susser 1996a p 671). By the late 1980s, however, there was a recognition that the usefulness of the technique and metaphor were diminishing as the major risk factors for many chronic diseases were now becoming well known and the attempts to identify more subtle 'environmental' or 'lifestyle' risk factors were 'plagued with biases, uncertainties, and methodological weaknesses' (Taubes 1995, Susser and Susser 1996a). In addition, there were concerns that the 'black box' technique had largely ignored the advances that had been made in biology, particularly at the molecular level, in understanding pathogenesis (Susser and Susser 1996a p 670). Further, critics pointed out that epidemiology had become an academic subject, seemingly divorced from public health, as though the practitioners were 'seeking universal laws' rather than solutions to diseases within the population (Susser and Susser 1996b p 675).

Based upon these methodological concerns and the conservative nature of Health Canada as an organisation, the health data and statistics produced by Health Canada in the 1990s are, for several reasons, remarkably enlightened. The studies were undertaken at the population level and were based on the assumption that there was sufficient heterogeneity of exposures to pollutants between the 17 Canadian Areas of Concern to result in variations in the mortality and hospitalisation rates, cancer incidence, or congenital abnormalities rates to enable identification of those populations at risk. This was not an 'academic' exercise but was undertaken to assist those professionals and communities in the Areas of Concern who were involved in preparation of Remedial Action Plans under the Great Lakes Water Quality

Agreement. The Health Canada health data and statistics are therefore directly relevant to the review of the operation and effectiveness of the Agreement through a forensic audit.

2.4.3 Causation and the reduction of uncertainty

Another of the threads in the debate relates to the philosophical nature of causation and epidemiologists have extensively reviewed and revised the categories of evidence that contribute to or detract from a relationship between a disease and its putative cause (Susser 1986, 1991). Causation is at the centre of the Great Lakes Water Quality Agreement: not only are the joint concerns of the Parties expressed in terms of injury to health caused by impaired water quality, but also Remedial Action Plans and Lakewide Management Plans are defined in terms of impaired beneficial uses caused by failure to meet water quality objectives. In the 1980s, the challenge was to find acceptable causal methodologies. Particularly, a forensic audit of the Great Lakes Water Quality Agreement, that alleges continuing injury to health from exposures to persistent toxic substances, requires consideration of a methodology for inferring causal relationships. The need was particularly acute, not only because of the severity of the effects and the general scientific scepticism, but also because of the apparent official scepticism among managers within government.

With the general fallibilism, the scientific side shifts its self-doubt over to the practical side and in addition forces upon it the alternative role of the *reduction of uncertainty necessary for action* (Italics in original) (Beck 1992 p.173).

The forensic toxicologists' response was to propose a method for reducing the uncertainty (Fox 1991, Gilbertson and Schneider 1991) based on the categories of evidence to evaluate the relationship between a suspect cause and a chronic disease (United States Department of Health, Education and Welfare 1964, Hill 1965, Susser 1986a,b). Though there are different formulations, they generally include the following guidelines: - Strength of Association; Consistency on Replication; Specificity in the Cause and the Effect; Temporality; Biological Gradients; Plausibility; Coherence; Experiment; Analogy; and Performance on Prediction. Application of these guidelines to the available evidence can help reveal how each supports a causal hypothesis, detracts from it or is indeterminate. As noted above, the International Joint Commission hosted three workshops on cause-effect linkages to apply the approach to the case histories of injury to fish, wildlife and humans associated with exposures to persistent toxic substances (Gilbertson and Schneider 1991, 1993 and Gilbertson 1996). The method is used in the thesis to review whether there are neurological effects resembling congenital Minamata disease, occurring in communities within the Great Lakes basin and that might be causally associated with exposures to methyl mercury (Chapter 5).

2.5 Limitations of the research

There are methodological limitations to being a participant observer (see section 2.3.1). While the 'insider' perspective yields insights that are likely more difficult for other researchers to obtain, the fact that I was one of the 'Inlaws' places constraints on my access to 'Outlaw' perspectives and knowledge. The beliefs, values, assumptions and biases of the 'Outlaws' can only be inferred from their contributions at meetings or the on-line consultation and from official documents such as minutes and

publications produced by them or containing a record of their words. This one-sidedness places limitations on the insights available to inform the dissertation.

There are several different research methods that have been used in preparing the forensic audit of the Great Lakes Water Quality Agreement. At the formal scientific level, there is an analysis of health effects data supplied by Health Canada as part of the Canadian contribution to the Great Lakes Health Effects Programme under the Great Lakes Water Quality Agreement. The data and statistics for morbidity as hospitalisation for cerebral palsy is the particular endpoint of interest in testing whether there might be neurological effects from exposures to methyl mercury occurring in Canadian communities in the Great Lakes basin. While there are several limitations to the approach (see section 2.3.3), the results (Gilbertson 2004) indicate outbreaks of congenital Minamata disease in several Great Lakes communities. There is, however, substantial further research that is needed to verify the initial findings, to search for cases and to extend the research into other areas inside and outside the Great Lakes. These and other research considerations are addressed in Chapter 7.

During the 1987 negotiation of the amendments to the Agreement, the Parties removed most of the responsibilities from the International Joint Commission. They then set up a Bilateral Executive Committee outside of the organisational structure of the International Joint Commission which has somewhat paralleled the previous responsibilities of the Great Lakes Water Quality Board. The thesis does not include consideration of the minutes of the BEC meetings, though these might provide further insights into the processes of implementing the Agreement and the processes of diversionary reframing of the purpose.

Other than including consideration of the findings from the interviews by Botts and Muldoon (2005), the research is not based on any formal interviews, questionnaires or surveys undertaken on the participants involved in the implementation of the Great Lakes Water Quality Agreement. Many of the original actors in government, industry, academia and from non-government organisations are retired or retiring. They potentially might provide further valuable sources of data, information and knowledge that could yield further insights into the origins, functioning of this important bilateral agreement.

2.6 Summary and conclusions

In developing a methodology for a forensic audit of the Great Lakes Water Quality Agreement it has been necessary to first review the assumptions, values and biases that I bring to the task. I see the Great Lakes Water Quality Agreement as a minimalist agreement between Canada and the United States about the quality of the boundary water of the Great Lakes and the injury to health, particularly from exposures to persistent toxic substances. The central empirical part of the thesis is a test of whether the Parties have implemented their agreement. The test uses Health Canada data and statistics on rates of morbidity as hospitalisation for cerebral palsy in the 17 Canadian Areas of Concern as a measure of whether there are neuro-teratogenic effects still occurring in communities in the Great Lakes basin. Epidemiologists are rethinking their science and are not only advocating reconnecting with public health and molecular epidemiology, but also including consideration of the social, economic and political contexts of the production of disease. Chapter 3 is a review of the epidemiological evidence of effects in Great Lakes populations from

exposures to persistent toxic substances, with particular reference to neuro-teratogenic endpoints.

CHAPTER 3: PCB AND MERCURY WITH PARTICULAR REFERENCE TO NEUROTOXICOLOGY: THE STATE OF KNOWLEDGE

3.1 Introduction

This chapter first briefly examines the development of the institutional arrangements for undertaking health research to implement the Great Lakes Water Quality Agreement (Section 3.2). The second part is a literature review of research results in relation to effects caused by exposures to Great Lakes pollutants with particular reference to effects on neurological development. The review serves as the scientific basis for determining whether injury to health is still occurring (Section 3.3). The third part identifies cerebral palsy as a human health endpoint with which to test the effectiveness of the administration of the Agreement (Section 3.4). The chapter ends with a review of the contribution of the thesis to knowledge (3.5) and of the limits of the literature reviewed (3.6).

3.2 Institutional mechanisms

The Great Lakes Research Advisory Board of the International Joint Commission set up a Health Aspects Committee as early as January 1973 to advise on the implications of pollution on human health. However, for the first five years the committee seems to have had difficulty understanding its mandate or setting an agenda. On the eve of the signing of the 1978 Great Lakes Water Quality Agreement, a new Committee on the Assessment of Human Health Effects of Great Lakes Water Quality was set up jointly under the Science Advisory Board and Water Quality Board (International Joint Commission 1979 p 52). Its work was divided into two priorities:- A Health Hazard Evaluation of the Inventory of Great Lakes Chemicals; and An

Epidemiological Evaluation of Human Health Effects of Chemicals in the Great Lakes. Though significant resources were allocated to these priorities, little progress was made within the International Joint Commission or the Parties through the 1980s in applying the observations of the teratogenic effects in wildlife as a model of the potential effects that might be occurring in human populations. The situation radically changed in 1989 with the back-to-back workshops in Chicago on Cause-Effect Linkages, and on Human Health and with the work of the Great Lakes Science Advisory Board (International Joint Commission 1989). Canada and the United States subsequently established respective research programmes on the human health effects of exposures to persistent toxic substances in the Great Lakes.

3.3 Status of Great Lakes research on human neurological development

The 5th Biennial Report of the International Joint Commission was sent to the two governments early in 1990 and brought a renewed sense of urgency to the issues of reproductive and developmental effects of persistent toxic substances, particularly on humans. The response from governments was immediate and substantial. Environment Canada, the Department of Fisheries and Oceans and Health Canada jointly contributed to a review entitled *Toxic Chemicals in the Great Lakes and Associated Effects* that represented a consensus of the findings (Environment Canada 1991). Health Canada had already started a Great Lakes Health Effects Programme centred in Ottawa, under the directorship of Dr Andrew Gilman. Though Gilman had only a small number of staff, his job was to use funds allocated to Great Lakes research to entice human health researchers in Health Canada and elsewhere, to work on research questions that were relevant to Great Lakes toxicology (Great Lakes Health Effects Programme 1994).

In 1990 in the United States, Congress was debating amendments to the Clean Water Act (Hicks 1996) and Theo Colborn, through congressional staffers, added provisions to the Great Lakes Critical Programmes Act to give resources to the Agency for Toxic Substances and Disease Registry (ATSDR) to support the Great Lakes epidemiological research. Her fear was that if the funds were given to the U.S. Environmental Protection Agency it would simply disappear into the general funds for the Great Lakes Programme. These resources for ATSDR amounted to about \$2 - \$3 million annually for 1992-1994. In addition, the Critical Programmes Act required the United States Environmental Protection Agency, in consultation with the Agency for Toxic Substances and Disease Registry and the Great Lakes states to submit a report to Congress by September 30, 1994. The report was to assess the 'harmful human health effects of water pollutants in the Great Lakes basin.' When the report was prepared, it represented the first comprehensive acknowledgement by either government of the seriousness of the presence of toxic substances to human health in the Great Lakes basin (U.S. Environmental Protection Agency 1996). It had taken almost ten years for the results of the research undertaken by the Jacobsons to be acknowledged by governments.

These Canadian and United States initiatives yielded significant progress first, through the symposium on methodology, held in Detroit in May, 1994 (Rosemond et al. 1996) and secondly through a large conference for reporting results, held in Montreal in 1997 (De Rosa et al. 1999). By the end of the 1990s, there were important advances in the scientific basis for the belief that there were serious effects on human populations around the Great Lakes caused by exposures to persistent toxic

substances, particularly from the consumption of Great Lakes fish. The recent literature, with particular reference to neuro-developmental effects, can be briefly summarised as follows in terms respectively of exposures and effects for organochlorine compounds and for mercury.

3.3.1 Epidemiological studies related to organochlorine compounds

The research studies on exposures have confirmed that there are increasing body burdens of organochlorine compounds associated with increased fish consumption (Fitzgerald et al., 1996, 1999; Falk et al., 1999; Hanrahan et al., 1999). Several exposure studies have demonstrated that men eat more fish than women (Hanrahan et al., 1999, Tee et al. 2003) and tend to have higher levels of organochlorine contaminants (Falk et al. 1999) and that both men and women eat Great Lakes sport fish during most of their reproductive years (Courval et al., 1999, Fitzgerald et al., 1999, Lonky et al, 1996, Waller et al.,1996, Hanrahan et al., 1999, Tee et al. 2003). Of particular concern in relation to neurodevelopment are the findings that consumption of Lake Ontario sport fish by women of childbearing age increases the risk for prenatal exposure to the most heavily chlorinated PCBs (Stewart et al.,1999, Kostyniak et al. 1999). Several studies used cord blood analyses to confirm prenatal exposure of infants (Schwartz et al. 1983, Stewart et al. 1999) and subsequent exposure through breast feeding (Humphrey 1976, 1983, Fitzgerald et al., 1998, Stewart et al. 1999).

Studies have been undertaken to document the trends in levels of organochlorine compounds in Great Lakes fish-eaters. In 1989 and 1990, the Michigan Sport Angler Cohort that had been set up in 1980-1982 was re-characterised. A monotonic decline

in serum PCB levels was found among all participants from a mean value of 24 ppb in 1980 to 12 ppb in 1994 (Tee et al. 2003) and was associated with a 83% decrease in mean fish consumption. Effective communication of fish advisories have also led to a decline in the consumption of contaminated fish among native people (Fitzgerald et al. 1998, 1999).

Part of the research on exposure included socio-behavioural and demographic studies. A random telephone survey of adult residents of the eight Great Lakes states estimated that 4.7 million Americans consumed Great Lakes sport fish in a given year and that women represented 43.9% of these respondents (Tilden et al. 1997). There was considerable variation in knowledge of and adherence to health advisories for Great Lakes sport caught fish, which varies across different genders and populations. Fifty percent of respondents to the survey who had eaten Great Lakes sport fish were aware of the health advisory for fish, and awareness differed significantly by race, sex, educational level, fish consumption, and state of residence (Tilden et al., 1997). For example, men had more knowledge of the advisories than women, and whites knew more than Native Americans (Tilden et al., 1997).

3.3.2 Effects

Researchers have found a variety of health effects occurring within the cohorts that have been studied. In terms of reproductive effects, significant menstrual cycle reductions were indicated in women who reported consuming more than 1 meal per month of contaminated Great Lakes sport fish (Mendola et al.,1997). An association was found between men who consumed large amounts of Lake Michigan and Lake Huron sport fish and the risk of delayed conception in their spouses (Courval et al.

1999). But this was in contrast to findings in the New York State Angler cohort (Buck et al. 1999) in which paternal consumption of Lake Ontario fish was not associated with a delay in conception.

There have been several studies on the changes in neurological functioning of adults from the consumption of contaminated Great Lakes fish. Adults recruited in 1974 to the Lake Michigan Fish-eaters Cohort had markedly elevated levels of PCBs and DDE. Subsequent testing for neurological function indicated that exposure to PCBs, not DDE, was associated with lower scores on several measures of memory and learning (Schantz et al., 2001) but no effect on motor co-ordination (Schantz 1999). In contrast, in studies undertaken on the Red Cliff Indian Tribe Cohort, PCB concentrations were significantly associated with poorer pegboard performance which evaluates visual motor co-ordination and spatial orientation (Dellinger et al., 1995).

In terms of neurological development in children, researchers in the 1990s had the model of the research that had been undertaken in the previous decade by the Jacobsons. Their cohort of 313 infants had been established over a 16-month period starting in July 1980 and was based on interviews with over 8000 women who attended four major maternity hospitals near Lake Michigan (Jacobson 1994). Infants were assessed at birth and at seven months. At birth, the amount of Lake Michigan fish consumed and the PCB level in the cord blood predicted smaller birth weight, smaller head circumference, and reduced gestational age (Fein et al 1984). Infants were re-evaluated at five months and the prenatal growth retardation seemed to be persistent. At seven months, in terms of cognitive development in infancy, cord serum PCB and maternal fish consumption levels were both associated with poorer

performance on the Fagan Test of visual recognition memory. The epidemiological research was important because it elegantly demonstrated for the first time that when women consumed Great Lakes fish prior to or during pregnancy there were detectable developmental effects on their offspring linked to organochlorine compounds and particularly PCB.

Much of the information was incorporated into the 1990 Biennial Report of the International Joint Commission (1990 p. 13-16) to the United States and Canadian governments and formed the basis for the IJC programmes for the next four years. For example, the Great Lakes Science Advisory Board held a Workshop on Protocol Development for Determining Human Exposures to Toxic Chemicals, Body Burdens and Neuro-behavioural and Development Assessment (Manno unpublished manuscript 1991). The purpose was to recommend protocols to researchers engaged in correlative studies of chemical exposures and neuro-developmental effects.

Further study of the children of the mothers who had eaten Lake Michigan fish was undertaken at 4 years of age and revealed that prenatal PCB exposure predicted poorer scores on the McCarthy Verbal and Memory Scales and effects on short term memory processing (Jacobson and Jacobson 1993). Though these dose dependent deficits in memory were within the normal range, there were concerns that they could have a marked effect on the child's ability to master basic reading and arithmetic skills in school. Seventeen of the children who were from mothers with the highest fish consumption were so inattentive that they could not undertake the testing. These results influenced Daly in designing experimental studies of rats fed Lake Ontario fish. In 1991, she presented the results of her neuro-behavioural studies of the

offspring of rats fed Lake Ontario fish and demonstrated that the offspring “were fine as long as life was fine.” But if they were mildly frustrated, they became much more reactive than controls and never habituated to the frustrating events (Daly 1993). Daly replicated the Jacobsons’ research by undertaking epidemiological work on a new cohort of infants whose mothers had eaten Lake Ontario fish prior to or during pregnancy. Her experimental studies with rats influenced the design of these new epidemiological evaluations in the newly formed infant cohort study centred at Oswego, New York (Lonky et al. 1996).

Newborn infants of mothers who had eaten approximately 2.3 meals per month of Lake Ontario fish prior to and during pregnancy could not habituate to frustrating events such as:- a light shining in the eyes; or a bell ringing while they were trying to sleep; or a pin prick on the foot (Lonky et al., 1996). Impairment on the Brazelton habituation and autonomic scales at 24 and 48 hours after birth correlated with the most highly chlorinated PCBs (Stewart et al., 2000). In children tested at 6-months and at 12-months using the Fagan Test of Infant Intelligence (Darvill et al. 2000), there was a dose-dependent relationship between levels of total PCBs in umbilical cord blood and poorer performance. A similar relationship was found with highly chlorinated PCBs and scores for 12-month-old infants but not at 6-months. The children from the Oswego cohort were tested at 4-years-of-age (Stewart et al. 2003) and those with higher prenatal levels of PCB exposure showed significantly greater percent errors of commission in a continuous performance test (Catch-the-cat). There was an association between the children who were most frustrated with the test and high prenatal PCB exposure and high maternal mercury levels in hair thus posing the possibility that there was an interactive effect of these two neuro-teratogenic

substances. Children were assessed with MRI scans of their brains. The only neuro-anatomical structure that was significantly changed was the splenium volume which was inversely associated with greater errors of commission and with prenatal PCB exposure. The splenium is the site of inhibition and the finding of the inverse association indicates a possible neuro-anatomical lesion associated with the poorer performance on the response inhibition test in these children (Stewart et al. 2003).

3.3.3 Official institutional response

Most of the epidemiological research was funded by the Agency for Toxic Substances and Disease Registry (1994) through appropriations for implementation of the Great Lakes Critical Programmes Act (Hicks 1996). The decade of U.S. funding yielded a detailed account of the exposures and effects of persistent toxic substances on people consuming Great Lakes fish. Of particular concern are the associations between the neuro-developmental effects and exposures to the highly chlorinated PCBs. The introduction to the proceedings of the Montreal meeting asked the cogent question ‘do exposures to persistent toxic substances (PTS) result in short- or long-term adverse human health effects’. It then proceeded to lay out the case to show the diversity of evidence demonstrating that they did (Johnson et al. 1999). The proceedings concluded with a review of the public health implications of these continuing exposures of Great Lakes populations (Johnson and De Rosa 1999). It is interesting to note that staff members of the Agency for Toxic Substances and Disease Registry authored these two papers but no one from the Canadian Government, which cosponsored the conference, signed their names.

Here at last was a coherent series of published statements of the injury to health from pollution of the boundary waters. The injury had probably been occurring for more than forty years or since before the 1964 reference from the Parties to the International Joint Commission concerning pollution of the lower Great Lakes. These statements could have been a central resource for the International Joint Commission in the preparation of its 10th Biennial Report issued in 2000. But by this time, the issue of persistent toxic substances in the Great Lakes had been so far removed from the political agenda that there was no mention included of the studies or of the findings. Dr. De Rosa of the Agency for Toxic Substances and Disease Registry contacted U.S. Chairman Baldini directly and told him that the failure to include the evidence was ‘egregious.’ The response from Baldini was that the material had unfortunately been ‘inadvertently left on the cutting room floor.’

The failure of the International Joint Commission (2000) to include mention of these studies in its 10th Biennial Report poses the question whether the omission was done knowingly and willfully and was therefore a deliberate dereliction of duty. The words ‘injury to health’ come from Article IV of the Boundary Waters Treaty of 1909 and are included in the various versions of the Great Lakes Water Quality Agreement through the thirty-five years of its existence. The word ‘injury’ rather than ‘risk’ or ‘threat’ is important because it connotes that the two governments agreed not to pollute their respective sides of the boundary waters to harm people on the other side. After President Clinton came to the White House in 1993 and appointed new US commissioners to the IJC ‘who were not as green as the current bunch’ (Durnil 1995 p. 175), the word ‘injury’ tended to be omitted from discussions. Instead, the terms ‘risk’ and ‘threat’ were substituted. Partly in response to the outrage expressed by

DeRosa at the omission by the IJC of the new epidemiology from its 10th Biennial Report, the 11th Biennial Report contained the following statements:- ‘In short, we now know that injury is occurring. We believe that agencies’ political leaders and managers are obligated to act decisively to protect their citizens from further injury.’ (International Joint Commission 2002, p. 17). The commission stopped short of saying that it would be a dereliction of duty for politicians and managers not to meet their obligations. This particular omission was part of a much wider pattern of omissions of the environmental contamination and toxicological evidence and misrepresentations of the Great Lakes Water Quality Agreement not only by the International Joint Commission but also by the Parties to the Agreement. For further example, ‘methyl mercury.....has not been conclusively established as a teratogen’ (International Joint Commission 2004 p. 37).

The conflicted response of the Commissioners, as national governance authorities, can be compared in terms of the SARS/climate change heuristic device introduced in chapter 1. There was reluctance on the part of the Chinese authorities to notify the World Health Organisation of the SARS outbreak in Guangdong Province (Kilbourne 2006). However, the value systems of those responsible for public health in Canada and the United States explicitly treat epidemics caused by previously unidentified microbiological agents, such as the SARS coronavirus, and for which there is no established treatment, as an extremely high priority and the response of imposing quarantine is immediate (Gupta et al 2005). In contrast to the emergency response to microbiological agents, the national authorities responsible for the scientific investigations and the preventive and remedial interventions in relation to climate change have been tardy in responding to the hypothesis and initial findings.

Similarly, at the regional and local levels, in contrast to the response of the medical officers of health to the news of the SARS outbreak, the information about the teratogenic effects of exposures to organochlorine compounds and mercury has been treated as a low priority. Regional and local authorities almost seem to treat the information about the likely effects of climate change, such as changes in sea level, storms and droughts, with a sense of fatalism.

Part of the difficulty may be the precision of the perceived danger. In the case of the 2003 outbreak of SARS, it is known fairly exactly that there were about 8098 cases worldwide and that 774 people died (Centre for Disease Control and Prevention 2005). In contrast, the number of infants affected by maternal consumption of contaminated Great Lakes fish and the seriousness of the effects remains uncertain though, based on the telephone interviews, tens of thousands of infants were potentially exposed (Tilden et al 1997). Similarly, there are uncertainties about the numbers of people affected by climate change including mortality and property damage from increased duration and intensity of hurricanes (Emanuel 2005). Estimates of excess deaths from increased temperatures have become more reliable indicating that the heat wave in Chicago in 1995 contributed to 739 deaths (Klinenberg 2002) and the heat waves in Europe in the summer of 2003 were associated with more than 44,000 deaths (Kosatsky 2005).

Based on the foregoing review of the literature, it seems that there is extensive evidence that persistent toxic substances continue to cause injury to health, particularly from exposures of the Great Lakes population to PCBs from consumption of contaminated fish. The first question posed by these findings is whether there are

effects from exposures of communities within the Great Lakes basin to mercury, as indicated in several of the Areas of Concern, based on hospitalisation rates for cerebral palsy (Gilbertson 2004). The second question is whether, after thirty-five years of the operation of the Great Lakes Water Quality Agreement, officials within the various jurisdictions within the Great Lakes basin have knowingly neglected their duties to protect human health and wilfully omitted evidence of injury to health from reports and planning documents.

3.4 Cerebral palsy: Test of the effectiveness of the administration of the Agreement

Most of the studies reviewed above have demonstrated associations between exposures to PCBs, and particularly the higher chlorinated PCBs, and effects on neurological development. In addition, there are effects of PCBs on memory in adults from long-term consumption of Great Lakes fish. In contrast, there is almost no research that has been undertaken to find associations between populations in the Great Lakes and the effects of exposures to mercury. The initial findings that indicate that there are outbreaks of congenital Minamata disease in several Canadian Areas of Concern (Gilbertson 2004) suggest that serious injury has been occurring without the knowledge of anyone in authority. There are a few data indicating that certain Great Lakes populations have been exposed to high levels of mercury. For example, the mercury concentrations in three 1970 hair samples from Chippewas from the Walpole Island reservation, which is comprised of the delta marshes at the join of St Clair River with Lake St Clair, respectively had 4.36, 9.14 and 49.9 parts per million. Background mercury levels for Canadians during the 1960s averaged between 1.5 and 3 parts per million (Jervis et al. 1970, p. 34). The highest value is comparable to the

concentrations in maternal hair associated with children with congenital Minamata disease (Akagi et al 1998). Since the early 1970s, Health Canada has undertaken extensive hair sampling and analysis for mercury in First Nations and Inuit populations and reported the results in three volumes published respectively in 1979, 1984 and 1999. The official position is that ‘no provable direct clinical effects have been found in Canadian Native people’ (Health Canada 1999 p. xi). The levels in the three samples from Walpole Island can be compared with the ‘standards’ (Table 3) set by Medical Services Branch of Health Canada (1999 p. 3) for levels of methyl mercury in blood and hair. These indicate that one person was at ‘increasing risk’ and one person was ‘at risk’ of showing signs of methyl mercury exposure. These standards do not, however, relate to maternal levels associated with the risk to the offspring of developing congenital Minamata disease.

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

The question that is posed is whether there are effects that are occurring in Great Lakes populations and that have not been detected. In particular, are there neurological effects that are occurring in populations that are highly exposed to methyl mercury from the consumption of mercury contaminated fish from the Great Lakes? No assessment seems to have been made of whether there are neurological effects of mercury occurring in Great Lakes populations. There is a vast literature of over 50,000 papers on the environmental toxicology, epidemiology, sources and

environmental chemistry of mercury that has been published since the original outbreaks of Minamata disease. Any assessment of whether there are likely effects occurring in the Great Lakes must necessarily select representative texts that rely first, on source data and environmental chemistry undertaken within the Great Lakes basin and secondly on a review of epidemiological studies that have been undertaken outside the Great Lakes basin.

3.4.1 Potential for exposure

There are few direct measurements of mercury or methyl mercury in residents of any of the Areas of Concern. Surrogates of likely exposure of the communities may be available. For example, inventories of the quantities of mercury (3.4.1.1) that have been used in various industries in these Areas of Concern and data on concentrations in sediments (3.4.1.2) and in fish (3.4.1.3) might serve as surrogate measures of community exposures. Concentrations in fish may be a less indirect index of community exposure because the rates of biological methylation of mercury in sediments are affected by many site-specific environmental factors (Jackson 1998, Wiener et al. 2002). Further, based on a US national survey, blood mercury levels are associated with the amount of mercury contaminated fish consumed (Mahaffey et al 2004). Weis (2004) used a national database to determine whether concentrations of mercury in fish were associated with cerebral palsy rates in the 17 Canadian Areas of Concern. This seems to be the only published study undertaken specifically attempting to link incidences of cerebral palsy in different populations to exposures to mercury in fish.

3.4.1.1 *Uses of mercury in the Great Lakes basin*

Mercury has been used in a variety of applications in the Great Lakes basin. It was extensively used more than 150-years-ago as an amalgam and in laboratory assays for silver and gold in ores. It was used during the past century as the active ingredient in the slimicide, phenyl mercuric acetate on machines in the manufacture of paper. There are many pulp and paper plants on the Ontario side of the Great Lakes and St Lawrence River (Fimreite 1970a) coinciding with several of the Areas of Concern including Thunder Bay, Jackfish Bay, Peninsular Harbour, St Mary's River, Spanish Harbour, Niagara Falls, Bay of Quinte and Cornwall.

Large quantities of mercury were used in the manufacture of chlorine in the electrolytic chloralkali process. Table 4 reports the locations, companies, dates of operations and quantities of mercury used in the six chloralkali plants on the Ontario side of the Great Lakes and St Lawrence River (Tripp and Thorleifson 1998, cited in Gilbertson 2004). At Sarnia, nearly 400 tonnes of mercury were released either to air, land or water from the two chloralkali plants operated by Dow Chemical Canada Inc. During the 60 years of operation at Cornwall on the St. Lawrence River, nearly 200 tonnes of mercury were released from the ICI Ltd chloralkali plant, much of it to the St Lawrence River. More than 60 tonnes were released from the American Can of Canada Ltd chloralkali plant at Peninsular Harbour between 1952 and 1977. Just over 50 tonnes were used at the Canadian Industries Ltd plant in Hamilton and over 40 tonnes were used at the Dow Chemical Canada Ltd. plant at Thunder Bay.

Table 4. Ontario Mercury Cell Chlor-Alkali Plants: Operation Dates and Releases of Mercury in Tonnes^a

Location (Figure 1 Map Number)	Plant	Date Mercury Cells Opened	Date Mercury Cells Closed	Years in Operation	Operational Hg Release (Tonnes^b)
Thunder Bay (4)	Dow Chemical Canada Inc.	1966	1973	8	43.30
Peninsular Harbour (1)	American Can of Canada Ltd.	1952	1977	26	62.11
Sarnia (39)	Dow Chemical Canada Inc.	1948	1973	25	317.73
Sarnia (39)	Dow Chemical Canada Inc.	1970	1973	4	71.73
Hamilton (37)	Canadian Industries Ltd.	1965	1973	8	51.47
Cornwall (42)	ICI Ltd.	1935	1995	60	196.13

^aAfter Tripp and Thorleifson 1998

^b Does not include mercury released in solids

These Canadian data on the historic uses of mercury in the Great Lakes basin are important because they indicate that there seems to be an association between several of the Areas of Concern where elemental mercury and mercury compounds were used and where elevated rates of male hospitalisation for cerebral palsy occurred (Gilbertson 2004) (see detailed results and analysis in chapter 5). These include the pulp and paper mills at Thunder Bay and Jackfish Bay and the historic presence of mercury chloralkali plants respectively at Thunder Bay, Sarnia and Cornwall. These data on the quantities released from the anthropogenic sources can be placed in context by comparison with the quantities of mercury used in other locations. For

example, the current estimate of the amount of mercury and methyl mercury released to Minamata Bay, where environmental mercury poisoning was first identified, is between 70 and 150 tons (Yazawa 2001) indicating that the historic releases from Sarnia and Cornwall, at least, are much larger. The situation in each of the Great Lakes is further exacerbated by the extremely long residence times of the water and contrasts with the daily tidal fluctuations and currents characteristic of maritime environments such as Minamata Bay.

3.4.1.2 *Distribution of mercury in sediments*

Concentrations of mercury in sediment samples from the Great Lakes have been analysed over the past thirty years. During that period there have been changes in analytical methodology and instrumentation that potentially could bring into question the comparability of data obtained at different time periods. Though there do not appear to be references that discuss the comparability of analyses in different laboratories and at different periods, Marvin et al (2004 p 354) felt sufficiently confident in the data to compile a table of recent and historic sediment surveys of mercury in the Great Lakes.

In the following analysis, the data from Thomas (1974) and Thomas and Mudroch (1974) have been used for comparison with the cerebral palsy data for three reasons. First, the cerebral palsy data are for ‘all years’ of age from 1986-1992 and thus may reflect exposures before many of the more recent sediments were sampled and analysed. Secondly, mercury concentrations in the Great Lakes have generally declined since the 1970s when most uses were prohibited and most of the mercury chloralkali plants in Ontario were closed. Use of the data from the 1970s therefore

likely represents a period of highest exposures of communities. Finally, the use of one data set overcomes any possible variation in analytical techniques between laboratories that might invalidate the comparison.

The historic releases of mercury from mining operations, and from chloralkali and pulp and paper plants were reflected in the distribution of much of the mercury in Great Lakes sediments (Thomas 1974, Thomas and Mudroch 1974). Table 5 comprises the mean and range of total mercury in Great Lakes sediments. There were anomalously high mercury concentrations in nearshore and offshore sediments at Thunder Bay, Nipigon and Peninsular Harbour on the north shore of Lake Superior corresponding to historic releases. Mercury in sediments of Lake Huron were generally higher than those in Lake Superior, but extremely high values were found in the southern part of Georgian Bay, near Collingwood and Severn Sound that do not correspond to any known present or past industrial sources. Sediment sampling and analyses have shown the fate and distribution of the major releases of mercury from the two Dow chloralkali plants at Sarnia and the extent of their redistribution down the St Clair River into Lake St Clair. These mercury deposits have been remobilized and redistributed down the Detroit River and joined with one large source of release from Wyandotte Chemicals Corporation on the United States side (United States Senate 1970 p. 118, Oemke 2002) to be deposited in Lake Erie (Thomas 1974, Marvin et al. 2004). In Ashtabula, Ohio, Detrex Chemical Industries, Inc. operated a mercury cell chloralkali plant built in 1963 (United States Senate 1970) with releases to the Ashtabula River and to Lake Erie. Releases by Hooker Chemical Corporation and by Olin Corporation (United States Senate 1970 p. 118) from chemical manufacturing on the United States side of the Niagara River have contaminated large

parts of Lake Ontario. These mercury releases have been deposited in large concentrations in the Kingston Basin and near Wolf Island at the mouth of the St Lawrence River. At Lake St Francis, below Cornwall, some of the highest mercury levels in the Great Lakes basin have been recorded.

Table 5. Mean and Range of Total Mercury in Great Lakes Sediments

	Mean	Range
	Parts per billion	
Lake Superior	83	4 - 584
Lake Huron	22	54 - 805
North Channel	151	8 - 1,112
Georgian Bay	257	12 - 9,500
Lake St. Clair	632	70 - 2,565
Lake Erie	609	13 - 7,488
Western Basin	1,622	484 - 2,929
Lake Ontario	651	32 - 2,100
Kingston Basin	2,113	480 - 8,480
St. Lawrence River		
Wolf Island	11,440	1,010 - 20,600
Lake St Francis	133	0.15 - 4,000

After Thomas 1974

The elevated rates of hospitalisation of males for cerebral palsy at Thunder Bay, Jackfish Bay, Severn Sound and Collingwood, Sarnia and Cornwall are not inconsistent with the known distribution of mercury in sediments in the Great Lakes basin (Gilbertson 2004). Most of these sites have been heavily contaminated by industrial releases to the boundary waters, but the explanation does not hold for Collingwood and Severn Sound in southern Georgian Bay. Thomas (1974) noted that the high levels of mercury in the sediments in southern Georgian Bay were attributable to the presence of the mineral sphalerite in the dolomitic limestone of the Bruce Peninsula. High background levels of mercury have also been found in the Precambrian shales on the north shore of Lake Superior (Cameron and Jonasson 1972,

cited in Marvin et al. 2004) contributing to high mercury levels in sediments in Thunder Bay and Nipigon Bay (Marvin et al. 2004). Finally, given the extremely high levels of mercury from industrial sources and deposited in the Kingston Basin (Thomas 1974), it might be predicted that a high rate of hospitalisation for cerebral palsy for males might be expected at this location and this might be investigated if data were made available.

3.4.1.3 Estimates of mercury concentrations in fish (Weis 2004)

Over the past thirty-five years, many fish have been sampled from throughout Canada and analysed for mercury. Environment Canada has compiled the results of these analyses into a consolidated database that is available to researchers. Weis (2004) selected representative species from the database that had been sampled from close to the 17 Canadian Areas of Concern. Through multifactorial analysis he removed the effect of sampling year and age of the fish and made a rank ordering of each Area of Concern in relation to mercury contamination of fish. The rank order was then compared parametrically and non-parametrically with the rank order of the rate of hospitalisation for cerebral palsy of males and females in the Areas of Concern (Gilbertson 2004). These correlations were not statistically significant. If there is a relationship between mercury exposure of communities and the consumption of local fish from the Great Lakes and the rate of hospitalisation for cerebral palsy, the analysis was unable to demonstrate it statistically (see section 5.4.5.4 below).

3.4.2 Potential for effects of mercury

The two classic cases of environmental poisonings with mercury occurred respectively in Japan in the 1950s and in Iraq in the 1970s. To determine whether there might be effects of mercury in Great Lakes populations, these two outbreaks are reviewed in detail. In addition, there have been extensive clinical (Table 6) and epidemiological studies (Table 7) undertaken in other parts of the world to document the effects of mercury on other exposed populations.

3.4.2.1 Japanese and Iraqi poisonings with methyl mercury

Any test of the effectiveness of the administration of the Great Lakes Water Quality Agreement using epidemiological data to indicate the effects of exposures to methyl mercury must be informed by previous outbreaks. The investigations that were undertaken following the outbreaks of poisoning with methyl mercury in Japan and in Iraq provide detailed information on which to design a study to evaluate whether there might be neurological effects of exposures to methyl mercury in Great Lakes populations.

3.4.2.2 Minamata, Japan

The first outbreak of methyl mercury poisoning in a community occurred in Minamata, in Japan where the Chisso Corporation manufactured acetaldehyde. The first cases were children seen in 1956 at the paediatric department of a hospital run by the Chisso Corporation but cases in adults were also found (Harada and Smith 1975). The head of the hospital, Dr. Hajime Hosokawa, informed the Minamata Health Department on May 1, 1956 that ‘An unclarified disease of the central nervous system

has broken out.’ In August 1956, the Minamata Disease Research Group was formed in the Medical School of Kumamoto University to investigate the disease. It was first suspected that the disease was of viral aetiology, but by October 1956, it was shown that the disease did not have an infectious aetiology, but was linked to eating fish and shellfish from Minamata Bay. At that time there were 56 known victims.

As early as 1950, anomalous signs had been observed in wildlife in Minamata Bay, with mortality of birds in flight. Cats in some districts of Minamata became scarce after suffering from what the local people called ‘dancing cat disease’ (Harada 1975 p. 180, Harada 1995 p. 3).

The cats had obviously gone mad. They were dancing a weird dance, which consisted of circular and zigzag motions, as if they were drunk. Then the dancing became wilder. The cats rubbed their noses against the ground and threw their legs in the air, as if they wanted to stand on their heads (Michiko 2003 p 94).

Table 6. Clinical findings from studies of individuals exposed to elevated levels of methyl mercury

Location & Year of Initial Observation	Critical Sub-population	Study Design	Findings	Reference
Minamata City, Kumamoto Prefecture, Japan. 1956	Children of fishermen	Clinical observation	22 infants. Mental retardation, primitive reflexes, co-ordination disturbance, dysarthria, limb deformation, growth disorder, chorea-athetosis, hypersalivation. More severe effects on males.	Minamata Disease Research Group, 1968. Harada, 1978, 1995. Tsubaki and Irukayama, 1977.
Niigata City, Niigata Prefecture, Japan. 1965	Children of fishermen	Clinical observation		
Alamogordo, New Mexico. 1969	Family of 10 persons who ate hogs fed methyl mercury treated grain. 40-year-old mother ate contaminated hog meat during 3rd-6th months of pregnancy.	Clinical observation	3 children with ataxia, agitation, visual impairment and impaired consciousness. Infant born with intermittent gross tremulous movements of extremities that persist for several days. At 6 weeks, irritable with high pitched, weak cry, increased tone in extremities. At 3 and 6 months abnormal electroencephalograms. At 8 months hypotonic and irritable, nystagmoid eye movements without visual fixation.	Snyder 1971, 1972 Pierce et al. 1972
			At six-years-old, the child displayed severe neurological impairment (blindness, myoclonic seizures, neuromuscular weakness, inability to speak.	Snyder and Seelinger 1976

(After Agency for Toxic Substances and Disease Registry, 1999, National Research Council 2000 and Mahaffey et al 2004).

Table 6. (Cont.) Clinical findings from studies of individuals exposed to elevated levels of methyl mercury

Sweden, 1952	Child of mother who ate flour from mercury treated grain	Clinical observation	Infant born apparently normal, but later displayed brain damage as mental retardation, inco-ordination, and inability to move.	Engleson, and Heiner, 1952.
Iraq. 1972	Children of farmers and wives who ate mercury treated grain	Clinical observation	55 infants. Diffuse neurological disease, delay in motor and psychological development, inco-ordination, ataxia, involuntary movement, muscle paresis or paralysis, hearing loss, blindness, abnormal muscle tone and reflexes, or persistence of primitive reflexes.	Bakir et al. 1973. Amin-Zaki et al. 1974,1976, 1978.
Mistassini, Waswanipi, Great Whale, and Fort George, Northern Quebec. 1978	247 Cree Indian children in 4 bands	Clinical observation, interview with mother and maternal hair sampling and analysis Clinical examinations of 95% of the eligible children and their mothers for neurological abnormalities in offspring.	Dose-response between neurological effects and maternal mercury hair level. More severe effects in boys than girls. In boys , abnormality of muscle tone or reflexes was positively associated with the index of prenatal methyl mercury exposure.	Marsh et al. 1987, Cox et al. 1989. McKeown-Eyssen et al. 1983.

After Agency for Toxic Substances and Disease Registry, 1999, National Research Council 2000 and Mahaffey et al. 2004.

Table 7. Epidemiological findings from studies of individuals or communities exposed to elevated levels of methyl mercury

Tapajos River The Amazon	3 Amazonian communities near gold mining activities and a control community	Cross-sectional studies. Children 7-12 years of age. Neuropsychological tests of motor function, attention, and visuospatial performance.	Hair mercury concentrations associated with decrements in neuropsychological tests of motor function, attention, and visuospatial performance.	Grandjean et al. 1999a
French Guiana	3 Amerindian communities near gold mining activities	Cross-sectional studies. Neurological evaluation of sensory, motor, and behavioural signs and functions in children 9 months to 6 years. Neuropsychological investigation with McCarthy scales. Correlation analysis	Maternal hair mercury associated with deep tendon reflexes, poorer leg coordination and visuospatial organisation. Effects stronger in boys.	Cordier et al. 2002
Ecuador	Families in communities near gold mining operations	75 individuals (36 children and 39 adults) from gold mining area and 34 individuals (15 children and 19 adults) from control area.	Association of blood Hg levels in children only with hearing threshold in neuro-otological examinations.	Counter et al. 1998
Madeira	Children of mothers in fishing village	Cross-sectional: 149 children aged 6-7-years-old.	Maternal hair Hg levels associated with changes in brainstem auditory evoked potential and to visual-evoked potential.	Murata et al. 1999
Seychelle	Maternal consumption of seafood	Double-blind, prospective cohort study: Evaluation at 19 and 29 months	On the Bayley Infant Behaviour Record, activity level in boys , but not girls, decreased with increased mercury exposure.	Davidson et al. 1995.

After Agency for Toxic Substances and Disease Registry, 1999, National Research Council 2000 and Mahaffey et al 2004.

Table 7. (Cont.) Epidemiological findings from studies of individuals or communities exposed to elevated levels of methyl mercury

New Zealand	Information collected on 11,000 women; 935 women reported eating more than 3 meals of fish per week during pregnancy; 73 women had Hg levels greater than 6 ppm	Case-control: 39 exposed and 36 reference children with 30 matched pairs at 4-years of age. Follow-up at 6-years of age. 3 controls to each high Hg child Additional analysis of data set with maternal Hg as continuous variable rather than binary. Removal of data for one very high Hg child with normal test results.	On Denver Developmental Screening Test (gross motor, fine motor, language, and personal and social subscales) 52% of high exposure group versus 17% of controls had abnormal results (odds ratio of 5.3). Maternal Hg hair concentration associated with poorer scores on IQ, language development, visual-spatial and gross motor skills. Maternal hair Hg levels inversely associated with language and perceptual performance (concepts, letter test, general cognitive index, perceptual performance scale, grammar completion and understanding).	Kjellstrom et al 1986. Kjellstrom et al. 1989. Crump et al. 1998.
Faroe Islands 1986-1987.	Maternal consumption of pilot whale meat.	Cross-sectional cohort of 1022 infants. Clinical examination and neuropsychological testing of 917 children at 7 years of age. Mercury in cord blood and maternal hair. Case control of 112 children with maternal hair levels of 10-20 ug/g matched to 112 below 3 ug/g.	Mercury-related neuropsychological dysfunctions in domains of language, attention, and memory and to a lesser extent in visuo-spatial and motor functions even below 15 ug/g mercury in maternal hair. Slight delay in auditory evoked potential. Mild decrements in cases compared to controls in the domains of motor function, language and memory. Poorer results of boys in finger tapping, reaction time, and hand-eye co-ordination.	Grandjean et al. 1997, 1999. Budz-Jorgensen et al. 1999, 2000 Grandjean et al. 1998.

After Agency for Toxic Substances and Disease Registry, 1999, National Research Council 2000 and Mahaffey et al 2004.

The disease was experimentally produced in cats fed fish and shellfish from Minamata Bay and effluent from the Chisso Corporation (Togashi 1999). The Chisso Corporation discharged into Minamata Bay and had many chemicals in their effluent including a variety of metals. Researchers started to look for a link between the characteristics of the disease and the signs and symptoms caused by exposures to specific metals including manganese, thallium, arsenic, mercury, selenium, copper and lead. In 1958, Takeuchi made the connection between the signs and symptoms in the victims and those reported in the medical literature on the occupational poisoning of four British workers exposed by inhalation to methyl mercury dust (Hunter et al.1940) (cited in Harada 1978 p 182). The signs included numbness and tingling of limbs, unsteadiness in gait, difficulty in performing fine movements, irritability, and constricted vision (Hunter et al.1940). Subsequent experiments with methyl mercury demonstrated that this was the compound that caused dancing cat disease. Subsequent chemical analysis established high concentrations in cats with the disease, in fish and shellfish from the bay and in humans who had died. In 1960, analysis of hair samples from patients and from residents in the Minamata area showed the widespread contamination of the population with mercury.

At the time, Chisso Corporation argued that it had only discharged inorganic mercury and it was not responsible for any of the organic methyl mercury present in the environment. It was several years before the knowledge about the biological methylation of mercury was published (Jensen and Jernelov 1968, 1969). The Chisso Corporation used mercury as a catalyst in the manufacture of acetaldehyde and a recent re-evaluation of the process indicates that methyl mercury was an important component of the effluent that was released into Minamata Bay. Present estimates are

that between 70 and 150 tons of mercury were released (Yoshikuni 2001). Some of the mercury was redistributed from Minamata Bay into the Shiranui Sea and cases of congenital Minamata disease were found in communities remote from the original source (Harada 1995).

While Minamata disease had been well characterised in adults, Kitamura was the first to identify congenital Minamata disease in many children born after 1955 with 'symptoms resembling cerebral palsy' (cited in Harada 1978). This was at a time before the link to methyl mercury had been made: 'It is possible that the substance causing the poisoning was transferred to the infants through the placenta or mother's milk, producing symptoms similar to those of Minamata disease' (Kitamura in Harada 1978). At the time, there was a firm belief that the placenta and the blood-brain barrier protected the developing foetus and brain from toxic insults. By the early 1960s, Japanese researchers had demonstrated the trans-placental movement and the accumulation of methyl mercury in the foetal brain (Harada 1978). A Swedish child accidentally poisoned with methyl mercury had been examined and signs found of mental retardation and cerebral palsy (Engelson and Herner 1952) and the report was available to the Japanese researchers (Harada 1978). A second outbreak occurred in Japan in 1965 in Niigata (Osame and Takizawa 2001). The total number of Japanese people thought to be suffering from Minamata disease is about 12,000. The number of Minamata disease patients who are officially recognised is 2,200 people in Minamata and 800 in Niigata (Harada 2002).

3.4.2.3 *Iraq*

The second extensive outbreak of methyl mercury poisoning occurred in Iraq in the early 1970s (Marsh et al. 1987b, Agency for Toxic Substances and Disease Registry 1999). More than 90,000 tonnes of methyl mercury treated grain was imported into Iraq in October 1971 for planting. The grain was distributed to farmers free of charge throughout the country. Because the season for planting seeds was already nearly completed, much of the treated seed grain was ground and made into bread. The first cases were seen in December 1971 and the outbreak eventually hospitalised 6,530 people and 459 people died. Many more people were affected but were not hospitalised. Women who had been pregnant during the poisoning outbreak were identified and samples of hair were collected and analysed and used to demonstrate a dose-dependent increase in infant mortality related to foetal exposure to methyl mercury. In a study of 81 mother-infant pairs, the neurological development of the infants was evaluated through interviews with the mothers. Developmental milestones for sitting, walking and talking and the incidence of symptoms such as involuntary movements, seizures, impaired vision or hearing, lack of co-ordination were assessed to obtain a neurological score. From the score the authors demonstrated a dose-response relationship with peak concentrations of mercury in the hair of the mothers and a larger effect on boys compared to girls (Marsh et al. 1987b). The outbreak in Iraq in 1971 was not the first time that consumption of treated grain had caused a widespread neurological epidemic in that country. Previous outbreaks, caused by ethylmercury-*p*-toluene sulfonamide, had occurred in 1956 and 1960 and resulted in between 200 and 300 cases (Bakir et al. 1973).

While these outbreaks in Iraq may be useful as another analogue of the exposures and potential effects of methyl mercury on populations in the Great Lakes basin, there are important contrasts with the Japanese analogue. While the pathways of exposure were both oral, the Japanese outbreaks were from the consumption of contaminated fish over a long period of time, whereas the Iraq outbreaks were from consumption of methyl mercury contaminated bread and the exposures were of a relatively short duration. There are some differences in the pathology that have been noted between those reported by the Japanese researchers in the Minamata outbreak and those working on the poisonings in Iraq (Amin-Zaki et al. 1974). For example, while there was evidence of cerebral palsy, microcephaly, fretfulness, excessive crying and irritability in some of the children from both the Minamata and the Iraq outbreaks, blindness and deafness were only seen in some of the Iraq cases. Choi (1989) compared the clinical features of two Iraqi cases with those of two Minamata cases. He noted that the Iraqi infants, of symptomatic mothers, appeared normal at birth but died early in the postnatal period, whereas the Japanese infants with cerebral palsy, of asymptomatic mothers, lived to 2 years and 6 months and 6 years and 3 months respectively.

3.4.2.4 Relevance to Great Lakes Studies

As part of the Great Lakes Health Effects Programme, Health Canada compiled health data and statistics on the mortality, morbidity and congenital anomalies rates in Canadian Areas of Concern for over 70 health endpoints that 'might be related to pollution'. The rationale for including cerebral palsy as one of the health endpoints was based on the literature on these two outbreaks of organic mercury poisoning. Health Canada concluded that because cerebral palsy was one of the symptoms

associated with congenital Minamata disease, it would include health data and statistics on the mortality and morbidity rates for cerebral palsy for the 17 Canadian Areas of Concern. These data and statistics are the numerical core of the dissertation. It is, however, necessary to establish whether people in the Great Lakes basin are likely to be exposed to the concentrations that might pose risks to human health and particularly to the neurological development of infants. The opportunity for undertaking this presented itself in 2000 through the choice of mercury as a priority for the 2001-2003 Biennial Cycle of the International Joint Commission which held a Workshop on an Ecosystem Approach to the Health Effects of Mercury in the Great Lakes Basin Ecosystem (Gilbertson and Carpenter 2004).

3.4.3 An ecosystem approach to the health effects of mercury in the Great Lakes basin

The International Joint Commission priority on mercury was selected primarily based on the availability of research on modelling the atmospheric movement of the various forms of mercury at local, regional, continental and intercontinental scales. The distribution and chemistry of mercury in different environmental media have been extensively studied over the past thirty-five years and the workshop was an opportunity for Great Lakes scientists from a variety of disciplines to present their findings (Gilbertson and Carpenter 2004). Mercury in various forms can move between environmental media and in assessing the various potential pathways of exposure it is necessary to consider these. In designing the mercury workshop for the International Joint Commission, the Workgroup on Ecosystem Health decided that part of the workshop programme must reflect the multimedia complexity. This was achieved by using the IJC's ecosystem approach to pathway analysis (International

Joint Commission 1978b, Gilbertson and Carpenter 2004) to demonstrate that there are the following components of routes from sources to receptors:- routes by which mercury enters the environment from natural and industrial sources; historic distribution and redistribution of mercury; processes of transformation between various mercury species; factors affecting the equilibrium between methylation and demethylation of mercury; and releases of methyl mercury into the water column. Pathway analysis includes the uptake of methyl mercury into organisms; bioaccumulation in food-chains; and accumulation in top predators, including the routes of exposure to humans. The voluminous literature that has been published on each of these topics has fortunately been extensively reviewed (United States Environmental Protection Agency 1997, National Research Council 2000, Wiener et al, 2002).

The published reviews stress the global nature of the mercury problem and the manner in which mercury is transported as elemental mercury in the atmosphere, transformed into divalent mercury and deposited as wet or dry deposition onto land or water. About 5000 tons of mercury is put into the global atmosphere from all anthropogenic sources on an annual basis (Jackson 1997) and another 2000 tons are emitted from natural sources. About a half of this is deposited locally and the other half joins the global atmospheric reservoir. The amount of mercury released into the atmosphere from the United States was estimated to be 158 tons in 1994-1995 and about a third was deposited within the 48 contiguous states (U.S. EPA 1997). Combustion sources including utility boilers, municipal waste combustors and incinerators and commercial and industrial boilers contributed over 85% of the point source emissions. Models of the fate of atmospheric mercury predict that the southern

Great Lakes are among the locations with the highest deposition rates in the United States (U.S. EPA 1997). Fish in many inland lakes within the Great Lakes basin have become so contaminated with mercury from atmospheric deposition that they are considered unfit for human consumption. The IJC workshop reflected the importance of long-range atmospheric transport. Sources of atmospheric emissions up to 2000 miles away contribute significant deposition of mercury into the Great Lakes basin, particularly from coal combustion (Cohen 2004).

Significant progress has been made in preparing and maintaining national inventories of the releases of pollutants into the environment and both the United States and Canada have prepared inventories for the releases of mercury within their respective jurisdictions. For example, in an inventory of mercury for the province of Ontario, prepared in 1998 for the Canadian Council of Ministers of the Environment, the estimated quantities in products, such as dental amalgam, thermostats, and hospital equipment, was nearly 30 tons. Over 9 tons was released from breakage, wear, emissions and releases on an annual basis. These estimates resulted in priorities for reductions for the following sectors:- base metal smelting; coal fired power generation; hazardous waste; biomedical waste; municipal solid waste; and sewage sludge incineration (Trip et al 2004). The initial inventory was later critiqued and re-evaluated (Hagreen and Lourie 2004) and these initial estimates were increased by the inclusion of various other electrical switches in products, raising the estimates to over 70 tons in products, with over 10 tons released on an annual basis. Significant progress was made in reducing the emissions of mercury between 1988 when about 14 tons was emitted and 2000 when about 3 tons was emitted (Trip et al 2004). The largest reductions were the removal of mercury from manufacturing paint (5 tons) and

pesticides (2.5 tons) and closures or improvements in municipal and hospital incinerators (c.1.5 tons). While there are difficulties in preparing inventories to estimate reservoirs, fluxes, emissions and releases of mercury, there are adequate data for inferring that there are and have been significant quantities of mercury released from anthropogenic sources to the Great Lakes.

At the time that mercury became a concern in the Great Lakes in the late 1960s (Fimreite 1970 ab), little was known about the fate and distribution of this metal in the environment other than the then newly discovered phenomenon of bacterial methylation in anaerobic sediments (Jensen and Jernelov 1968,1969). Prior to that time, scientists and engineers in government and industry believed that elemental mercury remained in this relatively benign form unchanged (United States Senate 1970, pp 11, 18, 41). There has been a growing literature that has been extensively reviewed on the processes and conditions of the transformations of elemental mercury into inorganic mercury and subsequent methylation into methyl mercury (National Research Council 1978, 2000, U.S. EPA 1997, Wiener et al. 2002). Of particular concern are the 'mercury-sensitive habitats' including wetlands, areas that are flooded or with low alkalinity and with high humic content (Wiener et al. 2002). In these areas, mercury can be efficiently methylated through bacterial action resulting in levels in fish and wildlife that may be even higher than in areas highly contaminated by industrial discharges. Similarly, there is an extensively reviewed literature on the uptake of methyl mercury in aquatic organisms and bioaccumulation in aquatic food-chains (Wiener et al. 2002). The bioaccumulation factor for methyl mercury between water and fish is between 10^6 and 10^7 , thus even fractions of parts per trillion concentrations of methyl mercury in water can result in part per million

concentrations of methyl mercury at the top of aquatic food-webs. The contamination of Great Lakes fish with parts per million concentrations of mercury was first documented by Fimreite (1970b). Though mercury concentrations in fish from the 17 Canadian Areas of Concern were sometimes poorly correlated with the presence of known sources and deposits of mercury, they were still elevated compared with expected background concentrations, indicating bio-concentration and bioaccumulation in Great Lakes food-webs (Weis 2004). From the foregoing review, it can be concluded that there is a potential for human exposures to methyl mercury from the consumption of Great Lakes fish and the potential for effects to occur in human populations heavily dependent on this source of nutrition.

3.4.4 Threshold studies and differential male susceptibility

Since the severe outbreaks of methyl mercury poisoning in Japan and Iraq, there have been several studies that have attempted to determine the levels of methyl mercury exposure associated with no effect. Levels considered 'safe' have declined as diagnostic and statistical techniques improved since the early 1970s (Schettler et al 2000 p. 15). To determine the no effect level, researchers have undertaken several epidemiological studies (see Table 7) in communities where there were large amounts of seafood eaten, such as in the Faeroe Islands (Grandjean et al. 1998), on the Island of Madeira (Murata et al. 1999), in New Zealand (Kjellstrom et al. 1986, 1989) and on the Seychelles (Davidson et al. 1995). Similarly, research has been undertaken in communities where freshwater fish were eaten from locations close to gold mining operations, such as from the Tapajos River in the Amazon Basin (Grandjean et al. 1999), or in French Guiana (Cordier et al. 2002) or Ecuador (Counter et al. 1998). The neurological effects, particularly of prenatal exposure to methyl mercury, seem to

be similar in several different domains including changes in muscle tone or reflexes, motor function, attention, and in auditory and visuo-spatial performance.

Several of these studies significantly noted neurological effects on males occurring at lower concentrations than on girls indicating a peculiar susceptibility of males prenatally exposed to methyl mercury (see bold markings in Tables 6 & 7). These included the gross findings in the Japanese (Harada 1994) and in the Iraqi outbreaks (Marsh et al 1987a). But, in addition, male susceptibility was indicated in some of the studies of neurological function in children prenatally exposed to much lower concentrations. These included:- children of the Cree Indians in Northern Quebec (McKeown-Eyssen 1983); children of fish-eating communities in French Guiana close to gold mines (Cordier et al. 2002); children of the Seychelle islanders (Davidson et al. 1995) whose mothers ate seafood; and children of the Faeroe islanders whose mothers ate pilot whales (Grandjean et al. 1998).

3.4.5 Formulation of hypotheses

Based on the foregoing analysis of the potential for exposure (3.4.1), the analysis of the potential for effects (3.4.2), the diversity of local, regional and global sources of mercury to the Great Lakes (3.4.3) and the differential susceptibility of the developing males to exposures to methyl mercury, the following null hypotheses can be formulated as a further test of whether the Parties have successfully implemented the Great Lakes Water Quality Agreement:-

In Areas of Concern with elevated methyl mercury concentrations:-

Cerebral palsy hospitalisation cases are no more prevalent than in the rest of Ontario;

Cerebral palsy hospitalisation cases in males are no more prevalent than in females.

3.5 Contribution to knowledge

The observation of abnormalities in chicks of colonial fish-eating birds on the Great Lakes indicated the presence of teratogenic substances in the environment (Gilbertson et al 1976). The subsequent development of a forensic approach to the injury to fish, wildlife and human populations exposed to persistent toxic substances in the Great Lakes (chapters 1 & 2) has been a significant contribution to knowledge during the past thirty-five years (Gilbertson 1988). The thesis has extended that scientific approach to include a forensic audit of the communication and use of that science by the authorities. By placing the forensic audit within social, economic, political and diplomatic ‘frames’, it has been possible to encompass not only information about the production of hazards that cause injury, but also explanations of why agencies and individuals condone the wilful and knowing dereliction of duty to report and to act (chapter 4).

There are difficulties in diagnosing Minamata disease in individuals and even in identifying populations exposed to elevated levels of mercury in the environment. For those countries that keep national health statistics, the rate of cerebral palsy hospitalisation might provide a potentially useful index for detecting whether there are effects of methyl mercury occurring. Health Canada compiled health data and statistics on the rates of several other health endpoints that ‘might be related to pollution’. The interpretation of the Health Canada data on the rate of cerebral palsy hospitalisation might further demonstrate to policy makers in Health Canada that the methodology is a valuable epidemiological technique for identifying communities that are suffering from chemically-induced diseases (chapters 2 and 5).

The application of Hill's guidelines to the preliminary observations of increased rates of hospitalisation for cerebral palsy in males in several Canadian Areas of Concern has been a useful framework for 'reducing the uncertainties' (chapter 5). The methodology, first applied in the Great Lakes basin more than twenty-years ago, has now become widely endorsed internationally (Fox 1991, Gilbertson and Schneider 1991, United States Environmental Protection Agency 1992).

The initial forensic audit reveals that there are powerful influences within governments and within industry that would prefer that the Great Lakes Water Quality Agreement be transformed into a Great Lakes Ecosystem Management Agreement (reviewed in chapter 4). The several purposes of the latter would be:- to address all 'ecosystem stressors' in the Great Lakes; to provide, within the neo-liberal context of small government, a 'plausible' mandate for funding diverse Great Lakes programmes; and to remove the focus from the requisite costly preventive and remedial work on persistent toxic substances. The identification of the ambiguity and the use that it might represent to power through diversionary reframing is a further contribution to knowledge (Gilbertson and Watterson 2007).

3.6 Limits of the literature

During the past thirty-five years, the literatures on the environmental chemistry and toxicology of PCBs and mercury have become massive and it has thus been necessary, in preparing the literature review in this chapter to select the main findings relevant to neuro-toxicological events in the Great Lakes. It has focused on human epidemiological and associated chemical analytical studies rather than on laboratory research undertaken on animals; it therefore tends to be correlative rather than

experimental. The literature is oriented to analysing the situation within the Great Lakes basin, though comparable studies have been undertaken in Europe and in the Arctic. The number of substances that have been found in the Great Lakes epidemiological studies to be associated with effects on neurological changes in structure and function is extremely limited and mainly attributed to the higher chlorinated PCBs. While the review has been oriented towards neurological aspects, many other health effects, such as changes in immune and endocrine functioning, have also been studied, though studies on effects in Great Lakes populations are scarce.

The thesis has outlined that the Great Lakes Water Quality Agreement was initially a successful diplomatic instrument to respond to the manifest deterioration of water quality and was an expression of the 'special relationship' between the United States and Canada. The thesis has also indicated that there are reasons to believe that the Great Lakes Water Quality Agreement has failed to maintain and restore water quality. Chapter 4 is a review of the development and failure of the Great Lakes Water Quality Agreement.

CHAPTER 4: DEVELOPMENT AND FAILURE OF THE GREAT LAKES WATER QUALITY AGREEMENT

4.1 Introduction

The negotiation of the Great Lakes Water Quality Agreement in 1972 was a manifestation of the ‘special relationship’ between Canada and the United States as two nations with different identities (4.2). New science demonstrating the injury to health from exposures to persistent toxic substances lead to renegotiation in 1978 and to further amendments in 1987 (4.3). However, evidence indicates that, despite thirty-five years of implementation, injury to health still occurs. There are several sources of failure (4.4) including deteriorating relations between governments (4.4.1) and deficiencies in the quality of advice (4.4.2).

4.2 National identities within the bilateral relationship

The Great Lakes Water Quality Agreement is a bilateral instrument to prevent injury to health from trans-boundary pollution. The respective responses to the evidence of injury to health are likely to be informed by the respective national identities (Snider 2004). The United States is the largest imperial power that has ever existed and several characteristics follow including:- great authority over large territories, peoples and cultures; maintenance of dominance; expectation that neighbours accept their power, even though the imperial power does not have sovereign power over the territory; and belief in the right to break universal rules (Simes 2003 p. 92, 93). The cultural values of the United States population can act as filters to messages about injury (Fessenden MacDonald 1993 p. 28) and aspects of these have direct relevance to the expectations of Americans for implementation of the Great Lakes Water Quality Agreement. These cultural myths include:- the American Dream of family

and children, a home, wilderness and the ability to go to a park to swim, fish and hike; the American Style expecting a fast response to a threat, rather than another study, and involvement in and even control of the process; and the American Character of individualism and self reliance and the wish for the government not to tell the person what to do, but also the expectation that the government will not allow them to be injured.

In contrast, when Canada gained nationhood through the 1931 Statute of Westminster, it was always at risk of becoming a client state of the United States. The process of nation building was premised on capitalist principles for resource development at the frontier based largely on capital from the United States. Canada thus became a branch plant operation of the United States, with the Canadian government acting in a supervisory capacity (Grant 1995 p. 53, 54). Implicit in this policy network is a corporatist arrangement between government and industry to further the interests of the state and private wealth (Atkinson and Coleman 1985 p. 24). Canada is a liberal-capitalist democracy with governments that rely on the investment of private wealth to generate 'welfare' (Glasbeek 2002 p. 153). To accomplish this, governments try to provide optimal conditions including even dismantling much of the regulatory apparatus set up to curb the worst excesses of the productive process that result in harm to the public. There is a continuous tension within governments between encouraging private entrepreneurial activity to pursue profits on the one hand and protecting the public from consequent harm on the other. Because market capitalism is regarded as beneficial, harm to the public caused by corporations is not dealt with through the full criminal sanctions normally meted out on individuals. Instead, special welfare regulatory regimes have been set up to 'provide a framework in which

market activities can be conducted. They draw a balance between the benefits provided by uninhibited market activities and the amount of harm that people, as members of society, should be willing to tolerate to enjoy those benefits' (Glasbeek 2002 p. 154). The model of the balance between harms and benefits may provide a partial framework in which to understand the dereliction of duty of the commissioners to report the new research on injury caused by exposures to persistent toxic substances in the Great Lakes. It may also provide a framework in which to understand the reluctance of governments, in contrast to the SARS outbreak and similar to the climate change situation, to undertake their responsibilities and in this case, implement the remedial provisions of the Agreement such as removal of sinks of persistent toxic substances before they are redistributed throughout the entire Great Lakes basin.

While both countries were developing industrially, the scale of the developments on the United States side of the border was substantially larger than those on the Canadian side with concomitantly more pollution released to the boundary waters. Thus, the development of the 1972 Great Lakes Water Quality Agreement represented an opportunity for Canada to influence the United States in terms of trans-boundary pollution control. Despite the power inequality implicit in the bilateral relationship, several mechanisms have been devised to ensure parity in relation to the Boundary Waters Treaty and the Great Lakes Water Quality Agreement. These include the appointment of equal numbers of commissioners from each nation, and equal numbers of members on the Great Lakes Water Quality Board and the Science Advisory Board.

The 1970s were a period of responding to the environmental health concerns that had been raised through the new social movements, particularly among students (Adkin 1998 p.1, Habermas 1970). New institutional mechanisms, such as environmental protection departments, research facilities and legislation, were established in both nations to respond to the environmental health concerns. The 1980s, however, brought a sudden reversal in the balance, with elections, in both countries, of politicians espousing neo-liberal politics. With the signing of the Free Trade Agreement and subsequently, the North American Free Trade Agreement, the relevance of the International Joint Commission and the Great Lakes Water Quality Agreement seemed in doubt because of the negotiation of a side accord on environment that would include addressing pollution issues at the border.

Over the past thirty-five years, the ‘special relationship’ between the two nations has varied greatly and this has had implications in terms of attitudes towards implementing the Great Lakes Water Quality Agreement, particularly within the context of the prevailing neo-liberalism. The policy of the present administration in Washington on foreign relations is based on a unilateralist philosophy espoused by the neo-conservatives and exacerbated by the events of 9/11 and the moves of Canada and Mexico towards Deep Integration with the United States, not only from a security standpoint but also for economics and trade (Barlow 2005). Unilateralism and a focus on trade issues would seem to have special implications in terms of the ongoing review of the bilateral Great Lakes Water Quality Agreement. Similarly, the bilateral relationships between commissioners have been very variable and these have had major influences on the effectiveness of policy recommendations. The militarization

of the United States Section of the International Joint Commission during the 1990s was widely seen by the Canadian Section as an overt threat after the Durnil years.

4.3 Development of the Great Lakes Water Quality Agreement

The visibly deteriorating quality of the waters of the Great Lakes during the first half of the 20th century, was the stimulus for the United States and Canadian governments to send a reference to the International Joint Commission in 1964. Based on Article IV of the Boundary Waters Treaty, the two governments asked whether there was injury to health and property from pollution of the boundary waters in the lower Great Lakes. In 1969, the boards that had been set up by the International Joint Commission reported that there was injury to health and property from a variety of pollutants and detailed the process of eutrophication that was occurring as a result of nutrient discharges. The reports recommended controls on the releases of phosphates as a means to control the production of phytoplankton and attached filamentous algae.

The late 1960s and the early 1970s were a period of social unrest (Adkin 200) and within the Great Lakes basin, part of that unrest was expressions of outrage at the deteriorating quality of the environment including windrows of algae and dead fish on the beaches and the Cuyahoga River in flames at Cleveland, Ohio (Botts and Muldoon 2005 p 14, 39). The boards' reports on pollution of the lower Great Lakes were published by the International Joint Commission during this time of social unrest, and were used by the governments as a means of legitimating the public concerns. The boards' reports contained little understanding of the massive accumulation of persistent toxic substances in Great Lakes food webs, nor of their implications. But between the time that the boards reported to the International Joint Commission and

the time that the Commission reported to the two governments, information about contamination of the environment with both mercury and PCBs became available and was incorporated into the final reports to governments.

4.3.1 Negotiating the 1972 Great Lakes Water Quality Agreement

The reports led to two years of intense negotiation and culminated in the signing of the first Great Lakes Waters Quality Agreement by Prime Minister Pierre Elliot Trudeau and President Richard Nixon in 1972. The preamble to the Agreement laid out three general items to which the Parties agreed: The first item was to adopt common objectives; the second was to develop and implement cooperative programs and other measures, such as research and monitoring; and the third was to assign special responsibilities and functions to the International Joint Commission. The Agreement provided for the International Joint Commission to establish a Great Lakes Regional Office with staff to serve the following two new boards that initially reported annually:- the Great Lakes Water Quality Board, comprised mainly of federal, provincial and state regulatory officials; and the Research Advisory Board, comprised of research managers. There was provision for a public information service and through the newsletter, *Focus*, a Great Lakes community started to form not only of scientists and regulatory officials, but also of members of the public and the newly formed activist organisations such as Greenpeace and Pollution Probe and later, Great Lakes United. The International Joint Commission thereby not only continued as the administrative centre for bilateral work on the Great Lakes during the next fifteen years, with committees that, among other things, developed water quality objectives and prepared reports on the state of the lakes, including sources of pollutants, but also acted as a node to provide public information.

At the time, the International Joint Commission had enormous prestige and appointments to the Commission and to the boards were made largely on the basis of technical ability. Morale among the scientists and administrators was high and there was a sense that the work that was being undertaken was important. There were immediate tangible successes in control of loadings of phosphates through the construction and operation of improved wastewater treatment plants and through controls on phosphates in detergents and in runoff from agricultural fields (Botts and Muldoon 2005 p 27). During the five-year period leading up to the review of the operation and effectiveness of the 1972 Great Lakes Water Quality Agreement, there were the beginnings of an appreciation of the dangers posed by persistent toxic substances such as DDT, PCBs and mercury. Forensic research on wildlife indicated severe reproductive failure and teratogenic activity in various species of fish-eating birds (Gilbertson et al 1976, Botts and Muldoon 2005 p. 27, 190). Epidemiological work on a Lake Michigan cohort of fishermen demonstrated the uptake of DDT, PCBs and mercury from the consumption of fish (Humphrey 1976, Botts and Muldoon 2005 p 27).

4.3.2 Forensic ecotoxicology research on the Great Lakes

The North American Great Lakes have been one of the prime locations for research on these episodes of persistent toxic substances and several of the chemically-induced outbreaks of disease have not yet been resolved. ‘Controversies that began two decades ago have persisted’ (Nelkin 1992 p. ix). This research has been mandated under the Canada – United States Great Lakes Water Quality Agreement originally signed in 1972. In contrast to disease outbreaks caused by microbiological agents such as SARS-associated coronavirus, the cryptic nature of the signal of the

occurrence of effects has made it difficult to detect these toxicological events and to judge their significance. Detection has sometimes occurred serendipitously through observations on wildlife, particularly with changes in bird populations signalling the presence of imperceptible chemical risks. For example, detection of the presence of organochlorine chemicals was manifested in the United Kingdom with changes in the peregrine falcon population (Ratcliffe 1963) and in the Great Lakes basin with observations of reproductive and developmental effects in various fish-eating birds (Gilbertson 1988). More recently, changes in house sparrows in large urban areas in the United Kingdom signalled the presence of the fuel additive methyl tertiary butyl ether (MTBE) and combustion products (Summers-Smith in McCarthy 2000) and dramatic declines in Asian vultures revealed the unintended exposures to the veterinary drug diclofenac (Peregrine Fund 2003). Frequently these initial observations have been by lay people practicing an 'intuitive toxicology' to detect cryptic exposures (Neil et al 1994).

The difficulty of perceiving the significance of the 'signal' (Kasperson et al 2003 p. 17) has been further compounded by the variety of 'noise' from other contemporaneous events. In the Great Lakes basin, these include, for example, demographic trends and associated changes in land use and habitat, and the purposeful or inadvertent introduction of exotic species. Though there have been occasional observations of direct toxicity from high levels of persistent toxic substances, the challenge has been to give a coherent causal account of the subtle effects of persistent toxic substances that have had devastating long-term implications on exposed populations. While some of the evidence of the episodes came from chemical analyses of biological samples, much of the account has been based on

forensic observations of subtle effects. Much the most comprehensive evidence has come from studies, over the past fifty years, of various species of wildlife, particularly on birds (Gilbertson 1988). Though there were warnings in the 1970s of contamination of humans in Great Lakes communities (Humphrey 1976), the first epidemiological study was only set up in 1980 (Fein et al. 1983).

There was evidence from the 1960s of contamination of Great Lakes fish, but it was not until 2003 that the first convincing relationship was finally published asserting an association between the demise of the population of lake trout in Lake Ontario and exposures to persistent toxic substances with dioxin-like activity (Cook et al. 2003). The long delay in demonstrating a specific causal association between extirpation of a fish species and exposure to persistent toxic substances was the result of scientific assumptions of the multi-causal nature of changes in fish populations. One implication for fisheries management was that all putative factors that might affect Great Lakes fish populations should be controlled. One claim of the thesis is that the multi-causal assumptions of the fisheries scientists have had important implications for interpretation of the purpose of the Great Lakes Water Quality Agreement.

4.3.3 The 1978 Review and Renegotiation of the Great Lakes Water Quality Agreement

The review of the Agreement brought about two important changes during the 1978 renegotiation. First, there were two new policies. One reflected the existing domestic laws and concerned the prohibition of discharges of toxic substances in toxic amounts. The other, concerning the virtual elimination of discharges of persistent toxic substances, was a completely novel response to the new knowledge of the

dangers posed by these substances. From a technical perspective, there have been debates about how to determine whether the policy has been achieved and whether the measure should be based on chemical analysis of effluent or water samples or whether it should be on the basis of an absence of biological injury (Botts and Muldoon 2005 p. 63, Gilbertson 1988). One of the general principles in the Annex on persistent toxic substances clarifies the intent as “to protect human health and to ensure the continued health and productivity of living aquatic resources and use thereof.” Thus, from the standpoint of the forensic audit, the focus is on whether there is injury to health and property rather than whether a substance is analytically detectable. That is not to say that there should not be a precautionary approach to activities involving persistent toxic substances that are in commerce or that have been detected but that have not yet been shown to have caused injury.

The second change brought about by the review and subsequent renegotiation was the addition of the following statement of purpose in Article II:- ‘The purpose of the Parties is to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem.’ This accords closely with wording contained in the preamble to the Federal Water Pollution Control Act (United States Environmental Protection Agency 1972) with the exception of the addition of the word “Ecosystem”. The immediate question that was raised by this additional word was whether the intent was to make the Great Lakes Water Quality Agreement into an ecosystem agreement, reflecting the multi-causal assumptions of the fisheries scientists and managers, rather than an agreement on water pollution. The situation was temporarily resolved by the Director of the Great Lakes Regional Office in a decision that the intent of the Agreement continued to be concerned with water

quality and water pollution using an ecosystem approach (Oakley 1979). The question, however, has remained as a source of controversy and has become the defining debate in the ongoing review of the Great Lakes Water Quality Agreement that started in 2004.

Through the US National Pollutant Discharge Elimination Systems, resources had been put into ensuring that discharges of persistent toxic substances, particularly PCBs and mercury, were eliminated. Concentrations of many persistent toxic substances had decreased exponentially during the 1970s and early 1980s. But by the mid-1980s, the concentrations had become asymptotic at non-zero values that were still associated with injury to health and property, indicating that there were still sources and sinks that were not addressed through the permitting system. Traditional water quality agencies, however, were reluctant to address the multi-media sources and sinks of persistent toxic substances. The Great Lakes Water Quality Board became a useful mechanism for agency regulatory officials, constrained by media-specific legislation within their jurisdictions, to advocate new mechanisms to address multi-media sources of water pollution. First, the Board published a list of 11 critical pollutants that were to be the first, among the hundreds of substances detected in the Great Lakes, to be virtually eliminated. This list became important in the subsequent work on the Stockholm Convention on Persistent Organic Pollutants (Botts and Muldoon 2005 p. 195, 207). Second, the Board developed a process for the Parties to designate 42 Areas of Concern which were locations that chronically did not meet the water quality objectives. Third, the Board formulated a process for the Parties and jurisdictions to develop Remedial Action Plans for Areas of Concern to address these

violations. Finally, the Board devised a process for development of Lakewide Management Plans for Critical Pollutants.

The Great Lakes states were concerned about toxic substances and, in 1986, the governors signed the Great Lakes Toxic Substances Control Agreement committing themselves to the goals of the Great Lakes Water Quality Agreement. Part of the concern was the declining economic base as manufacturing industries left the region and the prospect of the states competing with each other on the basis of permissive environmental requirements indicated the need to lobby the federal government to set national water quality standards. Later, the governors signed, with the Premiers of Ontario and Quebec, a Memorandum of Understanding on the Control of Toxic Substances in the Great Lakes Environment (Botts and Muldoon 2005 p. 76, 77).

In the 1980s, public interest in the Great Lakes Water Quality Agreement was increasing and would become important in the struggle to implement the new policies concerning the virtual elimination of discharges of persistent toxic substances. ‘In the Great Lakes region, a battle rages against persistent toxic chemical contamination from organochlorines and heavy metals’ (International Joint Commission 1991 p 33). The various non-government organisations negotiated the formation of Great Lakes United which, for a decade, would play a central role in organising the public and activists at the biennial meetings of the International Joint Commission from 1987 onwards. Members of labour unions, such as the newly formed Canadian Auto Workers, developed interests in environment and not only participated in the committee developing the Remedial Action Plan for the Detroit River, but also in the Virtual Elimination Task Force of the International Joint Commission with particular

interest in the just transition for workers whose jobs might be eliminated with recommended changes in the chemical industry.

4.3.4 1987 Review and Protocol Amending the 1978 Great Lakes Water Quality Agreement

In 1987, the Parties negotiated several amendments to the Great Lakes Water Quality Agreement that were incorporated through a Protocol. Annex 2 was revised to include definitions and general principles for designating critical pollutants and Areas of Concern, and preparing Remedial Action Plans and Lakewide Management Plans for Critical Pollutants. The growing influence of neo-liberalism had resulted in questions about much of the research, surveillance and monitoring activities that were implicitly required to implement the Great Lakes Water Quality Agreement. New annexes were added through the Protocol to make these functions and responsibilities explicit. The Parties had become concerned about the influence of the International Joint Commission and decided to remove many of the roles and responsibilities, including the joint development of water quality objectives and reporting on the state of the lakes (Botts and Muldoon 2005 p. 103). The role of the International Joint Commission was now to evaluate progress under the Agreement from data and information supplied by the Parties. The Parties set up a Binational Executive Committee that met twice a year to oversee the implementation of the Great Lakes Water Quality Agreement. But the Binational Executive Committee did not establish a binational office with staff from both countries and thus many of the joint functions that had formerly been undertaken through the Great Lakes Regional Office were now undertaken unilaterally on a national basis.

Representatives of activist organisations were involved in the 1987 review of the Great Lakes Water Quality Agreement. At the same time, there was a growing expectation among the public that they would be consulted, particularly at the Biennial Meetings of the International Joint Commission. At the 1987 Biennial Meeting, held in Toledo, Ohio, the public participation had been constrained through participants having to submit written questions, which were then sorted and selected and to which the IJC staff drafted answers that were then read by the commissioners (Botts and Muldoon 2005 p. 40, 82, 117). The public outrage at the level of control resulted in the non-government organisations assembling ‘caravans’ of activists around each lake in preparation for the next Biennial Meeting that was to be held in Hamilton, Ontario in 1989. The objective was to focus the attention of the International Joint Commission on the injury to health caused by persistent toxic substances and on the need for the International Joint Commission to persuade the Parties to implement their policy of virtual elimination of discharges of persistent toxic substances.

In 1989, President George Bush (Senior) appointed Gordon Durnil as Co-Chair of the US Section of the IJC. Gordon Durnil had been on the Executive Committee of the Indiana Republican Party and his appointment to the IJC Chair was his political reward for delivering that state in the 1987 Presidential Election. At the Hamilton, Ontario, Biennial Meeting of the IJC, nearly 1000 people registered. The non-government organisations threatened that unless there was provision for the public to make representations of their concerns, they would host a competing meeting at the same time and location (Botts and Muldoon 2005 p. 119). The original agenda for the Biennial Meeting was altered and substantial amounts of time were given to

presentations by the public. Several other factors coalesced with this public movement. A new book, entitled *Great Lakes Great Legacy?* made the research findings of the effects of persistent toxic substances on humans, other mammals, birds and fish readily accessible to the public (Colborn et al 1989). The report of the Science Advisory Board included a detailed description of the human health effects and the report of the Council of Great Lakes Research Managers outlined the results of a workshop applying Hill's guidelines to six case studies of effects on humans and wildlife putatively caused by exposures to persistent toxic substances. Finally, Theo Colborn's explanation of her endocrine disruptor hypothesis resonated with Gordon Durnil because his family, which had been involved commercially in the estrogenic compound diethylstilboestrol, had suffered several mysterious and unexplained illnesses. Durnil was the driving force in subsequently preparing the radically different style of the 5th IJC Biennial Report to Governments, which focused on the virtual elimination of persistent toxic substances. Previous Biennial Reports had been primarily scientific and technical, but the 5th Biennial Report was also a political statement and further changed the relationship with the Parties.

4.3.5 Subsequent Reviews of the Great Lakes Water Quality Agreement

By 1989, there was an active movement centred on the Sierra Club and the Lake Michigan Federation, to transform the purview of the Great Lakes Water Quality Agreement to address many other Great Lakes issues (Botts and Muldoon 2005). The Agreement was reviewed in 1992 and the Commission advised the Parties that the Agreement was essentially sound and that the Parties should implement it. The Commission gave similar advice in 1998 and though there were many voices calling for significant changes and the Parties did some feasibility work to use the Great

Lakes Water Quality Agreement to address many of the other Great Lakes issues, the Parties decided not to reopen the Agreement for negotiation. In 2004, the Parties embarked on a major process of public consultation as part of the review of the Great Lakes Water Quality Agreement. The International Joint Commission, which had not been involved in previous reviews, sought a major role (Botts and Muldoon 2005 p. 224). It undertook public hearings around the basin and a four-day on-line consultation and issued a report advocating changing the purpose of the agreement from maintaining and restoring water quality to maintaining and restoring ecosystem integrity. The Parties through the Binational Executive Committee established an Assessment Review Committee to organise an elaborate public consultation on the Great Lakes Water Quality Agreement. Nine review working groups were set up to review particular articles and annexes against established evaluation criteria (Botts and Muldoon 2005 p. 221). Over an eight-month period and working through telephone conference calls and emailing of draft documents, hundreds of citizens in the Great Lakes basin participated.

Though the review process had the semblance of openness and fairness, it became apparent that the Parties had a hidden agenda. In the growing conservatism, characterised by the respective neo-liberal political economics in both countries, the Parties, for years, had used the ambiguity of the ecosystem approach to justify appropriations and funding for a wide array of Great Lakes programmes for conservation of biological resources that were unrelated to water quality. The hidden agenda was to change the stated purpose of the Great Lakes Water Quality Agreement by using the ambiguity of the ecosystem approach to justify having already implicitly broadened the Agreement. Though the ambiguity was not initially understood by

many of the participants on Review Working Group A which addressed Article 2 on the Purpose of the Agreement, at the end of the consultation period, a majority of participants voted to retain the focus on maintaining and restoring water quality. The draft report of the Assessment Review Committee recorded the differences of opinion, but the Executive Summary contained no reference to the lack of consensus and promoted transformation of the agreement into an agreement on ecosystem integrity.

The Parties have been strongly supported in the moves to transform the purpose by the Council of Great Lakes Industries (2002, 2003), which presumably wanted the focus removed from the virtual elimination of persistent toxic substances. Similarly, with the prospect of a significant infusion of funding through proposed US restoration legislation, the Lake Michigan Federation and the Sierra Club supported the Parties in their attempts to transform the purpose of the Great Lakes Water Quality Agreement into an agreement on ecosystem integrity (Botts and Muldoon 2005 p. 158-160, 192, Gilbertson and Watterson 2007). One of the central claims in the thesis is that the attempts to reframe the purpose of the Great Lakes Water Quality Agreement to address all issues related to the Great Lakes Ecosystem was one of the main factors among several in its failure, manifested by the continuation of injury to health.

4.4 Failure of the Great Lakes Water Quality Agreement

The thesis starts from the premise that there is continuing injury to health from exposures to persistent toxic substances and that the failure of the Parties during the past 35 years to restore water quality through implementing the Great Lakes Water Quality Agreement indicates that this is not the time to transform the stated purpose in Article 2. The ambiguity of the ecosystem approach and the consequent loss of focus

on the purpose of the Great Lakes Water Quality Agreement is an important factor in the failure. But the failure needs to be understood in the context of other sources of failure, such as deteriorating government relations concerning implementation and the quality of advice given by the International Joint Commission and its advisory bodies.

4.4.1 Government Relations and Implementation of the Great Lakes Water Quality Agreement

Since the Great Lakes Water Quality Agreement was first signed in 1972, governments in Canada and the United States have become progressively more ‘conservative’ resulting in environmental issues being removed from the political agenda in favour of economic considerations (Potts and Muldoon 2005 p. 90, 135, 139). While early conservatism in Canada was, like the Canadian liberal philosophy, concerned with accumulation of private wealth it was also concerned with nation building. However, starting with the election of Brian Mulroney in 1984 as Conservative Prime Minister, the balance shifted and Canada began to espouse neo-liberal political economics with its emphasis on small government, privatisation of public facilities and services, deregulation, laissez-faire economics, negotiation of ‘free trade’ agreements and globalisation, and the ideal of nation building tended to be marginalised in favour of individualism. Conservatism in the United States during this period was more complex. Not only did President Ronald Reagan embrace neo-liberalism, but much of the nation has since been swept by neo-conservatism, characterised, particularly since the fall of the Berlin Wall in 1989, by a triumphal self righteousness and belief that American values of ‘freedom’ and ‘democracy’ must be taken to the rest of the world, if necessary unilaterally and by force (Bokaer 2004, Barlow 2005, Hedges 2006).

4.4.1.1 The International Joint Commission

Current relations within the International Joint Commission and between the International Joint Commission and the Canadian and United States governments have seriously deteriorated compared with thirty-five years ago when the Great Lakes Water Quality Agreement was first signed. Initial tensions arose in the 1970s as a result of the funding and resources needed by the federal, state and provincial governments to participate on the advisory boards and within the committee structures coordinated by the Great Lakes Regional Office of the International Joint Commission (Botts and Muldoon 2005 p. 61, 76). The relationship further changed when President Ronald Reagan fired all the US Commissioners and used the International Joint Commission to make patronage appointments as awards for political services (Botts and Muldoon 2005 p.74). The situation was exacerbated when Prime Minister Brian Mulroney took office in 1984 and appointed three new commissioners who had no experience with binational relations involving the boundary waters (Botts and Muldoon 2005 p. 75). When President George W. Bush took power in 2001, he not only determined to roll back the legislative advances in environmental protection, but also fired all the International Joint Commissioners appointed by former President Clinton and the positions lay vacant for several months. Traditionally, the International Joint Commission operated through consensus, but after he eventually appointed Dennis Schornack as Co-Chair of the United States Section, unilateral decisions started to be imposed despite the unanimous opposition votes of the full complement of the five other commissioners (Botts and Muldoon 2005 p. 167). Dennis Schornack's unilateralism came to a

sudden halt in July 2007 when he was fired by President Bush for opposing Department of Justice lawyers over the zealous enforcement of a boundary issue.

4.4.1.2 The United States and Canada: Loss of Binationalism

The triumph of the 1972 Great Lakes Water Quality Agreement was the decision that the United States and Canada would work jointly on developing water quality objectives, fact finding and undertaking research (Botts and Muldoon 2005 p. 204-205). The Great Lakes Regional Office of the International Joint Commission was the central focus for the Parties to undertake the joint work. With the 1987 Protocol amending the 1978 Great Lakes Water Quality Agreement, many of the roles and responsibilities formerly undertaken by the International Joint Commission reverted to the Parties. Though the Parties set up the Binational Executive Committee, much of the work to implement the Agreement was now undertaken through the secretariats operating independently in each country (Botts and Muldoon 2005 p. 127). After more than fifteen years of these arrangements, the corporate memory was lost and the principals from Environment Canada and from the Great Lakes National Programme Office of the United States Environmental Protection Agency involved in the review of the Great Lakes Water Quality Agreement were not even aware of the joint nature of the work in the previous period. Similarly, in the spirit of unilateralism, rather than bilateralism or binationalism, the United States Congress developed a United States Great Lakes Restoration Financing Act without knowledge of or reference to the Great Lakes Water Quality Agreement, Boundary Waters Treaty or to the International Joint Commission (Botts and Muldoon 2005 p. 137).

4.4.1.3 Federal – Jurisdictional Relations

The relations between the respective federal governments and the jurisdictions concerning the implementation of the Great Lakes Water Quality Agreement have mainly centred on funding. There are subtle constitutional differences in Canada and the United States in terms of responsibilities for control of pollution. In Canada, the provinces are mainly responsible for all aspects of pollution control, whereas, in the United States, the states are responsible for carrying out national programmes. The Canada-Ontario Agreement, first negotiated in 1972 prior to signing the Great Lakes Water Quality Agreement, was periodically renegotiated with the federal government contributing 15% to the implementation of the Great Lakes Water Quality Agreement (Botts and Muldoon 2005 p. 75). With declining funds to environmental programmes as neo-liberal values increasingly influenced the federal government in the 1980s and eventually, the provincial government in the 1990s, controversies inevitably arose about funding for implementing the Great Lakes Water Quality Agreement. During the negotiation of the 1994 Canada-Ontario Agreement, the federal government asserted that funding for upgrading sewage treatment plants to meet the requirements of the Great Lakes Water Quality Agreement should come from fees based on the use of the water and sewage systems. In turn, the Province of Ontario expressed concern about having to implement obligations that had been negotiated by the federal government (Botts and Muldoon 2005 p. 95).

In the United States, the status of the Great Lakes Water Quality Agreement has been a major factor in the relations between USEPA headquarters in Washington and USEPA operations in the Great Lakes region centred in Chicago. Through the US Clean Water Act, USEPA has the lead responsibility for implementing the goals of

the Great Lakes Water Quality Agreement (Botts and Muldoon 2005 p. 29). The Water Division of USEPA has had a policy of emphasising national programmes rather than regional programmes and even after the establishment of the Great Lakes National Programme Office in Chicago in the mid 1970s, regarded the Great Lakes as a regional rather than a national programme. Because the Great Lakes Water Quality Agreement is an executive agreement rather than a treaty, USEPA headquarters in Washington has regarded it as interfering with domestic policies and laws (Botts and Muldoon 2005 p. 52). In 1974, President Richard Nixon, through USEPA headquarters, reallocated the Congressional appropriations intended for upgrading sewage treatment plants in the Great Lakes basin, for a new environmental programme in Chesapeake Bay (Botts and Muldoon 2005 p. 57). The relationship between the US federal government and the eight Great Lakes states for implementing the Great Lakes Water Quality Agreement has centred on federal funding. As early as during the 1978 renegotiation of the Great Lakes Water Quality Agreement, the states were concerned about reductions of federal funding. To reduce costs of monitoring of water quality in the open lakes, as part of the renegotiation, the US offered as part of their contribution to implementation, to submit the data on water quality in the tributaries that were collected by the states as part of the NPDES system. Five of the states declined federal grants because of the concern that they would have to assume further responsibilities negotiated by the US federal government (Botts and Muldoon 2005 p. 64).

4.4.1.4 Conclusions about government relations

The early optimism and morale that characterised the government operations to implement the Great Lakes Water Quality Agreement have been eroded by several

factors. Neo-liberal values, implemented by conservative governments in both nations, accelerated decreases in funding for Great Lakes programmes and threatened government relations. The neo-conservative unilateralism in the United States not only undermined consensus building in the International Joint Commission, but also likely exacerbated the trend towards implementing national programmes independently and without joint binational structures at the working level.

4.4.2 Scientific advice and implementation

Much of the Great Lakes Water Quality Agreement details the scientific programmes required to fulfil the purpose of maintaining and restoring water quality at the boundary, particularly from the effects of discharges of persistent toxic substances. These programmes include not only research and monitoring on the sources, fate and effects, but also development of discharge control technologies and action levels for protecting human health. One of the central roles of the International Joint Commission is the ‘tendering of advice and recommendations..... on problems of and matters related to the quality of the boundary waters of the Great Lakes System.’ The commissioners are seldom trained in science and have therefore relied on technical advice provided particularly by the Science Advisory Board (formerly the Research Advisory Board). The process of appointing members to the board is critical to the advice that is given and the claim is made here that part of the failure of the Great Lakes Water Quality Agreement has been the appointment of members to the Science Advisory Board with unsuitable qualifications and expertise or with serious conflicts of interest.

Science policy can be divided into ‘policy for science’ concerned with how and what science is funded and conducted and ‘science in policy’ related to how science is used in decision making (Jasanoff 1990 p. 5). The terms of reference of the Science Advisory Board were mainly associated with ‘policy for science’ and influencing Great Lakes research on water quality. However, subsection b) above, relates to the provision of scientific advice to the Commission ‘on particular problems’.

The means of undertaking the ‘policy for science’ responsibilities was partly through the preparation of an Inventory of Research. This has been an ongoing project with occasional publications of compilations of the ongoing research. From the beginning, there was support for preparing the Research Inventory. But there was ambivalence about using it for managerial purposes because the research managers of the Great Lakes research agencies, who comprised the membership of the Science Advisory Board, did not ‘want the Commission setting their research priorities.’ The preparation of the Research Inventory thus became an end in itself and failed to bring about change in research programmes or enable joint and collaborative programmes to be undertaken.

Three models of the composition and functioning of scientific advisory bodies have been proposed (Irwin 1995 p. 64) and these may be useful in understanding ‘science in policy’ relative to the Great Lakes Water Quality Agreement :-

- The ‘expert’ approach (let the facts decide);
- The representative or ‘democratic’ approach (let the people decide); and
- The non-ideological or ‘pragmatic’ approach (let common sense decide).

While each of these three models has applications in the implementations of the Great Lakes Water Quality Agreement, it is the 'expert' model that most closely fits the operations of the Science Advisory Board and that is used here to critically analyse the advice that has been provided relative to the purpose of the Great Lakes Water Quality Agreement.

The strengths of expert advisory committees have been listed as:- independence, neutrality, objectivity, and scientific expertise (Irwin 1995 p. 66). Another commentator has provided specific insights into the North American committees:-

Scientific advisory committees occupy a curiously sheltered position in the landscape of American regulatory politics. In an era of bitter ideological confrontations, their role in policymaking has gone largely unobserved and unchallenged. Advisory committees are generally perceived as an indispensable aid to policymakers across a wide range of technical decisions. They offer a flexible, low-cost means for government officials to consult with knowledgeable and up-to-date practitioners in relevant scientific and technical fields, supplementing the unspecialised and sometimes pedestrian expertise available within the executive branch. Perhaps most important, they inject a much-needed strain of competence and critical intelligence into a regulatory system that otherwise seems all too vulnerable to the demands of politics. (Jasanoff 1990 p. 1)

These strengths of expert committees resonate with the experiences of the Great Lakes Science Advisory Board. However, too frequently the uncertainties and

limitations of scientific information are not acknowledged and the experts who are interpreting the facts hold assumptions and values that are socially formed by their training and the institutions that employ them. In addition, the expert approach tends to 'reduce the possibilities for a wider public debate' (Irwin 1995 p. 67).

The primary risk...is therefore that of social dependency upon institutions and actors who...are increasingly... alien, obscure and inaccessible to most people affected by the risks in question' (Beck 1992 p. 4).

Further, if the public challenges expert committees, it can be difficult for the committees to maintain their credibility (Irwin 1995 p. 68). There are 'issues of trust and credibility...in the risk field' and a variety of methods are used by institutions to 'adapt procedures and self-presentation in order to secure or repair credibility, without fundamentally questioning the forms of power or social control involved' (Beck 1992 p. 4). Too frequently, institutional mechanisms have been set up to oppose critical analysis that could bring about social change in the public interest.

There is a growing literature on the scale and means of the corruption of scientific processes by corporate interests (Egilman and Bohme 2005). Frequently, appointments to the Great Lakes advisory boards of the International Joint Commission have included professionals with direct or indirect links to corporations which have undermined the sense of trust within the boards as well as between the International Joint Commission and the public.

The following are three statements of significant failures to provide timely or defensible advice. The first concerns the IJC recommendation on sunseting the use of chlorine; the second is the failure to use a precautionary approach to brominated flame retardants; and the third is the active process of diversionary reframing of the purpose of the Great Lakes Water Quality Agreement to attenuate the risk messages and to justify other environmental programmes.

4.4.2.1 Sunsetting chlorine

In its 6th Biennial Report, the International Joint Commission (1992) overreached its credibility when it recommended that “the Parties, in consultation with industry and other affected interests, develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks.” The Science Advisory Board had given advice, mainly in relation to preventing contamination of breast milk, that the IJC recommend ‘that persistent toxic substances, particularly organochlorines, are a hazard to human health in the Great Lakes basin’ International Joint Commission 1991 p. 41). The Commission had expressed its interest in controls on ‘classes of chemicals.’ Normally, in regulatory work, classes of chemicals mean those substances containing the same or similar structural moieties or mode of action. However, the IJC extended the meaning to include all chemical manufacturing processes involving chlorine. The response from the chemical manufacturers, which had formerly been benign and uninvolved, was immediate and overwhelming. More than 200 representatives from the chemical manufacturers attended the 1993 Biennial Meeting of the International Joint Commission held in Windsor, Ontario. In November 1993, President Clinton won the US Presidential Election and the chemical industry lobbied the White House to ensure that the “next lot of commissioners is not be as green as

the current bunch” (Durnil 1995). While the recommendation was popular with the activist organisations and became the focus of the 1993 IJC Biennial Meeting in Windsor, Ontario, it became the turning point in the politics, functioning and morale of the IJC as an effective bilateral organization. It exposed the Great Lakes Water Quality Agreement as having the potential to interfere with industrial power and the accumulation of capital and thus a threat to prevailing neo-liberal values.

4.4.2.2 Brominated flame retardants: Failure of precautionary decision-making.

While monitoring of the concentrations of organochlorine compounds in annual samples of herring gull eggs and lake trout showed significant exponential decreases throughout the Great Lakes, analysis of samples early in the millennium, revealed increasing concentrations of brominated flame retardants (Norstrom et al 2002). All activities in Canada involving polybrominated biphenyls had been proscribed by regulation under the Environmental Contaminants Act in 1979. The action followed an industrial incident in Michigan in which polybrominated biphenyls were put into bags labelled magnesium oxide and shipped to feed merchants throughout Michigan. The subsequent contamination of livestock and humans, the associated health effects and the economic disruption were used as persuasive evidence for proscribing all activities involving polybrominated biphenyls in Canada. There are particular concerns about the effects of brominated flame retardants on neurological development. The industry seems to have been undeterred by the incident and by the regulation and started to promote the use of polybrominated diphenyl ethers as flame retardants. Regulatory officials responsible for the Environmental Contaminants Act and the subsequent Canadian Environmental Protection Act seem to have been unaware of the substitution and of the growing threat of contamination. The neo-

liberal politics of the past twenty-five years seems to have played a role in rendering all decision-making on the control of chemicals through the Canadian Environmental Protection Act inefficient and ineffective and to the failure to prevent the increasing concentrations of polybrominated flame retardants. In that the purpose of the Parties in developing the Great Lakes Water Quality Agreement was ‘to maintain....the chemical....integrity of the waters of the Great Lakes Basin Ecosystem’, it seems apparent that the Parties failed to use a precautionary approach in decision-making concerning the brominated flame retardants.

4.4.2.3 Diversionary reframing

The loss of focus caused by the superimposition of an ambiguous ecosystem approach has been a major cause of the failure of the Great Lakes Water Quality Agreement (Gilbertson and Watterson 2007, Included as Appendix B). The ambiguity was introduced through a report, entitled “The Ecosystem Approach”, prepared by the Research Advisory Board, as advice for the International Joint Commission (1978b). The intent of the document was to advocate a better understanding of the sources of pollutants into the Great Lakes, the complex pathways and transformations of substances, and the routes of exposures of organisms, including humans (Botts and Muldoon 2005 p 191). The ambiguity was exacerbated because the Great Lakes Fishery Commission was developing a different “Ecosystem Approach” which referred to the multiple “ecosystem stressors” that were believed to have caused the declines and extirpations of various fish stocks in the Great Lakes.

The two “Ecosystem Approaches” represent two antithetical paradigms (Kuhn 1962) (see Table 8): one based on assumptions of parsimony of causality; the other based on

complex multi-causal explanations. Though the wildlife evidence indicated that the injury to the reproduction and development of fish-eating birds was caused by a small number of organochlorine compounds, the biological advice from the Research Advisory Board to the International Joint Commission was prepared by biologists with training in fisheries science and implicitly subscribed to a multi-causal ecosystem stressor interpretation of the Great Lakes Water Quality Agreement.

With the impending review of the Great Lakes Water Quality Agreement in 1987, a committee was formed, headed by two ecologists, through US National Research Council and the Royal Society of Canada (1985). Though the report of the committee mainly addressed issues of water quality and particularly pollution by persistent toxic substances, it also included extensive reference to implementing the ecosystem approach. But it had the following more ambitious subtitle: “*An Evolving Instrument for Ecosystem Management.*” Since its inception in 1972, academics had wanted to use the Great Lakes Water Quality Agreement for “multiple purpose management of the Great Lakes” (Dworsky and Francis cited in Botts and Muldoon 2005 p. 35). During the subsequent 1987 review of the Great Lakes Water Quality Agreement, the Parties decided not to use the agreement as a general binational mechanism for addressing other Great Lakes issues. The public, however, tends not to differentiate between work undertaken under the agreement and that which is undertaken through other mandates (Botts and Muldoon 2005 p. 32). Similarly, there seems to be little differentiation within government between funding for environmental programmes within the Great Lakes basin and funding allocated for implementing the Great Lakes Water Quality Agreement (Michael Goffin personal communication 2 September, 2007). With the growing scarcity of research funding from government sources

following the application of neo-liberal values, particularly through the 1994 Programme Review under the new Liberal Government of Prime Minister Jean Chretien (Kelly 2000), many parts of the scientific community within the Great Lakes basin tended to view the agreement as a mandate that potentially could justify their work even though it was unrelated to water quality. The publication of the RSC/NRC report in 1985 had framed a struggle, during the subsequent twenty years, between various networks of Great Lakes scientists and this has become the central debate in the present review of the Great Lakes Water Quality Agreement. At the core of the struggle is the question of what the Great Lakes Water Quality Agreement is about and what it is not about (Gilbertson and Watterson 2007, see Appendix B). Is it an agreement about maintaining and restoring water quality or is it about maintaining and restoring the ecosystem integrity of the Great Lakes basin (Botts and Muldoon 2005 p. 192)?

4.4.2.3.1 Failure to prevent mandate drift, substitution and withdrawal

The implications of these two interpretations of the Great Lakes Water Quality Agreement affect every aspect of its implementation (see Table 9) including: - priorities and programs; funding; selection of indicators for program evaluation; preparation of Remedial Action Plans and Lakewide Management Plans; appointments to the advisory boards; and consultations with the public and constituencies; as well as setting the agenda for Biennial Meetings of the International Joint Commission and for State of the Lakes Ecosystem Conferences hosted by the Parties.

Table 8. Contrasting Meanings of the Ecosystem Approach in relation to the Great Lakes Water Quality Agreement		
Water Quality Approach	Criterion	Ecosystem Management Approach
Multimedia Approach to Water Pollution	Point of Ambiguity	Multi-causal Approach to Biological Resource Management
International Joint Commission	Proponents	Great Lakes Fishery Commission
Boundary Waters Treaty	Mandate	Great Lakes Fishery Convention
Forensic eco-toxicologists: wildlife and environmental health researchers and authorities	Practitioners	Fisheries ecologists and managers
Species, population, individual, organ, cellular, and molecular	Level of biological organisation	Community and ecosystem
Toxicological injury: Population declines, increased mortality, morbidity, reproductive failure, congenital anomalies	Problem statement	Ecosystem alterations and loss of ecosystem integrity
Specific pollutants cause specific toxicological injury to exposed populations	Causal agents	Cumulative and synergistic effects of multiple stressors “flip” ecosystems into new equilibrium states
Hypothetico-deductive, parsimony of explanations; chemicals affect humans and wildlife	Scientific assumptions, biases, values and methodologies	SCOL consensus; Relativistic, post-normal science; Fish are insensitive to chemicals; Contaminants stigmatise the fisheries
Simple linear relationships that are knowable with high level of certainty;	Causal theory	Complex, non-linear, and chaotic relationships based on catastrophe, hierarchy, multiple attractors and self organization and that are likely unknowable because of uncertainty
Communication of precise causal statements with narrow constituencies and regulatory officials. Tendency toward exclusive statements.	Official and public communication with constituencies	Communication of concerns about ecosystem alterations to broadly-based constituencies, inclusive, formation of pluralistic coalitions of diverse interests
Health and population changes reversible	Management assumptions	Ecosystem changes irreversible
Proscribe activities involving specific chemical agent(s)	Management prescription	Manage all ecosystem stressors
Selection and monitoring of status and health of affected populations	Effectiveness evaluation	Ecosystem improvements cannot be related to specific management actions

After: Gilbertson 2000a & 2000b

Table 9. Contrasting Operational Implications of the two interpretations of the Great Lakes Water Quality Agreement.		
Water Quality Interpretation	Criterion	Ecosystem Management Interpretation
Reduce chemical exposures to reduce human injury and restore populations of wildlife	Operational Goals	Manage biological resources for human use by interlinking all Great Lakes issues and addressing the fragmented institutional and governance arrangements
Identification of chemicals and effects; Control of specific chemicals causing injury	Priorities	Identification of ecosystem stressors; management control of as many ecosystem stressors as possible
Statements of local injury caused by exposures to chemical and microbiological pollution; description of sources and sinks and proposed remedial actions; monitoring improvements	Remedial Action Plans	General local planning process for ecosystem and amenity improvements;
Statements of large scale injury caused by exposures to chemical pollution; description of sources and sinks and proposed actions; monitoring of improvements	Lakewide Management Plans for Critical Pollutants	General planning process for management of resources within a lake ecosystem;
Reestablishment of self-sustaining populations of extirpated indigenous species extirpated by pollution	Definition of Restoration	Establishment of an ecosystem with appropriate structure and function
Selection of organisms for trend monitoring of chemical exposures, effects and status of populations	Indicators	Selection of wide range of phenomena for ecosystem trend monitoring
Maintain existing provisions for research, monitoring and control of water pollutants contained in the current Great Lakes Water Quality Agreement.	Scientific Goals of the Review.	Transform into a Great Lakes Ecosystem Management Agreement: Incorporate provisions for addressing all aspects of Great Lakes ecosystem management including:- exotic species; physical habitat; wetlands; sustainable development; fisheries and wildlife management; climate change; education and transport.
Fulfill a routine requirement of Article X of the Great Lakes Water Quality Agreement.	Political Goals of the Review.	White House acting on behalf of chemical industry; Maintaining sea lamprey control and hatcheries budgets of the Great Lakes Fishery Commission and associated agencies.

After Gilbertson 2000a,b

In terms of the sociology of scientific knowledge, the community of Great Lakes scientists, regulatory officials, the International Joint Commission and its advisory boards and the Parties are confronted with two divergent causal stories (Stone 1989). Until recently, there was reluctance to choose between the hypotheses. But with persistent reiteration of the Parties and the International Joint Commission, much of the public and the civil service associated with the programme have come to believe that the Great Lakes Water Quality Agreement is about maintaining and restoring ecosystem integrity. Awards and selection of keynote speakers (Merton 1973) are other ways of impressing a message on a community and for the past three Biennial Meetings, the International Joint Commission has awarded science prizes to Great Lakes ecologists and selected others to deliver the keynote addresses.

4.4.2.3.2 Sociology of failure to acknowledge and resolve ambiguity

In recent years, the assumptions, biases and methodologies of the ecosystem management interpretation have encountered a serious scientific challenge that has not yet been acknowledged by Great Lakes fisheries scientists. In the 1980s, despite the prevailing beliefs that fish were not susceptible to persistent toxic substances and despite the dangers of stigmatising the use of the resource, efforts were made to determine whether persistent toxic substances were having an effect on fish reproduction and particularly on salmonid species (reviewed in Mac and Edsall 1991). These efforts yielded returns in the 1990s when Cook et al. (2003) started to research the role of the presence of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin on the historic status of Lake Ontario lake trout.

About six tons of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin had been released into Lake Ontario mainly from the manufacture of 2,4,5-trichlorophenol since the beginning of the 20th century, representing the largest known environmental accumulation of this compound in the world (Pearson et al 1997 p 2907). Based on toxicology experiments with a variety of species, lake trout embryos were demonstrated to be the most sensitive vertebrate tested to this compound (Walker et al 1991). Reconstruction of the history of dioxin contamination of Lake Ontario was determined from two radio-dated sediment cores (see frontispiece). And through a retrospective risk assessment it was demonstrated that Lake Ontario lake trout embryos were experiencing serious mortality by the 1940s and complete embryo mortality by the 1950s (Cook et al. 2003). Based on the risk assessment, the demise of the Lake Ontario lake trout was attributable to the 2,3,7,8-tetrachloro dibenzo-*p*-dioxin acting “alone.” There are several substances with dioxin-like activity including some other chlorinated dioxins, furans and biphenyls, and these might have contributed to the extirpation of the Lake Ontario lake trout through the same mechanism of action. These results posed the following immediate questions:- whether the demise of other fish species from Lakes Ontario were attributable to exposures to dioxins; and whether the demise of fish in other Great Lakes might be attributable to chlorinated organic compounds with dioxin-like activity (Gilbertson 1992a,b). Publication of the paper was long delayed because sets of measurements for two sediment cores from different locations on Lake Ontario had not been reconciled. However, presentations of the results and publication of individual components of the research were available from the early 1990s, but for more than a decade, fisheries researchers and research managers avoided the implications for their science.

2,3,7,8-tetrachloro dibenzo-*p*-dioxin is exquisitely potent to lake trout embryos (Walker et al 1991). The implications of the finding were the subject of a subsequent letter (Gilbertson 1992a,b) that explored the ‘deep-seated reluctance of fisheries researchers to invoke toxic chemicals as a cause of injury to fisheries resources and their inability to link causes with effects’. The letter went on to challenge the premises on which fisheries research was funded, and suggested that the entire body of 20th century knowledge on which Great Lakes fisheries policy was based should be re-evaluated in the light of these new findings.

This brief overview of the case study of the role of dioxins in the demise of the Lake Ontario lake trout population has been included because the new science challenges the prevailing paradigm of the Great Lakes fisheries researchers and the rationale for their long-standing proposal to transform the Great Lakes Water Quality Agreement into an agreement to manage the Great Lakes basin ecosystem. ‘Sometimes new evidence may change the character of disputes’ (Nelkin 1992 p. xxii). A more detailed history may be warranted because this might serve as an exemplary case study to further inform those involved in the sociology and philosophy of science. Suffice it to say that the social behaviour of the research scientists and managers seems to accord more to a Lakatosian model than a Kuhnian one. The ‘negative heuristic’ has been to place a ‘protective belt’ (Chalmers 1982 p 80) around Great Lakes fisheries science to ensure that the basic assumptions underlying the research programme, its hard core, are not rejected or modified. The hard core is the assumption from the 1971 SCOL Symposium that the ‘appropriate organisational level’ (Dunbar 1980 p. 127) at which to undertake Great Lakes fisheries research is at the ecosystem level. From this arises the ‘positive heuristic’ that the guidelines for

development of the research programme for maintenance and restoration of the Great Lakes fisheries will be undertaken inclusively, by investigating all putative factors and rejecting none. From it also arises a logic for action to manage all conceivable ‘ecosystem stressors’.

Deconstruction of Great Lakes fisheries science might have far-reaching implications for fisheries programmes in both countries that are structurally dependent on decisions made in the past. ‘The interests reflected in one choice of classification rather than another may become structural, embodied in institutional routines, rather than voluntaristic’ (Wynne 1989 p. 25). During the past fifty-years since the signing of the Great Lakes Fishery Convention and the establishment of the Great Lakes Fishery Commission, a large programme has been put in place for research and control of the sea lamprey. Similarly, fisheries jurisdictions around the Great Lakes have ‘managed around’ the poor reproductive success of wild fish stocks in the Great Lakes by constructing and operating large hatcheries. The process of securing the appropriations for these two substantial programmes is an annual event in negotiations between the Great Lakes Fishery Commission and the Canadian and United States federal governments. The suggestion that contamination by persistent toxic substances rather than depredations by the sea lamprey were the critical factor affecting lake trout populations could seriously disrupt these negotiations and the annual funding for the existing sea lamprey control programme.

4.5 Summary and conclusions

The development of programmes to implement the 1972 Great Lakes Water Quality Agreement was undertaken enthusiastically by a growing community of Great Lakes

scientists and administrators in an era of optimism and high morale, particularly through binational administrative arrangements centred on the International Joint Commission and its Great Lakes Regional Office. New information about the effects and threats of exposures to persistent toxic substances lead to recognition that the task of maintaining and restoring Great Lakes water quality was more complex than had been initially understood. However, even before the application of neo-liberal politics in the 1980s, governments were concerned about the funding for involvement in the binational processes and the costs of implementation, and relations between governments deteriorated. Many of the binational roles and responsibilities of the International Joint Commission were removed in the 1987 Protocol amending the Great Lakes Water Quality Agreement, but though the Parties set up a Binational Executive Committee, they failed to understand or implement the most basic joint functions such as the adoption of water quality objectives in common.

In the late 1980s and early 1990s, a growing number of activists and members of the public joined the Great Lakes community and were successful in lobbying the International Joint Commission at its Biennial Meetings to urge the Parties to implement the policies of the Great Lakes Water Quality Agreement, particularly concerning the virtual elimination of discharges of persistent toxic substances. The recommendation of the International Joint Commission to ‘sunset’ the use of chlorine provoked the chemical manufacturers who successfully lobbied the Clinton White House in the appointment of the next group of US Commissioners. Increasing concentrations of brominated flame retardants indicated the general failure to the Parties to implement a precautionary approach to the introduction of new persistent toxic substances as substitutes for those proscribed. Through a process of

diversionary reframing, based on the ambiguity of Article 2 of the 1978 Great Lakes Water Quality Agreement, the Parties are poised to renegotiate the Agreement to remove the focus from maintaining and restoring water quality and to substitute an agenda of maintaining and restoring ecosystem integrity to the Great Lakes Basin. The reframing represents a radical policy change and needs to be examined within the context of Article IV of the Boundary Waters Treaty and the agreement not to pollute the boundary waters to the injury of health.

During the period leading up to the 1972 negotiation of the Great Lakes Water Quality Agreement, there was a growing awareness of the threats posed by PCBs and mercury. There is extensive evidence of the effects of PCBs on human health in the Great Lakes basin. There is only limited information on the suspected effects of mercury (Gilbertson 2004). The results of the epidemiological research, using cerebral palsy hospitalisation of males as an index of congenital Minamata disease, are reported in Chapter 5 and are discussed in relation to Hill's guidelines. If there are convincing grounds for believing that mercury, as well as PCBs, is causing injury to health, the proposed refocusing may need to be rethought.

CHAPTER 5: TESTING EFFECTIVENESS OF IMPLEMENTATION OF THE AGREEMENT

5.1 Introduction

The purpose of this chapter is to further test the limitations of the Parties in implementing the Great Lakes Water Quality Agreement. The results of the analysis of the Health Canada health data and statistics for cerebral palsy (5.2) and the lack of institutional response (5.3) are detailed. The uncertainties from the original observations are reduced through the application of Hill's viewpoints (5.4).

5.2 Results

At the time of the signing of the Great Lakes Water Quality Agreement in 1972, mercury had already been identified as one of the persistent toxic substances that were of concern. During the more than three decades of research under the Agreement there has been the development of an extensive literature on the effects of PCBs on human populations. However, section 3.4 noted that there had been no research that had been undertaken to find an association between effects on human populations and exposures to mercury in the Great Lakes basin. This posed the question of whether there were no effects of mercury in Great Lakes communities or whether the health authorities had failed to attempt to find effects that were occurring. The finding of elevated rates of hospitalisation of males for cerebral palsy in several Canadian Areas of Concern and the apparent association with elevated mercury concentrations (Gilbertson 2004) suggested the latter. The methodology for undertaking the further test has been detailed in section 2.3. The test is based on the use of Health Canada health data and statistics for cerebral palsy hospitalisation for males as an indicator of outbreaks of congenital Minamata disease.

Figure 2 comprises the male and female age standardised rates of morbidity as hospitalisation for cerebral palsy per 100,000 population for Ontario and for each of the 17 Canadian Areas of Concern (see Figure 1). The figure starts with rates for Thunder Bay (AOC #4) at the western end of Lake Superior and follows the shoreline east and south to Cornwall on the St. Lawrence River (AOC #42). Rates that are statistically significantly elevated at the 95% level of confidence are marked with a 'b' and those at the 99% with an 'a'. Rates that are significantly lower at the 99% level are marked with a 'z'. Locations where there were fewer than 4 cases and where rates were either elevated or lower are marked, as in the original Health Canada tables of morbidity as hospitalisation, with flag a #.

One of the first possible anomalies in these data is that the overall rate of hospitalisation for Ontario males seems to be elevated compared with the rate for females. The apparent excess number of hospitalisation cases for males appears to be 161 cases above the 723 cases for females. The apparently larger number and rate for males (22% higher) may present problems in calculating the 'expected' number of hospitalisations in each locality and thereby may influence the statistical significance of the observed numbers of hospitalisation cases for males. If the excess number of hospitalisation cases for males were significantly elevated, the question arises whether they indicate neurological effects of methyl mercury detectable at the provincial level (see section 5.4.6 on strength of association below).

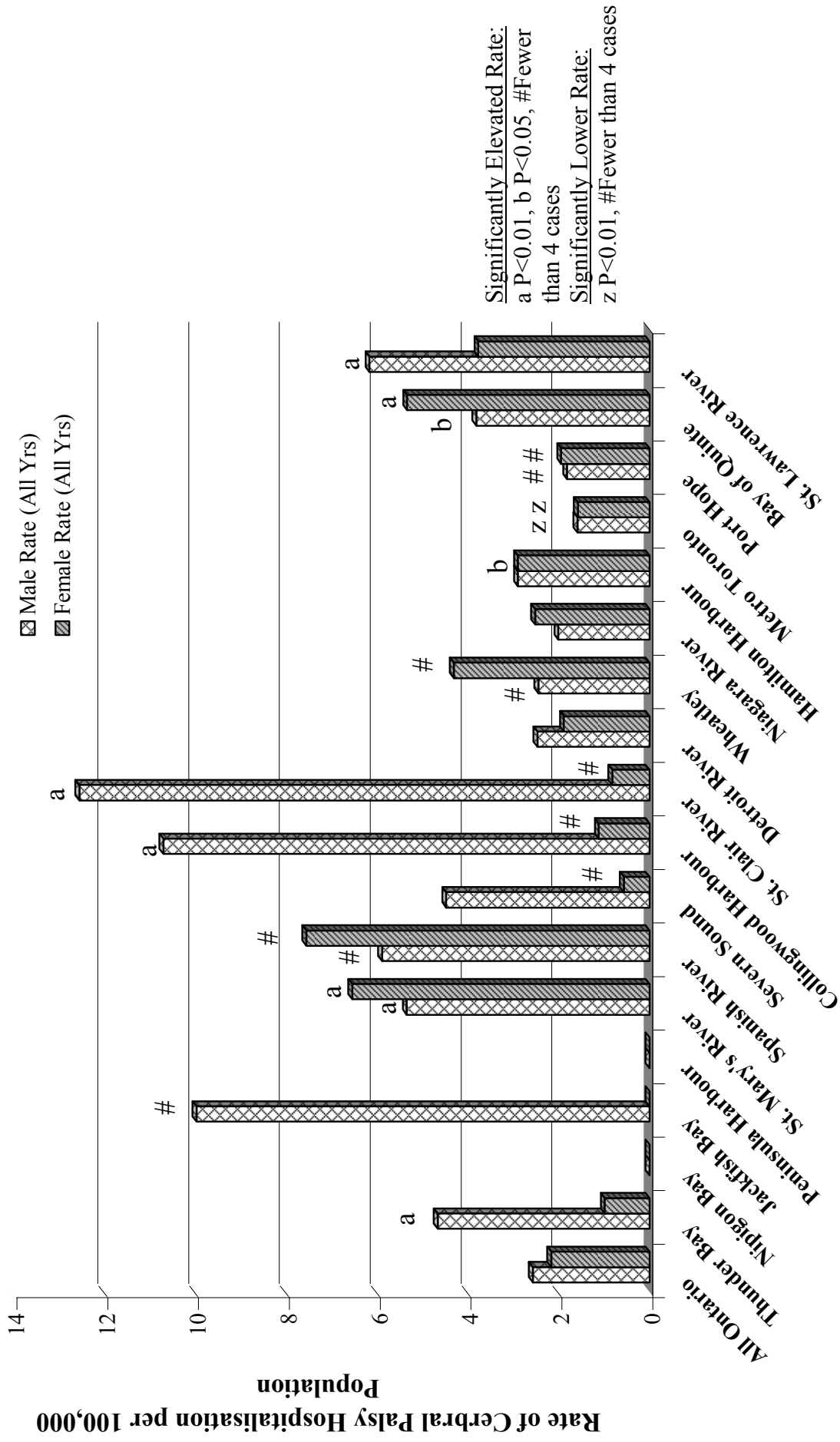


Figure 2. Cerebral palsy hospitalisation rates in 17 Canadian Areas of Concern all years, 1986 – 1992 (From Gilbertson 2004).

The rates of male and female hospitalisation for cerebral palsy in the former Metro Toronto (AOC #36) were not only similar, but also were significantly lower than the expected rate. This may indicate the availability of tertiary care facilities for cerebral palsy patients in this large metropolitan area. The possibility must also be posed that rates of hospitalisation in other large municipalities, such as Hamilton (AOC #37), Niagara Falls (AOC #41) and Windsor (Detroit River AOC #40) may be similarly affected by the availability of tertiary care facilities.

There are several Areas of Concern where the rate of male cerebral palsy hospitalisation is elevated compared to the rate for the rest of the province. The rates at two Areas of Concern on Lake Superior were elevated. At Thunder Bay, the rate was statistically significantly elevated to 3.32 times the provincial rate. While the rate at the very small community of Jackfish Bay (AOC #2) was 3.89 times the provincial rate, the sample size was less than 4 and has been marked with a flag #. In the two communities at the southern end of Georgian Bay off Lake Huron, the rates at Severn Sound (AOC #19) and Collingwood Harbour (AOC #43) were, respectively, 1.71 and 4.02 times the provincial rate. The rate for Collingwood Harbour was statistically significant. On the St Clair River (AOC #39), the rate for Sarnia and surrounding areas was 4.98 times the provincial rate. In all three of these locations, the rates for females were lower than the provincial rate and were flagged (#) by Health Canada because there were less than 4 cases (Table 2). On the St Lawrence River, the rate for males at Cornwall was 2.42 times the rate in the rest of the province.

Hamilton Harbour was the only Area of Concern where there was an elevated rate of cerebral palsy hospitalisation for females that was statistically significant. There

were, however, more male hospitalisation cases (60 cases) than females (58 cases) suggesting that there likely was a problem with using the apparently elevated provincial rate for males to calculate the expected number of cases.

There were two other Areas of Concern where elevated rates were statistically significantly elevated for both males and females. These were at the St Mary's River Area of Concern (AOC #38) at Sault Ste. Marie located between Lake Superior and the North Channel of Lake Huron, and at the Bay of Quinte Area of Concern (AOC #34) on the north-east shore of Lake Ontario. The same pattern of elevated rates in males and females occurred at Spanish River (AOC #20) and Wheatley (AOC #29), but these were marked with flags (#) because there were fewer than 4 cases. Conversely, the rates for males and females at Port Hope (AOC #35) were lower than expected, but these were flagged (#) because there were fewer than 4 cases.

From these data and statistics, it can be concluded that six of the seventeen Areas of Concern on the Canadian side of the Great Lakes have elevated rates of hospitalisation for cerebral palsy for males. These locations are in the following communities:- Thunder Bay and Jackfish Bay situated on Lake Superior; Severn Sound and Collingwood Harbour, located at the southern end of Georgian Bay off Lake Huron; in the community at Sarnia and district on the St Clair River; and at Cornwall beside the St Lawrence River. Health Canada originally collected data and statistics on health endpoints in Areas of Concern to generate hypotheses in relation to community exposures to pollution. Cerebral palsy was included because of the association with exposures to methyl mercury in communities at Minamata and Niigata in Japan in the 1950s and 1960s, respectively, and with the Iraqi population in

the 1970s. Epidemiological studies have demonstrated the differential neurological susceptibility of male fetuses and infants compared to females from exposures to methyl mercury and male susceptibility has been demonstrated experimentally. Thus these elevated rates of hospitalisation for cerebral palsy in males in these six Areas of Concern may indicate that these communities are exposed to elevated levels of mercury associated with harmful exposures of developing fetuses and infants.

5.3 Institutional responses and uncertainty of initial findings

This early analysis indicates the possibility that there has been a series of previously undetected outbreaks of congenital Minamata disease in several Canadian communities located on the shoreline of the Great Lakes. Exposures of populations to environmental contaminants could shift intelligence downwards, thereby contributing costs to society from mental illness and loss of intelligence and can be compared with costs associated with other environmental controversies such as SARS (Weiss 1997). The annual losses of earnings from a 1-point and a 5-point decrease of IQ for the population of Ontario are, respectively, \$2.3 billion and \$11.5 billion (1999 CDN dollars) (Muir and Zegarec 2001). The SARS outbreak in Toronto tended to stigmatise the city and the rest of Ontario and Canada. Analysis of 2003-2004 Ontario Finances suggested that direct costs of the quarantine in response to the SARS outbreak were about \$12 million (Gupta et al 2005). In April, 2003, in the Toronto area, bus trip cancellations cost between \$5 and 6 million and hotel cancellations cost \$39 million and the total cost from 2003-2006 were estimated to be \$722 million (CBC News 2003).

Too frequently, preliminary observations of this kind entail either determinations of concentrations of pollutants in asymptomatic people who have been sampled from a contaminated area, or detection of possible occurrences of effects without any exposure data. The observations reported in the study, fit the latter category. There have been claims that ‘junk science’ has been used in U.S. federal processes to regulate risks (Graham 1995 pp 394, 401). Specifically, the fish restaurant trade in the United States has attempted to discredit Dr. Phillippe Grandjean, Dr. Jane Hightower and Dr. Kathryn Mahaffey as ‘activists’ for their work on the toxicological effects of mercury on human health (<http://www.fishscam.com/activists.cfm>). The methodological limitations and the inherent uncertainties in these indications of congenital Minamata disease in Canadian Great Lakes communities make the findings prime candidates for these epithets and attacks. The preliminary findings were therefore presented at an IJC Consultation on Cerebral Palsy (February 27, 2002) and to the following organisations, for critical review:- The National Water Research Institute, at Burlington, Ontario; The Occupational Health Clinics for Ontario Workers (Sarnia); The Great Lakes Water Quality Board; The Council of Great Lakes Research Managers; and the Workgroup on Ecosystem Health – Great Lakes Science Advisory Board. After much revision, the final paper was presented at the International Joint Commission’s Workshop on An Ecosystem Approach to the Health Effects of Mercury in the Great Lakes (February, 26-27, 2003) and published, after peer-review, in *Environmental Research* (July, 2004). Electronic copies of the galley proofs were sent to the Ontario Regional Director General of Health Canada in Toronto and to the Director of the National Water Research Institute in Burlington who forwarded them to Health Canada. The apparent lack of response from all these senior civil servants and from their organisations would suggest that there is an

extensive social process of attenuation of the risk message occurring (Kasperson et al 2003 pp 13, 25).

Despite the process of attenuation, there are potentially far-reaching implications of these preliminary findings. On the one hand, the findings indicate that women of childbearing age in the Great Lakes basin may be being exposed to concentrations of methyl mercury that are injurious to foetal, infant and child development. They may also show that the precautionary measures, such as fish consumption advisories, taken by governments more than thirty-years-ago were unsuccessful in protecting human health. They also suggest that if there are cases of cerebral palsy that have been caused by early exposures to methyl mercury, then there is likely a much larger number of infants who were, and are being born with other developmental disorders. These might include seizures, mental retardation and strabismus, to mention but a few of the possible conditions associated with exposures to methyl mercury (see section 5.2.2.2 below). These developmental deficits in infants are irreversible and represent not only untold misery for the victims and their families, but they also place a massive financial burden on society through medical and child care costs, loss of employment potential and the need to provide compensation in the form of pensions. Delay in raising the alarm might result in harm to another generation.

On the other hand, as was pointed out in the testimony before the United States Senate (1970), the Great Lake fisheries are worth a great deal of money. Information about the presence of contaminants such as PCBs and mercury in fish has resulted in closures of commercial fisheries and advisories on the consumption of sport fish. Information about the possibility of the occurrence of a series of outbreaks of

congenital Minamata disease might have disastrous economic effects on fisheries and tourism. For example, the livelihoods of the commercial fishermen and charter boat captains could be jeopardised. Similarly, the incomes of all those associated with the native food fisheries and with the sport fisheries including the bait and tackle suppliers, and marina and tourism operators could be at risk.

The dilemma posed by these preliminary observations is not unique in the field of environmental health but it does pose ethical questions about communication of the results, particularly to those affected (Sharp 2003). The European Environment Agency (2001) published a series of case studies of 'early warnings' and the action that was or was not taken to respond to them. One of these case studies concerned the effects of toxic substances in the Great Lakes basin (Gilbertson 2001). As occurred with the other case studies (European Environment Agency 2001, Gee 2005), we are now confronted with uncertainty not only in the reliability of the observation and its implications, but also in terms of the scale and severity of the injuries posed and the responses that are appropriate to these circumstances. One of the effective ways that action could be undertaken expeditiously without raising alarm and frightening the fishermen and Great Lakes communities is to undertake a critical review of these data in relation to the wealth of published and unpublished reports on mercury in the environment. This might reduce the uncertainty around the case and give indications of the research, remedial and regulatory actions appropriate to the situation.

Health Canada compiled health data and statistics on health endpoints that might be related to pollution. One of these health endpoints was cerebral palsy hospitalisation because of its association with exposures to methyl mercury. Within the limitations

of the methodology, there are indications that there are elevated rates of hospitalisation for cerebral palsy, particularly among males, in several Canadian Areas of Concern in the Great Lakes basin and these locations are associated with high mercury concentrations. The findings may form the basis for not only concluding whether injury to health is still occurring, but also for evaluating the adequacy of the response of officials in the various Great Lakes jurisdictions to the information. The method chosen to reduce the uncertainties is by applying Hill's viewpoints.

5.4 Reducing uncertainty: application of Hill's viewpoints

The application of the methodology is facilitated by the availability of several systematic reviews of the literature on the toxicology and environmental chemistry of mercury (United States Environmental Protection Agency 1997, Agency for Toxic Substances and Disease Registry 1999, National Research Council 2000). Certain facts, theories and references are repeated because the same piece of information may have relevance in relation to more than one epidemiological viewpoint and thereby contribute to the corroboration or falsification of the hypotheses.

5.4.1 Probability

Probability had been used 'as a means of quantifying and excluding chance events' (Susser 1973) and has been introduced as one of the 'criteria' for inferring a causal relationship (Susser 1986b). Intrinsic to the aspect of probability in judging whether there is a causal relationship is the need to consider statistical power, particularly for small study areas. The size of the populations in each of the 17 Areas of Concern and

thereby the statistical power of the test that was being applied was a consideration in compilation of the data (Health Canada 1998).

There has been a growing interest in the problems of detecting anomalous rates of disease within communities associated with industrial activities or the disposal of hazardous wastes. For example, using postal codes and hospital discharge data for New York State, 15% higher rates of coronary heart disease and 20% higher rates of acute myocardial infarction were found for patients from postal code areas adjacent to a landfill site containing persistent organic pollutants (Sergeev and Carpenter 2005). Similarly, an association has been shown between residence near PCB-contaminated landfill sites in New York State and the risk of a male child being born with a low birth weight (Baibergenova et al 2003).

In Britain, some of this research has been undertaken on a national basis by the Small Area Health Statistics Unit, at Imperial College, London (Elliott and Wartenberg 2004), but fewer associations have been found. For example, no increase in rates of abnormalities, low birth weight or stillbirths were found in 61 Scottish communities located within 2 km of special landfill sites (Morris et al 2003). Similarly, no increase was found in a series of cancers in Great Britain associated with residence within 2 km of landfill sites or special (hazardous) waste sites, (Jarup et al 2002). There was no evidence of an association between residence in proximity to coke operations in England and Wales and hospital admissions for respiratory or cardiovascular disease (Aylin et al 2001). However, children near a plant on Teesside, had higher hospitalisation rates for respiratory disease and asthma (Aylin et al 2001). The Unit did, however, find an association between proximity to landfill sites in Great Britain

and a small increased risk of congenital anomalies and low birth weight (Elliott et al 2001). The researchers undertaking these respective epidemiology studies in New York State and Great Britain were using large databases and the inconsistencies in some of the results may reflect real differences in the dangers to residents living near New York State compared to British operations.

In the specific case of the Health Canada data and statistics, there were insufficient numbers (data not shown) of mortality cases for cerebral palsy to indicate Areas of Concern where the community might be exposed to methyl mercury. The only exception was Thunder Bay that had 4 deaths between 1986 and 1992 attributed to cerebral palsy, to yield a rate that was 3.32 times higher than the provincial rate ($p < 0.05$). By contrast, the data on hospitalisation for cerebral palsy provided a sufficient number of cases that there was statistical power to identify those Areas of Concern that might have communities exposed to elevated levels of methyl mercury. For example, the rates for males at Thunder Bay, Collingwood, Sarnia, and Cornwall were all statistically significantly elevated at the 99% probability level above the provincial rate. Similarly, this was the probability level for the elevated rates for both males and females at St Mary's River, and the elevated hospitalisation rates for females at the Bay of Quinte. The decreased hospitalisation rates for males and females in Toronto compared with the provincial rate were, similarly, at the 99% level of probability. There were Areas of Concern where the rates of morbidity as hospitalisation were significantly different from the provincial rate at the 95% probability level including elevated rates for females at Hamilton and males at the Bay of Quinte.

The consideration of the probability viewpoint is important because it indicates that there is sufficient statistical power in the Health Canada datasets to conclude that, for the many locations where elevated hospitalisation rates for cerebral palsy were found in males, there is a low probability that the deviations from the provincial rates arose by chance.

5.4.2 Specificity

Specificity has been defined as the precision with which the occurrence of one variable will predict the occurrence of another and while it is comforting, it is not essential (Susser 1986a p.120). This epidemiological viewpoint has two components. First, there is the specificity in the causes of a given effect: does only methyl mercury lead to cerebral palsy or is cerebral palsy caused by other agents? Secondly, there is the specificity of the effects of a given causal factor: does methyl mercury lead only to cerebral palsy or does it lead to other pathologies and conditions?

Cerebral palsy is a condition that has attracted much attention from the legal profession, particularly in the United States, as a possible disease related to the quality of the management of labour, particularly in hospital deliveries. In the past, cerebral palsy has been assumed to be associated with perinatal asphyxia. Escalating legal claims against obstetricians, alleging injury to the infant during delivery resulting in cerebral palsy, have cost the medical professionals dearly not only in compensation and increased insurance but also in reluctance of doctors to enter this specialty within the medical profession. Recently, there have been several reviews of the literature from within the professions (Mandelbaum and Paneth, 2000, American College of Obstetricians and Gynaecologists, and American Academy of Paediatricians 2003). These reviews have provided much more complete assessments of the relative

importance of other risk factors, including consideration of exposures to methyl mercury.

5.4.2.1 *Specificity in the causes of cerebral palsy*

In terms of specificity in the cause, at the IJC Consultation on Cerebral Palsy, Paneth reviewed the risk factors associated with cerebral palsy (see Table 10). He noted, first, that there was a tendency for infants born with extremely low birth weight to develop cerebral palsy. Survival of very low birth weight infants has markedly improved since the 1960s resulting in an increasing proportion of infants with cerebral palsy in the population.

Term Infants	Congenital viral infections (rubella, possibly cytomegalovirus)
	Intrauterine strokes
	Congenital anomalies not yet diagnosed
	Metabolic disorders (hypoglycaemia, hyperbilirubinemia, aminoacidurias)
Preterm Infants	Very low birth weight
	Chorioamnionitis
	Low levels of thyroid hormone
	Ventilatory management

^aAfter Mandelbaum and Paneth 2000

An exhaustive review of the literature on risk factors associated with cerebral palsy has been published (The American College of Obstetricians and Gynaecologists and the American Academy of Paediatrics 2003). Though intra-partum hypoxia can result in neonatal encephalopathy and cerebral palsy, there are many other risk factors that account for most of the cases. These other risk factors include developmental

abnormalities, metabolic abnormalities, autoimmune and coagulation defects, infection, and trauma or a combination of these factors.

More importantly in terms of 'specificity', the report included the following reaffirmation of the relationship between cerebral palsy and exposures to methyl mercury:- 'Cerebral palsy, cerebral atrophy, and neurological dysfunction have been associated with maternal exposure to concentrations of organic mercury exposure' (The American College of Obstetricians and Gynaecologists and the American Academy of Paediatrics 2003 p 20). Further, the report also noted under the general heading of 'Chemicals' that:- 'No scientific data support an association of neonatal neurological maldevelopment or damage from maternal occupational exposure to organic solvents (eg, painters, gas station attendants), general chemicals (eg hairdressers, dry cleaning workers), or various pesticides (with the exception of methyl mercury)'. The last parenthesis is the key in terms of 'specificity' in that methyl mercury is the only compound known to be associated with cerebral palsy.

Based on these reviews, it would appear that there is a consensus on the role of methyl mercury in causing cerebral palsy and that there is agreement that there is no specificity in methyl mercury being the only cause of cerebral palsy. But it appears that methyl mercury is the only chemical compound known to cause cerebral palsy and in this sense there is a high degree of specificity in relation to exposures from either environmental or occupational sources of chemicals.

5.4.2.2 *Specificity in the effect of methyl mercury*

In terms of specificity in the effect, methyl mercury is associated with many lesions in addition to cerebral palsy. The gross lesions, in addition to cerebral palsy, associated with congenital Minamata disease and their frequency of occurrence from prenatal exposure to alkylmercury compounds are listed in Table 11 (Harada 1978). There are many signs and symptoms associated with prenatal exposure to methyl mercury in addition to cerebral palsy. Therefore, it seems that there is no specificity in cerebral palsy as the only effect caused by prenatal exposure to methyl mercury. This is important because without a specific lesion it has proved extremely difficult to reliably diagnose victims and thereby decide compensation cases.

Table 11. Gross Effects of Prenatal Exposure to Methyl mercury (After Harada 1978)

Instability of the neck
Convulsions
Failure of the eyes to follow
Intelligence disturbance
Primitive reflex (grasp)
Cerebella symptoms
Disturbance of body growth and nutrition
Dysarthria (speech)
Limb deformities
Hyperkinesia (chorea, athetosis)
Hypersalivation
Paroxysmal symptom
Strabismus
Pyramidal symptom (motor)
Microcephaly
Clumsiness
Symptoms on the left and right sides undifferentiated

5.4.2.3 *Conclusions about specificity*

The lack of specificity in both the cause and the effect need to be re-examined in relation to the null hypotheses of the thesis which state that:-

- In Areas of Concern with elevated methyl mercury concentrations, cerebral palsy hospitalisation cases are no more prevalent than in the rest of Ontario; and
- In Areas of Concern with elevated methyl mercury concentrations cerebral palsy hospitalisation cases are no more prevalent in males than in females.

The second null hypothesis concerns the differential susceptibility of males compared to females and initially derived from observations on Cree children (McKeown-Eyssen et al. 1983) and the research on victims in the 1970 Iraqi outbreak (Marsh et al. 1987b, Clarkson 1993). Within the general population, the gender of the infant has not been identified as a risk factor for developing cerebral palsy. Though methyl mercury has been associated with a higher incidence of neuro-developmental anomalies in males, the epidemiological literature (Table 7) does not identify cerebral palsy specifically as one of these and this remains an assumption of the thesis. If prenatal exposure to methyl mercury were shown specifically to be related to a higher incidence of cerebral palsy hospitalisation in males, this would improve the reliability of the measure as an index of outbreaks of congenital Minamata disease. The exception is expected to be in circumstances where maternal methyl mercury exposure levels are so high that there is differential mortality of the males and a consequent higher hospitalisation rate for females with methyl mercury associated disease (Harada 1994). There is some specificity in methyl mercury being the only chemical compound known to cause cerebral palsy and to be differentially more neurotoxic to males. There are thus aspects of specificity that are relevant to the hypothesis in both the cause and in the effect.

5.4.3 Time order

Time order or temporality refers to the necessity that the cause precedes the effect in time (Fox 1991, Susser 1986b, Hill 1965). This is a powerful epidemiological viewpoint for rejecting spurious putative factors. But the converse, *post hoc ergo propter hoc*, is a fallacy: Just because the effect came after the exposure to the putative factor it does not mean that it was necessarily caused by it. Another aspect of temporality relates to:- ‘Elimination or modification of the putative cause.....should decrease the incidence of the disease (control of polluted water or smoke or removal of the specific agent)’ (Evans 1976 p 192). For example, the introduction of unleaded gasoline in the mid-1970s resulted in the reduction of the concentration of lead in the blood of children and in improvements in neurological development and function (Needleman and Bellinger 1991).

At this point, there is no information readily available on when the elevated rates of hospitalisation for cerebral palsy started occurring in some of the Canadian Areas of Concern. More specifically, there are no readily available data on when there were grounds for believing that the rates of hospitalisation for cerebral palsy in males started to occur. All that can be achieved with the Health Canada health data and statistics is to demonstrate that for the period 1986-1992, it is not plausible to demonstrate, on temporal grounds, that communities in the Areas of Concern with elevated rates of male cerebral palsy hospitalisation were not potentially exposed to high mercury levels.

Though such a viewpoint seems so obvious, there have always been difficulties in finding retrospective data or historical samples on which to base a time-order case.

Ideally, there would be data on levels of mercury in blood or carefully preserved samples of hair. Biological materials have become available retrospectively to provide samples for reconstructing a time order series. For example, in Japan, a short length of the umbilical cord is commonly taken as a talisman, dried, and preserved. These were available, fortuitously, for those (Nishigaki and Harada 1975) investigating the original Minamata disease outbreaks to determine levels of mercury exposure on a temporal basis (Harada et al. 1999). Health Canada has large numbers of hair samples, particularly from First Nations people, that have been analysed, but these data are not readily available except to the individuals and to their bands (Health Canada 1999).

In relation to temporality, there are other less direct data that potentially might serve as surrogates of exposure including the dates when the mercury chloralkali plants were constructed and became operational. There are some radio-dated sediment cores that can be used to show the time course of contamination, though these reflect concentrations at the scale of the lake-wide systems rather than for the local Areas of Concern. Finally, there are extensive data on levels of mercury in fish sampled from across Canada and that have been analysed for temporal trends in levels of mercury in the 17 Areas of Concern (Weis 2004).

Table 4 contained information on the dates when the mercury chloralkali plants became operational. The Thunder Bay mercury chloralkali plant operated from 1966 to 1973 which preceded the period of the Health Canada data from 1986-1992. In Sarnia, one of the Dow Chemical of Canada plants started in 1948 and the second came on stream in 1970. It would seem that there are no temporal grounds for

rejecting mercury as a putative factor in the elevated rates of male cerebral palsy hospitalisation in Sarnia (St Clair River Area of Concern) in the period 1986-1992. Similarly, the plant at Hamilton operated from 1965 to 1973 and thus the possibility of exposure cannot be excluded on temporal grounds. Similarly, the mercury chloralkali plant at Cornwall operated between 1935 and 1995 which preceded and was coincident with the time (1986-1992) covered by the Health Canada health data and statistics. This leaves St Mary's River and the Bay of Quinte for which time order data are required. The distribution of the industries that had used mercury has been presented in maps that indicate use as a slimicide in pulp and paper plants at both Sault Ste Marie on the St Mary's River and at Napanee on the Bay of Quinte before 1970 (Fimreite 1970a,b). Thus, for each of the communities in Canadian Areas of Concern with rates of hospitalisation for cerebral palsy that were statistically significantly elevated, on the grounds of time order, the possibility that the populations could not potentially have been exposed to elevated concentrations of mercury can be rejected.

There are other Areas of Concern where the rates of hospitalisation for cerebral palsy were elevated but for which there were statistically insufficient numbers of cases to establish significance. These included:- Jackfish Bay (males only); Severn Sound (males only); and Wheatley (males and females). Both Jackfish Bay and Severn Sound are locations with elevated geological levels of mercury. Wheatley is a small fishing harbour on the north shore of Lake Erie and was seriously affected by the closures of the commercial fisheries in the 1970s because of mercury. Thus, on temporal grounds, the possibility of exposures of the communities to locally elevated concentrations of mercury cannot be rejected for these Canadian Areas of Concern.

5.4.4 Consistency on replication

The consistency on replication viewpoint relates to the degree to which other scientists, working on other populations in other locations and at other periods of time have found the same relationship. This is a potentially powerful viewpoint because if there is agreement across a variety of studies on the effects and on the relationship with exposure to a particular agent, then the relationship is likely causal.

Tables 6 and 7 respectively comprised the clinical and epidemiological studies of the effects of methyl mercury on child development particularly from prenatal exposure from poisoning episodes with treated seed or contaminated fish. In the most serious cases, such as occurred at Minamata and Niigata in Japan (Harada 1995), and in Iraq (Clarkson 1993), there was a series of lesions associated with damage to the developing central nervous system. Congenital Minamata disease is generally characterised by mental retardation, primitive reflexes, cerebellar ataxia, disturbances of physical growth, dysarthria, and limb deformities (Harada 1995, National Research Council 2000, p.175). Among the children with congenital Minamata disease, there was a 9% incidence of cerebral palsy. Excluding those children living in the most affected areas of Minamata and officially diagnosed with congenital Minamata disease, 29% of the children born between 1955 and 1958 were mentally retarded (Harada 1995). Similarly, with the Iraqi children with the highest levels of exposure there were gross signs of severe sensory impairment (blindness and deafness), general paralysis, hyperactive reflexes, cerebral palsy, and impaired mental development (Amin-Zaki 1974, National Research Council 2000).

Since these severe outbreaks, there have been several epidemiological studies (see Table 7 for details) that have attempted to determine the levels of methyl mercury exposure associated with no effect. Researchers undertook these studies in communities where there were large amounts of seafood eaten, such as in the Faeroe Islands, on the Island of Madeira, in New Zealand and on the Seychelles. Similarly, research has been undertaken in communities where freshwater fish were eaten from locations close to gold mining operations, such as from the Tapajos River in the Amazon Basin, or in French Guyana or Ecuador. The neurological effects, particularly of prenatal exposure to methyl mercury, seem to be similar in several different domains including changes in muscle tone or reflexes, motor function, attention, and in auditory and visuospatial performance.

Several studies noted that neurological effects on males occurred at lower concentrations than on girls indicating consistency between studies in the findings of a peculiar susceptibility of males prenatally exposed to methyl mercury. These included the gross findings in the Japanese (Harada 1994) and in the Iraqi outbreaks (Marsh et al 1987b). Male susceptibility was even indicated in some of the studies of neurological function in children prenatally exposed to much lower concentrations. These included children of the Cree Indians in Northern Quebec (McKeown-Eyssen 1983), children of fish-eating communities in French Guiana close to gold mines (Cordier et al. 2002), and children of the Faeroe Islanders whose mothers ate pilot whales (Grandjean et al. 1998). There does not, however, seem to be a specific reference to the incidence of cerebral palsy being more prevalent in males than in females, as compared to other neurological endpoints.

The fourth epidemiological viewpoint relates to consistency on replication between studies, undertaken by different researchers, at different places and periods of time and using different designs. There seems to be a high level of consistency between studies in terms of the neurological effects of prenatal exposure to methyl mercury and of the particular susceptibility of males compared to females in the development of neurological effects.

5.4.5 Coherence

The coherence viewpoint requires that ‘the cause-and-effect interpretation of our data should not seriously conflict with the known facts of the natural history and biology of the disease’ (Hill 1965 p 298). The viewpoint is generally divided into the following four elements:-

- Theory (5.2.5.1): Are the findings plausible in relation to pre-existing theory?
- Facts (5.2.5.2): Are the new results compatible with the pre-existing facts?
- Biology (5.2.5.3): Does the supposed relationship make biological sense in terms of pathways and mechanisms of causation of effects and relative to experiments?
- Statistics (5.2.5.4): Is there a strong relationship between dose and response?

5.4.5.1 Theory

The Health Canada reports on the health data and statistics for the 17 Canadian Areas of Concern in the Great Lakes arose from an administrative need in relation to the Great Lakes Water Quality Agreement. The theory for undertaking the project was that if communities were exposed to specific pollutants at concentrations that were toxic, then the health data for that particular population would reflect these exposures

in measures of elevated rates of mortality, of morbidity as hospitalisation, or of congenital anomalies. The purpose of the project was to generate hypotheses about communities with elevated rates of disease and with exposures to specific pollutants. From these hypotheses, Health Canada through its Great Lakes Health Effects Programme, could undertake further research, surveys or even contribute information for regulatory decision making.

Health Canada included cerebral palsy as a pollutant-induced disease on the following pre-existing theoretical grounds. Prenatal exposure to high levels of methyl mercury had, in the past, been associated with cerebral palsy in infants in Minamata and Niigata in Japan (Harada 1995) and in Iraq (Marsh 1987a). Some of the 17 Canadian Areas of Concern have high levels of mercury to which some people, including women of childbearing age, in these communities may be exposed. Therefore, in these Areas of Concern the incidence of cerebral palsy should be elevated. The theoretical basis for emphasising the data on cerebral palsy in males is as follows:- The neurological effects of prenatal exposures to methyl mercury include an increase in the incidence of infants with cerebral palsy; Males are more susceptible to the neurological effects of prenatal exposures to methyl mercury; Therefore males prenatally exposed to methyl mercury may be more likely to suffer from cerebral palsy than females (Gilbertson 2004).

It is difficult to estimate the incidence of cerebral palsy within a community. There have been specialised estimates of the prevalence of cerebral palsy in several countries or regions including:- Parts of England (The North and at Avon); in Ireland; Italy; Germany; Australia; Japan; Sweden, Norway (Vestvold and Nordland); and

Finland (Mandelbaum and Paneth 2000). Health Canada could have undertaken specialised surveys of the incidence of cerebral palsy in the 17 Canadian Areas of Concern. These would have been costly, particularly for a pilot study that surveyed over seventy other health endpoints. In the Health Canada database, the implicit theoretical assumption was made that any increase in the incidence of cerebral palsy caused by prenatal exposure to methyl mercury could, more simply, be detected through compilation of the mortality or morbidity data.

In conclusion, the new findings of an increased rate of hospitalisation for cerebral palsy for males in the Areas of Concern with known sources of mercury are not incompatible with the known theory of the disease. Much further research and surveys are required to infer a causal relationship through identifying victims, and establishing exposure levels on a retrospective and prospective basis.

5.4.5.2 Facts

The new facts are that there are several locations on the Canadian side of the Great Lakes where there are statistically significantly elevated rates of hospitalisation for cerebral palsy in males. These locations coincide with areas with known sources of mercury. These are either from natural sources or from past industrial practices, such as, mercury chloralkali production, use as a slimicide in pulp and paper production or in gold mining. These new facts have been extensively compared (section 3.4.1) with the known facts concerning previous poisonings with methyl mercury (section 3.4.2). At present, there are neither special surveys that have been undertaken or that are planned to identify the affected individuals, nor are there direct measurements of the exposure levels to mercury of affected people.

The new information concerns the elevated rate of hospitalisation of males for cerebral palsy associated with some of the Canadian Areas of Concern in the Great Lakes basin with high levels of mercury in the environment from industrial or natural origin. These new facts are not incompatible with the pre-existing facts documented by researchers on outbreaks of methyl mercury poisoning in other parts of the world.

5.4.5.3 *Biology*

The third aspect of the coherence viewpoint addresses whether the supposed relationship makes biological sense in terms of pathways and mechanisms.

The literature on the environmental *pathways* of mercury has been reviewed in section 3.4.3. particularly in relation to designing the IJC Workshop on an Ecosystem Approach to the Health Effects of Mercury in the Great Lakes (Gilbertson and Carpenter 2004). The environmental pathways of mercury are complex and there is a need to demonstrate that there are the following components of routes from sources to receptors:- the routes by which mercury enters the environment from natural and industrial sources; the historic distribution and redistribution of mercury; the processes of transformation between various mercury species; and the factors affecting the equilibrium between methylation and demethylation of mercury; and release of methyl mercury into the water column. Pathway analysis includes the uptake of methyl mercury into organisms; bioconcentration in food-chains; and accumulation in top predators, including the routes of exposure to and concentrations in humans. After nearly fifty years since the first outbreaks of Minamata disease in Japan, and after more than thirty years since the presence of mercury in the Great

Lakes became generally known, there has been an enormous volume of research published on each of these topics. Fortunately, there are excellent reviews available and in the interests of concision for the thesis, these are referenced (United States Environmental Protection Agency 1997, National Research Council 2000, Wiener et al, 2002) and the salient findings abstracted into Table 12.

There are remarkably few published data on the concentrations of mercury in samples from the general population living within the Great Lakes basin. Much of the data on materials such as hair and blood is from native people and is confidential, though summaries have been published (Health Canada 1999). As recorded in 3.4.1 of the literature review, hair samples were collected in 1970 from three Chippewas from the Walpole Island reservation, downstream of Sarnia (Jervis et al. 1970, p. 34) and these showed the severity of the contamination.

In terms of biology as a component of the Coherence viewpoint, there must be a plausible *mechanism of toxic action* linking prenatal exposure to methyl mercury and injury to neurological development. The mechanistic literature has been reviewed and shows the diversity of molecular and metabolic processes that are affected by mercury and methyl mercury including:- increased oxidative stress; disruption of microtubule formation; increased permeability of the blood-brain barrier; disruption of protein synthesis, disruption of DNA replication and DNA polymerase activity; impairment of synaptic transmission; membrane disruption; impairment of immune response and disruption of calcium homeostasis (Agency for Toxic Substances and Disease Registry 1999).

Table 12. Environmental Pathways Analysis for Mercury in the Great Lakes

Pathway Process	Findings	Reference
Multimedia Sources	Complex sources of mercury into the environment require an ecosystem approach.	Carpenter and Gilbertson 2004
Natural Sources in the Great Lakes Basin	Mercury released from mineral-rich areas. Volatilisation from rocks and soils.	U.S. EPA 1997, Jackson 1997, Marvin et al. 2004
Local Industrial Sources in the Great Lakes basin	Multiple historic uses in gold and silver mining, chloralkali plants and as slimicides in pulp and paper manufacturing result in aqueous releases. Inventories of mercury use in products and aqueous releases and atmospheric emissions.	Fimreite 1970a, U.S. EPA 1997, Trip, 2004, Hagreen and Lourie 2004,
Regional, National, International and Global Sources	Elemental mercury releases into the atmosphere join the global reservoir traversing the oceans and continents. Transformation into ionic mercury results in deposition onto land and water.	U.S. EPA 1997, Jackson 1997, Cohen et al. 2004.
Background and 'new' mercury; distribution and redistribution	Mercury from natural and industrial sources redistributes by lake processes, deposition into profundal areas and carried towards lower lakes.	Thomas 1974, U.S. EPA 1997, Jackson 1997, Rossman 1999, Weiner et al. 2002, Marvin et al. 2004.
Transformation processes between mercury species;	Mercury species transform in biogeochemical cycle between elemental, ionic and organic forms in atmosphere, land and water.	U.S. EPA 1997, Jackson 1997, Weiner et al. 2002
Methylation and demethylation	Biogeochemical factors, including wetlands, low pH, flooding, humic compounds, and anoxia, influence the processes of methylation and demethylation of mercury.	U.S. EPA 1997, Weiner et al. 2002
Release into the water column	Methylation of mercury increases the bioavailability of mercury.	U.S. EPA 1997, Weiner et al. 2002
Uptake into organisms;	Methyl mercury readily crosses biological membranes; rapid uptake into organisms, with very slow elimination.	U.S. EPA 1997, Weiner et al. 2002
Biomagnification in food-webs and accumulation in top predators,	Efficient biomagnification from water to algae, zooplankton, invertebrates, fish and avian and mammalian top predators. Bioaccumulation factors of 106 - 107 between water and fish.	U.S. EPA 1997, Weiner et al. 2002
Human exposure	Detailed knowledge available on the toxicokinetics and toxicodynamics of methyl mercury. Efficient uptake of methyl mercury from the gut into blood, recycling through portal hepatic system, transplacental uptake into foetus and into foetal brain.	U.S. EPA 1997, National Research Council 2000.

For the purposes of the thesis, it is necessary to determine:- whether there is a plausible mechanism, among the diverse array of molecular and metabolic processes, to explain the observed increased rate of cerebral palsy hospitalisation from exposure to methyl mercury; and whether there is a plausible mechanism for increased susceptibility in males compared to females. One approach is to consider the effects at different levels of biological organization. At the level of the individual human infant, microcephaly has been observed in both the Minamata and the Iraq poisoning outbreaks (Amin-Zaki 1974, Murakami, 1972). The distribution of lesions in the brains of infants with congenital Minamata disease has been compared to those with non-congenital Minamata disease, and to those in adults with Minamata disease (Harada 1975). Among the prenatally exposed infants, lesions were throughout the cerebral hemispheres and the cerebellum, with slight lesions to the brainstem. In the infants with non-congenital (post-natal) Minamata disease, though the lesions still occurred throughout the cerebral hemispheres they were focussed in the parietal and occipital regions as well as in the cerebellum, but not in the brainstem. In adults with Minamata disease, lesions tended to be focussed only in the occipital and parietal regions and in the cerebellum.

Neuro-pathological studies (Matsumoto et al. 1965) on two dead Minamata children who had been diagnosed with cerebral palsy were reviewed by Choi (1989). At the gross level, the sizes of the brains were greatly reduced compared to controls with underdevelopment of several structures. At the microscopic level there was marked disorganisation of many cellular structures believed to be 'characteristic features of foetal Minamata disease' (Takeuchi 1968). Methyl mercury therefore profoundly disrupts normal developmental processes at the cytological level.

There are plausible mechanisms at the sub-cellular and molecular levels. The autopsies of the two Japanese children had shown an 'abnormal pattern in the organization and a distorted alignment of neurons in the cerebral cortex' (Choi et al. 1978, Matsumoto et al. 1965). Neuronal migration occurs from the 7th week of gestation through to the third trimester and requires the normal functioning of microtubules in the cells for both cell division and cell migration. In vivo experiments on the effects of methyl mercury on the developing cerebella cortex cells of 2-day-old mice demonstrated that injury to the cells was caused during mitosis through dysfunction of the micro-tubular spindles (Sager et al. 1982). At the molecular level of biological organization, methyl mercury is a potent inhibitor of microtubule assembly (Vogel et al. 1985). The inhibition is mediated through methyl mercury binding to the free sulphhydryl groups on the ends and on the surface of the microtubules. Normal cell division during mitosis requires spindle formation comprised of microtubule assembly and disassembly and these processes are effectively disrupted by exposures to methyl mercury. A coherent mechanism of action of methyl mercury on neurological development is therefore demonstrable at all levels of biological organization.

A plausible mechanism for the differential susceptibility of males compared to females, first observed in Cree Indians (McKewan-Eyssen et al. 1983), is required. Subsequent reanalysis of the Japanese and Iraqi epidemiological data revealed the differential susceptibility of males. The same phenomenon has been found in experiments on rodents. The differential susceptibility of developing brains of males to the effects of early exposure to methyl mercury in terms of locomotor activity

related to alterations in dopamine has been shown (Rossi et al. 1997, Gimenez-Llort et al. 2001). There seems to be only one experiment in which the differential susceptibility of males compared to females was looked at in relation to the antimitotic effects of methyl mercury in the cerebella cortex of 2-day-old mice (Sager et al. 1984). The experiment, however, does not provide a molecular mechanism of the differential susceptibility.

Epidemiological and experimental evidence exists of the differential neurodevelopmental susceptibility of males to prenatal or early postnatal exposure to methyl mercury, but the literature seems to be indeterminate about the molecular mechanism of the sex-based difference.

5.4.5.4 *Dose-response relationship*

One of the powerful ways of inferring a causal association is to determine whether there is a dose response relationship. The unsuccessful attempt to correlate cerebral palsy rates of hospitalisation with mercury levels in fish has been reviewed in 3.4.1 (Weis 2004). It is important to place the failure to find a correlation into perspective in relation to the epidemiological viewpoints. If there were a statistically significant correlation between mercury concentration in fish and the rate of male cerebral palsy hospitalisation, this would be powerful evidence affirming the hypothesis of a causal relationship. The converse, however, is not true. Merely because a statistically significant relationship was not found this does not provide a sound basis for rejecting the hypothesis; it merely means that if there is a relationship, it was not demonstrated by the approach on this occasion. Thus the effect on the hypothesis is indeterminate rather than detracting.

More particularly, this should not be used as the basis for postponing further research and monitoring. Analysis of hair and blood samples from mothers and children are more direct measures of mercury exposure than data on levels of mercury in fish and might provide data that could be used for new correlation analyses. Further, the lack of a correlation should not be used for deferring implementation of remedial actions or delaying providing more effective advice to people, particularly young women of childbearing age, who consume fish from the Great Lake.

5.4.6 Strength of association

The viewpoint refers to the degree to which the supposed cause and outcome coincide in their distribution and the size of the effect produced by the presumptive cause (Fox 1991). The most frequently used measures of the strength of association are relative risk which is a statistic for comparing the numbers of cases among exposed and unexposed populations. For very rare diseases with only a few cases among large populations, the relative risk is almost identical with another statistic, the odds ratio for which upper and lower confidence intervals can be calculated. Several 2X2 contingency tables have been constructed based on the number of cases of hospitalisation for cerebral palsy reported by Health Canada for the 17 Canadian Areas of Concern and for the Province of Ontario. The Health Canada reports did not, however, include data on the number of males and females in each of the Areas of Concern that could be used as denominators for the odds ratio calculations.

Table 13 contains data on the number of males and females in Ontario and in the 17 Areas of Concern, based on data from the 1991 Census of Canada (Statistics Canada

1992). In some places, such as Sault Ste Marie, reporting of the population data for the number of males and females in certain native reserves were ‘suppressed’, presumably for political reasons. Health Canada, in compiling the data for the total population for the Area of Concern, seems to have omitted these small populations.

Table 13. Numbers of Males and Females and Number of Hospitalisation Cases for Cerebral Palsy, by Gender, in all Ontario and in the 17 Canadian Areas of Concern in Geographic Shoreline Sequence from Western Lake Superior to the St Lawrence River: All Ages, 1986-1992.

Location (Figure 1 Map #)	Number of Males		Number of Females	
	In Ontario Population	Cerebral Palsy	In Ontario Population	Cerebral Palsy
All Ontario	13,454,580	884	13,842,280	723
Thunder Bay (4)	61475	20	62935	4
Nipigon Bay (3)	1945	0	1815	0
Jackfish Bay (2)	1265	1	1215	0
Peninsular Harbour (1)	2670	0	2395	0
St Mary’s River (38)	42440	17	44335	20
Spanish River (20)	4775	2	4845	2
Severn Sound (19)	26775	8	27160	1
Collingwood Harbour (43)	12525	9	13155	1
St Clair River (39)	45830	44	47590	3
Detroit River (40)	133535	24	140625	18
Wheatley (29)	9540	2	9370	3
Niagara River (41)	183070	25	192350	30
Hamilton Harbour (37)	300175	60	313115	58
Metro Toronto (36)	1727235	180	1807250	173
Port Hope (35)	7675	1	7895	1
Bay of Quinte (34)	125745	33	132125	44
St Lawrence River (42)	33280	15	35410	9

This, however, should not significantly affect the denominators for the relative risk calculations, as the number of native people is less than 2% of the population in the Area of Concern. Similarly, the numbers of males and females in the Kettle Point native reserve were ‘suppressed’ in the Census of Ontario tables and Health Canada omitted them from the population data for the St Clair River Area of Concern. At the Severn Sound Area of Concern, the population data for the Gibson 31 native reserve

was partially suppressed: while there were 130 people in the reserve, no figures were given for the number of males and females. The numbers were arbitrarily assigned in the same proportion as the nearby Moose Point 79 native reserve.

Factor 1 was to determine whether the number of hospitalisation cases in males (884) was statistically significantly higher than the number of hospitalisation cases for females (723) in the Province of Ontario compared to the respective number of males (13,454,580) and females (13,842,280) in the population. This represented an odds ratio of 1.26 (Confidence Intervals 1.14 - 1.39) and indicates that being male in the Province of Ontario is a significant risk factor for hospitalisation for cerebral palsy. The finding is anomalous in that the incidence of cerebral palsy is generally evenly spread between males and females, but is not inconsistent with the known differential susceptibility of males to disturbances of neurological development from prenatal and postnatal exposure to methyl mercury. Caution needs to be exercised, however, in interpreting the result since it is possible that males with cerebral palsy may be preferentially hospitalized depending on the policies and practices within individual hospitals serving small populations and this possibility should be further researched.

Factor 2 investigated whether being male in an Area of Concern was a significant risk factor compared with being male in the rest of the Province of Ontario. The number of cases of hospitalisation of males for cerebral palsy within the Areas of Concern was 441 in a total AOC population of 2,719,955 males compared with 443 cases in locations that were not Areas of Concern and with a male population of 10,734,625. This yielded an odds ratio of 3.93 (Confidence Interval from 3.44 – 4.48). A similar calculation for females in the Areas of Concern gave an odds ratio of 3.99

(Confidence Interval 3.45 – 4.61). These odds ratios for males and females indicate that living in an Area of Concern is a significant risk factor for cerebral palsy hospitalisation compared with the rest of the Province of Ontario. If the cases for Toronto were excluded from the calculation of the number of cases for the Areas of Concern because there are tertiary treatment facilities available, the odds ratio increases for males to 5.26 (Confidence Intervals 4.55 – 6.08). Similarly, the odds ratio increased from 3.99 to 4.53 (Confidence Intervals 3.85 – 5.34) when Toronto was excluded as an Area of Concern in the odds ratio calculation for females. Caution needs to be exercised in interpreting the result because it is possible that families with a child with cerebral palsy may move to an urban area and many of these are on Great Lakes shorelines and have been designated Areas of Concern.

Factor 3 investigated the historic presence of mercury chloralkali plants in the Areas of Concern. In males, the 141 cases of cerebral palsy hospitalisation in the total male population of 670,885 in Areas of Concern with historic chloralkali plants yielded an odds ratio of 1.44 (Confidence Intervals 1.18 – 1.75) when compared to the 300 cases in the 2,049,070 male population in Areas of Concern without this historic association. The result, however, should be treated with caution because it is likely to be significantly influenced by the very large size of the population in Toronto where there has never been a mercury chloralkali plant. The results of a similar analysis for females was not significant (OR = 0.81, CI 0.63 – 1.05).

Based on these statistical analyses using odds ratios, it is concluded that the strength of association viewpoint has been affirmed though further research is needed to

determine whether the associations are partly a result of hospitalisation practices in small communities or movement of families with a child with cerebral palsy.

5.4.7 Performance on prediction

The Performance on Prediction viewpoint relies on the testing of a deduction and requires that a hypothesis drawn from an observed association predicts a previously unknown fact or consequence and must, in turn, be shown to lead to that consequence (Susser 1986b p. 715). The list of over seventy health endpoints, compiled by Health Canada (1998), that could result from exposures to environmental contaminants, included infantile cerebral palsy on the basis that prenatal exposure to methyl mercury may result in cerebral palsy, based on the following four references:- Woods et al. (1991); Marsh et al. (1987a); Choi (1989); and WHO (1990). The inclusion of cerebral palsy, in the Health Canada (1998) study as one of the endpoints that might be related to exposures to pollutants, was, in a sense, a prediction based on a hypothesis drawn from an observed association. If there were elevated levels of methyl mercury in the Great Lakes environment, this would be manifested in an elevated incidence of the disease. The absence of registries for cerebral palsy within the Province of Ontario hinders the process of investigating whether this prediction holds. But the absence of registries does not invalidate the use of hospitalisation records as a surrogate index of cerebral palsy incidence. The apparent coincidence between mercury releases from chloralkali plants and the morbidity as hospitalisation incidence of infantile cerebral palsy supports affirmation of this prediction drawn from the hypothesis. Health Canada did not include a reference to male susceptibility in their rationale for including cerebral palsy as a health endpoint associated with

exposures to methyl mercury. Thus no conclusion can be made on the effect on the hypothesis.

In section 3.4.1.2, it was predicted that based on the elevated mercury concentrations in the Kingston basin of Lake Ontario, elevated hospitalisation rates for male cerebral palsy would be expected in Kingston, Ontario. At this point, a new prediction can be made that similar elevated rates of cerebral palsy hospitalisation for males will likely be found in communities on the United States side of the Great Lakes. These would be expected to be in the following locations:- Port Edwards, Wisconsin from the Wyandotte Chemical Corporation plant; Saginaw and Bay City, Michigan, downstream from the General Electric Co. plant at Edmore, Michigan; Trenton, Michigan, downstream from the Wyandotte Chemical Corporation plant located close to the Detroit River, and at Ashtabula, Ohio from the Detrex Chemical plant (United States Senate, 1970, p.70, 118). There is a priority need to undertake comparable research on cerebral palsy hospitalisation in these communities to verify whether these predictions are correct and whether reductions of exposures and remedial actions should be implemented.

During the on-line consultation, the failure of industry and governments to undertake the requisite remedial actions was commented on by the Mayor of the Town of Marathon (Peninsular Harbour) and he predicted the likely implications of continuing contamination (David Bell in International Joint Commission 2005):

My concern is related to old deposits of mercury that continue to sit on the bottom of our lakes and rivers. I readily acknowledge that linking specific

people or companies to the deposits will in many cases be difficult and to that end I believe that the main agenda should be to remove as many of the known deposits as possible regardless of who was responsible. The continued existence of the blobs of mercury will continue to have an effect on safe food consumption, recreation opportunities and economic development. It would be best addressed by all three orders of government i.e.; federal, provincial (state) and municipal where, in partnership, the problem area can be identified and removed.

5.5 Summary and conclusions

In this chapter, the results of the analysis of the Health Canada health data and statistics on cerebral palsy hospitalisation are used to further test whether the United States and Canadian governments have failed to fulfil their policy commitment to restore water quality in the Great Lakes basin and to protect human health through implementation of the 1978 Great Lakes Water Quality Agreement. Within the limitations of the methodology, the elevated rates of male cerebral palsy hospitalisation in several Canadian Areas of Concern indicate previously unidentified outbreaks of congenital Minamata disease. The means chosen for ‘reducing uncertainty’ (Beck 1992 p 173) in these preliminary findings is the application of the ‘viewpoints’ first enunciated by Hill (1965).

In terms of probability, the Health Canada approach seems to have been successful in obtaining sufficient cases, even in small communities, for the detection of statistically significant differences in rates of hospitalisation for cerebral palsy on a gender-specific basis. There are useful aspects of specificity in that methyl mercury is the

only chemical risk factor linked to cerebral palsy and the only chemical risk factor associated with differential neuro-developmental susceptibility on a gender basis. There are no temporal grounds for believing that the communities with elevated rates of hospitalisation for cerebral palsy were potentially unexposed prior to the study period (1986-1992). There is a consistency of these new findings in Great Lakes communities with other studies undertaken on other populations, by other scientists, at other locations and at other periods of time. The new facts cohere with the existing body of theory concerning the role of methyl mercury in relation to cerebral palsy pathogenesis and there are coherent pathways, sources, and routes of exposure of Great Lakes communities to methyl mercury. There are plausible mechanistic interpretations of toxic action on neurological development at different levels of biological organisation. There are, however, at this time no data that have shown a dose-response relationship between cerebral palsy hospitalisation and mercury exposures in the 17 Canadian Areas of Concern. Analysis of odds ratios has demonstrated the strength of association between Canadian communities in proximity to the Great Lakes and hospitalisation for cerebral palsy in both males and females and an association between male hospitalisation for cerebral palsy and the historic presence of chloralkali plants. Finally, the implicit prediction of Health Canada that Areas of Concern with elevated mercury concentrations would have higher rates of cerebral palsy has been affirmed.

In addition to the documented neuro-developmental effects of PCBs from maternal consumption of contaminated Great Lakes fish (section 3.3.2), there are now grounds for believing that there are neuro-developmental effects from exposures to mercury. Hill (1965 p 300) ended with a brief discussion of 'The Case for Action'. On a

precautionary basis, the observation of elevated rates of male hospitalisation for cerebral palsy at several Canadian Areas of Concern and the association with elevated levels of mercury from natural and industrial sources could serve as the basis for public health interventions to prevent prenatal neurological damage from consumption of Great Lakes fish containing elevated concentrations of methyl mercury. Similarly, though the Parties have failed to implement the Great Lakes Water Quality Agreement during the past twenty-five years, the observations of injury to health in communities located near the boundary waters indicate that the Parties need to stay focused on maintaining and restoring water quality in the Great Lakes basin. Finally, the association further indicates that changing the Great Lakes Water Quality Agreement into an ecosystem agreement to manage biological resources and address other Great Lakes issues would undermine existing efforts to address injury to human health caused by exposures to pollution.

The thesis has identified a series of failures of the International Joint Commission and the Parties to fulfil their roles and responsibilities under the Great Lakes Water Quality Agreement and these are formulated into a series of specific conclusions in chapter 6.

CHAPTER 6: FINDINGS AND CONCLUSIONS

6.1 Introduction

The extensive epidemiological evidence indicates that, despite the decreasing levels of persistent toxic substances in the Great Lakes, injury to health is still occurring, and thus the Parties have failed to maintain and restore water quality pursuant to their Great Lakes Water Quality Agreement. The proximate causes of the injury to health are continuing exposures to PCBs (section 3.3.1). There are strong indications of outbreaks of congenital Minamata disease implicating exposures of communities to methyl mercury (sections 2.3, 3.4 and chapter 5). The purpose of this chapter is to draw conclusions based not only on the scientific evidence, but also on the social, economic and political contexts (6.2). From the identification of the ultimate causes, the politics of the options for reform are explored (6.3) and these are framed within the wider context of the viability of civilisations (6.4).

6.2 Specific Findings

Though concentrations declined in many indicator species in the 1970s and early 1980s in response to new legislative and regulatory initiatives in both nations, epidemiological studies indicate that there is still injury to health associated with exposures to persistent toxic substances. In this sense, the 1978 Great Lakes Water Quality Agreement has failed. Within the context of the three research questions, the purpose of this chapter is to review the goals and objectives of the Great Lakes Water Quality Agreement and to formulate a series of specific findings based on the evidence of failure. While there are many factors that have contributed to the failure of the Great Lakes Water Quality Agreement, such as the politicisation of the

appointment process to the International Joint Commission, the following represent the most serious failures. There is an urgency to carrying out the forensic audit because the Great Lakes Water Quality Agreement is undergoing an extensive review and there are powerful forces attempting to reframe the interpretation of the Agreement and divert the focus from pollution of the boundary waters, particularly by persistent toxic substances (Gilbertson and Watterson 2007).

6.2.1 Finding 1: Injury is continuing

The United States and Canadian governments introduced the 1972 Great Lakes Water Quality Agreement by stating that they were:-“Seriously concerned about the grave deterioration of water quality on each side of the boundary to an extent that is causing injury to health and property; and determined to restore and enhance water quality in the Great Lakes System.” At the time, the priority was on eutrophication and remedial action was swift and effective in bringing about improved water quality through control of discharges of phosphorus. Even after the publication of *Silent Spring* (Carson 1962), there was little knowledge among Great Lakes scientists about the dangers posed by persistent toxic substances in the Great Lakes. At the time of the signing of the 1972 Great Lakes Water Quality Agreement, scientists and administrators were only beginning to understand that, in addition to DDT and its metabolites, the newly discovered PCBs and mercury needed to be addressed.

The first research question of the thesis asked whether:- “After 35 years of the operation of the Great Lakes Water Quality Agreement, is there continuing injury to health from pollution of the boundary waters?” The thesis has set out the published evidence that describes the effects on health from exposures to persistent toxic

substances, particularly from prenatal exposures to PCBs. Chapter 3 provides an overview of the present state of knowledge of the effects on human health with particular reference to the neuro-developmental effects of prenatal exposure to PCBs from maternal consumption of Great Lakes fish. As a method of protecting human health from the developmental effects of exposures to persistent toxic substances, epidemiology is a crude instrument: injury must occur in the population before it can be investigated; large numbers of people often need to be included to make a sample size that provides sufficient statistical power for the effects to be detected; and in prospective studies, results are available only after several years of developmental testing. Further communications delays seem to occur in transmitting the evidence from epidemiologists to decision makers. While the concentrations of PCBs have declined markedly since the signing of the first Great Lakes Water Quality Agreement, even the most recent epidemiological studies indicate that effects are still occurring from continuing exposures to PCBs (section 3.3.1, 3.3.2). Pollution by exposures to persistent toxic substances is still causing injury to health and thus the Parties have failed to meet their objective of restoring water quality.

Populations in the Great Lakes have been exposed to mercury released from a variety of human activities and from natural geological sources. While there has been extensive sampling of human populations to document exposures to mercury, it has proved extremely difficult to diagnose effects. In chapter 2, a method is set out for detecting whether effects from exposures to mercury might be occurring in Great Lakes communities. The method is based on the differential susceptibility of male infants to prenatal exposures to methyl mercury causing cerebral palsy as one sign of congenital Minamata disease (Gilbertson 2004). Thus the second research question

is:- “To what extent has the Great Lakes Water Quality Agreement addressed the problems of human health and the possible reproductive hazard of pollution in relation to cerebral palsy?” The results of the analysis of the health data and statistics provided by Health Canada on the 17 Canadian Areas of Concern gave a preliminary indication that there were several locations where there might be previously undetected outbreaks of congenital Minamata disease. The uncertainties implicit in the preliminary findings were reduced by applying the epidemiological “guidelines” initially enunciated by Hill (1965) and subsequently elaborated by Susser (1986, 1991). The application of Hill’s framework for analysis of the preliminary results indicates that there is a diversity of evidence that would have to be disregarded to believe that there was no relationship between the elevated rates of male hospitalisation for cerebral palsy in several of the Canadian Areas of Concern and exposures to mercury from industrial activity and from natural geological sources (section 5.4). Within the limitations of the method and based on the available evidence, it can be concluded that, after 35 years of the implementation of the Great Lakes Water Quality Agreement, there is continuing injury to health from exposures to mercury in the Great Lakes boundary waters.

6.2.2 Finding 2: Failure to implement a precautionary approach

In Article II (d) of the 1972 Great Lakes Water Quality Agreement, under the General Water Quality Objectives, the Parties agreed that “These waters should be: Free from substances entering the waters as a result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life.” Article II of the 1978 Great Lakes Water Quality Agreement states that the ‘purpose of the Parties is to...maintain the chemical...integrity of the waters of the Great Lakes Basin Ecosystem.’ The sections

would seem to imply a commitment by the Parties to a precautionary approach to ensure that substances new to commerce do not cause harm. During its advocacy phase, the International Joint Commission (1990 pp 21, 53) recommended that “the Parties strengthen programmes concerned with the introduction of new chemicals, through appropriate legislation and/or regulations that include mandatory pretesting prior to approval for production and use.” Based on the precautionary interpretation, the second finding is that the Parties had a duty to ensure that no new persistent toxic substances were released into the Great Lakes.

By the 1960s, there was a growing appreciation of the way that persistent toxic substances were bioconcentrated in food webs and causing effects on fish and wildlife and posing threats to human health (Carson 1962). By the early 1970s, there was extensive evidence of the effects of persistent toxic substances on fish and wildlife in the Great Lakes (Gilbertson 1988). In the early 1970s, there was a mysterious outbreak of disease in humans and farm animals in Michigan that was eventually traced to a small chemical manufacturer and the accidental incorporation of polybrominated biphenyl flame retardants into animal feed (section 4.4.2.2). Based on an assessment of the dangers posed, Canada promulgated a regulation under the Environmental Contaminants Act in 1979 to prohibit all activities involving polybrominated biphenyls including importation, manufacture, use, distribution, sale and release into the environment. However, though PCBs were successfully regulated under the Toxic Substances Control Act, through litigation by the chemical manufacturing industry opposing all other proposed regulations under the Act, the United States Environmental Protection Agency has been unable to control any existing other substances, including the polybrominated biphenyls. A precautionary

approach to the information that was available in both countries by the end of the 1970s would have led to a prohibition of all activities involving all brominated flame retardants.

Despite the Canadian prohibition and as a consequence of the inability of the United States to regulate existing chemicals, manufacturers of brominated flame retardants produced polybrominated diphenyl ethers that were incorporated into a wide variety of consumer products. The consequence is that polybrominated diphenyl ethers have become widespread in the global economy and environment and have contaminated fish, wildlife and humans. Canadian scientists have reconstructed the history of the contamination using archived samples of herring gull eggs and have shown the gradually increasing concentrations since the early 1980s (Norstrom et al 2002). Toxicological testing of polybrominated diphenyl ethers has shown them to be carcinogenic and to cause effects on the thyroid and on neurodevelopmental processes (Agency for Toxic Substances and Disease Registry 2007). Based on the available evidence, the second finding is that the Parties failed to implement a precautionary approach to the introduction of new persistent toxic substances and allowed widespread contamination of the Great Lakes with polybrominated diphenyl ethers.

6.2.3 Finding 3: Consequences of the recommendation to ‘sunset’ chlorine

Though there has been a serious mandate drift and withdrawal in recent years (section 4.4.2.3.1), much of the work of the International Joint Commission in relation to the Great Lakes Water Quality Agreement is meant to be focused on the preparation of a Biennial Report advising the governments on water quality. In turn, the International Joint Commission is advised by its Water Quality Board and Science Advisory Board.

In sections 2.4.4.3 and 4.4.2 the characteristics of three kinds of advisory committees are identified:- the expert (let the facts decide); the democratic (let the people decide); and the pragmatic (let common sense decide) (Irwin 1995 p. 64). While the two boards can be described as expert committees and mainly operate on the basis of facts, in the past twenty years the International Joint Commission has frequently acted as though it is not constrained by any particular advisory model.

As detailed in section 4.4.2.1, in the preparation of its 6th Biennial Report, the International Joint Commission (1990) took the expert advice of its Science Advisory Board concerning declaring ‘that persistent toxic substances, particularly organochlorines, are a hazard to human health in the Great Lakes basin.’ It listened to the activist messages expressed at the 1989 and 1991 Biennial Meetings held respectively in Hamilton, Ontario and Traverse City, Michigan. In formulating the recommendation to the Parties to ‘develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks’ the International Joint Commission seems to have been acting in what it considered a ‘pragmatic’ manner by treating organochlorine substances ‘as a class’ (International Joint Commission 1992 pp 29, 30) What may have seemed common sense to the International Joint Commission, however, was rejected by the Parties and formed the basis for a massive campaign by the chemical manufacturing industry to ‘capture’ the International Joint Commission (Durnil 1995 p 40, 175).

In the 1980s among the Parties and jurisdictions, confidence in the International Joint Commission started to wane with the perceptions that participation in the various committees was becoming burdensome and that the Great Lakes Regional Office had

too much influence in priority setting and the committee processes (Botts and Muldoon 2005). The consequence was that there was a re-evaluation of the roles and responsibilities, and the Parties took over many of the functions that had formerly been undertaken through the International Joint Commission. The finding is made that the recommendation to ‘sunset’ the use of chlorine undermined the trust of the Parties in the judgement of the International Joint Commission and that this has led to its marginalisation and a decrease in the morale and prestige of the organisation.

6.2.4 Finding 4: Systematic attenuation of the evidence of injury

Article VII of the 1972 Great Lakes Water Quality Agreement sets out the Power, Responsibilities and Functions of the International Joint Commission. In essence, the Commission is charged with collecting and analysing data and information on water quality and pollution and tendering advice and recommendations through reports to governments. Because the Great Lakes Water Quality Agreement is about injury to health, the claim is made that any person or persons in authority who knowingly and wilfully omit evidence of health effects commits a serious dereliction of duty.

In 1989, Health Canada initiated a Great Lakes Health Effects Program and held a Collaborative Meeting in Aylmer, Quebec in March, 1994. In 1990, through the Critical Programmes Act under the amendments to the Clean Water Act, Congress directed the Agency for Toxic Substances and Disease Agency to undertake a Great Lakes Human Health Effects Programme and the Agency hosted a Methodology Meeting in Detroit in May, 1994. Health Canada and the Agency for Toxic Substances and Disease Registry collaborated with the Quebec Ministry of Health and Social Services in hosting the Health Conference '97 – Great Lakes/ St Lawrence, in

Montreal, in May 1997. Members of the IJC were present at the conference when the extensive new evidence of injury was reported. The papers from the conference were published in the February 1999 issue of *Environmental Research* and formed a significant new body of evidence of the kinds and severity of injury to health from exposures to persistent toxic substances in the Great Lakes. However, when the IJC published its 10 Biennial Report, 18 months later, in July 2000, it purposely omitted all this new evidence. Instead, the report contained a table in an appendix that reported the results of health effects research that had been undertaken more than a decade before and had already been reported in previous Biennial Reports. Dr Christopher De Rosa who directed the United States programme for the Agency for Toxic Substances and Disease Registry confronted then Chairman Baldini and stated that the omissions were “egregious.” Chairman Baldini replied that the information had been “inadvertently left on the cutting room floor.” The process of systematically attenuating risk messages about human health effects of persistent toxic substances within the International Joint Commission seems to have originated at this time.

More recently, in February 2003, the IJC hosted a workshop on the health effects of mercury in the Great Lakes basin. I gave a presentation of the epidemiological methods used by Health Canada in compiling the health data and statistics for the 17 Canadian Areas of Concern and presented the results of the analysis of the hospitalisation rates for cerebral palsy as an indicator of outbreaks of congenital Minamata disease. The papers from the workshop were published in the July 2004 issue of *Environmental Research* (Gilbertson and Carpenter 2004), but the evidence of the indication of these possible outbreaks of congenital Minamata disease was omitted from the IJC Biennial Reports issued in 2005 and 2007. In the first decade of the

implementation of the Great Lakes Water Quality Agreement, a published claim that there are several outbreaks of congenital Minamata disease in the Great Lakes basin would have produced an immediate response from the environmental health authorities. However, after 25 years of neo-liberal political economics it seems that these former societal norms have been abandoned. The finding of mercury in the Canadian environment and particularly in the boundary waters of the Great Lakes was one of the factors that defined the need for Canada and the United States to negotiate the 1972 Great Lakes Water Quality Agreement. During three of the conference calls for the recent review of the Great Lakes Water Quality Agreement by the Parties, I mentioned the publication of indications of congenital Minamata disease, but the participants from government, industry and non-government organisations were unresponsive. Evidence of several outbreaks of congenital Minamata disease indicates the failure of the Parties to implement the Great Lakes Water Quality Agreement during the past 35 years. To find the authorities and participants on the review of the Great Lakes Water Quality Agreement unresponsive to evidence of a chemically-induced disease and of the failure indicates social processes of collusion and silencing.

The process of the release of the draft Lakewide Management Plan for Critical Pollutants for Lake Ontario provides further evidence of attenuation of risk messages by the Parties. In 1997, the draft plan was released at a news conference held in Niagara-On-The-Lake, Ontario. By 1996, there was extensive epidemiological evidence of the effects of exposures to persistent toxic substances, particularly the effects of PCBs on neurodevelopmental processes. The published results of the research on the 1980s cohort of infants whose mothers had consumed Lake Michigan

fish prior to or during pregnancy were available (Jacobson 1994, Jacobson and Jacobson 1993, Jacobson et al 1984 a,b). The research had been replicated experimentally with rat feeding studies using Lake Ontario Coho salmon (Daly 1993) and through establishing a new cohort of infants at Oswego whose mothers had consumed Lake Ontario fish prior to or during pregnancy (Lonky et al 1996). None of these studies was included in the draft report. The plan was drafted by four parties: the United States Environmental Protection Agency (Region 2); the New York State Department of Environmental Conservation; Environmental Canada; and the Ontario Ministry of Environment. As a test, copies of the relevant studies were handed by myself and another IJC staff member at the meeting to the representatives of USEPA and NYSDEC, and the next day copies were given to the representatives of EC and OMOE. None of the studies was included in the final report, published one year later, indicating an active process of collusion in attenuating risk messages.

6.2.5 Finding 5: Diversionsary reframing

The thesis has extensively reviewed the evidence of an active process of proposals to change the purpose of the Great Lakes Water Quality Agreement from maintaining and restoring water quality to maintaining and restoring ecosystem integrity of the Great Lakes Basin Ecosystem (Gilbertson and Watterson 2007). There seem to be at least three interests that are served by the process. First, the Canada – United States Great Lakes Water Quality Agreement is a mandate pursuant to the Boundary Waters Treaty. In an era of neo-liberalism, with decades of budget cuts to government programmes, particularly for conservation of biological resources and for environmental protection, managers are constantly looking for potential mandates to justify existing programmes. The temptation afforded by the ambiguity of Article 2 to

transform the purpose of the Great Lakes Water Quality Agreement into maintaining and restoring ecosystem integrity and to thereby protect and enhance a wide array of programmes unrelated to water quality has proved overwhelming (section 4.4.2.3 and appendix B). Similarly, environmental non-government organisations that have become progressively dependent on government contracts and grants have embraced the wider interpretation of the Great Lakes Water Quality Agreement in the expectation of justifying funding such environmental programmes as biodiversity, habitat protection and control of the introduction of exotic species. The process has become particularly acute recently with proposals in the US Congress for a Great Lakes Restoration Act (Botts and Muldoon 2005).

The second thread to the diversionary reframing process is in terms of attenuation of the risk message. With the application in the early 1980s of neo-liberal politics in the United States and Canada respectively by President Reagan and Prime Minister Mulroney, the Parties appear to have had no intention of implementing the Great Lakes Water Quality Agreement signed during previous administrations in 1978. As long as there was little information about injury to health, the Parties could escape serious criticism. But with the publication in the scientific literature of epidemiological evidence of developmental effects on infants from maternal consumption of contaminated Great Lakes fish prior to or during pregnancy, the public became informed and protested the lack of action. Similarly, industry has been active in attenuating the risk message by representing the problems of persistent toxic substances in the Great Lakes as issues of past decades that have now been resolved (Council of Great Lakes Industries 2003).

The third thread of the diversionary reframing is the substitution of the water quality interpretation with an agenda on ecosystem integrity. Here again, industry has been actively promoting to governments and the public consideration of a wide array of issues in the preparation of Remedial Action Plans and Lakewide Management Plans, including habitat protection, species diversity and land use and controlling the introduction of exotic species (Council of Great Lakes Industries 2003).

The SARS/climate change heuristic device affords potentially useful insights into the respective value systems of industry and government in relation to the temptation for diversionary reframing. With the SARS outbreak in Toronto, it was small businesses and the hotels owned and operated by multinational corporations that suffered the economic losses from cancellations. Though the Ontario Government was pressured by the media to declare the outbreak ended (as it happened prematurely) to restore economic activity to the city (SARS Commission 2006), there is no evidence that any person or organisation was tempted to reframe the issue and divert the focus from quarantine of suspected contagious persons to contain the outbreak. Similarly, despite the rhetorical denials of the President of the United States about climate change (Gore 2007 p 194), the US government and the multinational petrochemical corporations have begun planning for the increase in sea level and severe storm surges, forecast by the Intergovernmental Panel on Climate Change, particularly for the US Gulf Coast where 69% of the US waterborne commerce, 85% of US Outer Continental Shelf (OCS) oil and gas production and 66% of oil imports occur (United States Geological Survey 2005).

The present statement of purpose of the Great Lakes Water Quality Agreement is ambiguous. To overcome the tendency for diversionary reframing, the following new wording was proposed during the public consultative process (Gilbertson and Watterson 2007):-

Pursuant to Article IV of the Boundary Waters Treaty, the purpose of the Parties in signing the Great Lakes Water Quality Agreement is to prevent injury to health and property from pollution of the boundary waters by restoring and maintaining the chemical, physical and biological integrity of the Great Lakes basin.

The proposed wording solves five problems associated with the present wording. First, to overcome any ambiguity about the authority for the Great Lakes Water Quality Agreement, it locates the purpose within the mandate of the 1909 Boundary Waters Treaty to distinguish it from any other potentially claimed mandate. Secondly, it directly links the purpose to Article IV of the Boundary Waters Treaty by using the words “injury to health and property” to differentiate the programmes for its implementation from other Great Lakes programmes, such as for the conservation of biological resources. Third, the focus is placed on maintaining and restoring water quality from degradation by pollution. Fourth, because the Boundary Waters Treaty and the Great Lakes Water Quality Agreement were diplomatic instruments between two sovereign nations, the purview relates to the quality of waters at the boundary that might cause injury to health from trans-boundary pollution. Finally, to overcome the thirty-year ambiguity of the ‘Ecosystem Approach’, the word ‘Ecosystem’ has been omitted.

6.3 Reform from chaos

There is a need to reform the International Joint Commission and its advisory bodies as well as reinvigorate the commitment of the Parties to implement the Great Lakes Water Quality Agreement. The process, started in the 1980s by President Reagan, of appointing commissioners on the basis of patronage awards for political service needs to end (Botts and Muldoon 2005). Reform of the process of appointments to the Science Advisory Board is more complex and has become political. First, after more than twenty-five years of neo-liberalism, it has become almost impossible to find qualified experts, particularly from academia and non-government organisations, who do not have major conflicts of interests because of dependence on corporate or government funding. Similarly, the presence of two representatives of industry on the Science Advisory Board undermines the impartiality of the advisory process. The second reform relates to the appointment of members with qualifications relevant to the purpose of the Great Lakes Water Quality Agreement. Until there is consensus on the purpose (Gilbertson and Watterson 2007), there will be confusion about whom to appoint, and the apparent bias within the Commission in endorsing the multi-stressor ecosystem interpretation of the Agreement would seem to preclude the necessary reforms, at least in the near term (International Joint Commission 2005). ‘The very existence of conflicting technical interpretations generates political activity’ (Nelkin 1992 p. xx).

These reforms, however, are trivial compared with the reforms needed to counter the three right-wing revolutions that have swept the United States in the past quarter century. These revolutions include neo-liberalism, neo-conservatism and the

ascendancy of the Religious Right to make a theocracy. There are signs that neo-liberalism, which was put forward as an economic theory in the 1970s by Milton Friedman, has come to the end of its irresistible logic that was implemented politically in the 1980s:

We are transiting one of those moments that separate more driven or coherent eras. It is like being in a vacuum, except that this is a chaotic vacuum, one filled with dense disorder and contradictory tendencies.....Yet, a period of uncertainty is also one of choice, and therefore of opportunity (Saul 2005 p. 4).

Both nations are politically in crisis and part of the crisis is attributable to the neo-liberal hubris of the past twenty-five years. In Canada, at the provincial level, Justice O'Connor (2002) attributed the *E. coli* drinking water tragedy at Walkerton, Ontario, to the policies of the Mike Harris government based on neo-liberalism (Snider 2003, 2004). More recently, the federal Liberals under Prime Minister Paul Martin, already reeling from the findings of the Gomery Inquiry into the Quebec sponsorship scandal, have dispatched the military to the Kashechewan native reserve on James Bay to provide clean drinking water. In Canada, native reserves are the responsibility of the federal government. Neglect of the infrastructure, including water treatment plants, of native reserves, brought on by more than two decades of neo-liberal policies, has resulted in widespread suffering. In January 2006, the Liberals, who were politically vulnerable because they had a minority government that was supported by the left-wing National Democratic Party, fell and the country was plunged into an unwanted winter election narrowly won by the Conservatives. The new Prime Minister,

Stephen Harper is an economics graduate from the University of Calgary which seems to have both neo-liberal as well as neo-conservative tendencies and these may bode ill for programmes of the Canadian federal government on environmental health.

The chaos within the current United States administration is a palpable sign of the end of the neo-liberal revolution, made worse by the deliberate implementation of a neo-conservative agenda after the Twin Towers and Pentagon attacks on 9/11/2001. Through the international media, the world saw New Orleans transformed into a Third World nightmare by hurricane Katrina, with the Federal Emergency Measures Agency impotent to respond. Though Congress had been accurately warned of the scale and implications of the potential disaster, funds for reinforcing the levees were diverted, particularly to the War in Iraq, which is where the Mississippi National Guard was located during the New Orleans crisis. The Administration had already alienated international opinion through the unilateral declaration of war, based on false information about weapons of mass destruction in Iraq. The suspicion persists that the economic elites within the United States will be the beneficiaries of the privatised war in Iraq, while the American public begins to question the loss of more than 2,000 American lives (Barlow 2005). In Washington, the ascendancy of the Religious Right threatens to capture the Supreme Court after taking the Presidency as well as the majority in both houses of Congress, and thereby transform the American experiment into a theocracy (Bokaer 2004, Barlow 2005, Hedges 2006). Senior members of the Administration have been indicted for leaking the name of a CIA operative. Other sources of instability are the disparities in wealth within the nation and the accumulated national debt of nearly \$9-trillion, mainly held by the central banks of China and Japan.

The model according to which the planned reconstruction of society is to proceed is taken from systems analysis. It is possible in principle to comprehend and analyse individual enterprises and organisations, even political and economic subsystems and social systems as a whole, according to the pattern of self-regulating systems (Habermas 1970, p. 106).

The question arises whether the ongoing chaos in both nations will produce change through evolutionary or revolutionary processes. The evolutionary changes that followed the neo-liberal revolution tend to have favoured the corporations through their powerful and relentless processes of lobbying politicians and bureaucrats and controlling the media. ‘The citizens must engage. We must get them aroused to action. This is a war, right here in the USA/Canada between corporations against the common people’ (Mark Coleman in International Joint Commission 2005). The resistance might be ‘expressed in the moral fundamentalism characterising the increasing number of protests against science and technology that are framed in terms of ‘rights’ and particularly ‘the rights of future generations’ (Nelkin 1992 p. xvii). In the 1960s, the social unrest led to a decade of change during the 1970s, for improvement of the commonweal, before the activists and the non-government organisations were co-opted by corporatist governments, corporatised academia and by the corporations themselves.

The question is whether the chaos in both countries will be sufficiently prolonged that the review of the Great Lakes Water Quality Agreement will be quietly neglected until after the next federal elections in both countries. The newly elected

Conservatives to Ottawa show few signs that they espouse anything but neo-liberal values and thus the Agreement might be even more vulnerable. Americans, however, are not scheduled to go to the polls until November 2008 which gives ample time for the Washington Administration to review and renegotiate a diversionary reframing of the Agreement with the newly elected Canadian government.

6.4 Role of government within civilisation

Civilisations can break down in one of two ways (Toynbee 1972 p 169): ‘In one version the subject errs through an ultimate passivity, while in the other he rushes actively to seek his doom’. The United States, as an empire (Simes 2003), would seem to be simultaneously following both courses. Through the neo-liberal revolution, expressed as small government, there are signs that the United States has opted for ‘an untimely passivity’ in terms of maintaining its national infrastructure for survival. ‘This posture is only tenable so long as the environment happens to remain constant, and it spells disaster as soon as the environment begins to change’ (Toynbee 1972 p 169). Through the neo-conservative model, it seems that ‘he rushes actively to seek his doom’.

[This] second version of the plot is familiar in Greek literature as a tragedy in three acts: *koros* (surfeit), *hybris* (outrageous behaviour), and *ate* (disaster) - an active psychological catastrophe in which the subject spoils the success, loses his mental and moral balance and courts disaster by attempting the impossible (Toynbee 1972 p. 169).

The loss of New Orleans from hurricane Katrina through failure to invest in the levee infrastructure would seem to be an example of the consequences of neo-liberal

policies despite detailed warnings (American Meteorological Society 2005). The war in Iraq is an example of application of the neo-conservative hubris. These, however, are the easily perceptible disasters unlike the harms done by exposures to chemicals released into the global environment. Chemicals, particularly endocrine disruptors that influence normal developmental processes, have been listed among the twelve environmental factors that can contribute, possibly synergistically, to the collapse of civilisation (Diamond 2005 p 6, 491-2). With the growth of the power of corporations, the application of neo-liberal economics and neo-conservative foreign policy within the context of an apocalyptic End Times, civil servants have been impotent to reverse these trends. Indeed, during the past twenty-five years, career advancement has depended on their active participation.

The review of the Great Lakes Water Quality Agreement is being undertaken within the context of these neo-liberal and neo-conservative philosophies. The precautionary and prevention principles were mentioned in the IJC on-line consultation: ‘the prevention principal (sic) translates into environmental impact assessment, prior authorization and scientific testing procedures before a project is undertaken or a product is placed on the market’ (Christine Elwell in International Joint Commission 2005). In addition, there have been proposals for product substitution and implementation of state legislation for toxic use reduction (Geiser 1999a). Despite this, there seems little acceptance of a precautionary approach to pollution by persistent toxic substances in the Great Lakes boundary waters. This contrasts with the prudential philosophy adopted as the basis for rulemaking on the chlorination of drinking water and the dangers posed by the by-products: ‘It is therefore prudent public health policy to protect against this potential public health concern in light of

the uncertainties and given the large population (over 200 million people) potentially exposed' (United States Environmental Protection Agency 1998 p 69407).

There would seem to be a large difference between attitudes in Europe and those in North America (Raffensperger and Tickner 1999 p. 8). In contrast to other international agreements on the precautionary principle, the European Union published a communication on the precautionary principle that 'requires intervention to maintain the high level of protection chosen by the EU' (United Nations Educational, Scientific and Cultural Organisation 2005 p 12). The contrast was exemplified by the reception of the EU representative in Washington concerning the Regulation, Evaluation and Authorisation of Chemicals (REACH) proposals.

It's a principle of common sense, to Europeans anyway. I think it's a cultural difference. If there is a scientific uncertainty as to the nature of the risk, we say to those in public office charged with protecting public health that they have a duty to respond and not wait until their fears are realised, until the worst is happening. I think the Americans are more daring. As long as there's no known risk, they go ahead (Schneider quoted in Lane 2003).

The insight is valuable as far as it goes, but the experience of the past fifty years reveals a more sinister cultural difference. In North America, even when there is extensive forensic evidence of proven injury, there is a tendency for no action to be taken by those in authority until some form of social protest is belatedly mounted. That is why the public hearings and on-line consultation of the International Joint Commission (2005) on the review of the Great Lakes Water Quality Agreement were

important, despite their being skewed toward diversionary reframing: they were an official outlet for the public to express their legitimate outrage. There are many interests that want to co-opt the Agreement to their ends (Gilbertson and Watterson 2007). Fisheries researchers and managers want to use the Agreement as a means for accessing government funding for programmes that are in danger of being axed. Similarly, wetland specialists look to the Agreement ‘given the limited funds that seem to be available for environmental issues these days’ (Patricia Chow-Fraser in International Joint Commission 2005). The two federal governments and the chemical manufacturers want to divert the focus away from persistent toxic substances because the cost of remedial action is so large. That is why the thesis has concentrated on the ongoing injury to health from exposures to chemicals. Despite the continuous pressures for ‘downsizing’ of government programmes, constant efforts, informed by initiatives in forensic environmental toxicology, are required to sustain the focus on ‘injury to health’ from trans-boundary pollution as the only legitimate interpretation of the Great Lakes Water Quality Agreement.

Based on the public and on-line consultations of the review of the Agreement (International Joint Commission 2005), it is important to recognise not only the long list of Great Lakes issues that need to be addressed, but also the number of people from various disciplines and backgrounds who are seeking an institutional mechanism(s) through which to effect change at the scale of the Great Lakes Basin ecosystem. While the theme running through the thesis has opposed transforming the Great Lakes Water Quality Agreement into a bilateral instrument for addressing this long list of issues, national, regional and local governments may need to advise politicians about the inadequacy of existing instruments, or propose new instruments

for addressing these bilateral issues without defacing the coinage of the original Agreement. ‘Participants agreed that attention to a broad range of issues affecting healthy ecosystem functioning is needed, but not that the scope of the Great Lakes Water Quality Agreement should be broadened’ (International Joint Commission 2005). It seems that consideration of the social, economic and political contexts, in addition to the scientific and technical aspects, has provided significant new insights into the failure of the Parties to implement the Great Lakes Water Quality Agreement.

6.5 Conclusions

The development by Canada and the United States of the Great Lakes Water Quality Agreement was a far sighted diplomatic response to the social unrest of the 1960s and to the growing evidence of deterioration of water quality in the Great Lakes basin. There have been significant successes, such as curbing eutrophication through controls on the discharges of phosphorus and declining concentrations of organochlorine compounds and mercury. The thesis has used a forensic audit approach to examine whether there is evidence of continuing injury to health and to locate the sources of the failure. The first finding is that injury to health is still occurring as a result of exposures to the two persistent toxic substances, PCBs and mercury, that were of concern at the time of signing the first agreement in 1972. The second finding is that the Parties failed in their goal of maintaining water quality by not exercising a precautionary approach to the introduction of new chemicals such as the brominated flame retardants. The third finding is that the demise of the International Joint Commission as a viable advisory organisation on Great Lakes water quality originated in its recommendation to ‘sunset’ the use of chlorine in chemical manufacturing. The fourth finding is that there is an active process within

the International Joint Commission and within governments of attenuating the communication of risk. The final finding is that governments, industry and some environmental non-government organisations have, for a variety of purposes, engaged in a process of diversionary reframing of the purpose of the Great Lakes Water Quality Agreement based on the inherent ambiguity of the 'ecosystem approach'. The chapter ends by identifying the need for reform of the appointment process, both to the International Joint Commission itself and to its Science Advisory Board and by placing the failure of the Great Lakes Water Quality Agreement within the larger context of imperial decline of the United States.

The final chapter addresses the limitations and uncertainties that have been identified in the process of preparing the thesis and the further research that is required to respond to these gaps in information.

CHAPTER 7: FURTHER RESEARCH, AND THESIS SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The purpose of this final chapter is to review the limitations of the evidence in terms of the further research needed on forensic epidemiology (7.2) and toxicology and interaction studies (7.3). There are major re-evaluations that are required in Great Lakes fisheries science (7.4). The story of the presence of toxic substances in the Great Lakes needs to be made part of the larger global series of ethnographic studies of toxic communities (7.5) as part of the next steps (7.6) in researching contamination of the Great Lakes basin. The chapter ends with a summary and conclusions and a series of recommendations, informed by this thesis, that were presented to the International Joint Commission and to the Ontario Ministry of the Environment during recent hearings on the Agreement.

This thesis has drawn on several different disciplines, not only in the field of science, but also relating to the social, economic and political contexts as well as administrative aspects of the Great Lakes Water Quality Agreement. Throughout the thesis, some of the limitations and uncertainties have been indicated in each of these fields and these are reviewed. In addition, the experiences of communities, in other parts of the world, which have been exposed to mercury can inform the research needed within the Great Lakes basin through the proposed new academic discipline of 'Minamata studies' that would be a:

Scholarly and scientific production that values and defends life, and that must benefit the weak, the oppressed, and the marginalised. It should strive to

transcend the separation between lay folk and academic specialists, between the former's experiential wisdom, deep life philosophy, and holistic vision of the world and the specialised, compartmentalised, often all-too-theoretical knowledge of intellectual and academic elites (Harada cited in Michiko 2003 p. ix-x).

7.2 Forensic epidemiology

The SARS/climate change heuristic comparisons indicated that there was a need to make estimates of the number of infants in the Great Lakes basin prenatally exposed to PCBs from maternal consumption of fish prior to or during pregnancy. The estimates should include the severity of effects and the economic impact of the effects.

The preliminary epidemiological findings indicate that there are previously undetected outbreaks of Minamata disease occurring in several of the Canadian Areas of Concern in the Great Lakes Basin. There is a priority need to verify these preliminary indications and to find the cases if they are occurring in Canadian Areas of Concern. Further preliminary research needs to be undertaken to determine whether there are similar occurrences in the United States Areas of Concern (section 5.4.7).

If hospitalisation rates for cerebral palsy in males are a reliable index of congenital Minamata disease, the index could be applied to several other locations on the Canadian side of the Great Lakes not included in the original list of the 17 Areas of

Concern (section 6.2.7). In addition, the feasibility of using the index as a general surveillance technique for public health should be explored.

From this preliminary analysis of the cerebral palsy data, there are several critical areas indicated on the Canadian side including Sarnia, Cornwall, Thunder Bay and Collingwood. There is a need to undertake retrospective as well as prospective studies. Despite the continuing difficulties of diagnosing Minamata disease (Cyranoski 2001) and the inherent reluctance of health authorities to find environmentally-mediated morbidity, retrospective studies, including clinical and case-control studies, are needed to identify the victims of prenatal exposures to methyl mercury within these critical communities. These are needed not only to improve the scientific case for the purposes of informing remedial policy, but also for establishing a basis for compensation.

Prospective case-control studies are needed to determine the extent of neuro-developmental deficits within the Areas of Concern. There are other developmental endpoints, such as immune deficits, anomalies in anatomical differentiation and endocrine function that may be affected by prenatal exposures to chemicals from the Great Lakes. The feasibility of including these in any research protocol for undertaking prospective epidemiological research on cohorts of infants established in the Great Lakes basin needs to be considered.

Though the Health Canada database has been the subject of one workshop and several published papers, it is possible that there are other episodes waiting to be discovered within the database. Statistical techniques, such as a principle component analysis, are

available for identifying clusters of diseases that might be related to exposures to Great Lakes pollutants. These might yield new 'early warnings' of the occurrences of pollutant-induced diseases in the Great Lakes basin.

A new generation of Great Lakes scientists will inherit the unresolved debates about the nature of causality. There is a priority need for those involved in fisheries and wildlife research to explore the premises of their beliefs (section 2.4.4.4). From this exploration, attempts should be made to bridge the differences in their approaches to making statements about the cause or causes of changes in the status of fish and wildlife populations.

7.3 Toxicology and interaction studies

The differential susceptibility of males to the neuro-developmental effects of methyl mercury seems to be well established from the epidemiological and experimental literature. However, there does not appear to be a published mechanism to explain the differential toxic action. If the male hospitalisation rate for cerebral palsy is to be used as an index of congenital Minamata disease, the mechanism of differential toxic action may need to be understood.

The preliminary finding of a possible interactive effect of mercury and polychlorinated biphenyls on neurological development in children prenatally exposed from maternal consumption of Great Lakes fish needs to be further elaborated (Stewart et al. 2003). This can be undertaken through inclusion of these and other environmental contaminants in protocols for further epidemiological

research. They can also be investigated experimentally through undertaking further neuro-toxicological studies.

7.4 Fisheries research

In a Kuhnian sense, the multi-stressor ecosystem paradigm that has informed Great Lakes fisheries science since the 1971 consensus at the Symposium on Salmonid Communities of Oligotrophic Lakes has been challenged by an alternative toxicological story that is unicausal. Management of the multiple stressors that have been identified has not restored the extirpated fish populations. It appears that there is a Lakatosian ‘protective belt’ that has been placed around a ‘hard core’ of assumptions and findings. Little management progress is likely until the scientific assumptions and findings are re-examined. There is a need to deconstruct all of 20th century and to construct a new paradigm with consideration of using the scientific method, including parsimony of explanations, and with the inclusion of persistent toxic substances as putative factors. Despite the absence of evidence of interactive effects between 'ecosystem stressors' and the extirpations of Great Lakes fish species, there is new evidence from research on endocrine disruptors on the interactive effects of pesticides and environmental stresses on frogs (Hayes et al 2000, Relyea 2003). The scientific reconstruction of 20th century Great Lakes fisheries research may need to consider such interactive stresses between toxic substances and environmental stresses.

7.5 Ethnography

Many critical subpopulations within the Great Lakes basin are exposed to high levels of persistent toxic substances from a variety of sources and pathways. The effects produced by these exposures are difficult to determine and may remain undetected for decades resulting in a widespread morbidity, mortality and congenital anomalies in structural and functional development. Special techniques, such as body mapping, participant-action research and community-based research may help identify these occurrences, some of which may be ubiquitous, low-grade and difficult to detect. For example, the profound change in sex ratio among the offspring of the Aamjiwnaang First Nation, in Sarnia, Ontario, in the St Clair River Area of Concern, was only detected after these special techniques were applied by members of the band, working in collaboration with health specialists (Mackenzie et al 2005).

The Great Lakes Water Quality Agreement has been in operation since 1972. Many of the originators of the Agreement are still alive and many of the first cadres of civil servants hired to implement the Agreement are in the process of retiring. This provides a unique opportunity to use ethnographic techniques to collect their 'stories'. Together with the tapes of the interviews by Botts and Muldoon (2005), these might include the following research questions:-

- How 'environmental health' was so effectively curtailed as an administrative issue after 1980;
- How the 1987 Protocol to amend the Agreement removed most of the responsibilities from the International Joint Commission;
- How the participants in the 'renewal of resistance' during the Durnil years (1989-1994) perceived their role;

- How Great Lakes fisheries scientists regard the challenges posed by the findings that dioxins “alone” caused the demise of the Lake Ontario lake trout;
- How the Bilateral Executive Committee has fared as the bilateral federal locus of operation for implementation of the Agreement since 1987;
- How the ‘Outlaws’ perceived themselves in relation to the Agreement;
- How the perceptions of the Commissioners and Parties’ managers changed over time and the causes of these changes;
- How the composition of the Great Lakes advisory boards and the affiliations and sources of funding influenced scientific and policy advice to the Commission;
- How industry has influenced the administrative processes to implement the Great Lakes Water Quality Agreement, particularly since the recommendation of the IJC concerning the ‘sunsetting’ of chlorine; and
- How environmental non-government organisations influenced policy formation and in turn, how they were influenced by their networks and sources of funding.

7.6 Next steps

This case study has demonstrated the diversity of research approaches needed in forensic toxicology to inform society about the dangers of chemicals in the environment. While toxicology as a discipline has a massive following with membership in international professional societies, such as the Society for Environmental Toxicology and Chemistry, reaching the tens of thousands, the number of people engaged in forensic environmental toxicology is very small. In the neo-liberal world of the past 25 years, government and corporate funding for identifying and investigating outbreaks of chemically-induced disease is not forthcoming. Nevertheless, in the absence of a viable application of the precautionary principle in

North America, the process of informing the citizenry about the harms done to them by chemicals seems to be one of the only ways of eventually controlling compounds within a liberal-capitalist democracy. New initiatives and institutions are needed to valorise this approach to the protection of health and the environment.

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APPENDIX A

COMMUNITY HEALTH PROFILE OF WINDSOR, ONTARIO, CANADA: ANATOMY OF A GREAT LAKES AREA OF CONCERN

**MICHAEL GILBERTSON AND JAMES BROPHY
ENVIRONMENTAL HEALTH PERSPECTIVES • VOLUME 109
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Community Health Profile of Windsor, Ontario, Canada: Anatomy of a Great Lakes Area of Concern

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The rates of mortality, morbidity as hospitalizations, and congenital anomalies in the Windsor Area of Concern ranked among the highest of the 17 Areas of Concern on the Canadian side of the Great Lakes for selected end points that might be related to pollution in this relatively highly industrialized city. Mortality and morbidity rates from all causes were higher than in the rest of the province. Anomalously high rates of diseases included various cancers; endocrine, nutritional, metabolic, and immunity disorders; diseases of the blood and blood-forming organs, nervous system and sense organs, circulatory and respiratory systems, digestive system, genitourinary system, skin and subcutaneous tissue, musculoskeletal system and connective tissues; congenital anomalies, and infant mortality. Of particular concern was the early onset of the elevated rates of many of these diseases and conditions. Comparison of these incident rates with those in Hamilton, another industrial municipality in southern Ontario, suggested that in addition to a variety of local sources of industrial pollution from automobile manufacturing and use, transboundary air and water pollution from Detroit, Michigan, should be investigated as potentially important causes of these health outcomes in the Windsor Area of Concern. Some of the institutional and political trends of the past decade may need to be reversed before effective remedial programs are implemented for cleaning up contaminated sediments and for containment of leaking hazardous waste sites. This pilot project would seem to be a useful preliminary method of integrating human health concerns and of priority setting for the administration of the Great Lakes Water Quality Agreement and the Canada–United States Air Quality Agreement. *Key words:* injury to health, methodology, transboundary pollution. — *Environ Health Perspect* 109(suppl 6):827–843 (2001). <http://ehpnet1.niehs.nih.gov/docs/2001/suppl-6/827-843gilbertson/abstract.html>

The Canadian and United States governments have been involved since 1972 in the implementation of the Great Lakes Water Quality Agreement (1), pursuant to the 1909 Boundary Waters Treaty (2). Water quality in the Great Lakes basin had deteriorated throughout the 19th century with the growth of cities and industries, and particularly through the first half of the 20th century with the growth of chemical manufacturing. The signing of the Great Lakes Water Quality Agreement was not only a diplomatic acknowledgment that pollution of the boundary waters between the two nations had caused injury to health and property on the respective other sides but also represented a scientific and regulatory response to this injury. Similarly, in 1991 the two governments signed the Canada–United States Air Quality Agreement (3) to address issues of transboundary air pollution, with particular reference to human health. The International Joint Commission, which was established under the Boundary Waters Treaty of 1909, has responsibilities for assisting the parties in implementing these agreements through evaluation of progress and through public consultation and information programs.

In recent years there has been substantial progress in integrating the science concerning the pollutant-induced injury to Great Lakes populations of humans (4,5) from exposures

to persistent toxic substances, particularly polychlorinated biphenyls (PCBs) and dioxins. Many of the original observations of injury were concerned with reproductive and developmental effects reported in Great Lakes wildlife (6), particularly in colonial fish-eating birds. These wildlife served as useful models of the structural and functional effects that might have been occurring in human populations exposed to teratogenic substances. These observations of effects in Great Lakes populations of wildlife and of humans were particularly influential in the original formulation of the hypothesis on endocrine disruptors (7,8). Since the late 1980s and early 1990s, this progress has been achieved not only through extensive funding of toxicology and epidemiologic research and monitoring by both governments (9,10) but also through application of epidemiologic criteria (11) to the various case histories to attain a higher level of certainty in the causal statements relating the chemically induced epizootics and epidemics to exposures to specific persistent toxic substances. Much of this research undertaken by the governments has been to identify critical subpopulations and to determine the exposures to and effects of persistent toxic substances, particularly in relation to human consumption of contaminated fish from the Great Lakes and from the St. Lawrence River (12).

Health Canada Studies of the Designated Areas of Concern

In the mid-1980s, the two governments had designated 42 Areas of Concern, under the Great Lakes Water Quality Agreement, that represented locations where water quality conditions routinely exceeded the established objectives. In the mid-1990s, Health Canada, as part of the Canadian government's responsibilities for implementing the Great Lakes Water Quality Agreement, collated health data and statistics for the populations in the 17 Areas of Concern on the Canadian side of the Great Lakes. Some of these locations were on interconnecting channels and therefore potentially susceptible to proximate sources of transboundary pollutants. The interconnecting channels include the St. Lawrence River, Niagara River, Detroit River, St. Clair River, and St. Mary's River. Canada has a national health service, and health data are collected from the provinces and territories and stored on a national basis by Statistics Canada. Within each of these 17 communities, the data were selected by Health Canada (13) related to the cases of mortality and morbidity as hospitalization for selected health outcomes, including cancers, that might be related to pollution. In addition,

This article is based on a presentation at the Workshop on Methodologies for Community Health Assessment in Areas of Concern held 4–5 October 2000 in Windsor, Ontario, Canada.

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This article is based primarily on the 17 Health Canada reports compiled by staff members of the former Great Lakes Health Effects Program and by their contractors. R. Whitehurst of the Windsor Cancer Prevention Coalition tabulated the cancer data, and many of the additional references were supplied by J. Hummel and by the staff of the Windsor Occupational Health Information Service.

This report was initially prepared as a technical background paper. The information in this document is based on the methodology, health data, statistics, and references compiled by Health Canada, but the interpretation is that of the authors in their personal and professional capacities and should not be construed to represent either the views of Health Canada, the International Joint Commission, the Occupational Health Clinics for Ontario Workers, or of any parts of their organizations.

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data were accessed concerning the incidence of congenital anomalies and low birth weights.

The 17 reports were prepared by Health Canada to provide quantitative data as a resource to professionals to begin to investigate the health status of populations within and around the Areas of Concern and to compare rates of human disease with the rates in the population in the rest of the Province of Ontario. No attempt was made to explain causal relationships between exposures to contaminants or other risk factors and any specific health outcome. The objective was to provide a basis for forming hypotheses that could be further investigated about whether the rates of human diseases and conditions might be linked to exposures to pollutants that were being or had been discharged or emitted to the Canadian Areas of Concern. Previous research in the United States on the distribution of cancer had demonstrated a "lake effect" of increased incidences of stomach and esophageal cancers in counties on the Great Lakes shoreline (14).

Though the reports were published in November 1998, they were not released until November 1999 after a news reporter with the Canadian Broadcasting Corporation on camera produced a copy of the report for the Detroit River Area of Concern during an interview with a Health Canada official. This reluctance to release the reports was because of the responses from environmental agencies concerned about costs of cleanup, the reactions of the medical officers of health to the widespread public dissemination of uninterpreted data and statistics, and the potential liabilities of governments for exposures of communities to pollutants and for any remedial actions. The medical authorities are learning how to collaborate in responding to these kinds of evidence of diseases suspected to be induced by pollutants. For example, responsibilities for health in Ontario are divided among the following three ministries: the Ontario Ministry of Health is responsible for healthcare delivery and for the local health units, headed by the medical officers of health; occupational aspects of human health are the responsibility of the Ontario Ministry of Labour; and environmental aspects of human health are the responsibility of the Ontario Ministry of Environment. The recurrent challenges of these kinds of epidemiologic data are the estimation of the contribution of occupational and environmental exposures of communities to chemicals, and the separation of these factors from genetic, lifestyle, nutritional, and other factors, particularly when there are split jurisdictions. The Health Canada reports were focused on diseases that might be linked to pollutants and were therefore outside the direct jurisdiction of the local health units.

Selection of Windsor for Intensive Study

One of these 42 Areas of Concern is the Detroit River, which is a severely polluted interconnecting channel between Lake St. Clair and Lake Erie and forms part of the boundary waters between Canada and the United States. Windsor was selected by the Great Lakes Science Advisory Board of the International Joint Commission as a model community for a detailed study of the efficacy of the use of health data in the Remedial Action Plan process at the local level for the following reasons:

- It is located beside the Detroit River, which is a large interconnecting channel and has been the subject of investigations of transboundary air and water pollution for several decades.
- Windsor is one of several Canadian cities in southwestern Ontario (including Toronto, Hamilton, and London) on a major transportation corridor, resulting in poor air quality.
- The community is large enough to provide a population size that can potentially yield statistical significance for all except the rarest of diseases but is not so large that all variations from the provincial rates of disease become statistically significant.
- There has been a community-based movement, including an occupational health clinic and information service, since the discovery in the late 1970s of a mesothelioma epidemic among auto workers (15).
- There are previous reports and studies of the cancer risks from air pollutants (16), of the geographic distribution of cancers (17), and of mandated community health profiles (18,19).
- The Great Lakes Regional Office of the International Joint Commission is located in Windsor, enabling the development of a level of familiarity with the study area including the city, the medical establishments, the unions, the university, and various industries.

Health Canada (13) prepared the report on the Canadian part of this Area of Concern using the selected health data and statistics for the 7-year period from 1986 to 1992 for the Ontario municipalities close to Windsor. For the purposes of this article, these conterminous municipalities are referred to as the "Windsor Area of Concern" or "Windsor," though it is only part of the Detroit Area of Concern, and includes more than just the municipality of Windsor.

Sources of Contaminants and of Population Exposures

Until recently, residents in the Windsor Area of Concern thought they were being exposed to a variety of pollutants from a

variety of well-known sources. In addition to well-characterized occupational exposures of the workforce to a variety of products during automobile manufacturing, residents believed they knew the major sources of water and air pollutants to which they were exposed not only in Windsor but also in Detroit. For example, the major industries in Windsor include three car assembly plants (General Motors and two Daimler-Chrysler plants), a Ford engine plant and a foundry, and the Zalev scrap-metal recycling plant. Similarly, Windsor is immediately downwind of the Rouge Steel and National Steel Corporation steel mills with associated coking operations in Detroit; the wastewater treatment plant of the city of Detroit and associated sludge incineration facilities; the Greater Detroit Resource Recovery Authority municipal waste incinerator; and the Conners Creek Power Plant, which until recently was coal fired (16). Detroit is a large, mature metropolitan area largely dependent economically on car manufacturing and associated industries, such as chrome-plating plants. These have left an appreciable legacy of environmental contamination and toxic waste dump sites, some of which are being addressed through the Superfund program.

In previous studies, using air sampling and analysis, emission inventories, and cancer risk assessment modeling, the major air pollutants of concern for carcinogenesis in the Windsor community were ranked as follows: chromium (VI), benzene, 1,3-butadiene, chloroform, carbon tetrachloride, polycyclic aromatic hydrocarbons (PAHs), acetaldehyde, perchloroethylene, ethylene dichloride, formaldehyde, methylene chloride, cadmium, and 1,4-dichlorobenzene (16). Ingestion was identified as a major route of exposure for formaldehyde, cadmium, chromium (VI), dioxins, furans, and mercury. Subsequently, mapping techniques were used to investigate the possible relationships between the distribution of cancer rates for breast, lymphoma, lung, oral, prostate, colorectal, stomach, ovary, brain, uterine, and leukemia in the population in the city of Windsor and exposures to several of the above environmental contaminants (17). A recent review of air quality studies for toxic substances undertaken in the Detroit-Windsor region (20) concluded that "modeling and health assessment studies continue to predict concentrations in the region that exceed the 1:10⁶ risk ratio for air toxics."

More recently, significant new databases have become available in Canada and in the United States (21), respectively, using data on the National Pollutant Release Inventory and the Toxic Release Inventory. In Windsor the top three sources of releases of toxic chemicals

were from a little-known plant called Maple Roll Leaf (616,091 kg of pollutants); the city of Windsor (562,747 kg); and ADM Agri-Industries Ltd. (473,500 kg). Similarly, the three largest releases of toxic substances on the Detroit side were from Wayne Disposal in Belleville (8,267,660 lb); Detroit Edison (2,029,702 lb at the River Rouge Power Plant, and 1,772,349 lb at the Trenton Channel Power Plant); and from the General Motors assembly plant at Hamtramck (1,105,809 lb).

The purposes of this article are

- to demonstrate how the Health Canada health data and statistics can be used by lay public involved in remedial action plans at the local level to describe the health of their communities in relation to sources of a variety of chemical pollutants;
- to compare community health in Windsor with that in Hamilton and with some other Canadian Areas of Concern, such as Sarnia; and
- to generate hypotheses about potential pollutant-induced health effects in Great Lakes communities as a template for further research, particularly in Windsor.

Methods

Health Canada (13) detailed the methods used in the study under the following headings: assigning standard geographic codes; selecting health outcomes; gathering data; and analyzing the data.

Assigning Standard Geographic Codes

Briefly, each of the 17 Areas of Concern was described using standard geographic codes, which not only contain provincial, census division, and census subdivision information, but also coincide with the Canadian process for collection of human health data. Each of the 17 reports contained detailed background information on the study area and its population, methods used in the study for assigning standard geographic codes, and gathering associated health data. In the specific case of preparing the report on the Windsor Area of Concern, the following municipalities with associated standard geographic codes were selected: Windsor (3537039); Amherstburg (3537029); Tecumseh (3537044); Sandwich West (3537034); Essex (3537054); Belle River (3537059); St. Clair Beach (3537052); Anderdon (3537031); Malden (3537026); Colchester North (3537018); Sandwich South (3537046); Rochester (3537058), and Maidstone (3537051). The population in this area in 1991 was 274,145, which represented 2.71% of the Ontario provincial population of 10,104,317. Data for the rates for diseases and disorders for the populations for all the Areas of Concern were age standardized by gender, and comparisons were made with the

rates for the rest of Ontario. Comparisons are made throughout this account with the health data and statistics for the Hamilton Harbour Area of Concern, which is another industrial municipality in southern Ontario comprising the following municipalities with standard geographic codes: the cities of Hamilton (3525014), Burlington (3524002), and Stoney Creek (3525003); the towns of Ancaster (3525014), Dundas (3525026), Flamborough (3525030), and Milton (3524003); and the township of Glanbrook (3525009). All represented a population of 613,315 or 6.07% of the provincial population.

Though the population in the Hamilton Harbour Area of Concern is more than twice the population included by Health Canada in the Detroit River Area of Concern, the populations were similar in terms of many demographic and socioeconomic measures, including the percentage of the population who were 15 years of age and older; basic education, families and dwellings, and average income; these were similar to the rest of the Province of Ontario (22). Health Canada did not include detailed consideration of demographic and socioeconomic risk factors. These have been shown to be important, together with other risk factors, in relation to the geographic distribution of the incidence of cancer in the province (23,24), though there still remains a need to investigate these and other possible risk factors in relation to the incidence of other diseases.

Selecting Health Outcomes

Health Canada (13) selected about 70 categories of health end points, using the *International Classification of Diseases, Ninth Edition (ICD-9)* (25). Because this project was undertaken by the former Great Lakes Health Effects Program (13) under the mandate of the Great Lakes Water Quality Agreement, there was an orientation toward selecting diseases and disorders, based on references in the published literature, that might plausibly be linked to exposures to contaminants in the Great Lakes environment. Although the Health Canada documents included a consideration of a wide variety of physical, chemical, and biologic agents that could cause selected diseases and disorders, this community health profile for Windsor, Ontario focused particularly on the possible environmental and occupational agents. A second consideration in selecting the health outcomes was that data would be available for these diseases and disorders.

There is a possible discrepancy between different interpretations of "pollutants" and "contaminants." Several of the categories of selected outcomes included microbiologic agents such as bacterial infections and viruses and other agents such as helminths. For the

purposes of this paper, diseases and disorders caused by these biologic agents are omitted. Table 1 contains the selected health outcomes used in this article and based on those of the *ICD-9* (25).

Gathering and Analyzing the Data

Population census data for the years 1986 and 1991 were accessed from the Demography Division of Statistics Canada to calculate mortality and morbidity rates on an age-specific and gender-specific basis. Mortality data were provided by Statistics Canada to Health Canada's Laboratory Centre for Disease Control and included information on the cause of death, reported by ICD code, the last location of residence based on the census subdivision, and the sex and age of the deceased (13). Hospital separations data were supplied by the Canadian Institutes for Health Information, and included data on sex, age, and residence, and the ICD code for the diagnosis for the main cause in cases of hospitalization. Health Canada (13) warned about some of the pitfalls of using hospital separations data, and these concerns included multiple visits or transfers between or within hospitals. They also exclude visits to clinics, doctors' offices, and outpatient departments. Similarly, there may have been difficulties in transforming residence information based on a postal code or an Ontario residence code into a census subdivision. Further, these data for Ontario Province do not include Ontario residents who were hospitalized in another province. These pitfalls were addressed in the Health Canada reports in analyzing the data and statistics. For example, in using the hospital separations data, Health Canada referred to morbidity rates rather than incidence rates. One potentially significant pitfall not mentioned in the reports relates to the possible differences between large metropolitan areas and small municipalities in local policies concerning hospital admittance; the latter may be more inclined to admit a patient than the former.

The age-standardized rates were calculated based on 19 age groups, and the report presented the rates for the following five age ranges: all ages, 0–24 years, 25–44 years, 45–74 years, and over 75 years. The age-adjusted mortality and morbidity rates were compared with the rates for the rest of the Province of Ontario, and ratios were calculated comparing the local rates with the provincial rates. Appreciable sampling variation may arise from considering small numbers of deaths, cases, or incidences within some of the age groups and the Poisson test was applied to overcome these possible inaccuracies. In the following account of community health in Windsor and its

comparison with some other Areas of Concern, only those rates of disease outcomes that are statistically significantly elevated at or above the 95% level are generally commented on. Health Canada also occasionally included a flag to warn that though a rate or ratio, compared with the rest of the province, was not statistically

significant, the limited sample size could undermine the accuracy of such a statistical determination of nonsignificance. In interpreting the data and statistics for the Windsor Area of Concern, there has been considerable reliance on the references in several Health Canada reports (13,26,27), as well as other reference sources.

Results

Mortality and Morbidity Rates Based on Hospitalization Records, 1986–1992

The rate at which people die or go to the hospital can be taken as an indication of the overall health of the community. During the 7-year period between 1986 and 1992,

Table 1. Health outcomes that might be linked to pollution.^{a,b}

ICD-9 category	ICD-9 number	Disease or condition	ICD-9 category	ICD-9 number	Disease or condition
Category II		All malignant neoplasms	Category VIII	460–466	Acute respiratory infections
	140–149	Malignant neoplasm of lip, oral cavity, and pharynx		470–478	Other diseases of the upper respiratory tract
	146–148	Malignant neoplasm of the pharynx		470–487	Pneumonia and influenza
	150–159	Malignant neoplasm of digestive organs and peritoneum		490–496	Chronic obstructive pulmonary disease and allied conditions
	150	Malignant neoplasm of oesophagus		491	Chronic bronchitis
	151	Malignant neoplasm of stomach		492	Emphysema
	153–154	Malignant neoplasm of colon and rectum		493	Asthma
	155	Malignant neoplasm of liver and intrahepatic bile ducts		500–537	Pneumoconioses and other lung diseases due to external agents
	156	Malignant neoplasm of gallbladder and extrahepatic bile ducts	Category IX	530–537	Diseases of esophagus, stomach, and duodenum
	157	Malignant neoplasm of the pancreas		555–558	Noninfective enteritis and colitis
	160–165	Malignant neoplasm of respiratory and intrathoracic organs		560–569	Other diseases of intestines and peritoneum
	162	Malignant neoplasm of the trachea, bronchus, and lung		570–579	Other diseases of digestive system
	170–175	Malignant neoplasm of bone, connective tissue, skin, and breast	Category X	580–589	Nephritis, nephrotic syndrome, and nephrosis
	172	Malignant melanoma of skin		590–599	Other diseases of urinary system
	174	Malignant neoplasm of female breast		600–608	Diseases of male genital organs
	179–189	Malignant neoplasm of genitourinary organs		606	Infertility, male
	183	Malignant neoplasm of ovary and other uterine adnexa		610–611	Disorders of the breast
	185	Malignant neoplasm of the prostate		617–629	Other disorders of female genital tract
	186	Malignant neoplasm of testis		617	Endometriosis
	188	Malignant neoplasm of the bladder		628	Infertility, female
	189	Malignant neoplasm of kidney, other, and unspecified urinary organs	Category XI	630–639	Pregnancy with abortive outcome
	190–199	Malignant neoplasm of other and unspecified sites		634	Spontaneous abortion
	193	Malignant neoplasm of thyroid gland		640–648	Complications mainly related to pregnancy
	200–208	Malignant neoplasm of lymphatic and haematopoietic tissue		642	Hypertension complicating pregnancy, childbirth, and the puerperium
	200,202	Non-Hodgkin lymphoma		644	Early or threatened labor
	201	Hodgkin disease		680–686	Infections of skin and subcutaneous tissue
	204–208	Leukaemia		690–698	Other inflammatory conditions of skin and subcutaneous tissue
Category III	240–246	Disorders of thyroid gland		700–709	Other diseases of skin and subcutaneous tissue
	250–259	Diseases of other endocrine glands	Category XII	710–719	Arthropathies and related disorders
	250	Diabetes mellitus		720–724	Dorsopathies
	255	Ovarian dysfunction		725–729	Rheumatism, excluding the back
	257	Testicular dysfunction		730–739	Osteopathies, chondropathies, and acquired musculoskeletal deformities
	270–279	Other metabolic disorders and immunity disorders	Category XII		All anomalies
Category IV	280–289	Diseases of blood and blood-forming organs		740.0–742.9	Central nervous system anomalies
Category VI	330–337	Hereditary and degenerative diseases of the central nervous system		740.0–740.2	Anencephalus and similar anomalies
	332	Parkinson disease		741.0–741.9	Spina bifida
	340–349	Other disorders of the central nervous system		742.1–742.2	Microcephalus and brain reduction
	340	Multiple sclerosis		742.3	Congenital hydrocephalus
	343	Infantile cerebral palsy		743.0–743.9	Eye anomalies
	350–359	Disorders of the peripheral nervous system		745.0–746.9	Congenital heart defects
	359	Muscular dystrophies and other myopathies		745.4	Ventricular septal defect
	360–379	Disorders of the eye and adnexa		745.5	Atrial septal defect
	369	Blindness and low vision		747.1–747.9	Circulatory system anomalies
	380–389	Diseases of the ear and mastoid process		747.3	Pulmonary artery anomalies
Category VII	401–405	Hypertensive disease		748.0–748.9	Respiratory system anomalies
	410–414	Ischemic heart disease		749.0–749.2	Cleft lip and/or palate
	415–417	Diseases of pulmonary circulation		750.1–751.9	Digestive system anomalies
	420–429	Other forms of heart disease		752.6	Hypospadias, epispadias
	440–448	Diseases of arteries, arterioles, and capillaries		753.0–753.9	Urinary system anomalies
	440	Atherosclerosis		753	Renal agenesis and dysgenesis
				754.5–754.7	Clubfoot
				755.0–755.1	Polydactyly, syndactyly
				755.2–755.3	Limb reduction anomalies
				758	Down syndrome
			Category XIV	760–779	Certain conditions originating in the perinatal period

^aBased on the *International Classification of Diseases, Ninth Edition (25)*. ^bAdapted from Health Canada (13).

people in the Windsor Area of Concern died at significantly higher rates (males: 8% higher, 613 excess deaths; females: 5% higher, 366 excess deaths) than in the rest of Ontario Province. This increased mortality occurred significantly among people 45–74 years of age for both males (14% higher, 496 excess deaths) and females (10% higher, 232 excess deaths). In contrast, the mortality rates in both males and females in Hamilton, Ontario, were the same as those in the rest of Ontario, but were about 10% lower for males up to 44 years of age and 14% lower for females up to 24 years of age. The rates of mortality from all causes for both Windsor men and women ranked sixth out of 25 Canadian census metropolitan areas in a recent analysis of 1994–1996 data and were significantly elevated above the rates for Canada (28).

The number of cases of people in the Windsor Area of Concern being hospitalized for all causes during the 7-year period between 1986 and 1992 was 122,776 cases, or 21% higher in males (20,987 excess cases of morbidity), and 165,344 cases, or 15% higher for females (21,567 excess cases of morbidity). All age categories had significantly elevated morbidity as hospitalization rates: among those between birth and 24 years of age, the rate was 12% higher for males (2,809 excess) and 9% higher for females (2,866 excess) but rose to 32% higher in males (5,610 excess) who were between 25 and 44 years of age compared with 10% higher for females (5,729 excess). For those 45–74 years of age, the rate was about 25% higher (10,955 excess for males and 9,819 excess for females); for those over 75 years of age, the morbidity was 14% higher for males (2,290 excess) and 20% higher for females (4,649 excess). In contrast, rates of morbidity as hospitalization in Hamilton are about 15% lower than those for the rest of the province, and significantly lower rates are apparent throughout all age categories. It would seem that, despite the apparent similarities in latitudes, locations in southern Ontario, degree of industrialization, and several demographic and socioeconomic measures, the community in Windsor has much higher rates of morbidity and mortality than Hamilton, suggesting that there are serious public health issues that might possibly be related to exposures to pollutants.

Of 11 Canadian cities studied (29) in relation to mortality and air pollution, Windsor had the highest daily mortality, followed by Hamilton (2.09 vs 2.02 deaths/day/10⁵ population). This mortality in Windsor did not seem to be explained by concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, or ozone, or by consideration of these pollutants in aggregate, but these pollutants were associated with

hospital admissions (30). These results pose the question of whether there were other factors in Windsor that might have accounted for the high mortality rate.

ICD-9 Category II: Cancer Mortality and Morbidity

The following is a description of the cancer mortality and incidence based on the health data and statistics from 1986 to 1992. Among the 17 Canadian Areas of Concern, the Windsor Area of Concern was the only location that had a cancer incidence rate for the aggregated age groups in either males or females that was statistically significantly elevated. Cancer incidence in the population in the Windsor Area of Concern was 4,275 cases for males and 3,941 for females. The incidence rate for males for the aggregated age groups was 7% above the rate for the rest of the province, resulting in about 280 extra cases. The elevated cancer incidence rates occurred particularly among males and females 45–74 years of age, and were 10% (254 excess) and 5% (115 excess) higher, respectively, than the provincial rates.

In contrast, the incidence of cancers in the population in Hamilton was 3% lower than the provincial rate for both males and females, and no age category was significantly elevated. These results are not inconsistent with the predictions of the carcinogenesis risk assessment for the Windsor population (16) and indicate that the population in the Windsor Area of Concern is being exposed to carcinogenic compounds at concentrations that are probably injurious. The following classes of cancers that might be related to exposures to pollutants were significantly elevated in the Windsor Area of Concern.

Cancers of the Lip, Oral Cavity, and Pharynx (ICD-9: 140–149)

Health Canada (13) noted the possible involvement of air pollution as a potential factor in the development of cancer of the pharynx, but based on the review by Björklund and Wenersberg (31), also referenced the associations with several other potential risk factors including tobacco, marijuana, alcohol, diet, occupational factors, virus infections, genetic instability, and compounds that induce aryl hydrocarbon hydroxylase. The mortality rate from cancers of the lip, oral cavity, and pharynx among Windsor residents 45–75 years of age was 54% higher for males (about 32 extra deaths) and more than 2-fold (2.11 times) higher for females (about 15 extra deaths) than in the rest of the province. The cancer mortality and incidence rates in the Hamilton population were generally not statistically significantly lower than the provincial rates. The exception was in Hamilton males 45–74 years of age,

for whom the cancer incidence rate was significantly 12% below the provincial rate.

Thomas (32), in reviewing the epidemiologic evidence in relation to alcohol consumption as a risk factor for these cancers, remarked on the role of alcohol in potentiating the carcinogenic effect of cigarette smoke on the increased risk of oral and pharyngeal cancer. The feasibility of investigating the attributable role of carcinogenic air pollutants in causing these reported excess cancers in the Windsor population might be evaluated in relation to other recognized risk factors.

Cancers of Digestive Organs and Peritoneum (ICD-9:150–159)

This aggregated class of cancers included malignant neoplasms of the esophagus, stomach, colon and rectum, liver and intrahepatic bile ducts, gall bladder and extrahepatic bile ducts, and pancreas. Health Canada (13) relied heavily on the review of Ahlgren and Macdonald (33) in selecting these various cancers of the digestive organs and the peritoneum for inclusion in its study of diseases that might be related to pollution in the Areas of Concern. Major risk factors include various genetic, lifestyle, and socioeconomic factors. But Health Canada (13) also noted studies relating exposures to radiation as a risk factor in colon and rectal cancer (34), and long-term consumption of chlorinated drinking water as risk factors in colon cancer (26). More recently, Paulu et al. (35) demonstrated an increased risk of colon and rectal cancer from contamination of a water supply with tetrachloroethylene.

Among this class of cancers, there was a 10% higher mortality rate among Windsor males than the rest of Ontario, particularly among those males 45–74 years of age. Much of this increased rate of mortality from cancer in males was attributable to cancer of the colon and rectum, resulting in about 48 excess deaths. The comparable mortality rate for Hamilton males 45–74 years of age is 12% below the provincial rate. The feasibility of further investigations of the factors associated with the elevated mortality rate from colorectal cancer in the population in the Windsor Area of Concern should be evaluated. There are, for example, several occupational and environmental risk factors associated with colorectal cancer, including exposures to soot, asbestos, cutting fluids and oils, and combustion gases from coal, coke, and wood (36). Trends could be monitored prospectively over the long term to track whether recent changes in drinking water treatment from a chlorination process to an ozonation process have an effect on the incidence of this cancer.

Of particular concern was the increased rate of mortality from pancreatic cancer among both Windsor males (44% higher, 42

extra deaths) and females (37% higher, 36 extra deaths), particularly for those 45–74 years of age. This significantly elevated mortality from pancreatic cancer among this age group was reflected in increased incidence rates in males (33% higher, 21 excess cases) and females (40% higher, 21 excess cases). An increased incidence rate from pancreatic cancer (43% higher, 20 excess cases) even persisted for those women over 75 years of age in the Windsor Area of Concern.

The Health Canada study (13) cited the review of Ahlgren and Macdonald (33) in identifying associations of pancreatic cancer not only with cigarette smoking, but also with occupational exposures to solvents, petroleum compounds, and β -naphthylamine in chemical and coke plant workers, sawmill workers, miners, and metal workers. A more recent review (37) indicated that the causes of pancreatic cancer are still obscure, but that higher rates seem to occur in more industrialized nations, though no single chemical agent has been consistently identified. Of particular interest in this latter study was the association of pancreatic cancer with pancreatitis and with non-insulin-dependent diabetes mellitus. Windsor is the largest Canadian manufacturing center for automobiles, and there are many workers involved in a variety of industries involving metal manufacturing. In addition, Windsor residents are downwind of several large coking operations in Detroit associated with steel production. The feasibility of investigating the factors associated with these elevated rates of pancreatic cancer incidence and mortality should be evaluated to determine whether they warrant special epidemiologic investigations on a priority basis, not only because a significant proportion of these cancers are likely preventable but also because the survival rate for this cancer is so low.

Cancers of the Respiratory and Intrathoracic Organs (ICD-9:160–165)

There were increased incidence rates and mortality from cancers of the respiratory and intrathoracic organs for both males and females in the Windsor Area of Concern (13). The mortality rate for males was 17% higher than the provincial rate, yielding 115 excess deaths and associated mostly with those 45–74 years of age. Of particular concern was the more than 2-fold rate (2.23 times, 14 excess deaths) for Windsor males 25–44 years of age from these cancers. The mortality rate for Windsor females was 12% higher than the provincial rate and was associated with 39 excess deaths. Whereas Hamilton males had a mortality rate for this cancer 6% higher (92 excess deaths) than the provincial rate, there was, in contrast to Windsor, a total of 2 deaths among males 25–44 years of age. The mortality rate was

statistically indistinguishable from the provincial rate for both Hamilton males and females 45–74 years of age. Only among those Hamilton males who were over 75 years of age was there a statistically significantly higher rate (13% and 53 excess deaths) from cancer of the respiratory and intrathoracic organs. Windsor men and women both ranked fourth out of 25 Canadian census metropolitan areas for mortality for lung cancer (28).

These elevated mortality rates in the Windsor Area of Concern were reflected in increased incidence rates in males (19% higher and nearly 165 excess cases) and in females (16% higher and 70 excess cases). Among males 25–45 years of age, the incidence rate was 77% higher than the provincial rate, and elevated incidence rates were evident for males (20%) and females (17%) 45–74 years of age. In contrast, the incidence rates for respiratory and intrathoracic cancer in Hamilton males and females were indistinguishable from the provincial rates, even among Hamilton males 45–74 years of age and among those over 75 years of age.

Health Canada (13) cited the work of Motta (38) in listing the following factors associated with lung cancer: mainstream and secondary-stream tobacco smoke, radon, asbestos, formaldehyde, end products of uncontrolled combustion, air pollution, and occupational exposures to a variety of substances. The following compounds were identified by the Windsor Air Quality Committee (16) in the inhalation cancer risk assessment for the Windsor population as having concentrations above the 10^{-5} risk level: 1,3-butadiene, benzene, chromium (VI), chloroform, carbon tetrachloride, PAHs, acetaldehyde, perchloroethylene, ethylene dichloride, formaldehyde, methylene chloride, cadmium, and 1,4-dichlorobenzene. The health data and statistics for the elevated rates of mortality and incidence of respiratory and intrathoracic cancer in the population in the Windsor Area of Concern, the contrast in these rates with the rates for Hamilton, and the elevated risk levels from the identified substances of concern indicate that there are atmospheric sources of carcinogens to the Windsor–Detroit airshed that are injurious to the health of the Windsor community. The feasibility of undertaking investigations of these specific sources should be assessed on a priority basis, and controls that could lead to significant reductions in the incidences of these preventable cancers should be undertaken.

Cancers of the Genitourinary Organs (ICD-9:179–189)

Health Canada (13) selected the following cancers of the genitourinary organs as potentially linked to pollutants: ovary, prostate,

testis, bladder, kidney, and other urinary organs. A statistically significant increase in bladder cancer incidence was evident for Windsor males (19% higher, 29 excess cases) 45–74 years of age. Health Canada noted that the risk factors for this category of cancers (ICD-9:189) are as yet unknown but may include tobacco use, obesity, and a rich diet of animal fats and cholesterol (39).

Cancers of the Lymphatic and Hematopoietic Tissues (ICD-9:200–208)

The following three kinds of cancers of the lymphatic and hematopoietic system were selected by Health Canada (13) as potentially associated with exposures to pollutants: non-Hodgkin's lymphoma, Hodgkin's lymphoma, and leukemia. The incidence rate for this category of cancers in Windsor females 45–74 years of age was 23% higher (37 excess cases) than in the rest of the province. In Hamilton males over 75 years of age, there was a 17% higher (32 excess cases) incidence for this category of cancers.

Of particular concern was the incidence rate from leukemia in Windsor males of all ages, with a 21% higher rate (29 excess cases). The incidence rate from leukemia was elevated in both males (33% higher, 24 extra cases) and females (44% higher, 21 extra cases) 45–74 years of age compared with the rest of the province. The Hamilton mortality and incidence rates and ratios from leukemia in males and females were comparable with those for the rest of the province.

Health Canada (13) noted the association of the leukemias with heritable factors, viruses, radiation, electromagnetic fields, pesticides, chemicals such as benzene, and other occupational exposures, and drugs (34,39,40). In the risk assessment undertaken by the Windsor Air Quality Committee (16), benzene was ranked second only to hexavalent chromium as the leading chemical of concern for cancer, with an upper risk factor between 10^{-4} and 10^{-3} . At that time, 3,611,000 kg benzene was emitted to the atmosphere in the Detroit area, representing 96.3% of the emissions in the airshed, and 139,201 kg (3.7%) was emitted from Windsor and vicinity.

The six females over 75 years of age who had Hodgkin's disease represented more than a 2-fold (2.75 times) increase in the incidence rate compared with the rest of the province. There were 12 deaths attributable to Hodgkin's disease in females, representing more than a 2-fold (2.26 times) rate compared with the rest of the province. Though the numbers of deaths in females in each age category were too small to attain statistical significance, the more than 2-fold elevated mortality rates occurred consistently in all age categories. In Hamilton females 25–44 years of age, there was a 63% higher incidence (13

excess cases) of Hodgkin's disease compared with the rest of the province. The deaths of five Hamilton males who died from Hodgkin's disease between birth and 24 years of age represent a mortality rate more than 3-fold the rate in the rest of the province. Health Canada (13), in addition to the associations of Hodgkin's disease with heritable factors, surgical procedures including tonsillectomy and appendectomy, and infectious diseases such as mononucleosis, mentioned exposures to pesticides, electromagnetic fields, benzene, and radiation (39,40).

A recent review of the epidemiology of Vietnam veterans has reaffirmed earlier reports of associations between exposures to the chlorophenoxy herbicide mixture Agent Orange and Hodgkin's and non-Hodgkin's lymphoma as well as an increased risk of a rare childhood leukemia, acute myelogenous leukemia (41). A possible interactive effect between Epstein-Barr virus and higher concentrations of organochlorine chemicals, particularly hexachlorobenzene, has been associated with the risk of hairy cell leukemia, one of the group of non-Hodgkin's lymphoma malignancies (42). The feasibility of investigating the excess incidence and mortality from cancers of the lymphatic and hematopoietic systems in the community in the Windsor Area of Concern should be assessed, as these cancers may be preventable through controls on the releases of known and previously unsuspected carcinogenic compounds.

ICD-9 Category III: Endocrine, Nutritional and Metabolic, and Immunity Disorders

In recent years there has been a growing appreciation of the effects of environmental contaminants on the functioning of the endocrine systems (7), and thereby concerns about the development and functioning of the immune (43) and neurologic systems (44).

Disorders of the Thyroid Gland (ICD-9:240-246)

There were 314 cases of morbidity as hospitalization for disorders of the thyroid gland in females in the Windsor Area of Concern, representing a 24% increase over the provincial rate. In contrast to all the other 16 Areas of Concern, the onset of the increased rate of thyroid disease in females occurred in the Windsor Area of Concern between birth and 24 years of age, and this increase was more than 2-fold (208%) the provincial rate. Further, there were elevated rates for thyroid disease in Windsor women occurring in all age categories. These findings contrast with the rates of thyroid morbidity in the Hamilton population that had a 30% lower rate in males and 28% lower rate in females compared with the rest of the province, suggesting the possible

presence of thyroid-active agents in the Detroit/Windsor environment.

The Detroit/Windsor area has had endemic goiter since early times, but this has been successfully counteracted through the use of iodized salt. Despite this endemic goiter, observations of Great Lakes fish and wildlife have demonstrated that the most severe thyroid hyperplasia, unrelated to iodine status, occurs in the region of the Detroit River and Western Lake Erie and implicates environmental goitrogens (45,46). There are a variety of compounds that can affect the thyroid gland, including naturally occurring goitrogens such as flavonoids in legumes; drugs such as phenytoin and lithium; pesticides such as DDT, thiocarbamates, and aminotriazole; and industrial chemicals such as polyhalogenated aromatic compounds, phenol derivatives, and phthalates (47). Interference with thyroid function has recently been implicated in the abnormal structural and functional development of the fetal and infant brain, with consequences for learning and behavior (48). The feasibility of undertaking epidemiologic investigations, possibly including mapping of the distribution of prescriptions for thyroid supplement, should be evaluated to investigate the possible presence, identity, and sources of thyroid-active agents in the Windsor Area of Concern, with the intention of bringing in strict controls, including prohibitions of releases.

Diseases of Other Endocrine Glands (ICD-9:250-259)

There are increased rates of morbidity for diseases of other endocrine glands in both males (41% higher, 625 excess cases) and females (41% higher, 735 excess cases) in the Windsor Area of Concern.

Diabetes Mellitus (ICD-9:250)

In contrast to Hamilton and Toronto, which had rates of morbidity from diabetes 30-40% lower than the provincial rates, the rates in the Windsor Area of Concern were 44% higher for males (604 excess cases) and 41% higher for females (637 excess cases). Of particular concern is the early onset of diabetes. In common with other relatively polluted locations such as Thunder Bay, Sault Ste. Marie, Spanish River, and Niagara Falls, the onset of the increase in the rates of diabetes in the Windsor Area of Concern occurred between birth and 24 years of age (58% for males or 112 excess cases, and 41% for females or 94 excess cases). For Windsor males 25-44 years of age, the rate of hospitalization for diabetes was 51% higher than the rest of the province and 59% higher for females, and the respective rates for those 45-74 years of age were 49 and 40% higher. These data indicate that there is a much

higher rate of morbidity as hospitalization for diabetes in the Windsor community for all age groups up to 75 years of age. Diabetes was practically an unknown disease among First Nations and Inuit people 50 years ago, but Health Canada has acknowledged there is an epidemic of type 2 diabetes in some First Nations communities and among Aboriginal children as young as 5 years of age, and has responded with an Aboriginal Diabetes Initiative.

Health Canada (13) reviewed the factors associated with diabetes (49,50). In addition to hereditary and immune-mediated factors, it can be related to a variety of viruses such as mumps, rubella, cytomegalovirus, Coxsackie viruses, retroviruses, and reoviruses, or linked to encephalomyocarditis caused by a group of small RNA picornaviruses. There are several substances, such as nitroso compounds, that are toxic to beta cells located in the pancreatic islets of Langerhans. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin has been shown to decrease blood sugar and insulin levels in treated rats and to result in hypersensitivity to insulin (51). Vietnam veterans exposed to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in Agent Orange have an increased incidence of diabetes, and those without diabetes had a higher incidence of hyperinsulinemia (52). The association between exposure to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin and diabetes has been recently affirmed (41,53). An association has been demonstrated between elevated PCB levels in serum and diabetes in pregnant women (54). Associations between exposures to arsenic and the incidence of diabetes have been published (55,56), and more recently, a mechanism has been proposed through interference with the action of glucocorticoids (57). The feasibility should be assessed of undertaking epidemiologic investigations into the causes of the markedly elevated rates for diabetes in all age categories in the Windsor Area of Concern, including consideration of the possibility that pollutants released to the environment are interfering with the normal functioning of the pancreas.

Ovarian Dysfunction (ICD-9:256)

Similarly, in contrast to Hamilton and Toronto, which had morbidity as hospitalization rates of ovarian dysfunction related to diseases of the endocrine system well below the provincial rate, the rate in the Windsor Area of Concern was more than twice (2.12 times, 30 excess morbidity cases) the provincial rate. This rate was comparable with the rates at Thunder Bay (2.19 times) and Sault Ste. Marie (2.34 times), though not as high as at Spanish River (5.84 times). There was an early onset of the significantly elevated rates of hospitalization of women for ovarian dysfunction in the Windsor Area of Concern;

the increased rates began in the group under 25 years of age with a rate that was 96% higher than the provincial rate and increased to over 2-fold (2.18 and 22 excess cases) in females 25–44 years of age.

Health Canada (13) included the following in this category of disease: hyperestrogenism, hyperandrogenism, ovarian failure, premature menopause, and polycystic ovaries. Risk factors associated with ovarian dysfunction including obesity, heredity, enzymatic defects, autoimmune disorders, congenital anomalies, radiation, chemotherapy, viruses, cigarette smoking, surgery, and other idiopathic conditions (13,58). There are several experiments in animals that demonstrate that exposures to reproductive toxicants such as benzo[*a*]pyrene (59) and hexachlorobenzene (60), affect ovarian follicle development. Exposure of monkeys to lead resulted in suppression of circulating luteinizing hormone, follicle stimulating hormone, and estrogen levels (61). The feasibility of investigating the risk factors associated with the high morbidity rates of ovarian dysfunction in the Windsor Area of Concern should be evaluated.

Other Metabolic and Immunity Disorders (ICD-9:270–279)

This category of disorders, selected by Health Canada (13), includes not only metabolism and/or transport of amino acids, carbohydrates, lipids, plasma proteins, minerals, and fluid, electrolyte and acid-base balance, but also disorders of immune development and function. Health Canada (13) noted the wide array of substances, including halogenated aromatic hydrocarbons, asbestos, benzene, and heavy metals, that have been associated with immunosuppression and immunodeficiencies in humans (40,62). Of specific interest is the relationship between prenatal exposures to PCBs and dioxins and changes in immune function [reviewed in Weisglas-Kuperus (63)].

In terms of morbidity as hospitalization from disorders of the metabolic and immune systems, Windsor males had rates that were 42% (196 excess cases) and females were 49% higher (413 excess cases) than the rest of the province. There was an early onset of this excess morbidity (30% higher) in Windsor males under 25 years of age. In males and females over 45 years of age, the morbidity rate as hospitalization was 47% higher and 61% higher, respectively, and rose for those over 75 years of age to 60 and 94% higher, respectively.

The 46 females who died of these disorders yielded a rate that was 33% (11 excess deaths) higher than the rest of the province. Most of this increased rate of mortality (86% higher than the rest of the province) occurred among females 45–74 years of age.

There is a need to disaggregate these data to determine whether the increased rates are mostly associated with changes in metabolic or in immune functioning. This determination should be used to determine the feasibility of undertaking an epidemiologic investigation of the factors associated with this increased morbidity and mortality.

ICD-9 Category IV: Diseases of the Blood and Blood-Forming Organs (ICD-9:280–289)

Health Canada (13) described the various anemias, coagulation defects, hemorrhagic conditions, and diseases of white blood cells included in this category and their variety of risk factors. Of particular interest for this study on possible health effects of pollutants are the references (40,64) used by Health Canada to various associations of certain anemias, platelet disorders, haemolytic conditions, effects on heme-containing enzymes, and vascular disorders, with environmental exposures to organic or inorganic contaminants or low-level radiation.

The population in the Windsor Area of Concern tended to have higher morbidity rates for diseases of the blood and blood-forming organs compared with the rest of Ontario. Males had a 29% higher rate (229 excess cases) and the corresponding figure for females was 13% higher (138 excess cases). As with the previous category, there was an early onset of the increased rates (68% higher, 210 excess cases) among males between birth and 24 years of age, but females in this age category also had elevated rates (19% higher, 46 excess cases). Males over 45 years of age had rates 15% higher, and among females over 75 years of age the rate was 10% higher than the corresponding provincial rates.

There was a contrast between the Windsor and Hamilton Areas of Concern in terms of the morbidity rates for diseases of the blood and blood-forming organs. Females in Hamilton had rates 12% lower and particularly in the age group from birth to 24 years of age had rates that were 27% lower than the provincial rates. In contrast to the Hamilton females and to the Windsor males, Hamilton males under 25 years of age were not significantly different from the rest of the province, but those 25–44 years of age were 25% higher.

ICD-9 Category VI: Diseases of the Nervous System and Sense Organs (ICD-9:330–337)

Health Canada (13) selected several diseases of the central and peripheral nervous systems and of the sense organs that might be affected by exposures to pollutants. For the central nervous system, these included Parkinson's disease, multiple sclerosis, and infantile cerebral palsy. Muscular dystrophies and

other myopathies were included relative to the peripheral nervous system, together with disorders of the eyes and ears.

There were several disorders of the central nervous system and sense organs that exhibited significantly higher rates in the Windsor Area of Concern than in the rest of the province. The rate of hereditary and degenerative diseases of the central nervous system in males was 14% higher (52 excess cases) and 16% in females (64 excess cases) than the rate for the rest of Ontario. For both males and females 25–44 years of age, the rate rose to 44 and 54%, respectively, above the provincial rate, but continued higher than the provincial rate up to 75 years of age. These excess cases of morbidity from hereditary and degenerative diseases of the central nervous system did not seem to be related to increased rates of Parkinson's disease. They also contrast strongly with the 25% lower rate in Hamilton males and 30% lower rate in Hamilton females. There is a priority need to investigate whether some significant proportion of these excess cases might be related to autoimmune disorders, central nervous system infections, metabolic disorders, drug intoxications, other diseases, or brain tumors, as some pollutants are suspected to be involved in neurodegenerative disorders such as Parkinson's disease, dementia, and amyotrophic lateral sclerosis (Lou Gehrig's disease) (65,66).

Similarly, for other disorders of the central nervous system, the morbidity rate for Windsor males was 31% higher (217 excess cases) and for females was 21% higher (188 excess cases). Of particular concern, in addition to the elevated rates for all age categories, was the early onset for both males (50 excess cases) and females (35 excess cases) between birth and 24 years of age. The mortality rate for males 25–44 years of age for disorders of the central nervous system was more than 2-fold (2.31 times) the provincial rate and resulted in 8 excess deaths that did not seem to be related to an increased rate of multiple sclerosis or infantile cerebral palsy. In contrast, Hamilton had rates for morbidity as hospitalization for other diseases of the central nervous system in males and females that were generally nearly 30% below the rates for the rest of the province. The notable exception for Hamilton was the number of morbidity as hospitalization cases for infantile cerebral palsy. There were 60 males and 58 females yielding a rate of 2.9 cases per 100,000 population, and anomalously, this was statistically significant only for the females. Further work is under way to analyze the morbidity data on infantile cerebral palsy, which were included by Health Canada because of the association with prenatal exposures to methylmercury (67), for all the 17 Canadian Areas of Concern. Meanwhile, there is a need to better

define the specific disorders that contribute to these elevated rates of morbidity in the Windsor population and to determine whether they might be demyelination disorders possibly linked to organophosphorous insecticides or other neurotoxic chemicals (68).

Disorders of the peripheral nervous system were 46% higher in males (153 excess cases) and 43% higher for females (183 excess cases) than the provincial rates. Among those 25–44 years of age, the rates rose to 99% higher for males (86 excess cases) and to 81% for females (87 excess cases) above the provincial rate and continued high to 74 years of age, and even for females over 75 years old (37 excess cases). Hamilton had an increased rate of diseases of the peripheral nervous system in females, particularly among the age group 25–44 years of age (93 excess cases). There is a need to better define the parts of the peripheral nervous system that have significantly elevated rates of disorders within the population in the Windsor and Hamilton Areas of Concern. Health Canada (13) noted that disorders of the peripheral nervous system are most often caused by metabolic disorders, predominantly diabetes mellitus, and these have already been shown to be elevated in this population. In addition to several risk factors for disorders of the peripheral nervous system, including infections, Hodgkin's disease, recent surgery, pregnancy, vaccination, and pharmacologic immunosuppression, Health Canada (13) cited various industrial and environmental neurotoxic agents such as triorthocresyl phosphate, hexacarbons, acrylamide, dimethylaminopropionitrile, organophosphorous compounds (especially insecticides), lead, arsenic, and thallium salts. Of particular concern are the changes in the central and peripheral nervous system from exposures to polychlorinated dibenzo-*p*-dioxins (69).

The rate of disorders of the eye and adnexa was 21% higher among males (213 excess cases) and 11% higher for females (144 excess cases) than the provincial rate among those in the Windsor Area of Concern 45–74 years of age, and the excess cases continued for males over 75 years of age (81 cases). These increased rates were not associated with morbidity as hospitalization from increased blindness. In addition to the hereditary and congenital factors, penetrating wounds, ulcers, infections, and ultraviolet radiation that cause eye disorders, Health Canada (13) listed chemicals, ischemic and immunogenic factors, drugs, and allergies. Health Canada (13) noted that *a*) air pollution causes eye irritation; *b*) methylmercury (70) and organochlorine compounds can result in deficits in the visual field; and *c*) alcohol, lead, arsenic, and carbon dioxide cause toxic polyneuritis (71). There is a need to investigate whether significant proportions of these elevated rates of

disorders of the eyes and adnexa are caused by occupational or environmental exposures to chemicals and pollutants.

ICD-9 Category VII: Diseases of the Circulatory System (ICD-9:401–440)

There are several diseases of the circulatory system for which the population in the Windsor Area of Concern had significantly higher rates of mortality and morbidity than the rest of the province (13). The mortality rate for heart disease for Windsor women ranked fourth behind those for Sudbury, Thunder Bay, and St. Catharines–Niagara in the analysis of 1994–1996 data for 25 Canadian metropolitan census areas, and seventh for Windsor men (28). Of particular concern was the rate of mortality for hypertensive disease in males, which was 56% higher (20 excess deaths), and ischemic heart disease in both males (21% higher, 427 excess deaths) and females (25% higher, 453 excess deaths). Mortality from diseases of the arteries was 65% higher for males, associated with an excess of 142 deaths, and 92% higher for females, with 244 excess deaths. Atherosclerosis was more than 2 times the rate in the rest of the province for males (2.23 times, 99 excess deaths) and for females (2.45 times, 248 excess deaths).

This elevated mortality from diseases of the circulatory system was reflected in the high morbidity as hospital separations from these diseases. There were 1,390 excess hospitalization cases of ischemic heart disease in males (18% higher than the rest of the province) and 1,736 excess cases in females (36% higher). Similarly, there were 624 excess cases of diseases of the pulmonary circulation and other forms of heart disease in males and 945 excess cases in females. Diseases of the arteries, arterioles, and capillaries were elevated more than 25%, resulting in 392 excess cases in males and 217 excess cases in females. Of particular concern was the early onset of an elevated morbidity rate from heart disease (37% higher) in females from birth to 24 years of age and from 25 to 44 years of age. Similarly, there was an early onset of a higher rate (38% higher) in males 25–44 years of age for ischemic heart disease, resulting in 214 excess cases.

There is a sharp contrast between Windsor and Hamilton in terms of mortality from circulatory diseases. Whereas Windsor had a 56% higher mortality rate for hypertension in males, Hamilton was nonsignificantly different from the rest of the province. Similarly, the percentage spread between Windsor and Hamilton females was 39%. Similarly, for diseases of the arteries, arterioles, and capillaries, there was a 76 percentage point spread for males and a 116 percentage point spread for females between Windsor and Hamilton. The

only disease of the circulatory system that had elevated mortality in the Hamilton population was ischemic heart disease, which was 6% higher for males and 11% higher for females than the provincial rates compared to the 21% higher rate for Windsor males and 25% higher rate for Windsor females.

These contrasts were reflected in the morbidity rates for circulatory diseases between Windsor and Hamilton. There was a 69% spread between the morbidity rate for hypertensive disease in Windsor males (41% higher than the provincial rate) compared to Hamilton (28% lower than the provincial rate). Ischemic heart disease was 17 percentage points higher in Windsor males than in Hamilton males, and Windsor females were 33 percentage points higher than Hamilton females. There were similar contrasts for other forms of heart disease and for diseases of the arteries, arterioles, and capillaries, but both Hamilton and Windsor males and females had significantly elevated morbidity from atherosclerosis: Hamilton males were 91 percentage points above the provincial rate; Windsor females were 66 percentage points above; Hamilton females 63 percentage points; and Windsor males 23 percentage points. Atherosclerosis is the only circulatory disease for which there was an early onset of morbidity as hospitalization in Hamilton, though this is not associated, as in Windsor, with an elevated mortality rate. Hamilton males 25–44 years of age had an 81% higher morbidity than the rest of the province with 13 excess cases; Hamilton males 45–74 years of age had more than twice (2.13 times) the provincial rate with 500 excess cases; and Hamilton females had 95% higher than the provincial rate with 220 excess cases.

The patterns of circulatory disease in Windsor and Hamilton seem to be distinctly different and there would seem to be a need for further investigation as to whether these differences might be attributable to occupational or environmental factors in the Windsor community and thereby be preventable. Health Canada (13) noted that there was very little information on the effects of environmental contaminants on cardiovascular diseases. Apart from the many genetic, nutritional, metabolic, and lifestyle factors that have been implicated, Health Canada (13) included mention of the following references: hypertension is a known outcome of lead poisoning (72) and exposures to cadmium (73); ischemic heart disease may be caused by atherosclerosis, which may be associated with some contaminants (74); diseases of pulmonary circulation may be caused by radiation and exposure to contaminants through air pollution; diseases of the arteries, arterioles, and capillaries may be affected by certain chemicals; there are unsubstantiated

studies of the relationship of atherosclerosis with mineral content in drinking water, trace elements, blood groups, coffee, climate, noise, air pollution, the urban environment, a low socioeconomic status, and education (74). Burnett et al. (75) showed a relationship between the daily number of hospitalizations for congestive heart failure (*ICD-9:427*) in the elderly in 10 Canadian cities, including Windsor and Hamilton, and levels of carbon monoxide, primarily from common transportation sources. In other research on 16 Canadian cities including Hamilton and Windsor, Burnett et al. (30) demonstrated associations between hospital admissions for all ages and concentrations of ambient air pollutants, including ozone, carbon monoxide, and particulate matter.

Because diseases of the circulatory system account for a high proportion of the excess mortality and morbidity in the Windsor Area of Concern, and because the pattern of disease is so different from, and the rates more severe than, the equivalents in the Hamilton Harbour Area of Concern, there is a priority need to determine whether epidemiologic investigations of the possible contributory role of occupational and environmental exposures to chemicals and pollutants are feasible.

ICD-9 Category VIII: Diseases of the Respiratory System (ICD-9:460–508)

Health Canada (13) included the following diseases of the respiratory system in its survey of health data and statistics for the 17 Canadian Areas of Concern: acute respiratory infections; other diseases of the upper respiratory tract; pneumonia and influenza; chronic obstructive pulmonary disease and allied conditions, including chronic bronchitis, emphysema, and asthma; and pneumoconioses and other lung diseases due to external agents. Though many of these diseases are microbiologic in etiology, they are included because they may not only reflect the general infectivity of the local environment, but also indicate the effects of pollution on the general functioning of the immune system. Health Canada (13) noted that *a*) other airborne pollutants such as sulfur dioxide and nitrogen dioxide, and trace metals such as vanadium and cadmium can result in acute bronchitis; *b*) high levels of ozone and other atmospheric contaminants cause histopathologic changes in the nasal mucosa; *c*) sinusitis and laryngitis may be promoted by certain toxic agents; and *d*) atmospheric sulfur dioxide and organic solvents may affect the sense of smell (76–78). Atmospheric sulfur dioxide and particulate matter are directly implicated in chronic obstructive pulmonary disease (79). The pollutants associated with the various pneumoconioses and other lung diseases due to external agents have been well established

and include coal dust, silica and silicates, inorganic dust, chemical fumes and vapors, solids, and liquids. Asbestos has become a ubiquitous air pollutant and causes asbestosis and mesothelioma.

In terms of the rates of diseases of the respiratory system, mortality from pneumonia and influenza was lower than in the rest of the province, but chronic obstructive pulmonary disease and allied conditions among Windsor males 45–74 years of age was 30% higher than the rest of the province, resulting in 38 excess deaths. Similarly, the rate for Windsor females of the same age category was 32% higher, resulting in 25 excess deaths. Of particular concern was the mortality from chronic bronchitis in males that was more than 2-fold higher (19 excess deaths) than the rest of the province, with 8 of these deaths occurring among those over 45 years of age. Two females under 25 years of age died of chronic bronchitis, yielding a rate 14.32 times the provincial rate.

Elevated rates of morbidity for other disorders of the respiratory system included acute respiratory infections (682 excess cases in males and 456 in females); other diseases of the respiratory tract (210 excess cases in males and 270 excess cases in females); pneumonia and influenza (230 excess cases in males and 233 excess cases in females); chronic obstructive pulmonary disease (549 excess cases in males and 694 excess cases in females), particularly chronic bronchitis (30% higher in males, 45 excess cases, and 77% higher in females, 100 excess cases); and asthma in females (9% higher, 198 excess cases). Much of this increased morbidity as hospitalization for acute respiratory infections in males and females, for other diseases of the upper respiratory tract in males and females, and for pneumonia and influenza in males, was in those under 25 years of age. Of particular concern was the number of cases of hospitalization for asthma between birth and 24 years of age between 1986 and 1992, which was 1,637 for males (490 per 100,000 population) and 1,239 for females (380 per 100,000 population).

There was a marked contrast between the morbidity rates for Hamilton versus those for Windsor for the respiratory systems in both males and females. Rates in Hamilton for acute respiratory infections and other diseases of the upper respiratory tract, pneumonia, and influenza, and for chronic obstructive pulmonary diseases including chronic bronchitis, emphysema, and asthma, were markedly below the provincial rates in contrast to those in Windsor, which were significantly elevated. For example, the morbidity rates for acute respiratory infections were separated by more than 70 percentage points, and by about 60 percentage points for chronic obstructive pulmonary diseases. The

feasibility of investigating the much higher rates of respiratory disease in the population in the Windsor Area of Concern should be evaluated, and existing clean air regulations should be enforced.

ICD-9 Category IX: Diseases of the Digestive System (ICD-9:530–579)

Health Canada (13), in selecting the following four categories, noted that the digestive system may be exposed to environmental pollutants through the consumption of contaminated drinking water and food: diseases of the esophagus, stomach, and duodenum; non-infective enteritis and colitis; other diseases of intestines and peritoneum; and other diseases of the digestive system. Significant increases in mortality for diseases of the digestive system occurred in males 45–74 years of age, accounting for 11 excess deaths. A significant increase in diseases of the esophagus, stomach, and duodenum occurred in females over 75 years of age, accounting for 12 excess deaths. Mortality from these diseases tended to be only slightly higher in Windsor than in Hamilton. For example, for those 45–74 years of age, there were only 2 or 3 percentage points between the mortality rates for diseases of the esophagus, stomach, and duodenum in Windsor and Hamilton males (67% vs 65% higher) and females (57% vs 54% higher). There were, however, for those 45–74 years of age, large parallel differences between males and females for noninfective enteritis and colitis in Windsor (99 percentage points) and Hamilton (86 percentage points), with males in both locations having the higher rates. But this situation was reversed for mortality from other diseases of the intestines and peritoneum, with females tending to have the higher rates.

Significantly elevated rates of morbidity as hospitalization separations over the provincial rates were evident for all four categories and resulted in 3,665 excess cases in males and 5,059 excess cases in females as follows: diseases of the esophagus, stomach, and duodenum (39% higher for males, 685 excess cases, and 58% higher for females, 934 excess cases); noninfective enteritis and colitis (67% higher for males, 930 excess cases, and 46% for females, 829 excess cases); and other diseases of the intestines, peritoneum (23% higher for males, 456 excess cases, and 33% for females, 872 excess cases), and digestive system (16% for males, 516 excess cases, and 20% for females, 1,012 excess cases). Of particular concern were the increased rates compared with the rest of the province for these diseases among young males and females between birth and 24 years of age, with rates about 70% higher than in the rest of the province for diseases of the esophagus, stomach, and duodenum,

about 80% higher for noninfective enteritis and colitis, 20% higher for other diseases of intestines and peritoneum in young males, and 14% higher in young females. Higher rates occurred in all age categories for both sexes compared with the rest of the province.

The rates of morbidity as hospitalization separations in Hamilton for these four categories of diseases of the digestive system were all significantly lower than the provincial rates and none were significantly elevated in any of the age categories. For diseases of the esophagus, stomach, and duodenum, there was a spread of 60 percentage points for males and 87 percentage points for females between Windsor and Hamilton. For noninfective enteritis and colitis, there was a spread of 90 percentage points for males and 74 percentage points for females. For diseases of the intestines and peritoneum, there was a difference of 32 percentage points for males and 50 percentage points for females. For other diseases of the digestive system, there was a 24 percentage point spread for males and a 27 percentage point difference for females.

These substantial differences between rates of morbidity for diseases of the digestive system in the communities in Windsor and Hamilton and the high rates for all age categories and for both sexes indicate the need for epidemiologic studies to investigate the causes and whether these diseases are preventable in the Windsor Area of Concern.

ICD-9 Category X: Diseases of the Genitourinary System (ICD-9:580–628)

Health Canada (13) chose the following diseases of the genitourinary system as being potentially related to exposures to pollutants: nephritis, nephrotic syndrome, and nephrosis; other diseases of the urinary system; diseases of the male genital organs, including male infertility; disorders of the breast; and other disorders of the female genital tract, including endometriosis and female infertility.

Several of the rates of morbidity from diseases of the genitourinary system in the population of the Windsor Area of Concern were elevated, and these increased rates occurred in several age classes. For females 25–44 years of age, there was a 33% increased morbidity from nephritis, nephrotic syndrome, and nephrosis, resulting in 19 excess cases. However, for other diseases of the urinary system and for all ages, there was a 60% increase in males, resulting in 1,798 excess cases, and in females the rate was 64% higher, yielding 1,583 excess cases. Of particular concern was the early onset of elevated morbidity rates in males under 25 years of age (23% higher than the rest of the province, with 70 excess cases).

For diseases of the male genital organs, there was a 40% higher rate than in the rest

of the province, leading to 1,582 excess cases, with 58 excess cases (13% higher) occurring in those males under 25 years of age. Forty-one males were hospitalized for infertility at a rate 55% above the provincial rate, and the seven males under 25 years of age who were hospitalized for male infertility represented a morbidity rate nearly 7 times (6.90 times) the provincial rate. Similarly, there was an excess of 50 males with disorders of the breast, representing a rate 44% above the provincial rate. Among those 25–44 years of age, this rose to 60% higher than the provincial rate, to 96% higher than the provincial rate for those 45–74 years of age, and finally, to 2.5 times the provincial rate for those over 75 years of age. For females there was a 30% higher rate of disorders of the breast than the rate in the rest of the province, resulting in 302 excess cases, and although the 14% rate (29 excess cases) in those under 25 years of age was not statistically significantly different from the rate for the rest of the province, the rate rose to 34% higher for females 25–44 years of age (130 excess cases) and continued at 37% higher than the provincial rate for those 45–74 years of age (141 excess cases).

The 22% higher rate of other disorders of the female genital tract resulted in 733 excess cases for those 25–44 years of age, and even the 5% higher rate for those 44–74 years of age yielded 119 excess cases. Part of this excess morbidity as hospitalization is attributable to the 48 excess cases of endometriosis and part to the 43 excess cases of female infertility among the group 25–44 years of age.

These markedly elevated rates of morbidity for diseases of the genitourinary systems are in contrast to the corresponding data and statistics for the Hamilton Harbour Area of Concern in which nearly all the health end points were 10 or 20 percentage points below the provincial rates. For example, there was a spread of 42 percentage points for Windsor males 45–74 years of age for nephritis, nephrotic syndrome, and nephrosis compared to equivalent-age Hamilton males. For other diseases of the urinary system, there was a spread of 74 percentage points for males and 86 percentage points for females. There was a difference of 47 percentage points for the rates of diseases of the male genital organs and 100 percentage points for male infertility. The contrasts between the rates of disorders of the female genital tract in Windsor females compared with the rates in Hamilton females were less marked than in the males but were still separated by 31 percentage points for the group 25–44 years of age, specifically by 21 percentage points for endometriosis, and by 27 percentage points for female infertility. Interestingly, these elevated rates of diseases of the male and female genitourinary systems in the population in the Windsor Area of

Concern were not associated with elevated rates of complications of pregnancy, child-birth, and the puerperium. All these measures were significantly lower in the Windsor Area of Concern than in the rest of the province.

Although there are many factors known to affect the health of the genitourinary system, Health Canada (13) referenced effects of toxic substances such as lead (80), cadmium (81), and 1,1-dichloroethylene (82) on the kidney. The effects of pesticides on diseases of the male genital organs, particularly male infertility, have been linked to pesticide manufacturing plants (83), occupational exposure to lead (84), and organochlorine compounds (85). References to disorders of the female genital tract included *in utero* exposure to diethylstilbestrol, and exposure to hexachlorobenzene and to pesticides (58). Endometriosis has been associated with exposure of monkeys to organochlorine compounds (86). Hormonal disorders through exposure to organochlorine compounds and heavy metals are suspected to cause female infertility through interfering with ovulation.

The marked increase in the rates of morbidity as hospitalization for diseases of the male and female genitourinary system among the population in the Windsor Area of Concern indicate priority needs for evaluating the feasibility of investigation of the specific causes, implementation of existing regulatory controls, and development of new controls for sources of compounds causing these elevated rates for diseases of the genitourinary system.

ICD-9 Category XII: Diseases of the Skin and Subcutaneous Tissue (ICD-9:680–709)

There were significantly elevated morbidity rates from inflammatory conditions and other diseases of the skin and subcutaneous tissues in both males (235 excess cases) and females (401 excess cases), and elevated rates occurred in all age classes. The rates in males and females between birth and 24 years of age were, respectively, about 60% and 30% higher than those for the rest of the province, rose to about twice the provincial rate in the group 25–44 years, and continued high compared to the rest of the province through to those over 75 years of age. This morbidity was not related to infections of the skin and subcutaneous tissues.

Health Canada (13) referenced a wide variety of physical, chemical, and biologic agents and conditions associated with atopic and contact dermatitis (87). Of particular interest are the reports in the literature of associations of chloracne, hyperpigmentation, hyperkeratosis, and conjunctivitis with exposures to high levels of PCBs, dioxins, and furans. The feasibility of investigating the specific causes of the elevated rates of diseases of the skin and subcutaneous tissues needs to

be evaluated and controls placed on sources and pathways of exposure.

ICD-9 Category XIII: Diseases of the Musculoskeletal System and Connective Tissues (ICD-9:710-739)

The rates of morbidity as hospitalization cases for diseases of the musculoskeletal system and connective tissues in the population of the Windsor Area of Concern were significantly elevated for the following: arthropathies and related diseases (12% for males, 11% for females); dorsopathies (26% for males, 21% for females); rheumatism, excluding the back (2-fold for males, 88% increase for females); and osteopathies, chondropathies, and acquired musculoskeletal deformities (27% for males, 30% for females). These elevated rates tended to occur in all age classes up to 75 years of age. Five females 45-74 years of age died of diseases classified as osteopathies, chondropathies, and acquired musculoskeletal deformities, resulting in rates more than 3-fold (3.61 times) the provincial rate.

This category of diseases was included because exposures to cadmium are associated with skeletal diseases, possibly linked to kidney damage (82). Among the wide variety of agents associated with diseases of the musculoskeletal system and connective tissues, Health Canada (13) mentioned the relationship between arthropathies and metabolic disorders and changes in the endocrine system, such as diabetes mellitus and hypothyroidism. The feasibility of investigating whether environmental pollution is contributing to the elevated rates of morbidity for diseases of the musculoskeletal system and connective tissues in the Windsor population needs to be evaluated.

ICD-9 Category XIV: Congenital Anomalies and Infant Mortality (ICD-9:740-758)

The Windsor Area of Concern had 13,196 females born in the 7-year period between 1986 and 1992. Of these girls, 779 had some kind of anomaly diagnosed within the first year. This was 25% higher (156 excess cases) than the rate in the rest of Ontario and included 13 females born without brains (anencephaly) at a rate 3 times that in the rest of Ontario; 149 girls born with heart defects (56% higher, 53 excess cases); 95 with clubfoot (69% higher), and 10 with reductions in the length of their limbs (2.24 times the provincial rate). Ninety-three girls died within the first year at a rate that was 24% higher than the provincial rate.

Similarly, there were 13,950 boys born between 1986 and 1992, and 885 had anomalies (13% higher than the provincial rate, 101 excess cases). Twenty-four had water on the brain (congenital hydrocephaly) at a rate that was 88% higher than that of the rest of

the province; 172 had congenital heart defects (65% higher, 68 excess cases), and 89 had clubfoot (36% higher); 97 boys died within the first year at a rate comparable to that of the rest of Ontario.

From a statistical standpoint it is impossible to determine whether the infants who died had significantly elevated rates of anomalies, but the table in the Health Canada report flags several conditions, including anomalies of the nervous system and heart, renal and urinary systems, circulatory and respiratory systems, and Down syndrome. Only further analysis of the existing databases in Statistics Canada for a greater number of years would provide a sufficient number of cases to determine whether the apparently elevated rates of these anomalies had arisen by chance.

Recent data on the rates of congenital anomalies for 1998 (19) confirm continuing elevated rates in females (27% higher) and in males (13% higher) born in Windsor and Essex County; the rate of congenital heart defects remains at 56% higher than the provincial rate. By contrast, the overall rates of congenital anomalies in the Hamilton population were 20-30% lower than the Ontario provincial rates, thus the rates for males in Hamilton were 35% lower than those in the Windsor area and 53% lower for females.

In reviewing the possible teratogenic agents to which the Windsor population is exposed, it is necessary to distinguish between increased abnormality rates caused by exposures to alcohol (88) and those associated with exposures to environmental teratogens. Health Canada (13) noted the reproductive and teratogenic effects of organochlorine compounds such as PCBs and dioxins and heavy metals such as lead, cadmium, and mercury on laboratory animals and wildlife but remarked on the uncertainty about whether existing levels in the Great Lakes basin could have affected people. The contrasts between the rates in Windsor and Hamilton could indicate the presence of teratogenic contaminants in the Windsor environment that might be increasing the rates of congenital anomalies.

The literature on the teratogenic actions of chemicals has recently been reviewed (89). Occupational exposures of males to solvents have been related to anencephaly (90), and exposures to benzene have been related to a greater probability of hydrocephaly in their offspring (91). Defects of the fetal heart from occupational exposure during pregnancy have been associated with benzene (92) and organic solvents (93). In a survey of the contamination of drinking water for 75 New Jersey towns, those with higher levels of benzene were associated with a higher rate of major heart defects (94). Similarly, exposures to groundwater contaminated with trichloroethylene, and trace

amounts of dichloroethylene and chromium in a neighborhood near Tucson, Arizona, have been associated with congenital heart defects (95). Another location where studies have shown an association of heart deformities with exposures to solvents is Santa Clara County, California (96). These findings are consistent with the findings of congenital heart defects in animal studies (97,98). The findings of an elevated rate of clubfoot in the Windsor population is of concern. A high rate of clubfoot has been a characteristic among a population on a small island off Australia with rich manganese deposits (99). There is a priority need to investigate the cause of the elevated rates of clubfoot in the Windsor population, particularly because of the recent introduction of methylcyclopentadienyl manganese by Ethyl Corporation as a gasoline additive, and because there is evidence of synergistic effects of mixtures of metals, including manganese with chromium and lead, on prenatal development at very low doses (100).

The apparent stability of the elevated rates of congenital anomalies over more than a decade, particularly for heart defects, indicates a priority need for epidemiologic investigations to determine the causal agent(s). If the increased rate is from the consumption of alcohol during pregnancy, public health interventions can be devised and implemented at the local level to prevent these abnormalities. If the increase is from exposures to teratogens that are being released to the environment, an effective public health program would first require identification of the source(s) and subsequent control, surveillance, and monitoring.

Discussion

The mandate for this project derived from the United States-Canada Great Lakes Water Quality Agreement, based on Article IV of the 1909 Boundary Waters Treaty, which states that the boundary waters shall not be polluted on either side to the injury of health or property on the other side. Since the mid-1980s the International Joint Commission has assisted the parties to the agreement by developing a list of 42 Areas of Concern that did not meet the water quality objectives developed in common by the parties and for which Remedial Action Plans have been developed. The former Great Lakes Health Effects Program was originally developed in the late 1980s by Health Canada as part of the implementation of the agreement by the government of Canada. The project on health data and statistics was part of that program to generate hypotheses on whether pollution was affecting the health of the communities in the 17 Canadian Areas of Concern. Previous work undertaken on the United States side of the Great Lakes basin using similar tech-

niques (14) suggested an association between the rates of mortality for stomach and esophageal cancers and living in the border counties close to the Great Lakes. Other research on the significant regional patterning of the incidence of cancer in Ontario (23) has reconciled this geographic variation with several risk factors, suggesting that these diseases are not associated with variations in air and water quality at the regional scale (24). This still, however, leaves the possibility of associations between certain health end points and variations in air and water quality at the local scale. It would seem that the consistently elevated rates of mortality, morbidity as hospitalization, and congenital anomalies in the community in the Windsor Area of Concern for health end points that may be linked to pollution indicate that this population in this location is an example of health effects occurring at a local scale.

Methodologic Limitations

From a methodologic standpoint, these ecologic analyses of the health of circumscribed populations are in contrast to the cohort studies that have heretofore been carried out to study the effects of pollution on human health. The cohort studies have focused on critical subpopulations known to be highly exposed or susceptible to pollutants from the Great Lakes. For example, cohorts were established in 1980, in western Michigan (101), and in 1990, at Oswego, New York (102), particularly to investigate the effects of maternal consumption of contaminated Great Lakes fish, prior to or during pregnancy, particularly on child behavior and neurologic development.

The statistical analyses undertaken so far have compared the rates of mortality, morbidity as hospitalization separations, and congenital anomalies in each of the 17 Areas of Concern with the rates in the rest of the Province of Ontario, and these have provided opportunities to describe the profile of diseases that might be related to pollution within the communities. There are, however, several limitations to this approach. First, there are limitations in terms of the selection of the end points based on published associations with exposures to pollutants. For example, although the broad list of selected end points is fairly comprehensive, there are other end points such as malignant neoplasms of the brain (103–105) that are suspected to be affected by pollutants, particularly pesticides (106,107), and that might have been valuable in assessment of the community health profiles had they been included.

Similarly, although data on morbidity, mortality, and congenital anomalies are useful in describing gross differences between communities that might be related to

pollution, there are other more subtle end points derived from the endocrine disruptor hypothesis, such as neurologic and immunologic functioning, that need to be investigated and compared on a community basis. For example, recent data for the year 1998 (19) indicate that the morbidity rates as hospitalization separations for mental disorders (*ICD-9:290–319*) are 44% higher for females and 60% higher for males compared with the rates for the rest of the province. Similarly, the rate of hospitalization for suicide (*ICD-9:e950–e959*) is 20% higher in females and 54% higher in males. A recent survey by the Ontario Ministry of Community and Social Services found that Windsor and Essex County are the areas of southwestern Ontario with the highest rate of usage of these child protection and residential services. There is a list of about 700 children waiting for mental health services, and over half the children who receive services in Essex County have disabilities in addition to their mental health disorders. Although Windsor and Essex County are underserved in terms of medical practitioners in general and psychologists in particular, the possible contributory involvement of pollution to these excess rates of hospitalization for mental disorders and suicides needs to be investigated so that preventive approaches can be formulated. Similarly, there is reliable information from pediatricians of an increased rate of autism, and from teachers of an increased rate of attention deficit and hyperactivity disorder in classes in certain parts of Windsor and Essex County. The number of school-aged children with the highest level of special needs has significantly outpaced the provision of provincial funding made available for this purpose. These concerns have recently resulted in the formation of a Mental Health Task Force by the Windsor–Essex Health Unit. One of the orders of business will be to investigate whether these concerns portend a local manifestation of the epidemic of learning, behavioral, and developmental disorders from preventable exposures to neurotoxins (108).

A second limitation is the use of the rates in the rest of Ontario as the standard by which to judge statistical significance. The first concern is that there are several diseases, such as prostate cancer and breast cancer, that are increasing on a provincial, national, and international basis. Comparison of health data and statistics for the community in an Area of Concern with the provincial rate can only indicate whether the rate in the community is the same as the changing provincial rate. The second concern is that the provincial rate for a particular health end point may be elevated relative to those in other countries or to a previous period of time. Thus, there is a need for communities not only to analyze the long-term trends in particular diseases

within their community, but also to compare their rates of diseases with those of other communities, other jurisdictions, and other countries. For example, there is a need to establish whether the elevated rates of thyroid disease in Windsor females, particularly the early onset, are a recent phenomenon, and to investigate whether comparable epidemics are occurring in other parts of Ontario, elsewhere in Canada, the United States, or other parts of the world.

A third limitation is the use of narrative associations for generating hypotheses about the relationship between statistically significant differences in the rates of selected health end points and the plausibility of an association with pollution. The Health Canada (13) study listed a wide array of potential factors and agents associated with the selected health end points, and this account for Windsor, in the interests of brevity, has been oriented toward those related to pollution. However, any inference of a causal relationship between the increased rates of disease within a community and exposures to pollutants will require more than this narrative association if effective regulatory action is to be undertaken based on scientifically defensible evidence of injury, though there is a growing sentiment that preventive public health action should not require this level of proof when a causal factor is suspected.

A fourth limitation in this approach is the failure to detect known epidemics. For example, in Windsor and Sarnia there have been serious outbreaks of asbestosis in the past 20 years related to the industrial use of asbestos in foundries in these two communities, but these were undetected using these techniques to collect data on pneumoconioses and other lung diseases due to external agents (*ICD-9:500–508*). The epidemics of asbestosis are associated with epidemics of mesothelioma, and it is possible that the cases of mesothelioma were included in the cases on malignant neoplasms of respiratory and intrathoracic organs (*ICD-9:160–165*) that were seriously elevated in the two communities. This may exemplify the loss of some of the sensitivity of the analysis through the aggregation of data and the masking of specific epidemics in larger categories of diseases. Similarly, there are concerns that the rates of scleroderma, which has been associated with exposures to silica and various solvents (109), may be elevated in this community but that this specific condition is subsumed within the larger categories of inflammatory conditions and diseases of skin and subcutaneous tissues (*ICD-9:690–698;700–709*).

There is much more information that could be gleaned from these databases; the feasibility of using further statistical techniques such as principal component and

cluster analyses on the databases for the 17 Areas of Concern is being carefully evaluated.

Institutional Capabilities and Constraints

Modern epidemiology is seeking new methods of analysis and synthesis, and an ecoepidemiologic approach has been proposed over the past decade (12,110–112), including tying individual and population epidemiology to molecular epidemiology, reconnecting these to public health, and placing these in social, economic, and political institutional contexts. Windsor, Ontario, is a useful location in which to study the institutional constraints to implementing the Great Lakes Water Quality Agreement and the Canada–United States Air Quality Agreement. This project of the former Great Lakes Health Effects Program and the process for preparation of the Detroit River Remedial Action Plan were undertaken not only within a scientific context involving toxicologists, epidemiologists, chemists, and ecologists, but also within social, economic, and political contexts at the local, provincial, and federal levels.

Windsor is known as “The Automobile Capital of Canada” and as such has a long history of union activism dating back to the 1930s. In the late 1970s, union health and safety activists in Windsor began the modern occupational health movement when it was revealed that workers at the Bendix Automotive Plant were dying of asbestos-related cancers. When a brief was being presented to the former Ontario Worker’s Compensation Board on behalf of three widows whose husbands had died of laryngeal cancer, officials of the board gave the union representatives copies of government orders that had been issued in 1966 and again in 1970 to control asbestos exposures (15). These orders were never enforced even at the time that the union representatives were meeting with the compensation officials. Several occupations are now recognized by the workers’ compensation authorities to be associated with injury (113), including metalworker exposures to metalworking fluids and other toxicants in the workplace; auto industry workers with elevated mortality from laryngeal, stomach, and colorectal cancer; steel industry workers with increased rates of lung cancer; electrical workers and increased rates of brain cancer and leukemia; dry cleaners with elevated rates of digestive tract cancers; firefighters with brain and blood-related cancers at many times the expected levels and miners with rates of respiratory cancer many times higher than expected; and women in the plastics and rubber industry with greater risks of uterine cancer and possibly breast cancer.

In response to the specific knowledge about the cancer mortality in their Windsor

membership and the general information about cancer and exposures to carcinogens, the Canadian Auto Workers (CAW) supported a cancer prevention campaign to activate workers to learn about cancer, to rid the workplace of carcinogens, and thereby prevent exposures to agents that cause cancer. This local initiative eventually became a national CAW campaign. At the local level there is a Windsor Cancer Prevention Coalition with groups working on research, communications, and political action.

Windsor also became the scene for grassroots activists working on environmental issues. Through the CAW, the Clean Water Alliance was formed. However, there is often tension between the blue-collar workers in the trade unions and the environmentalists because of concerns among workers about jobs. Windsor is unusual in that it has generated leaders, particularly through the union movement, in both the areas of occupational and environmental health. In addition, in the early 1980s, community groups and the unions, against some strong local opposition (15), organized the Windsor Occupational Health Information Service as the first community-based health and safety information service in Canada. In the late 1980s these same groups in Windsor successfully lobbied for the establishment of a clinic on behalf of the Occupational Health Clinic for Ontario Workers to diagnose diseases and disorders related to employment and to help injured workers with their claims for compensation from the Ontario Worker’s Compensation Board. Though Ontario law, as in the United States, requires employers to disclose health studies relevant to their employees, local auto manufacturers did not bring the existence of more than 120 health and hygiene studies undertaken on U.S. auto workers to the attention of Ontario workers, even though they were undertaking the same occupational operations. The Windsor Occupational Information Service and the Occupational Health Clinic for Ontario Workers have become important conduits for information on the dangers of particular jobs posed by specific substances.

In the same way that Windsor is the “Automotive Capital of Canada,” Sarnia is the “Chemical Capital of Canada,” where more than 40% of the Canadian bulk chemicals are manufactured mainly through branch plant subsidiaries of United States corporations. In the late 1990s, based on the discovery of a large cluster of occupational disease in Sarnia, Ontario, senior management from the Windsor Occupational Health Information Service and from the Windsor Occupational Health Clinic for Ontario Workers set up a new clinic and information service in Sarnia, against some continuing local and provincial

opposition. The immediate concern was that Sarnia has the highest rates of mesothelioma in Canada. Since opening the clinic, over 2,000 people have registered with a variety of cancers and respiratory and neurologic diseases, and 500 new registrations are expected in 2001. The rates of these diseases were known for a long time to be elevated but seemed to be tolerated within the community. “Sarnia men die young” were the words of the daughter of a Sarnia worker who died of lung disease related to asbestos exposure, and they reflect an implicit sense of fatalism within the community (114). In turn, the Sarnia clinic, in addition to the diagnostic work and claims for injured Sarnia workers, has become a resource center for helping a nearby rural community investigate its suspicions about the apparently high rates of various cancers.

Recently, the community of Sarnia has undergone a profound psychosocial change. In the past year there has been a series of accidental releases of pollution to the air, to industrial land, and to the St. Clair River from different industrial facilities. One recent release to the atmosphere engulfed the police station, resulting in several officers being taken to the hospital. The media are reporting that spokespersons for the industries are acknowledging that the trust of the public within this community has been lost. There is a pressing need for social and political scientists and anthropologists to document the community, institutional, and political processes that are occurring and perhaps to help with the predictable psychosocial changes.

Through a unique partnership between the Windsor Occupational Health Clinic for Ontario Workers and the Windsor Cancer Treatment Centre, oncologists are collecting occupational histories of cancer patients. Expansion of the partnership to include the university has resulted in a grant from the Ontario Worker’s Compensation Board for a case–control study of breast cancer and for a second study involving men with laryngeal cancer. The intent is that, eventually, occupational histories will be collected for every cancer patient in the province of Ontario (113).

If some or all of these increased rates of mortality, morbidity, and congenital abnormalities in the Windsor Area of Concern are partly or completely attributable to exposures to pollutants in the environment, this would place these issues in a series of complex political circumstances. Environment tends to be perceived as an issue of the political left, along with occupational health. Gordon Durnil, the former U.S. co-chairman of the International Joint Commission urged his Republican colleagues to embrace conservation, environment, and health as right-wing issues and has expressed his disappointment

that they have, in his opinion, so far declined (115,116). The specifics of the situation in Windsor need to be seen in the context of a much broader politics, expressed by some Canadian liberal politicians, of globalization and corporatism and reflected in a growing body of political writings (117–119) exploring these issues, and in a world movement opposing these economic trends. In Ontario an inquiry into the deaths and hospitalizations from an outbreak of *Escherichia coli* in the community of Walkerton, Ontario, has requested testimony from the Conservative Premier Mike Harris to ascertain whether the cuts in staffing and budgets of the Ministry of Environment during the first mandate contributed to the tragedy. At the federal level, there has been a general shift of power away from the social and environmental toward the industrial and economic portfolios, and this has fueled the writings of several social, economic, and political commentators (117–119). In Windsor the fear produced by the recurrent experiences of long-term cyclical unemployment in the automotive industry has produced an implicit multilateral understanding between industry, labor and the unions, and the municipality. There is, however, also an implicit ambivalence about occupational health and environment in case these might somehow threaten jobs.

John Ralston Saul (118) has explored the consequences of the prevailing motif in Western governments of corporatism and the power of the multinational companies in influencing the affairs of states based only on interests. The affairs of Windsor, of Ontario, and of Canada are no less influenced by these political forces than are the affairs of other municipalities, jurisdictions, and nations. A second motif that has developed in the past 20 years has been the general fiscal restraints within national governments, the specific reductions in government staff and funding for research and monitoring in environmental toxicology and public health, and the devolution of these responsibilities from national to regional governments and from regional to local governments. For example, fiscal restraints within Health Canada led to the closure of the Great Lakes Health Effects Program on 31 March 2000, at the end of the Canadian fiscal year, bringing to an end further work on this community-based epidemiology, though there is a stated intention to reconstitute a federal program in the Ontario region.

The concerns raised by corporatism and the devolution of responsibilities were exemplified at the local level in the attempts to prepare the Remedial Action Plans for the Detroit River Area of Concern. The Remedial Action Plan process is part of the Great Lakes Water Quality Agreement,

which is an agreement between the United States and Canada as national governments. The process for the Detroit River was originally undertaken on a bilateral basis, with representatives from all levels of governments, from industries, and from nongovernment organizations. The bilateral process failed about 4 years ago because these groups could not come to a consensus about the specific concerns that required remedial actions. At that time there was no objective consideration of human health using epidemiologic data and statistics as a scientifically defensible basis for costly remedial actions on contaminated sediments and hazardous waste sites. Federal funds for remedial actions are made available to the local conservation authorities rather than to health and environmental protection authorities and are used for habitat improvements, such as tree planting, and for improvements to amenities, such as access to and pathways beside the river. The public health issues inferred from the health data and statistics in the Health Canada (13) document on the Windsor Area of Concern suggests that there is a priority requirement for the Canadian federal government to remain involved at this local level and to reallocate the funds specifically to the investigation and control of sources of pollution and to remedial action on contaminated sediments and hazardous waste sites. Because some of the pollutants that are likely contributing to these public health issues are from transboundary sources from the United States, and specifically from Detroit in the state of Michigan, the Canadian federal government must remain involved, as it has sole jurisdiction in Canada to undertake international consultations and negotiations. In addition, the financial resources needed to implement Remedial Action Plans relevant to protection of public health, particularly for the interconnecting channels, are on a scale that neither a Canadian municipality nor probably the province of Ontario acting alone could underwrite. The International Joint Commission (119) has recently commented on the relative lack of progress in Canada in addressing contaminated sediments.

At the local level, there seems to be a ubiquitous reluctance to acknowledge these public health issues. This is not only at the level of local governments, but also in relation to industries, the unions, and the academic and medical establishments. Local activist organizations have been effectively sidelined into projects on preservation of wetland and woodland habitats rather than focused on issues of injury to health and property from air and water pollution. The scale and significance of these public health issues are known by many individuals, but the technical skills to research and monitor aspects of the epidemics

tend to be fragmented. Recently, there is evidence of a nascent institutional vision and leadership that is a prerequisite to galvanizing the local community and authorities into coalescing these individuals and their skills into a coherent environmental and occupational research program on which sound regulatory and remedial actions can be based.

The Health Canada reports of health data and statistics for the 17 Canadian Areas of Concern in the Great Lakes basin have potentially provided radical challenges, not only to environmental managers responsible for implementing the Great Lakes Water Quality Agreement and the Canada–United States Air Quality Agreement, but also to those authorities responsible for enforcing provincial control orders and municipal bylaws. If Windsor, Ontario, is a representative model of the institutional constraints in other Areas of Concern, not only in Canada but also in the U.S. portion of the Great Lakes basin, is it likely that further interpretations of the Health Canada health data and statistics for the other Areas of Concern will be both necessary and sufficient to lead to significant decreases in levels of pollution that may be linked to human health? Will the public health concerns raised by the Health Canada data and statistics for Windsor be sufficient to galvanize renewed political actions to implement these bilateral agreements on local and transboundary pollution of the Great Lakes ecosystem? Or will the political processes of corporatism and devolution of responsibilities need to be reversed before significant progress can be made in terms of remedial actions to clean up the existing sources, the legacy of contaminants in the sediments and the leakages from hazardous waste sites?

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APPENDIX B

DIVERSIONARY REFRAMING OF THE GREAT LAKES WATER QUALITY AGREEMENT

**MICHAEL GILBERTSON AND ANDREW E. WATTERSON (2007)
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Diversionsary Reframing of the Great Lakes Water Quality Agreement

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ABSTRACT

The United States and Canadian governments are undertaking a periodic review of the operation and effectiveness of the 1978 Great Lakes Water Quality Agreement through extended public meetings and conference calls. The stated purpose of the Agreement is to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. For a variety of motives, several interest groups have represented the water quality agreement as being instead about maintaining and restoring ecosystem integrity for the entire Great Lakes basin. Through analysis of social, economic, political and diplomatic discourses, we have discovered and described these motives. The scientific evidence of continuing injury to health and property from trans-boundary pollution convinces us that this reframing is an unwarranted diversion from the original intent.

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INTRODUCTION

Canada and the United States share a common border, part of which passes through the St Lawrence Great Lakes. The Great Lakes contain 20% of the world's freshwater resources, and the protection of water quality has been a concern of both nations for more than a century. In 1909, the plenipotentiaries of the United States and of Great Britain on behalf of Canada signed the Boundary Waters Treaty to prevent disputes over the use of the boundary waters. Among the various provisions was Article IV, which stated that the Parties agreed not to pollute the boundary waters "on either side to the injury of health and property on the other". The treaty also

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established the International Joint Commission, with powers to examine matters referred to it and to advise the Parties. In 1964, the United States and Canadian governments (the Parties) sent a *reference* under the Boundary Waters Treaty to the International Joint Commission, asking it to examine whether there had been any injury to health and property from trans-boundary pollution of the lower Great Lakes (Lake Erie and Lake Ontario) and the interconnecting channels (the Detroit River, Niagara River, and the international section of the St. Lawrence River). The response of the International Joint Commission (1) documented the severe damage that was occurring. This finding formed the basis for the negotiation of the Great Lakes Water Quality Agreement, signed in 1972, with a provision for “a comprehensive review of the operation and effectiveness of this Agreement”. The Parties are currently undertaking one of these periodic reviews through an extensive series of public teleconferences and meetings, and the International Joint Commission has assisted the Parties by holding public meetings within the Great Lakes basin and through a public four-day, computer-based discussion on which they based their advice to the Parties (2,3). This report is based not only on transcripts, minutes, and published reports from these extensive and prolonged processes, but the report also situates the policy debates about the Great Lakes Water Quality Agreement within the present and historic social, economic, and political contexts (4) of the United States and Canada.

The focus of the 1972 Great Lakes Water Quality Agreement was on the prevention of eutrophication. This was successfully undertaken through negotiated control of phosphorus loadings for each lake. During the 1970s, the seriousness of injury to the health of wildlife and humans caused by exposures to persistent toxic substances began to be appreciated. This new priority was reflected in the 1978 renegotiation. In 1987, the 1978 Agreement was amended by a protocol, rather than through renegotiation and contained planning provisions for restoration of water quality in “Areas of Concern” through development of “Remedial Action Plans” and, in each lake, through development of “Lakewide Management Plans for Critical Pollutants”. Long-term monitoring of the levels and health effects of persistent toxic substances has documented the substantial improvements in water quality, while

revealing the continuing injury to health and property at current concentrations.

INJURY TO HEALTH AND PROPERTY

The public consultations and teleconferences lacked the involvement of knowledgeable scientists who had undertaken the forensic research on the injury to health and property. Similarly, administrators who had responsibilities for protection of human health and fish and wildlife resources from water pollutants, particularly from persistent toxic substances (2,5), were noticeably absent. The presence and effects of persistent toxic substances pose risks of modernity that are largely imperceptible except through the special techniques of science(6). While the public provided valuable insights, the consultations would have benefited from the involvement and contributions of technical specialists. During the past 30 years, scientific evidence has accumulated of injury to human health from exposures to persistent toxic substances in the Great Lakes. Epidemiological findings centre on reproduction and development effects, particularly on cognitive and behavioural development consequences caused by prenatal exposures from maternal consumption of Great Lakes fish (7–9). Prior research on wildlife informed research on these toxicological effects on human health.

For 50 years, forensic toxicological research into the effects of exposures of Great Lakes wildlife populations to specific organochlorine compounds has yielded a remarkably coherent picture of the injury from these water pollutants, including embryo mortality, deformities, and population declines and extirpations, particularly among fish-eating birds (10). Declining concentrations of DDT and its metabolites, PCBs, and dioxins have permitted the re-establishment of self-sustaining populations in many parts of the Great Lakes. The viabilities, however, of the offspring of all Great Lakes bald eagles (W.W. Bowerman, personal communication) and some Caspian tern populations (J.P. Ludwig, personal communication) are still negligible.

The methodology used by the wildlife researchers to make specific, parsimonious statements concerning the toxicological causes of the declines and extirpations in wildlife (11), contrast with the multi-stressor methodology of the Great Lakes fisheries

researchers. The latter have produced few coherent case studies linking declines and extirpations in Great Lakes fish populations to specific toxicological agents. A retrospective risk assessment of 2,3,7,8-tetrachloro dibenzo-*p*-dioxin in Lake Ontario which showed that the extirpation of the lake trout was attributable to releases of this compound acting “alone” (12), recently challenged the multi-stressor assumptions of the fisheries researchers (13). We believe that all Great Lakes fisheries science for the past century needs to be re-evaluated by considering the role of persistent toxic substances and by refuting spurious putative agents. Instead, rather than challenging the multi-stressor assumptions of the Great Lakes fisheries ecologists, these assumptions have been embraced by policy analysts (14) involved in the review of the Great Lakes Water Quality Agreement. These assumptions now form the basis of an active process of *diversionary reframing*.

DIVERSIONARY REFRAMING

During the review proceedings (2,5), participants learned that the purpose of the Great Lakes Water Quality Agreement had been written ambiguously, wittingly or unwittingly, when it was incorporated into Article II of the Agreement during the 1978 renegotiation. The Article states that:-

The purpose of the Parties is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.

The ambiguity was whether the Great Lakes Water Quality Agreement had been transformed into an agreement on ecosystem integrity or remained one on water quality. Such a policy transformation would affect all aspects of the implementation of the Agreement including, for example, problem definition, research and monitoring, remedial planning, selection of indicators, and priorities for funding. Since the signing of the 1972 Agreement, a small group of academics in fisheries and environmental policy departments has wanted to reframe the Agreement to address many Great Lakes issues in addition to water quality (14,15). This reframing would have included radical proposals for new governance arrangements for the Great Lakes Basin (16). Those advocating

this policy transformation have made their case plausible by omitting the words “of the waters” from the statement of purpose, by transforming “the chemical, physical, and biological integrity” into causes rather than effects, and by representing the introduction of exotic species as “biological pollution” (3,17). Over the years, this small group has built a substantial constituency and, during the Parties’ review, a Special Issues Work Group compiled 29 Great Lakes issues that might potentially be included in the Great Lakes Water Quality Agreement. Three of these issues – Biodiversity (including Aquatic Invasive Species), Climate Change, and Watershed Planning and Land Use – were eventually addressed in detail.

Advocates for the policy transformation to an ecosystem integrity agreement came from industry and from non-governmental environmental organizations as well as from the two federal governments and academia. Over the years, the motives of those advocating the reframing of the Great Lakes Water Quality Agreement have been difficult to discern. Some insight is possible from theories of risk management and communication. As Freudenburg (18) has noted, in risk amplification and risk attenuation, “Rather than responding to the substance of citizen concerns, policy makers of the past have often employed... ‘diversionary framing’ – that is, attempts to divert attention away from the citizen’s real concerns by ‘reframing’ the debate as being ‘about’ something else”. Most participants in the review tended to represent interests, and there was an explicit acknowledgement at the first meeting that everyone had a conflict of interest from which it was inferred that this could not be used as grounds for discounting an opinion.

Industry and government have been reluctant to implement the 1978 Great Lakes Water Quality Agreement because of the enormous costs of remedial actions, particularly for persistent toxic substances. The United States, for example, has undertaken remedial action on only 3.7 of the 75 million cubic yards of contaminated sediments, while Canada has removed only 0.045 of the 44.7 million cubic yards of contaminated sediments (19–21). Interest among government and industry in reframing the Agreement seems to be intended to divert attention from injury to health and property, particularly that caused by exposures to persistent toxic substances. Attenuation of the scientific risk messages seems, however, insufficient to explain the scale of the diversionary reframing seen in the

present review of the Great Lakes Water Quality Agreement. Analysis of social, economic, and political discourse may help inform this process of policy analysis (4).

SOCIAL DISCOURSE

The Great Lakes Water Quality Agreement can be perceived as a result of the period of social unrest in the 1960s when a series of diverse struggles, known as the New Social Movements, coalesced into coherent messages for reforms (22). University campuses around the world became the locus of social activism, (23) and students' resistance to the perceived social, economic, and political outrages was legitimated by governments. New legislation and new institutional arrangements emerged – establishment of the United States Environmental Protection Agency and the Department of the Environment, in Canada. With the visible successes of these measures in countering the outrages, and with the employment of this generation of students within the mainstream society, activism was essentially extinguished by the end of the 1970s. After the 1972 Great Lakes Water Quality Agreement was renegotiated in 1978, with its focus on evaluation and control of persistent toxic substances, there was little political enthusiasm for implementing the new Agreement.

Between 1988 and 1992 there was a brief resurgence of public activism, particularly through non-governmental organisations, around implementation of the Agreement. The International Joint Commission was the focus of this activism and expressed its new radicalised attitudes in its Fifth Biennial Report (24). The International Joint Commission, however, overreached its credibility in its Sixth Biennial Report when it recommended the development of “timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks” (25). The recommendation produced a massive reaction from the chemical industry which, after the next Presidential election, successfully “captured” the United States section of the International Joint Commission by lobbying the Clinton White House for new US commissioners “who would be more sympathetic to industry’s old way of thinking” and who were “not as green as the current bunch” (26). Thus, industry has an interest in the process of diversionary reframing of the Great Lakes

Water Quality Agreement to remove the present focus on injury to health and property from exposures to persistent toxic substances released to the boundary waters from current and past industrial manufacturing, use, or disposal. Although the International Joint Commission has a duty to report problems of water quality, it has sometimes deliberately omitted details of new research on the injury to health (21,27,28). Recently, the Commission has joined those advocating the policy transformation of the Great Lakes Water Quality Agreement into a broad agreement on ecosystem integrity (3).

POLITICAL ECONOMIC DISCOURSE

The political economy of the period from 1980s to the present has been dominated by neo-liberal philosophies, which asserted that public policy should be viewed through the economic lens of the market (29). The federal bureaucracies in both countries, including the International Joint Commission, have been politicized (14) and now reflect a lack of political will to implement the Great Lakes Water Quality Agreement. The tenets of neo-liberalism – small government, privatization of goods and services – have resulted in inadequate funding for government and programmes, particularly for environmental protection and conservation of natural resources. Managers of many Great Lakes government programmes facing reduced budgets or threatened with closure, have misrepresented the Great Lakes Water Quality Agreement as a broad ecosystem agreement. They thereby hope to secure funding and justify the continuation or expansion of their programmes.

Another tenet of neo-liberalism is deregulation. The Canadian and United States governments, following *laissez-faire* politics, have removed many environmental protection requirements faced by industry. The 1978 renegotiation of the Great Lakes Water Quality Agreement focused on contamination of the Great Lakes “particularly by persistent toxic substances”. More recently, with the neo-liberal political agenda in place, there has been little incentive for government or industry to restore water quality to prevent injury to health through costly remedial actions. Diversionary reframing of the Great Lakes Water Quality Agreement to include a wide variety of Great Lakes issues has been welcomed by government and

industry as a means to remove the focus from costly remedial activities for persistent toxic substances.

Attenuated activism in the late 1970s exposed vulnerable environmental non-government organizations to funding shortfalls in public contributions. To survive, these organizations became fiscally pragmatic and turned to foundations, corporations, and governments, with the inevitable tendency to become co-opted. In the 1999 review of the Great Lakes Water Quality Agreement, environmental non-government organizations opposed opening the Agreement. Because of neo-liberal politics, they feared elimination of existing policies, particularly those on the virtual elimination of discharges of persistent toxic substances (30).

A few environmental non-government organizations in the Great Lakes basin, unhappy with the slow progress on a range of issues, are tired of waiting for the neo-liberal politics to change. The policy transformation of the Agreement to a focus on ecosystem integrity is seen by this small part of the environmental non-government organizations community as a means to advance all Great Lakes issues through this bilateral instrument; even potentially to offer principals in some environmental non-government organizations an expanded role. Similarly during 1999, industry had opposed opening the Agreement review process, fearing new requirements and regulatory controls (30). The Council of Great Lakes Industries started to endorse the multi-stressor approach to the Great Lakes basin ecosystem. The Council advised the International Joint Commission that the risks posed by toxic substances were now historic; there was now a need to address other Great Lakes issues (31). Thus, in the ongoing review, the strategic interests of certain environmental non-government organizations now coincide with the chemical industry, promoting transformation of the Agreement into an agreement on ecosystem integrity rather than water quality.

Our initial analysis of the current review of the Great Lakes Water Quality Agreement is informed not only by science, but also by social, economic, and political disciplines. Each discipline has been explicit or implicit in the public consultations and teleconferences (2,5). At the centre of this review, confusion about the purpose of the Great Lakes Water Quality Agreement has not been resolved. To transform the Agreement into an agreement on ecosystem integrity is a radical departure from the minimalist policy provisions codified 35

years ago. They included: water quality objectives developed in common; development and implementation of cooperative programmes; and assigning special responsibilities to the International Joint Commission. These consultative provisions entailed no surrender of sovereignty and excluded clauses that would enable bilateral or third-party enforcement of the Great Lakes Water Quality Agreement.

The transformation currently under consideration would have profound implications for national sovereignty and might encroach on exclusive provincial and state rights and responsibilities – management and use of natural resources, and land use planning. We believe that the proposals should be analysed through the lens of diplomacy.

DIPLOMACY

No doubt, some ambiguity in the interpretation of legal and diplomatic documents, such as the Great Lakes Water Quality Agreement, offers flexibility for budget requests and programme justification, and perhaps for saving face when explaining differences in regulatory strategies and achievements. An ambiguous statement of purpose, however, has invited many interested parties to use the Great Lakes Water Quality Agreement to address diverse issues, rendering the water quality programmes unnecessarily dysfunctional. Widespread injury to health and property persists, after 35 years of this diplomatic instrument (9).

Current United States diplomacy, informed by neo-conservative philosophy, emphasizes unilateralism in foreign policy, avoiding reliance on treaties and international organizations. Any proposed agreement on ecosystem integrity would have indistinct boundaries, and agendas would be open-ended. From a diplomatic perspective, it would seem unlikely that the United States would further yield its sovereignty by supporting extension of the purview of the Great Lakes Water Quality Agreement or the associated institutions, particularly into areas that are traditionally under the jurisdiction of state and provincial powers. The Canadian foreign policy is dominated by considerations of trade with the United States. Despite public opposition, it is moving towards “deep integration” on security and energy, and harmonization of regulatory requirements for environmental protection (32). Canadian foreign policy is

indeterminate towards an open-ended agreement on ecosystem integrity of the entire Great Lakes basin.

The United States Congress has authorized funds to restore large ecosystems such as the Chesapeake Bay and Florida Everglades using partnerships with state and local jurisdictions (33,34). Environmental managers and environmental non-governmental organizations within the Great Lakes basin envy these substantial programmes and appropriations, and are planning a submission to Congress for similar funding. In contrast to the Great Lakes, Chesapeake Bay and the Florida Everglades are completely within the boundaries of the United States. Accordingly, Congressional funding has been relatively straightforward. Within the United States, the Great Lakes tend to be regarded as a local or regional issue rather than a national or international one. Over the past two decades, Congressional attitudes about funding have been ambivalent. As the US State Department representative indicated during a teleconference, with the priority of the present United States Administration on “homeland security” and the “war on terror”, budgetary constraints militate against the negotiation of an open-ended agreement to address ecosystem integrity.

Minor changes to the Great Lakes Water Quality Agreement can be made via diplomatic channels by notes or letters. Both countries have been reluctant to open up the entire Agreement for renegotiation as many of the existing provisions might be removed. When, in the past, for diplomatic reasons, it no longer seemed likely that the Parties would refocus the whole Agreement on ecosystem integrity, advocates successfully turned to a strategy of negotiating small incremental changes and influencing the decisions of the Binational Executive Committee that oversees administration of the Great Lakes Water Quality Agreement. During the negotiations that resulted in 1987 revision, for example, “habitat” was included as a “beneficial use” in the development of Remedial Action Plans for Areas of Concern. But was it to be all aspects of habitat that were to be restored or only those aspects of habitat damaged by water pollution, particularly by persistent toxic substances? The Binational Executive Committee was persuaded similarly to reframe Lakewide Management Plans for Critical Pollutants as planning tools for fish and wildlife management within the entire watershed of the Great Lakes basin ecosystem. Several management programmes for

biological resources unrelated to the water quality mandate were included: reintroduction of bison into Ohio; restoration of habitat for prothonotary warblers in the Lake Erie watershed, and ruffed grouse and caribou management in north-western Ontario. In the 1990s, these documents routinely omitted published evidence of injury to human health.

CONCLUSION

The Great Lakes Water Quality Agreement, a minimalist diplomatic instrument, was signed in response to the New Social Movements of the 1960s. In recent years, both federal governments have allowed the mandate to drift. Powerful forces have tried to transform the agreement from its narrow focus – “particularly on persistent toxic substances” – into a broad policy agreement on restoration of ecosystem integrity for the entire Great Lakes watershed. Counter-vailing forces within parts of the scientific community want to continue a focus on injury from exposures to persistent toxic substances to health and property. Others, within the US State Department and the Canadian Department of Foreign Affairs and International Trade may wish to avoid ceding further elements of national sovereignty.

From the reviews of the Great Lakes Water Quality Agreement, a central issue has emerged; the limits of the Agreement itself. Traditionally, the bilateral Agreement has been interpreted narrowly by diplomats. The Agreement’s authority derives from Article IV of the Boundary Waters Treaty, reflecting agreement that the Parties will not pollute their respective boundary waters causing injury to health or property on the other side. Thus, for an issue to be within the purview of the Great Lakes Water Quality Agreement seems to require that it relate to water pollution, with the potential to cross the boundary, and cause injury to health and property. Other Great Lakes issues have been addressed through alternative institutional arrangements, such as the Great Lakes Fishery Commission and the Great Lakes Regional Collaboration. These issues have traditionally been excluded from the purview of the Great Lakes Water Quality Agreement.

Officials at the State Department of the United States and the Canadian Department of Foreign Affairs and International Trade

face a difficult decision: should they enter into a renegotiation? Extensive public consultations have uncovered polar views expressed by opposing interests. The International Joint Commission, industry representatives, parts of governments and academia, and a small part of the environmental non-governmental community have advocated reframing the Agreement as a broad agreement on ecosystem integrity. The scientific arm of each government and the remainder of the non-government organizations prefer to keep the focus on maintaining and restoring water quality; to prevent injury to health and property from trans-boundary water pollution. Industry, using its access to the White House has influenced US appointments to the International Joint Commission (26). Will industry again use influence to sway the outcome towards reframing of the Agreement to focus on ecosystem integrity? Little enough has happened to implement the 1978 Great Lakes Water Quality Agreement, but if industry were to succeed, another generation of Great Lakes residents would surely be exposed to persistent toxic substances, producing all too predictably, further injury, particularly neurological developmental deficits in infants. The existence of several other Great Lakes institutions would seem to obviate any need for reframing the Great Lakes Water Quality Agreement that would divert the agenda towards a new focus, which would include a myriad of Great Lakes issues unrelated to water quality.

To overcome the intrinsic ambiguity of the present statement of purpose and the tendency for diversionary reframing, the following new wording was proposed during the public consultative process:

Pursuant to Article IV of the Boundary Waters Treaty, the purpose of the Parties in signing the Great Lakes Water Quality Agreement is to prevent injury to health and property from pollution of the boundary waters by restoring and maintaining the chemical, physical and biological integrity of the Great Lakes basin.

This simple wording would assure that the United States and Canadian governments and of the International Joint Commission maintain programmes to fulfil their treaty obligations to protect the quality of the waters of these unique resources.

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