Twelfth Biennial Report

Prepared pursuant to the Great Lakes Water Quality Agreement of 1978 for submission to the Governments of the United States and Canada and the State and Provincial Governments of the Great Lakes Basin

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Table of Contents

EXECUTIVE SUMMARY

The Great Lakes Water Quality Agreement (Agreement), created by Canada and the United States in 1972 to restore and protect the largest body of surface freshwater on the planet, provides an example to the world of how two countries can forge a commitment to restore the integrity of shared bodies of water. The Agreement's stated purpose is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem. It is this purpose, the integrity of the lakes and, by extension, the environmental integrity of both countries, that this *Twelfth Biennial Report on Great Lakes Water Quality* addresses.

The Agreement requires the International Joint Commission (Commission) to assess progress and assist both governments in achieving this commendable goal. As stated in our Declaration, issued at the conclusion of the Biennial Meeting in Ann Arbor, Michigan in September 2003, the Agreement has served as a blueprint for cooperation and coordination of largely successful stewardship of the Great Lakes for more than 30 years. Vigorous public participation and dialogue among all interested parties has and must remain a cornerstone of Agreement implementation.

The U.S. and Canadian governments, the Parties to the Agreement, must perform a comprehensive review of the Agreement after every third biennial report from the Commission. This Twelfth Biennial Report marks the beginning of the next required review process. We urge the Parties to be thorough, visionary and far-reaching as they review the Agreement, and as they address critical questions regarding its scope, the Commission's role, and emerging issues not included in the Agreement. In the September 2003 Declaration, the Commission commits to assisting the Parties in this review process and engaging the public in active dialogue to ensure input from all who care about the health of the Great Lakes basin ecosystem. The Commission will provide detailed advice to governments on the Agreement's review later in 2004.

Key Findings

The Parties have made progress on developing and implementing best management practices to accommodate the growing pressure of human development in the basin. Our understanding of the potential impacts of climate change on the Great Lakes is improving, and many toxic chemical releases have declined over the past decades. Research has been coordinated to understand Lake Erie's changing dynamics, including: the disappearance of some fish food organisms but the resurgence of others, the invasion of aquatic species, and increases in algae to nuisance levels.

However, natural habitat continues to be lost as our urban areas expand. The governments must address a fundamental question: collectively, are policy, program and management efforts sufficient to protect water quality from the effects of sustained expansion of major urban areas in the Great Lakes basin and to ensure ecosystem integrity?

Notwithstanding decades of research, new aquatic alien species continue to be introduced into the lakes at a rate of one per every eight months via ocean-going vessels, or from bait fish, aquarium fish, aquaculture and connecting tributaries. The Commission urges the governments of Canada and the United States to issue a standing reference to the Commission to coordinate prevention measures to help halt this invasion to the Great Lakes.

Without adequate safeguards, our health can be threatened by pathogens and disease-bearing microorganisms. The governments must focus increased attention on protecting the sources of drinking water supplies. In particular, coordinated action by all those responsible for managing watersheds is required to avoid impacts from expanded land use pressures from agriculture, development, industry and urban centers.

Chemical contamination continues to endanger human health and restricts the number of fish we can safely eat. Several adverse health effects associated with exposure to methyl mercury, a highly toxic substance, have been identified in human and animal studies. In the Great Lakes basin, people are exposed to methyl mercury almost exclusively by eating fish. The Commission urges the governments to implement programs that reduce mercury emissions from the coal-fired utility sector, to make the risks associated with eating mercury-contaminated fish clear and understandable to the public, and to further research health risks to the Great Lakes basin from exposure to mercury.

Because of their complex nature, addressing the overlapping and interacting issues affecting Lake Erie requires a greater level of binational communication and cooperation than ever before. The Commission urges the governments to determine the cause of recent ecological degradation in Lake Erie and to take appropriate steps to restore its ecological integrity.

Many of these findings were reflected in public testimony at the Commission's Biennial Meeting, held in Ann Arbor, Michigan, in September 2003. The very real threats we discuss in this report, and the public voice we heard at our Biennial Meeting, cause the Commission to urge that the governments of Canada and the United States take a precautionary approach to better face future threats and address current needs in order to enhance and protect the global treasure that is the Great Lakes.

IN LIGHT OF THE ABOVE FINDINGS, THE COMMISSION MAKES THE FOLLOWING RECOMMENDATIONS

Physical Integrity

1. The Parties take binational actions to address the impact of urban land use on Great Lakes water quality by:

    - evaluating under what circumstances best management practices[1] are effective in managing urban runoff;
    - ensuring that information on urban best management practices reaches local authorities and implementers; and
    - assessing the cumulative effects of management actions to minimize the impacts of urbanization on the Great Lakes, using the Lake Erie basin as an example.

Biological Integrity

2. The governments should take the following measures to eliminate the threat and impacts of aquatic alien invasive species in the Great Lakes:

   Take immediate action to:
   - in the United States, pass the National Aquatic Invasive Species Act (NAISA) reauthorizing the National Invasive Species Act (NISA);
   - in Canada, implement the National Action Plan to address the threat of aquatic alien invasive species; and
   - ratify and implement the International Maritime Organization's Convention for the Control and Management of Ships' Ballast Water and Sediments, and pursue more stringent measures and rapid timelines.

3. Issue a reference on aquatic alien invasive species to the International Joint Commission to:
   - help to identify the most effective ways to coordinate binational prevention efforts and harmonize national plans, particularly those dealing with residual ballast water and sediment in ballast tanks;
   - evaluate the effectiveness of current institutional arrangements;
   - assist with the establishment of a regional standard stronger than the minimum required by the International Maritime Organization Convention;
   - ensure that economic analyses carried out for projects with potential environmental effects include the environmental and societal costs of aquatic alien invasive species control, damage, and mitigation, and the costs and benefits of prevention measures; and
   - assist with public education and communications.

4. All levels of governments should create and implement coordinated planning actions to fully protect drinking water from increased pressures from industry, urban expansion, aging infrastructure and agriculture, including ecosystem and human health protection from large-scale animal operations.

Chemical Integrity

The Commission recommends that the two federal governments, in conjunction with the states and provinces and institutions:

5. Undertake retrospective and prospective epidemiological studies, in Areas of Concern and other pertinent locations of the Great Lakes basin, to better understand potential neuro-developmental effects associated with methyl mercury and PCBs.

6. Make fish advisories clear, simple, and consistent, and ensure that they are reaching the intended audiences.

7. Select and promptly implement programs in both the United States and Canada that would substantially reduce the deposition of mercury in its reactive gaseous form in the Great Lakes region; also pursue multi-lateral strategies for further control of this persistent toxic substance on a global basis.

Ecosystem Integrity

8. The Commission recommends that governments continue to fund binational research efforts begun in 2002 and 2003 to better understand positive and negative changes in the Lake Erie ecosystem and take appropriate action. The institutional model provided by the Lake Erie Millennium Network[2] should be considered for adaptation and adoption to the other Great Lakes to foster enhanced binational cooperation and communication.

INTRODUCTION

The governments of Canada and the United States (the Parties or Governments) signed the first Great Lakes Water Quality Agreement (Agreement) in 1972. They created the present Agreement in 1978, revised it in 1983 and, in 1987, added new annexes through a Protocol. Today, the Agreement remains one of the most farsighted international agreements, and is a model of cooperative environmental research and ecosystem management.

In this *Twelfth Biennial Report on Great Lakes Water Quality*, the International Joint Commission (Commission), as required by Article VIII of the Agreement, assesses the Parties' progress in implementing the Agreement by highlighting issues we conclude need timely and focused attention. We do not report on all subjects of importance to the Great Lakes but analyze and make recommendations around the Agreement's theme of physical, biological and chemical integrity leading to an ecosystem approach to ecological integrity. The Great Lakes are a global treasure. As such, our two great countries have a responsibility to treat them with the utmost respect and care; to not be complacent in their care and protection; and to reflect our own countries' ecosystem integrity in how we treat this global treasure.

The concept of physical integrity is illustrated in this report by land use issues, with a focus on urban systems and the exacerbating effects of climate change on runoff and pollution. The threats posed by aquatic alien invasive species and pathogenic pollution portray the concept of biological integrity. The concept of chemical integrity is reflected in mercury pollution and its effects on human health. The changing composition of the waters and biota of Lake Erie illustrate the concept of ecosystem integrity.

The Commission points out two areas here which, while not discussed further in the body of this report, it considers extremely important and continues to call on the Parties for action: the Remedial Action Plan (RAP) Program, and major spills in the connecting channels from Lake Huron to Lake Erie.

The Remedial Action Plan Program was created under Annex 2 of the 1987 Agreement. In April 2003, the Commission evaluated the status of restoration in all remaining 41 Great Lakes Areas of Concern (AOCs) and issued a report in April 2003.[3] We continue to call on the Parties, in cooperation with the jurisdictions and the communities, to provide the Commission and the public with precise and concise reporting about RAP accomplishments and challenges. Each of the AOCs is unique in scope, issues, and leadership. As such, there is no one solution to the problems faced by the AOCs and the organizations and individuals dedicated to remediate them. The Parties need to provide greater resources to undertake further remediation, wastewater and storm water treatment, habitat rehabilitation and protection, and other necessary actions. Documenting progress and future needs provides the public and elected officials with a better understanding of how government funding has contributed to restoring beneficial uses in the Great Lakes AOCs, and can achieve further goals. It would provide the evidence that previous investments have been worthwhile and that the substantial additional funding needed to fully restore ecosystem quality and beneficial uses for fish, wildlife and humans is worth the cost.

The Commission is seriously concerned that major spills in the connecting channel from Lake Huron to Lake Erie, particularly the St. Clair River section, have increased over the last two years. In April 2002, a very large oil spill (estimated at 378,500-1,000,000 litres / 100,000-264,200 gallons) in the Rouge River required the first full implementation of the Canada/U.S. Coast Guard joint response system (CANUSLAK[4]) that recovered 167,000 litres (~44,000 gallons) of oil during the response. In August 2003 a major regional power blackout led to not only several overflows from wastewater treatment plants, but also an unacceptable delay in Royal Polymer's reporting of a vinyl chloride spill in Sarnia. Less than six months later, on February 1, 2004, a leak in a heat exchanger at the Imperial Oil plant in Sarnia led to a discharge of methyl ethyl ketone and methyl isobutyl ketone into cooling water which was discharged into the river.

In April 2004, the Ontario Ministry of Environment appointed an Industrial Pollution Action Team of scholars and community leaders to evaluate measures that could reduce spills in the Sarnia area. On August 9, 2004, the Ontario Ministry of Environment released a report from the Industrial Pollution Action Team for a 60-day public comment period. The report contains 35 recommendations directed at government and industry.

Water treatment plant operators downstream are concerned about the frequency with which they have been closing their water intakes due to these spills, and the public is concerned about the safety of its drinking water. The Commission is exploring the issue, keeping abreast of investigations and proposed steps to prevent or mitigate future spills, and anticipates issuing a separate report on this issue as more information becomes available.

The Commission looks forward to a substantive response by the Parties to this report, in accordance with Article X of the Agreement and consistent with their commitments made under the Agreement.

PHYSICAL INTEGRITY: IMPACT OF URBAN AREAS ON GREAT LAKES WATER QUALITY

Introduction

The need to plan and manage urban growth and mitigate its impact on the natural environment, particularly on urban watersheds and nearshore areas, is one of the major challenges in restoring and maintaining the physical integrity of the waters of the Great Lakes basin ecosystem. **The fundamental question to be addressed by governments is whether the sum of their policies, programs and management efforts are sufficient to protect water quality from the impact of continued expansion of its major urban areas in the Great Lakes basin.** This is an important question that is best answered binationally at the lake basin level, with participants drawn from all three levels of government (municipal, state/provincial and federal). Lake Erie has extensively shared boundaries and major urban areas, and the Lakewide Management Plan as called for under the Agreement and ongoing Lake Erie Millennium Network ecological study could provide an important ecosystem context for such an integrative assessment of the impact of urban land use on Great Lakes water quality.

The Impact of Urban Development on Water Quality

Principal water pollution sources from urban areas include:
- treated effluents discharged from sewage treatment plants and untreated effluents that bypass sewage treatment plants;
- treated and untreated storm water runoff;
- combined sewer overflows that carry a mixture of untreated sewage and storm water;
- air emissions from incidental and accidental releases and mobile sources; and
- ground water discharges to adjacent receiving waters.

The multi-billion dollar investments in wastewater and combined sewer overflow controls substantially reduced the worst pollution problems during the 1970s to the 1990s. However, most urban and suburban watersheds – including nearshore areas of major Great Lakes cities — are still not safe for swimming, do not have fish that are completely safe to eat, or do not support diverse biological communities.[1] The increase in hardened surfaces from roads, roof tops and parking areas means more pollutants enter surface waters via runoff without undergoing treatment, which has a significant impact from a basin wide perspective. For example, recent Canadian estimates indicate that the sum of major storm water-related discharges to the Great Lakes are in excess of 90,000 tonnes/year (~100,000 tons/year) of sediment, oil, grease, metals, and other contaminants.[2]

The expansion of major urban areas in the Great Lakes basin (Figure 1) can be attributed to many factors: population growth; land use preferences (for example, favoring suburban greenfields over urban brownfields); the tendency towards fewer people living in each household, thus necessitating more housing; and large suburban commercial and retail properties with extensive hardened areas for parking and access to highways. Unless these trends are anticipated and managed effectively, the continued expansion of major urban areas in the Great Lakes basin will have serious consequences for Great Lakes water quality.

Science and Policy Approaches to Managing Urban Hydrology

Most modern urban hydrology management practices focus on storm water, combining elements of flood protection, groundwater recharge,[3] runoff reduction and protecting natural areas, and are based on widely accepted scientific understanding.[4]

Extreme weather events can produce very high pollutant concentrations during initial phases and can have a thermal impact from the "first flush" of standing water heated by hardened surfaces. Real time sensors used by some jurisdictions evaluate storm water quality to ensure adequate initial treatment, storage and then gradual treatment and release when water quality standards have been attained. Other innovative practices include the use of green roofs that incorporate living plants or pervious[5] pavement to allow rain and melting snow

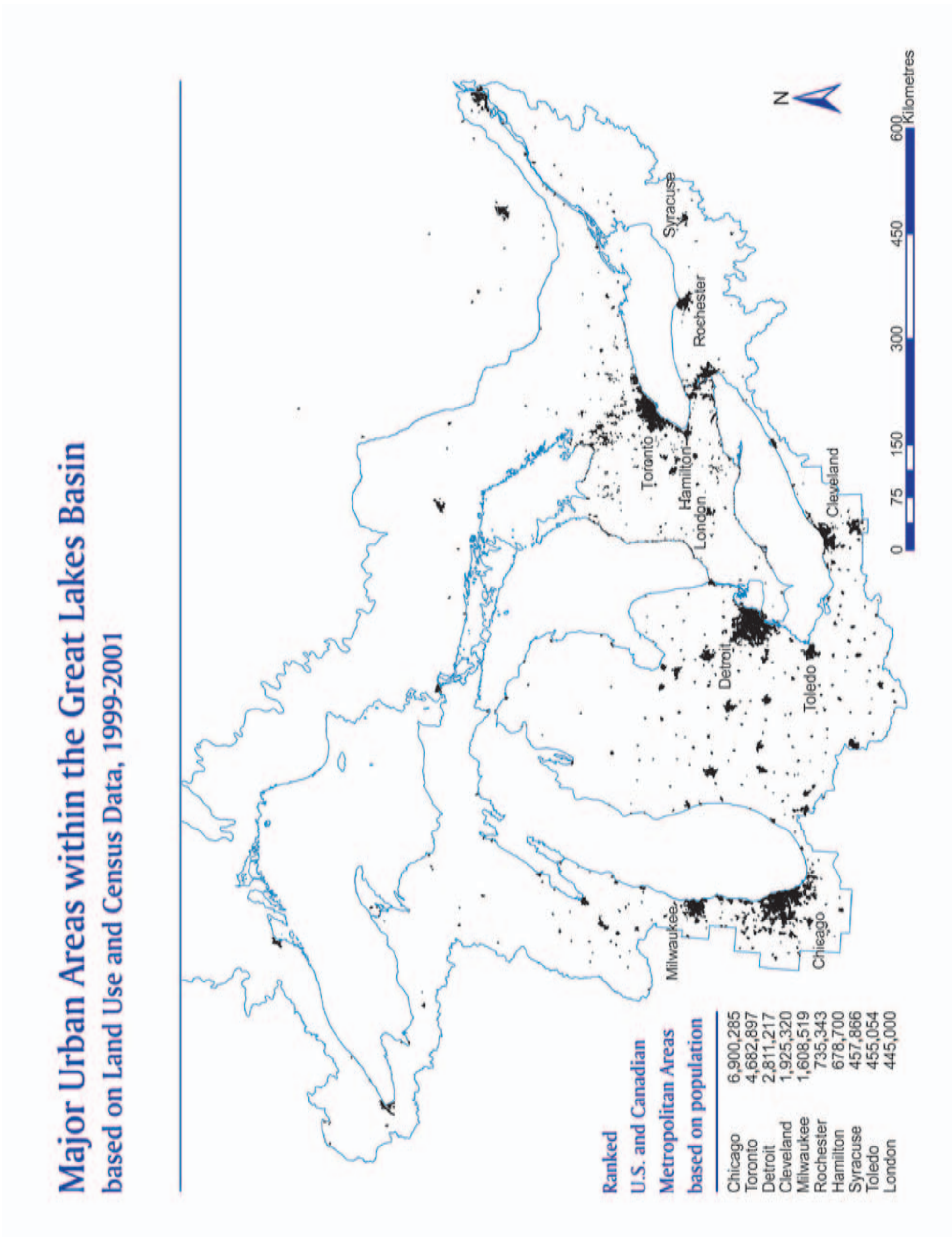


Figure 1. Major Urban Areas within the Great Lakes Basin based on Land Use and Census Data, 1999-2001

to percolate through to the subsurface and water gardens. Although best management practices can be easily identified in scientific literature and may be well understood by professional government agency staff, they are less familiar to local officials, citizens and developers who are making everyday land use decisions. A regional database of such practices and an information-sharing network among basin communities could provide an inventory to be used by local public and private decision makers. A U.S. initiative by the National Low Impact Development Clearing House illustrates how this could benefit Great Lakes developers and decision makers, and has particular merit for the binational context of the Great Lakes basin.[6]

The most innovative approaches recognize that successfully managing urban hydrology is more complex than simply managing storm water.[7] By applying concepts of ecological sustainability to land use management, a broader understanding and appreciation can be gained of a locality's natural processes, impacts and specific conditions. For example, the same commercial development may impact water quality differently depending on where it is located in that basin. Very specific everyday activities, such as the timing and frequency of street cleaning, can also affect water quality. In other cases, so-called best management practices can exacerbate negative impacts if not implemented in ecologically sound ways.[8] Many local and regional planning efforts fail to adequately link the fundamental relationship between the natural and built environments in this way, and thus inadvertently undermine the region's precious land and water resources.

In the United States and Canada, urban runoff is managed and regulated through a combination of federal, state and provincial programs implemented at the local level. The U.S. Environmental Protection Agency's (EPA) overall approach is one of pollution prevention within a larger context of watershed planning. The concept of watershed plans – as contrasted to community plans within city, township or county geopolitical boundary lines – is relatively new. Several planning commissions, councils of governments, and county and township planning boards throughout the region in the U.S. have written and adopted watershed and sub watershed plans. Many involve planning and implementation cooperation among neighboring local units of government. This degree of cooperation demonstrates that storm water management can be effectively addressed as a matter of national or regional policy, and then implemented at the local level using planning and best management practices.[9]

Ontario's experience of watershed planning represents one of the earliest water resource planning activities adopted by any jurisdiction in North America. Under the *Conservation Authorities Act* in 1946, Ontario established a system of conservation authorities throughout most of the province. In 1997, the province reaffirmed its commitment to watershed planning after an inter-ministerial review program that commenced in 1994 and culminated in a final report, *An Evaluation of Watershed Management in Ontario.*[10] The report concluded that **successful integrated planning for land and water uses depended on planning for entire watersheds.** The importance of watershed management gained further impetus in May 2002, when Justice Dennis O'Connor released the *Walkerton Inquiry, Part 2* report.[11] This report emphasized protecting the source of drinking water and pollution prevention, based on the premise that poor water quality at the source increases health risks at the tap. To implement the *Walkerton Inquiry's* recommendations, Ontario has proposed to establish 24 watershed-based planning areas to develop source water protection plans.[12]

Several policy initiatives in the United States and Canada have explored broad land use issues under the general term *smart growth.*[13] *Smart growth* encompasses a range of land policy and management concepts, including adopting a longer term vision in order to sustain economic and community development, while at the same time protecting the natural environment.

Urban policy issues of greatest relevance to water quality — land use, transportation and infrastructure — are also central to managing growth and protecting water resources.[14] Basin jurisdictions developing *smart growth* strategies and best practices should share these, which might collectively form the basis for future binational cooperation and coordination among local, state/provincial and federal governments. Future progress under the Agreement, particularly in relation to urban land use, will be further advanced by involving these local governments of Great Lakes cities who have created the programs and policies outlined. Their participation in broader policy and decision-making will recognize their potential role in the achievement of the broader purpose of the Agreement.

The Impact of Urban Development on Groundwater

Within the Great Lakes basin, a significant portion of groundwater discharge occurs directly to the lakes or their tributaries. Most groundwater contaminants are closely linked to urban land use practices: excessive pesticide and fertilizer use; leaking underground storage tanks; malfunctioning private septic systems; and spills or leachate from industrial sites, uncapped wells and road salts. Groundwater also serves as a pathway for bacterial pollution of urban beaches.[15] Within a watershed, the combination of extensive hardened surfaces and groundwater withdrawals for water use can limit the potential to recharge groundwater supplies, diminishing the ability to sustain historic and current stream flow rates. Reduced flows exacerbate the impact of urban pollutants, causing degradation in overall water quality. In some cases, especially under low flow conditions, base stream flow can be predominantly made up of wastewater discharge and urban runoff. Because of the variety of urban development activities that may significantly impact groundwater quality and quantity, any regional watershed plans must incorporate groundwater issues.

As noted in previous reports, progress and commitment to the implementation of Annex 16 of the Agreement, *Pollution from Contaminated Groundwater*, has been limited.[16] While the broad regional approach implied in Annex 16 would provide the best basin wide context for wise development decisions, an alternative approach could be to require developers to explicitly provide for ground water protection in their development plans. Such site hydro geological assessments would contribute to daily decision-making, and could also be compiled into a regional perspective to manage and control contaminated groundwater affecting the boundary waters of the Great Lakes system, as required under Annex 16.

The Impact of Climate Change on Groundwater and Surface Water Quality

Recent scientific research suggests that a new climate, quite distinct from that present at the turn of the 20th Century, may be already in place in the Great Lakes basin.[17] Of great importance is the potential change in water supply that may occur in parallel with increased demand for water as population increases in the basin.[18]

In 2001, the Commission identified the impact of climate change and variability for the Great Lakes region and its residents as a key priority to be addressed by the Water Quality Board during the 2001-2003 priority cycle. In response, the Water Quality Board developed a detailed report, *Climate Change and Water Quality in the Great Lakes Basin 2003*. The board's key findings indicate the potential for climate change to profoundly affect all aspects of the natural and built environment in the Great Lakes basin.[19]

Climate change scenarios continue to evolve as predictive capabilities and scientific models improve. The impact on urban areas, with their extensive hardened surfaces and inadequate storm water infrastructure to manage urban runoff, could be significant if total annual precipitation and the intensity of specific storm events increase as predicted. Extreme weather events can readily mobilize contaminants that have accumulated on hardened surfaces, and can increase the quantity of water bypassing water treatment facilities during storm events. Under such scenarios, the potential for more polluted runoff to bypass treatment is of real concern.

A full understanding of, or appreciation for, the magnitude and consequences of climate change is yet to emerge, and therefore there is no consensus on how to best adapt or mitigate its impacts at a local, regional, national or global level. However, best management practices at the local level could be effective in adapting locally and managing the impact of excessive storm water runoff due to extreme weather events. In the absence of scientific certainty and consensus for action, such practices could represent "no regret" decisions that, in some instances, could provide cost-effective alternatives to major new investments in urban storm water infrastructure.

Conclusions

Some gaps in knowledge may exist regarding the effectiveness of individual technologies, best management practices, policies and processes adopted by local jurisdictions to address the impact of their urban area on Great Lakes water quality. However, the overarching challenge in terms of Agreement goals is whether current approaches are sufficient from an overall, basin wide perspective. A comprehensive and binational assessment of the effectiveness of these policies and programs from a basin wide perspective could provide a broader context for local decisions, and at the same time advance achievement towards an ecosystem approach as envisioned by the Agreement. While a binational effort to link local, state/provincial and federal agencies to address the impact of urban land use on Great Lakes water quality has not existed since the days of the Pollution From Land Use Activities Reference Group[20], many other examples of binational strategic cooperation exist since that time, such as the Binational Toxics Strategy, Lakewide Area Management Plans and the State of the Lakes Ecosystem Conference (SOLEC). Given the growing interest and awareness of citizens, mayors, developers and all levels of government on the need for effective planning and management of urban growth, the opportunity for a binational Great Lakes basin wide approach to managing pollution due to land use activities is especially timely, practical and relevant.

In the United States and Canada, land use decisions are generally regarded as the exclusive domain of local government, yet local decisions cannot simply be viewed in isolation of other responsibilities at the provincial, state, and federal levels. Because wise land use decisions and effective land management are fundamental to implementing and progressing toward the ecosystem approach envisioned by the Great Lakes Water Quality Agreement, governments need to improve their institutional capacity to coordinate and integrate roles, responsibilities and decisions between and among all levels.

Recommendations

The Parties take binational actions to address the impact of urban land use on Great Lakes water quality by:

- evaluating under what circumstances best management practices[21] are effective in managing urban runoff;
- ensuring that information on urban best management practices reaches local authorities and implementers; and
- assessing the cumulative effects of management actions to minimize the impacts of urbanization on the Great Lakes, using the Lake Erie basin as an example.

Chapter Two

BIOLOGICAL INTEGRITY: IMPACTS OF AQUATIC ALIEN INVASIVE SPECIES AND PATHOGENS

Introduction

Many phenomena threaten the biological integrity of the Great Lakes. We highlight two: the continuing impacts of aquatic alien invasive species and the little-understood threats posed by disease-causing or pathogenic organisms. According to scientists' best estimates, a new aquatic alien invasive species finds its way into the Great Lakes system about every eight months. The impact of introduced species already in the system, from the sea lamprey to the zebra mussel, serve as harbingers of the economic and environmental costs to come if this crucial threat is not controlled. Similarly, documented surprise outbreaks of gastrointestinal diseases, sometimes with fatal consequences, should serve as a warning that residents of the Great Lakes basin face serious, largely unacknowledged threats from an everyday substance we all tend to assume is safe – the water we depend on for recreation and drinking. Fortunately, options exist to address both of these crucial challenges.

Aquatic Alien Invasive Species: Living with the Uncertainty of Biological Pollution in the Great Lakes

The Great Lakes ecosystem is an uncertain, fragile environment subject to biological pollution by alien species that continue to enter the lakes from the ballast water of foreign, ocean-going ships and other means. Since the release of the International Joint Commission's *Eleventh Biennial Report on Great Lakes Water Quality* in September 2002, possible actions to address ecological and economic costs of aquatic alien invasive species have been discussed in detail and some progress made.[1] Specifically:

- The U.S. National Aquatic Invasive Species Act reauthorizing the National Invasive Species Act of 1996 was introduced in Congress, but has not been passed.
- In Canada, regulations requiring mandatory ballast water management practices have been drafted, but not enacted.
- The Great Lakes states, the province of Ontario and many localities have instituted bans against the sale and/or transport of live Asian carp and snakehead species.
- The design and construction of a second electrical barrier in the Chicago Sanitary and Ship Canal, to prevent migration of invasive species between the Great Lakes and Mississippi River drainage basins should be finished in September 2004 before the existing electrical barrier reaches the end of its design life in 2005. This will ensure that a barrier remains in place to protect the Great Lakes from species such as Asian carp; however, a serious funding shortage must be addressed in order to complete this project as initially designed.
- The Canadian Council of Fisheries and Aquaculture Ministers' (CCFAM) Task Group on Aquatic Invasive Species has prepared a national action plan for ministerial consideration by September 2004, with an implementation plan to be submitted by September 2005. The federal/provincial/territorial task group's work is a key element of an overall national strategy to address the threat of invasive species, both aquatic and terrestrial, in Canada.
- A ballast water test facility established in Florida supports the U.S. EPA's Environmental Technology Verification (ETV) program to develop protocols to verify the performance of new ballast water treatment technologies.
- In the United States, the Coast Guard, EPA, National Oceanic and Atmospheric Administration and the Fish and Wildlife Service recently conducted public hearings to evaluate the environmental impact of several proposed options for ballast water regulation. The Coast Guard has instituted a shipboard technology evaluation program for experimental ballast water treatment systems.
- The state of Michigan is implementing its revisions to its ballast water law, Section 3103a of the Natural Resources and Environmental

Protection Act.[2] The Michigan Department of Environmental Quality now maintains a list of all oceangoing vessels it regards to be in compliance with ballast water management codes. Since March 2002, any owner or operator not on this list, or anyone in the state who has contracts to transport cargo with a vessel operator not on the list, are not eligible for new grants, loans or awards administered by the department.

- The International Maritime Organization adopted the Convention for the Control and Management of Ships' Ballast Water and Sediments in February 2004. This United Nations agency, responsible for the safety and security of shipping and preventing marine pollution by ships, is to be commended for their successful work in negotiating a ballast water convention. The new Convention requires all ships to: implement a ballast water and sediment management plan; carry and complete a ballast water management record book; and undertake ballast water management procedures to a specific standard. The Convention also contains noteworthy provisions allowing member states to adopt stricter standards, requires all ships to implement ballast water exchange by date certain, and states that no ships will be exempted indefinitely from complying with these standards. Moreover, the Convention provides incentives for shippers to test and evaluate promising ballast water treatment technologies (the Convention has not yet been ratified by the required 30 member states carrying 35 percent of global tonnage).

While these initiatives are encouraging and should prove beneficial over time, the flow of new invasive species to the Great Lakes has not been stopped. In 2001, scientists estimated that 162 invasive species had entered the lakes from all pathways. Today, some scientists have raised that estimate to more than 170 non-indigenous fish, invertebrates, plants, algae, protozoa and parasites, and predict that one new non-indigenous species will be discovered in the lakes about every eight months.[3] The International Maritime Organization standards for ballast water discharge will become effective 12 months after ratification by 30 member states, representing 35 percent of the world merchant shipping tonnage. Even under the best scenarios, provisions of the Convention could take at least five to eight years to come into full force. Given the current rate of introductions, the Great Lakes could be at risk from 8 to 12 additional non-indigenous species during that time. Any one of these new invaders could prove to be as ecologically and economically destructive as those already in the system, if not more so.

A binational, regional plan is essential if we have any hope of stopping this influx before the Convention is ratified and implemented. There are limited points where controls are needed to halt aquatic alien invasive species from entering the Great Lakes. For instance, sea-going ships gain access by a single gateway, the St. Lawrence River Seaway, which the United States and Canada share. The numbers and classes of foreign ships that ply the waters of the lakes — as well as the cargoes they carry — are well documented, and are significantly more manageable than those found throughout the entire international maritime shipping industry. The provisions of the International Maritime Organization Convention recognize the need for regional cooperation, stating that a party may individually, or jointly with other parties, impose additional measures to prevent, reduce or eliminate the transfer of harmful aquatic organisms and pathogens through ships' ballast water and sediment.

The Commission strongly encourages and remains hopeful that Canada and the United States will develop a regional approach for the Great Lakes. This approach should meet or exceed the International Maritime Organization standards, tighten requirements for ships carrying residual ballast water and sediment, and put the regulatory development process on a fast track.

Minding the Store

The Commission continues to express its concerns about other serious potential invaders to the Great Lakes via pathways other than ballast water. For example, the Commission has expressed great concern about the threat posed by Asian carp entering the Great Lakes through the Chicago Sanitary and Ship Canal. The federal governments should ensure that funding and authority to operate and maintain the electrical fish dispersal barrier is provided. In addition to governmental efforts, consideration should be given to market-based solutions and commercial opportunities to reduce the risk associated with Asian Carp.

The snakehead fish problems in Maryland and, more recently, concerns about genetically modified organisms, such as GloFish™ (fluorescent zebra fish specially bred by adding a fluorescence gene to the fish), have received much media attention. The Commission continues to support and work cooperatively with other federal, state and provincial agencies to help increase public awareness and discourage human activities that contribute to the invasive species problem in the Great Lakes, including the intentional or accidental release of bait, aquarium fish, and live fish sold for human consumption.

New introductions of aquatic species could add to the serious economic costs on the order of hundreds of millions a year and ecological damage in Great Lakes, affecting both countries.[4] The governments cannot afford to gamble with the future of this extraordinary natural resource and, until effective, strictly enforced prevention measures are put into place, the ecological sustainability of the lakes remains at risk.

Creating a Regional Approach: What We Can Do Better

A Great Lakes solution to invasive species must be a cooperative effort focused on regional concerns that includes a biologically protective standard for all the Great Lakes; requires technology certification to achieve the standard; requires enhanced measures of ballast management for ships carrying residual ballast water and sediment; promotes ongoing regional cooperation; and develops measures to ensure compliance. This regional approach should be coordinated through a well-defined process that includes key elements highlighted in the sections that follow.

Implement a Great Lakes Biologically Protective Standard

Science has shown conclusively that simply exchanging ballast water with highly saline water does not eliminate all aquatic alien invasive species, particularly those benthic[5] and dormant stages of species left behind in residual water and sediment in ballast tanks. Since mandatory ballast water exchange took effect in the Great Lakes over a decade ago (United States Coast Guard 1993), the rate of aquatic alien invasive species introductions has remained approximately the same. What has changed is the species composition, which has shifted to smaller open water forms such as zooplankton and phytoplankton.[6]

In February 2004, after years of discussion, the International Maritime Organization adopted a convention on ballast water. While providing a hopeful step forward, it is not an immediate remedy. Ballast treatment standards would take effect for new ships in 2009 (assuming it is quickly ratified) and for existing vessels beginning in 2014, if enough nations ratify the treaty. Therefore, while not yet in effect, the Commission is pleased that the International Maritime Organization Convention has mandated that 95 percent of ballast water be exchanged, which would help ensure that all vessels reach the theoretical maximum efficiency of exchange.

The economic and ecological sustainability of the Great Lakes depends on having a much more effective biologically protective standard than that which ballast water exchange currently provides.

A Great Lakes biologically protective standard should:

- virtually eliminate the risk of introductions of aquatic alien invasive species;
- kill or remove organisms of certain sizes or classes;
- reduce the threat of introducing pathogenic organisms; and
- ensure a standard that fully protects the freshwater Great Lakes environment, even if that standard exceeds the standard proposed through the International Maritime Organization Convention.

Because a large number of organisms could potentially be found in a ballast tank, sample analyses can be time-consuming and costly. The Commission agrees that analyzing a sample for a suite of certain indicator organisms is acceptable. This suite of indicators should include indicators of human pathogens like cholera at a minimum, as well as more traditional indicators of contamination by human or animal feces such as *Escherichia coli* or *Enterococci*. A standard that is biologically protective could lead to new technology to achieve the standard and new, rapid methods to measure their effectiveness. In determining the standard, the Commission advises the Governments to ensure that economic analyses include the environmental and societal costs of invasive species (control, damage, mitigation, etc.), and the costs and benefits of prevention measures. This economic analysis applies equally and importantly to any navigation study proposed for the Great Lakes, such as the governments' Great Lakes St. Lawrence Seaway Study.

Require Certification of Technology to Achieve the Standard

The Commission concurs with provisions in the International Maritime Organization Convention and proposed United States domestic legislation that requires certification of ballast water treatment systems by the country in which a ship is registered (e.g. by flag state). New ballast water treatment technology must be inspected to ensure that it is properly maintained and continues to operate within design specifications. Likewise, treatment methods must be tested and certified as environmentally safe, posing no danger to the ship and its crew. Research and development of rapid, effective sampling technology must be fully supported by the International Maritime Organization member states to provide inspectors with the tools they need to properly enforce newly established discharge regulations. Member states should also be required to provide relevant information needed to assist shipping companies in meeting ship certification requirements as set out in the Convention.

Require Enhanced Ballast Management Practices for No Ballast on Board (NOBOBs) Ships

Approximately 70 percent of the ships entering the Great Lakes fall into the NOBOB category, and have been previously exempted from regulatory requirements. Yet, all ships carry some leftover water and sediment in their ballast water tanks, and therefore are never truly "empty." Water and sediment below certain levels in ballast tanks become unpumpable, leaving behind residues that are likely to harbor viable eggs and cysts from invasive species.[7] Vessels entering the lakes declaring NOBOB should also be required to show compliance with mandatory ballast management practices aimed specifically at reducing the accumulation of sediment which can harbour organisms. Such practices are designed to reduce the potential for introductions of aquatic invasive species from residual ballast water and sediment.

The Commission encourages efforts in the United States and Canada to address the threat NOBOB ships pose by making new requirements applicable to all vessels capable of carrying ballast. The Commission agrees that this approach will help to address invasive species introduced in residual water and sediment found in "empty" ballast tanks. These regulations should require all ships entering the Great Lakes with residual ballast water and sediment in "empty" ballast tanks to employ enhanced ballast water management practices that reduce the amount of sediment in the tanks to provide a less-favorable environment for organisms and, conceivably, decrease the likelihood they could survive. However, since existing techniques such as "swish and spit" have yet to be proven effective or practical for all classes of ships, additional research is needed to find new techniques that reduce the risk of further introductions of aquatic invasive species from tanks containing residual water and sediment.

The Commission advises the governments to provide additional funding for research to:

- dedicate test platforms for full-scale tests of ballast water treatment technologies in the Great Lakes;
- develop and adopt alternative technologies to surpass the Convention's proposed standards for ballast water discharge;
- validate the effectiveness of ballast water discharge and its treatment in the Great Lakes ecosystem; and
- develop analytical tools and procedures to detect new high-risk invasive species, and techniques such as DNA finger printing[8] that could be used to trace the point of origin of these species.

Promote Ongoing Regional Cooperation

The Great Lakes have a long history of effective, cooperative work between United States and Canadian agencies. The Joint Marine Contingency Plan provides an excellent framework for binational response to spills of oil and hazardous chemicals. However, coordinated efforts to deal with aquatic alien invasive species face a tremendous challenge due to the issue's large scope and institutional complexity.

The governments' response to addressing aquatic alien invasive species has been complicated by factors such as the global nature of the shipping industry, and further compounded by the large number of federal, state and provincial agencies that must be involved: fish and wildlife; transportation; agriculture; pest management; forestry; food; and public health. These agencies all have missions and jurisdictions relating to a particular pathway or aspect of the invasive species problem. In addition, several tribal and nongovernmental organizations throughout the region are responding to this threat.

Not surprisingly, all of these responsible agencies often act in a disjointed fashion that leads to duplication of efforts and inefficient use of finite resources. Regional panels such as the Great Lakes Panel on Aquatic Nuisance Species, established by the United States Aquatic Nuisance Species Task Force and the National Invasive Species Council, have been formed to encourage cooperation between responsible agencies to address this problem. However, recent reports from the Canadian Commissioner of Environment and Sustainable

Development and the United States General Accounting Office have criticized the lack of regional coordination in responding to the threat of invasive species.[9]

An Executive Order signed on May 18, 2004 by President Bush created a U.S. Great Lakes Interagency Task Force intended to improve interagency regional coordination regarding all problems facing the Great Lakes. This action was welcomed by the Honourable David Anderson, Canada's Minister of the Environment in a statement released May 19, 2004 where he recognized the long history of cooperation between Canada and the United States in support of the Great Lakes Water Quality Agreement and Canada's willingness to work in collaboration with this newly created task force. The two nations should pursue this initiative and as part of the effort, harmonize national invasive species prevention plans and enhance preventive measures, particularly those procedures dealing with the threat of residual ballast water and sediment in ballast tanks. This could lead to establishing a regional cooperative agreement containing a unified, biologically protective, binational ballast water discharge standard for the Great Lakes region as a whole, as provided for by Article 13 of the International Maritime Organization Convention for the Control and Management of Ship's Ballast Water and Sediments.

Operational characteristics that can influence a regional solution include regionalized economics, ship traffic control, automatic vessel identification, and regulation by seaway authorities. Therefore, the involved governments and agencies should objectively consider a wide range of options targeted at eliminating the threat of introducing freshwater invaders. These include:

- shipboard treatment technology;
- shore-based technologies; and
- cargo transfer facilities coupled with entry restrictions for foreign ships arriving from ports containing biota that could pose a threat to the Great Lakes aquatic ecosystem.

Every option must be studied objectively from an economic and an environmental viewpoint to develop a workable Great Lakes prevention program that best serves the region's needs.

Develop Measures to Ensure Compliance

Future advances in source-tracking technologies, such as DNA fingerprinting, should enable regulating agencies to evaluate ballast water discharges for the presence of aquatic alien invasive species. Ideally this technology could be used to establish financial liability for damages arising from biological pollution. The day may come when the introduction of harmful aquatic alien invasive species and the resulting liabilities for damages will determine the cost or availability of marine insurance policies. Shipping companies' and their insurers' desire to eliminate potential liability, combined with penalties established by regulation, could then become a powerful incentive for compliance with discharge standards.

Enlist the Assistance of the International Joint Commission

The International Joint Commission is uniquely positioned to provide independent and objective advice to the Parties. The Commission remains firm in its opinion expressed in its Tenth and Eleventh Biennial Reports that the Parties should issue a reference[10] to the Commission to identify approaches that harmonize and coordinate binational efforts to prevent the introduction of aquatic alien invasive species to the Great Lakes.[11] Potential areas where the Commission may assist the Parties include:

- identifying a binational approach to effective program coordination by government agencies;
- examining tools and techniques to prevent introductions from vectors such as live food fish sales, the aquarium trade, bait buckets, and aquaculture;
- assessing the adequacy of existing programs and, where appropriate, recommending improved mechanisms to coordinate binational research and development, including research necessary to establish a regional standard;
- enhancing public awareness and outreach; and
- reporting on economic aspects, including the potential damages caused by aquatic invasive species, the cost of technological/transportation solutions to prevent new introductions, and the impact of alternative measures on the regional economy.

The borderless nature of aquatic alien invasive species requires continuing co-operation and vigilance by federal, state and provincial authorities to review all related legislation and regulations. Given the environmental costs of addressing species' impacts once populations are established, government agencies should make every effort to minimize the threat from intentional and unintentional introductions of invasive species. The Commission stands ready to assist the governments of the United States and Canada in meeting this challenge.

Recommendations

The governments take the following measures to eliminate the threat and impacts of aquatic alien invasive species in the Great Lakes:

Take immediate action to:

- in the United States, pass the National Aquatic Invasive Species Act (NAISA)[12] reauthorizing the National Invasive Species Act (NISA) of 1996;[13]
- in Canada, implement the National Action Plan to address the threat of aquatic alien invasive species; and
- ratify and implement the International Maritime Organization's Convention for the Control and Management of Ships' Ballast Water and Sediments, and pursue stringent measures and rapid timelines.

Issue a reference on aquatic alien invasive species to the International Joint Commission to:

- help identify the most effective ways to coordinate binational prevention efforts and harmonize national plans, particularly those dealing with residual ballast water and sediment in ballast tanks;
- evaluate the effectiveness of current institutional arrangements;
- assist with the establishment of a regional standard stronger than the minimum required by the International Maritime Organization Convention;
- ensure that economic analyses carried out for projects with potential environmental effects include the environmental and societal costs of aquatic alien invasive species control, damage, and mitigation, and the costs and benefits of prevention measures; and
- assist with public education and communications.

Microbial Contamination

The Commission remains concerned about microbial pollution in the Great Lakes basin ecosystem. While major problems occur infrequently, two relatively recent waterborne disease outbreaks in Wisconsin and Ontario make it clear that the potential for tragedy remains if drinking water is inadequately treated or challenged by high pollution loads. In 1993, an apparent failure in water treatment in Milwaukee, Wisconsin caused an estimated 400,000 cases of diarrheal disease and approximately 100 deaths, most caused by the *Cryptosporidium* parasite. Less than a decade later (2000), in the town of Walkerton, Ontario (located less than 40 km from Lake Huron), over 2,300 people were sickened and seven died after heavy rains compromised a municipal drinking water well and water treatment processes failed, leading to an outbreak of *Escherichia coli (E. coli.)* 0157 and *Campylobacter jejuni* bacteria.

Microbial infectious disease outbreaks demonstrate the fragility of barriers designed to protect public health. Research suggests these outbreaks are only a fraction of the actual number of gastrointestinal illnesses caused by microbial pollution each year.[14] The U.S. Centers for Disease Control have reported increasing incidents of waterborne infectious disease in the United States, and it's estimated that 6 to 40 percent of all gastrointestinal illness in the United States may be of waterborne origin.[15] Similar reports for Canada show that between 1974 and 1996, the last year for collected data, more than 200 reported outbreaks of infectious disease were associated with drinking water.[16]

Where are the Pathogens Coming From?

Figure 2 *(used by permission of Barry Rosen)* illustrates potential sources of gastrointestinal pathogens excreted in human and animal feces that find their way into the water bodies like the Great Lakes and drinking water by numerous sources, including: pet wastes from urban parks; animal and human waste from land-based sludge applications; manure storage piles; and leaking septic tanks. When multiple, adjacent communities use waterways, as is the situation for most of the U.S. and Canadian Great Lakes region, sewage overflows can put downstream communities at risk from high concentrations of microbial pollution.[17]

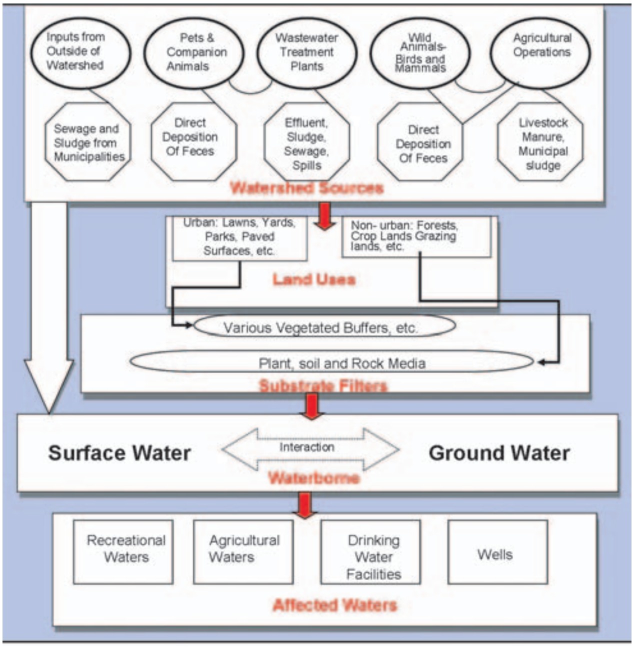


Figure 2. Potential Pathways for Waterborne Pathogens

Several factors that drive microbial contamination and can impact water quality and human health are identified in Table 1.

Table 1. Factors associated with the risk of new pathogens and impacts on water quality and health in the Great Lakes basin

FACTOR	ENVIRONMENTAL RELEVANCE	OUTCOME
Population Growth and Aging Infrastructure	• Increased waste, more untreated discharges • More runoff from hardened surfaces	• High loads of pathogens, bacteria, parasites, and viruses • More users of urban beach • Larger sensitive populations
Intensive Agriculture	• Greater quantity of manure generated per land area	• Runoff of pathogens to local water bodies and groundwater
Worldwide Transport	• Invasive species from ballast water discharges, products, or packing materials	• Known ecosystem risks, e.g. cholera in South America
Climate Change	• Increased storms and droughts that impact movement and survival of pathogens	• Increased risk of waterborne disease associated with rain, storms, and temperature

(Adapted from IJC 2003, *Priorities Report*)[18]

In many older cities, collection systems were designed to carry sewage and storm water runoff. During heavy rainstorms, the water surging through these systems threatens to overwhelm treatment. Combined sewer overflow systems allow this mixed runoff and sewage to bypass treatment plants, protecting the plants, but directing both runoff and raw, untreated sewage into lakes and streams.[19] The U.S. EPA estimates that trillions of gallons of untreated human sewage are discharged from combined sewer overflows after major rain events annually.[20] In 2001, municipalities discharged 196.6 billion litres (52 billion gallons) of sewage and partially treated wastewater into Michigan waters alone.[21] Similar conditions exist in major urban centres in Canada.

Pathogens enter the Great Lakes ecosystem from surface runoff and erosion from farm manure stockpiles, sludge applications, overflows or spills from holding pens or ponds, and storage lagoons, all of which can leach into soil and groundwater. Farmers apply treated sewage sludge from drinking water and wastewater treatment plants to their crop lands to add nutrients to soil, reducing the need for more costly chemical fertilizers. These treated waste products contain human pathogens and other pollutants that can contaminate ground and surface water under certain conditions. Larger feeding operations that concentrate thousands of cows, pigs, chickens or other animals in a more limited area generally have less land area relative to the amount of wastes generated. These facilities spread waste on adjacent land areas, sometimes in amounts too great for uptake by crop plants. Livestock producers in Ontario regulated under the province's Nutrient Management Act, 2002, have strict

Lake Huron West Shore Beaches Closed

A microbiologist for the Huron County Health Unit in 2003 analyzed 10 years of beach water data and found a 40 kilometre (25 miles) stretch south of Walkerton that routinely had high bacterial pollution. As a result, the beach water-sampling program was improved, resources were realigned, and the posting process was changed. Small streams, which are numerous in the area, have *E. coli* levels that exceed provincial water quality guidelines. A lab analysis undertaken for local property owners indicates that the *E. coli* comes from animal, rather than human, sewage. The contaminants are concentrated in the near shore area, which is also the critical habitat area for many aquatic organisms.[22] An Ontario project is currently underway to define whether shared pathogen sources from livestock, septic systems and wildlife are affecting water quality in the area.

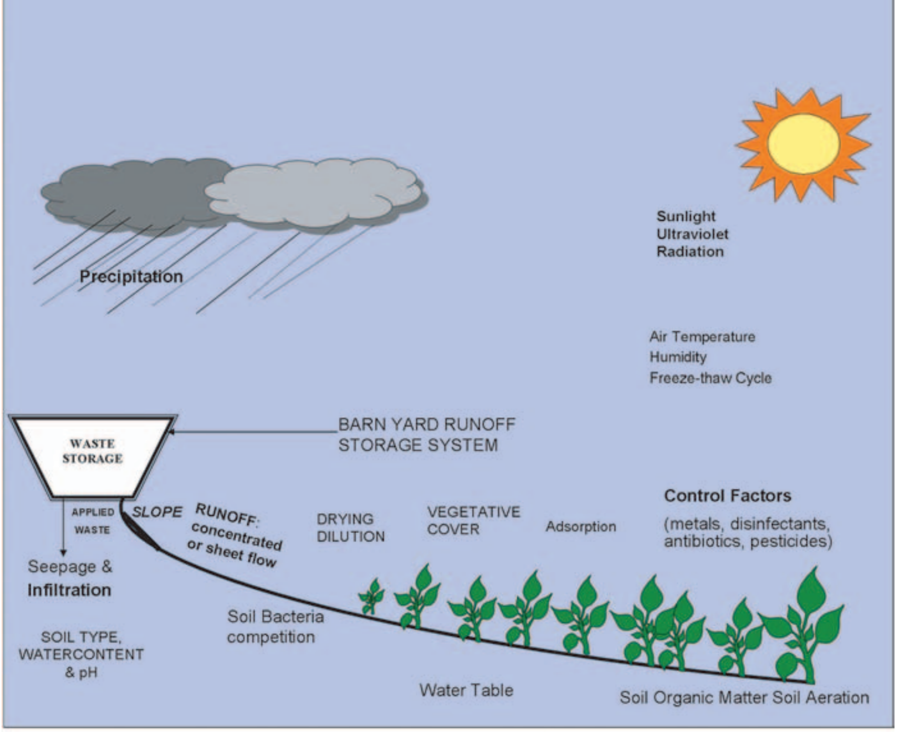


Figure 3. Factors Affecting Viability Along Transport Pathways

requirements to apply nutrients on an adequate land base. However, current approaches dealing with the large volumes of animal wastes may not be sufficient because numerous reports have linked discharges and contaminated run-off from large scale Concentrated Animal Feeding Operations (CAFOs) to impairments in the United States water bodies and, in Canada, to emerging diseases.[23, 24]

To better understand the source, extent, and type of microbial contamination, or impacts from contamination, information is needed on the numbers and size of each type of farm, size of herd per farm, amount of wastes generated, location of nearest surface waterbodies, and type of environmental protective control measures in place. Current best management practices of manure storage are thought to reduce transport of disease-causing microorganisms to nearby waterways. The traditional practice of spreading manure and sludge during ice free periods should also pose little danger to public health. However, results of research studies world wide have demonstrated the importance of environmental factors affecting the viability of microorganisms along transport pathways (Figure 3). Under certain conditions, such as increased rainfall, lower temperatures, and reduced available sunlight, bacteria, viruses, and parasites from manure or sludge spread on land can remain viable for several weeks to months. Runoff from this material can reach nearby water bodies, contributing to microbial contamination and degraded surface and groundwater water quality.

In February 2003, the U.S. EPA released new water quality guidelines for CAFOs *(National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFO): Final Rule)*.[25] The final rule requires that these facilities develop and enact a comprehensive, site-specific, nutrient management plan to protect the environment and public health. The rule sets effluent limitation guidelines and standards for nutrients, but does not establish guidelines for discharge of microbial contaminants.

Similarly, in June 2002, Ontario enacted the *Nutrient Management Act* (Bill 81).[26] Regulations under this act would require that facilities that generate nutrients (including sewage treatment plants and pulp and paper plants) or that apply nutrients (including commercial fertilizers to agricultural lands) must develop nutrient management strategies. In June 2003 Ontario revised the regulations, applying them to new and expanding large livestock farms. The regulations will become effective for existing large livestock farms in 2005 but do not include controls on microbial contamination from animal wastes.

The U.S. General Accounting Office reported in 2003 on the U.S. EPA's regulatory program for animal feeding operations to determine potential challenges that states and U.S. EPA may face when they begin to implement program revisions.[27] The GAO determined that the number of animal feeding operations subject to regulations will increase dramatically. States will need to increase their efforts to identify, permit, and inspect facilities and take appropriate enforcement actions against those in noncompliance. The GAO concluded that the U.S. EPA will need to increase its oversight of state programs to ensure that these new requirements are met, and that neither the states nor the U.S. EPA have determined how to deal with these challenges.

Detecting Pathogens and Assessing Risks

With human health at stake, the timing, frequency, speed and adequacy of water sampling and the interpretation of results are all critical to deciding whether to close a beach or issue a "boil water" advisory for drinking water. Detecting all pathogens is not possible for a number of reasons including costs, lack of appropriate tests, and sensitivity of certain tests. Therefore, water quality managers use the indicator, *E. coli*, to assess the likelihood that human pathogens may be present. Recent research indicates that at least some of the apparent high numbers of *E. coli* bacteria found in surface and recreational waters may not be of human origin, but rather from birds and other animals.[28] While this preliminary research may, in some cases, rule out human origins of *E. coli*, they do not report the presence of other pathogens such as *Giardia*, *Campylobacter*, or *Cryptosporidium* that are from animal wastes and can lead to waterborne disease outbreaks. Therefore, public health departments need tests aimed at other important pathogens to provide good information about beach safety. Authorities need to develop and use rapid, sensitive detection methods to analyze pathogens, which would enable communities to avoid unnecessary health risks by issuing earlier advisories for drinking water and swimming.

Gaps in Pathogen Detection

Parasites and viruses are detectable in most secondary treatment effluents, and a single sewage treatment plant can introduce large numbers of pathogens to a water body.[29] They can be viable for long periods of time in the environment, and bacterial fecal indicators do not provide adequate information on their survival and inactivation during wastewater treatment.[30] Regulatory agencies need additional data to construct models that estimate the potential risk for humans and wildlife exposed to microbial pathogens at beaches, in waters used for swimming, and in intake water for water treatment plants.

Local water authorities and private citizens do not typically monitor private wells for microbial contamination, leaving a large number of people potentially vulnerable to both chemical and microbial contamination.[31] In the *Summary Report of the Walkerton Inquiry* (2002), Justice O'Connor recommended that the Ontario Clean Water Agency and municipalities better educate and inform citizens using private wells about the types of contaminants to which they could be exposed.[32] Senior orders of government could provide additional resources to local health authorities so that private sources of drinking water can be evaluated for their safety.

Even when waterborne illness occurs, detecting it can be difficult. As a result, instances of disease caused by pathogens in water are probably under-reported to public health officials.[33] Most people afflicted by gastrointestinal illness caused by pathogens in water will experience flu-like symptoms several days after exposure, rarely suspecting the ingestion of contaminated water, and often assuming the illness is the result of food poisoning. Consequently, disease outbreaks are not detected consistently, rarely properly identified even by clinicians, leading public health agencies to underestimate total disease incidence from contact with or consumption of contaminated water.[34] As a result, the extent of waterborne infectious disease in the United States and Canada cannot be fully known.[35]

Clearly, environmental regulators and health officials need new tools to monitor and study microbial contaminants and their effects on human populations.[36] Fortunately, advances in molecular biology now enable researchers and epidemiologists to better track waterborne diseases and identify their sources.

The Emergence of New Pathogens

Recently, scientists have recognized many new or re-emerging infectious disease agents not previously associated with waterborne disease.[37] (Table 2).

Some experts believe that the massive and largely unregulated use of antibiotics in agriculture and aquaculture, coupled with the increasing number of antibiotic-resistant pathogens found in nature, may present the greatest risk to the aquatic environment and to public health.[39] Antibiotic-resistant bacteria have been spread in the environment through the indiscriminate use of antibiotics in human and animal health.[40] If antibiotic-resistant bacteria are allowed to evade water treatment, or if they infect humans during recreational activities, finding appropriate remedies for the diseased individual will represent a much more difficult challenge to physicians.

The Walkerton Tragedy: A Lesson for the Great Lakes?

The waterborne disease outbreak in Walkerton, Ontario in May 2000, caused by contamination from a well that was not adequately chlorinated in this distribution system, highlights the need for constant vigilance and the development of new methods to detect such threats.[41] The town of Walkerton, located less than 40 km (24 miles) from Lake Huron, is similar to many towns in the Great Lakes basin. The circumstances leading up to the tragic disease outbreak in Walkerton were the result of a cascade of human errors,

Table 2. Waterborne Pathogens, Associated Illnesses, and the Source of Wastes

Adapted from *Swimming in Sewage*, Table 1 Waterborne Pathogens (NRDC 2004)[38]

Pathogenic Agent	Acute Effects/Chronic or Ultimate Effects	Wastes
Bacteria:		
Campylobacter jejuni	Gastroenteritis/death from Guillain-Barre syndrome	Human/animal feces
Escherichia coli (pathogenic strains)	Gastroenteritis/ *E.coli O157:H7*	Domestic sewage
Leptospira	Leptospirosis	Animal urine
Salmonella typhi	Typhoid fever/reactive arthritis	Domestic sewage
Shigella dysenterriae	Bacillary dysentery	Human feces, domestic sewage
Vibrio cholera	Cholera/death	Domestic sewage, shellfish, saltwater
Yersinia spp.	Acute gastroenteritis/diarrhea, abdominal pain, arthritis	Water, milk, mammalian alimentary canal
Viruses:		
Adenovirus	Respiratory and gastrointestinal infections	Domestic sewage
Calicivirus	Gastroenteritis	Domestic sewage
Coxsackievirus (some strains)	Includes severe respiratory diseases, fever, rashes, paralysis, meningitis	Domestic sewage
Echovirus	Similar to Coxsackievirus	Domestic sewage
Hepatitis A	Infectious hepatitis (liver); kidney and spleen	Domestic sewage
Norwalk and Norwalk-like	Gastroenteritis	Domestic sewage
Poliovirus	Poliomyelitis	Domestic sewage
Rotavirus	Gastroenteritis	Domestic sewage
Protozoa:		
Cryptosporidium parvum	Gastroenteritis/death in immuno-compromised	Human/animal feces
Cyclospora cayetanensis	Gastroenteritis	Human feces
Entamoeba histolytica	Amoebic dysentery domestic sewage	Human/animal feces,
Giardia lambia	Giardiasis, diarrhea, lactose intolerance, joint pain	Human feces
Toxoplasma gondii	Hearing and visual loss, mental retardation/dementia and/or seizures	Cat feces
Helminthes (worms):		
Digenetic trematodes (flukes)		
Schistosoma sp.	Schistsomiasis	Human feces
Trichuris trichiura	Asymptomatic to chronic hemorrhage	Human feces
Ancylostoma duodenal	Iron deficiency anemia and protein deficiency	Human feces
Ascaris lumbricoides	Ascariasis	Human, pig, and other animal feces

accounted for in lost lives, lost health, lost productivity, and loss of public trust. This tragedy must not be repeated. In his review of the incident, Justice Dennis O'Connor concluded that the risk of unsafe drinking water could be reduced to a negligible level by introducing a multiple barrier approach, or a number of measures independent of each other, as a comprehensive barrier to waterborne contamination.[42]

The Canadian report, *From Source to Tap*, conveys a similar message that the protection of drinking water sources (source water), along with several layers of treatment at drinking water treatment plants such as coagulants, filtration and disinfection processes, provide a multiple barrier approach that minimizes risks to public health.[43]

The Ontario Ministry of Environment has embarked on a legislative approach to drinking water safety through the Safe Drinking Water Act and regulations and in June 2004 posted a draft source protection legislation on its Environmental Bill of Rights Registry.

As Population Grows, Water Infrastructure Must Be Updated

As economies grow and populations increase, we can expect new and greater challenges. In the United States, programs to maintain and upgrade the infrastructure for sewage treatment, storm water management, and drinking water treatment and distribution have been inadequately funded over the last half-century.[44] Some experts have described the state of infrastructure investment as "woefully under funded" since the 1990s.[45]

The U.S. EPA recently estimated that water utilities must increase investments nationally by $151 billion (USD) over the next two decades to maintain public water infrastructure and ensure safe water supplies.[46] The American Society of Civil Engineers' *Report Card for America's Infrastructure* notes some drinking water systems and sewer systems are more than 100 years old, and many are past their recommended life expectancy.[47] The *Report Card* indicated an annual national shortfall of $11 billion (USD) and $12 billion (USD) for drinking water and wastewater infrastructure, respectively.

Canadians recently learned in Justice O'Connor's *Report on the Walkerton Inquiry* that improving Ontario's water delivery system could require sizable investments, including: one-time cost for implementing the recommendations of $99 to $289 million (CAD); ongoing costs of $17 to $49 million (CAD) per year; one-time costs for steps already taken by the provincial governments since the incident of $100 to $520 million (CAD); and ongoing costs to the provincial governments of $41 to 200 million (CAD) per year.

Needed upgrades to wastewater treatment plants to handle the expected increased flow of human wastes as populations grow and expand, particularly during storm or "peak" events, could cost local communities around the Great Lakes billions of dollars. For example, the U.S. EPA recently proposed a new policy alternative to this expense by allowing wastewater treatment plants to partially treat or disinfect wastewater surges during big storms. The process, called "blending", would allow treatment plants to blend flows of sewage that is combined with storm water, together with flows that have gone through full wastewater treatment. To meet water quality criteria for bacteria, the levels of chemical disinfectants – typically chlorinated compounds – will likely be increased. In *Swimming in Sewage*, experts opposed to the policy expressed concerns about the potential risks to humans from not only exposure to microbial contaminants, but also to higher concentrations of disinfectant chemical by-products that pose a known cancer risk.[48] **Routine disinfection is not effective against reducing viruses and protozoa in treated wastewater discharges, and opponents to the policy argue that blending will release even greater loadings of these potentially pathogenic microorganisms.**

The *Walkerton Inquiry* report notes that, not accounting for the costs directly related to illness and death, the Walkerton tragedy alone cost more than $64.5 million (CAD). The incident demonstrates that even one system failure can impose enormous monetary as well as tragic human costs. If the U.S. and Canada do not invest in their aging water infrastructure systems, the potential for more outbreaks of waterborne diseases will increase. The investment costs to shore up the nations' water treatment facilities are high, but the potential costs of not doing so are even greater.

Conclusions

Risks of waterborne infectious diseases are increasing, are likely under reported, and are under appreciated by mayors, governors, public health officials and the public.
Systems for waste collection and water treatment and distribution around the Great Lakes are inadequate, or in decline. Increasing pressures from agriculture, development, industry, population growth, and urban expansion will require coordinated actions by all those responsible for managing watersheds and water resources to fully protect ecosystem and public health.

Improved, more efficient and more sensitive tools and methods are needed to monitor and model microbial risks to surface water and ground water. Watershed-wide risk reduction and management approaches that adequately protect the safety of water supplies are absolutely essential. Measures to detect, treat, and respond to multiple contaminants including microbial contaminants and their toxins, traditional pollutants, and emerging compounds of concern (such as pharmaceuticals, antibiotics and personal care products) are also needed.

Recommendation

All levels of governments should create and implement coordinated planning actions to fully protect drinking water sources from increased pressures from industry, urban expansion, aging infrastructure and agriculture, including ecosystem and human health protection from large-scale animal operations.

Chapter Three

CHEMICAL INTEGRITY: THE EXAMPLE OF MERCURY

Introduction

The chemical integrity of the Great Lakes is dynamic. The waters of the Great Lakes are continuously changing through the addition, interaction, and loss of both natural and man-made substances. Natural geophysical processes change these substances' spatial and temporal distribution within the Great Lakes system. While much is known, considerable uncertainty remains concerning the chemical integrity of the Great Lakes and the impacts of various chemicals, and combinations of chemicals, on the basin's human and other inhabitants.

Mercury, a persistent bioaccumulative toxic metal, provides an excellent example of the challenges inherent in understanding impacts on the chemical integrity of the Great Lakes. It occurs widely in nature, both in concentrated form in cinnabar (ore) and in small amounts in fossil fuels such as coal. Humans have used mercury for over 3,000 years in medicine and industry.[1] The Commission's Great Lakes Water Quality Board in 1985 identified mercury as one of a "dirty dozen" chemical substances for virtual elimination under the Great Lakes Water Quality Agreement. The governments included this list in the 1987 Agreement in Annex 12: Persistent Toxic Substances. In keeping with this Annex the United States and Canada developed a binational strategy for eliminating releases of 12 persistent toxic substances,[2] including mercury, that provides a framework to achieve specific actions from 1997-2006.[3]

Sources and Forms of Mercury

Mercury reaches the waters of the Great Lakes directly, through discharges into the waters, and indirectly, through disturbances of previous mercury deposition and through atmospheric deposition. This report focuses on contributions from atmospheric sources to the Great Lakes.

Mercury can be released into the air by human activities such as metallurgical processing, municipal and medical waste incineration, and electrical power generation such as from coal combustion. It is also released to the atmosphere by various natural phenomena, including volcanic eruptions, forest fires, and the weathering of geological formations.[4]

Mercury occurs principally in three different chemical forms, or species: elemental mercury, reactive gaseous mercury, and mercury associated with particulates. Different forms of mercury have different solubility, reactivity, and toxicity, behave differently in the atmosphere and the environment, and have different impacts on the ecosystem and on human health.[5]

Elemental mercury can persist for over a year in the atmosphere in a vapor state and, thus, can travel globally with the prevailing winds. Most mercury reaching the Great Lakes from distant sources is in this form.[6] Elemental mercury has limited solubility in water and, as a result, is largely unavailable to fish and other living things. It can be transformed to the other forms of mercury, including the reactive form; however, this reaction proceeds very slowly.

Reactive gaseous mercury (or the ionic form of mercury) is both substantially more soluble in water and more reactive than elemental mercury. It remains in the atmosphere from one to ten days, and therefore tends to be deposited locally and regionally – from a few miles to a few hundred miles from its source. Its limited range of travel, solubility, and high reactivity contribute to its ultimate presence in biota on a regional basis.[7]

Mercury particulate is mercury bound to airborne particles. Mercury particulate can remain in the atmosphere for one to ten days – comparable to reactive gaseous mercury – and thus is deposited regionally and locally. However, it is less available to living organisms than the reactive gaseous form.[8]

Mercury and Human Health

Once deposited in or discharged to water bodies, mercury can be converted by bacteria into organic mercury compounds, such as methyl mercury, that accumulate in the food chain. Human exposure to methyl mercury is predominantly through fish consumption.

Methyl mercury compounds can cross biological membranes, are soluble in lipids and adipose tissues, and can bind to various cell receptors and enzyme sites. Methyl mercury has not been found to be a carcinogen and has not been conclusively established as a teratogen (a chemical which causes a birth defect). Without cancer as a complicating factor, scientists have been able to conduct relatively straightforward analyses of the risks posed by human exposure to mercury compounds. At sufficient levels of accumulation of methyl mercury compounds, toxic effects occur. Serious toxic effects include neurotoxicity (brain and nerve tissue damage) and nephrotoxicity (kidney damage). These toxic effects can impact organisms from birds to mammals, including humans.

At very high levels of methyl mercury contamination, such as observed in Minimata Bay, Japan, in the 1950's, serious health effects occur.[9] Recently, scientists have been exploring the effects of chronic low doses of methyl mercury, particularly for higher risk populations including children, fetuses, and women of child-bearing age. Developing fetuses may be at greatest risk because of methyl mercury's ability to pass through the placenta.

Several cohort studies have been conducted on children who were exposed to methyl mercury before and after birth in the Seychelle Islands and in the Faroe Islands. No neurodevelopmental deficits were identified in the Seychelle Islands children, while some neuropsychological effects were identified in the Faroe Islands children. Notable differences exist between the two populations that may explain the differing results, including diet (ocean fish in the Seychelles versus the higher levels of methyl mercury in pilot whale meat in the Faroe Islands).[10] The studies also raise questions concerning the complicating factor of selenium, its interaction with mercury, and subsequent health effects.[11] Selenium, which is found in some ocean fish, provides a substitute for sulfur that permits a weaker bond with mercury, allowing the human body to remove mercury more easily and excrete mercury in greater quantities, reducing both the exposure period and the dose.[12] No comparable studies to these international efforts have been undertaken in the Great Lakes area. However, recent work intended to investigate the effects of PCB levels on the development of children whose mothers consumed large amounts of fish during pregnancy in the Oswego, New York, area, have also raised questions concerning effects of mercury.[13]

Studies reviewed by the U.S. National Academy of Sciences associate chronic low-dose prenatal methyl mercury exposure with poor performance by children on neurobehavioral tests that measure such things as attention, language ability, fine motor skills, and intelligence.[14] Further research is required to investigate methyl mercury exposure and coronary disease. The majority of epidemiological studies performed has been retrospective, in which linkages are inferred from past events; prospective studies are needed that make a hypothesis and then follow events to observe actual linkages.

Several organizations have established a "reference dose" for methyl mercury. A reference dose is an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime. Different agencies and organizations have established different reference doses, some of which are shown in Table 3. Different Great Lakes states also have different threshold levels for the general public and sensitive populations.[15]

Table 3. Organizations Reference Doses for Methyl Mercury

Organization	Reference Dose (micrograms/kilogram/day)	Uncertainty Factor[16]
U.S. Environmental Protection Agency	0.1	10
Health Canada	0.2	5
Agency for Toxic Substances and Disease Registry (U.S.)	0.3	4.5
World Health Organization	0.47	10
U.S. Food and Drug Administration	0.5	10

Mercury and Fish Consumption

Eating fish offers many nutritional benefits, including protein and omega-3 polyunsaturated fatty acids. However, caution must be taken to avoid eating too much fish containing excessive levels of methyl mercury or other persistent toxic substances. The primary human exposure to methyl mercury is through fish consumption.

In the United States in March 2004, the U.S. Environmental Protection Agency and the U.S. Food and Drug Administration issued a joint consumer advisory on methyl mercury in fish and shellfish for reducing the exposure to mercury in women who may become pregnant, pregnant women, nursing mothers, and young children. The advisory unified and superseded the agencies' 2001 advisories. It advised avoiding fish with relatively high levels of mercury (shark, swordfish, king mackerel, and tilefish), eating up to 12 ounces a week of a variety of fish and shellfish that are lower in mercury (including shrimp, canned light tuna, salmon, pollock, and catfish), and checking local advisories about the safety of fish caught by family and friends in local lakes, rivers and coastal areas (and eating up to 6 ounces a week of fish caught from local waters if no advice is available provided no other fish is consumed that week.)[17]

This third, and perhaps most complicated, provision of the EPA's and FDA's joint advice has particular resonance in the Great Lakes. Site-specific advisories continue to limit or ban consumption of certain fish caught in the Great Lakes because of methyl mercury contamination. In fact, due to localized contaminated sediment, methyl-mercury related fish consumption advisories are expected to exist for decades to come in some Great Lakes Areas of Concern. As an example, the Guide to Eating Ontario Sport Fish contains detailed advice on selecting fish for eating from Ontario rivers and lakes, including the Great Lakes; recommends not eating any organs, fat or skin of any fish; and advises eating smaller fish, eating bass, pike, walleye, perch, and pan fish from the Great Lakes instead of fatty species such as salmon and trout; and allowing fat to drip away when cooking fish.[18]

The Commission previously recommended in its 2000 biennial report that the governments improve fish consumption advisories in the Great Lakes, and the Commission's Health Professionals Task Force (HPTF) recently reported in detail on this issue. The HPTF members support a more effective approach to the development of fish consumption advisories, through better protection of those people at risk, without deterring the majority of people from fish consumption. To develop such an approach, environmental monitoring and exposure assessments are urgently needed to track trends in persistent organic pollutants. Efforts are needed to continue to reduce contaminant levels in all Great Lakes fish.[19]

The Commission's concerns remain relevant today. Advisories are often technical, sometimes offer conflicting advice, and typically fail to reach at-risk populations, including children and women of child-bearing age.[20] For example, according to a study by Kearney and Cole,[21] only 85% of licensed Ontario anglers were aware of the Guide to Eating Ontario Sport Fish, only 29% had a copy of the Guide and followed its advice at least sometimes, and 27% had a copy of the Guide but never followed the advice. Only 50 percent of Great Lakes sport fish consumers reported awareness of a health advisory.[22] Ontario's development of outreach programs directed at school children in non-english speaking communities (in two Areas of Concern) is an example of a communication tool that could improve these statistics.

Complications of Chemical Mixtures

Fish advisories often mention concerns with mercury and PCBs for the same species in the same water bodies. PCBs affect the thyroid, which controls brain development.[23] Mercury binds to brain tissue and may cause other problems. Both PCBs and mercury can pass through the placenta.[24] Therefore, their combination may pose a greater risk to a developing fetus than either alone. Current epidemiological studies are exploring this linkage, and further study is warranted.

Reductions in Mercury Emissions

The U.S. Environmental Protection Agency cites rough estimates showing that 20% of global mercury emissions are from natural emissions, 40% from global re-cycling of previous anthropogenic activity, and 40% from current anthropogenic[25] emissions.[26] As shown in Table 4, North America contributed approximately 11% of the total global anthropogenic mercury emissions in 1995.

Table 4. Global Emissions in Tonnes (~Tons) of Total Mercury from Major Anthropogenic Sources in the Year 1995 – (Pacyna & Pacyna)[27]

Continent	**Stationary combustion**	**Non-ferrous metal production**	**Pig Iron and steel production**	**Cement production**	**Waste disposal**	**Total**	%
Europe	185.5 (204)	15.4 (17)	10.2 (11)	26.2 (29)	12.4 (14)	249.7 (275)	13.1
Africa	197 (217)	7.9 (9)	0.5 (0.6)	5.2 (6)		210.6 (232)	11
Asia	860.4 (948)	87.4 (96)	12.1 (13)	81.8 (90)	32.6 (36)	1074.3 (1184)	56.1
North America	104.8 (116)	25.1 (28)	4.6 (5)	12.9 (13)	66.1 (73)	213.5 (235)	11.2
South America	26.9 (30)	25.4 (28)	1.4 (2)	5.5 (6)		59.2 (65)	3.1
Australia & Oceania	99.9 (110)	4.4 (5)	0.3 (0.3)	0.8 (0.9)	0.1 (0.1)	105.5 (116)	5.5
Total Year 1995	1474.5 (1625)	165.6 (183)	29.1 (32)	132.4 (146)	111.2 (123)	1912.8 (2108)	
Total Year 1990§	1295.1 (1428)	394.4 (435)	28.4 (31)	114.5 (126)	139 (153)	2143.1‡ (2362)	

§ Estimates of maximum values, which are regarded as close to the best estimate value.

‡ The total emission estimates for the year 1990 include also 171.1 tonnes (189 tons) of mercury emission from chlor-alkali production and other less significant sources.

With their later industrialization, mercury emissions are now increasing in developing countries. Preliminary findings from U.S. Environmental Protection Agency and Environment Canada indicate that increases in global anthropogenic mercury emissions reaching North America, largely from Asia, offset anthropogenic mercury reductions achieved within the United States and Canada. In the 2001-2003 Great Lakes Priorities Report to the Commission, the findings of the International Air Quality Advisory Board on the transportation and deposition of mercury to each of the Great Lakes via the atmospheric pathway enlarge on these issues.[28] With respect to Lake Superior, the lake most remote from regional industrial sources, the majority of specific sources of mercury deposition were located at a distance greater than 700 kilometres away. Although global emissions are largely of the unreactive form, the sheer volume and increasing proportion of the global mercury balance warrants attention.

Mercury emissions arising from human activity in both the United States and Canada dropped substantially between 1990 and 1999. In the United States, significant mercury reductions came principally from emission controls on municipal and medical waste incinerators, as well as improved screening and removal from the waste stream of commercial products such as batteries and paint. In Canada, significant reductions were achieved largely through controls and process alterations in the metal smelting industry, the near-complete closure of the chlor-alkali industry, and further control and restrictions on waste incineration. In 1999, U.S. mercury emissions were estimated as approximately 124 tonnes (137 tons); further detailed verification of these data now indicate total 1999 emissions were 105 tonnes (116 tons). Canadian mercury emissions were approximately 11 tonnes (12.1 tons). Coal-fired utilities account for approximately 35% and 27% of mercury emissions in the U.S. and Canada, respectively. (See Figures 4 and 5).[29]

Governments in both countries are examining ways to reduce mercury emissions from coal-fired electrical generation facilities. The removal of mercury from coal is technologically challenging.

On December 17, 2003, the Environmental Protection Agency proposed significant reductions in sulfur dioxide (SO2) and nitrogen oxides (NOx) emissions from power plants. Although the proposal targets these chief components of acid rain, it is anticipated that actions taken to meet those standards

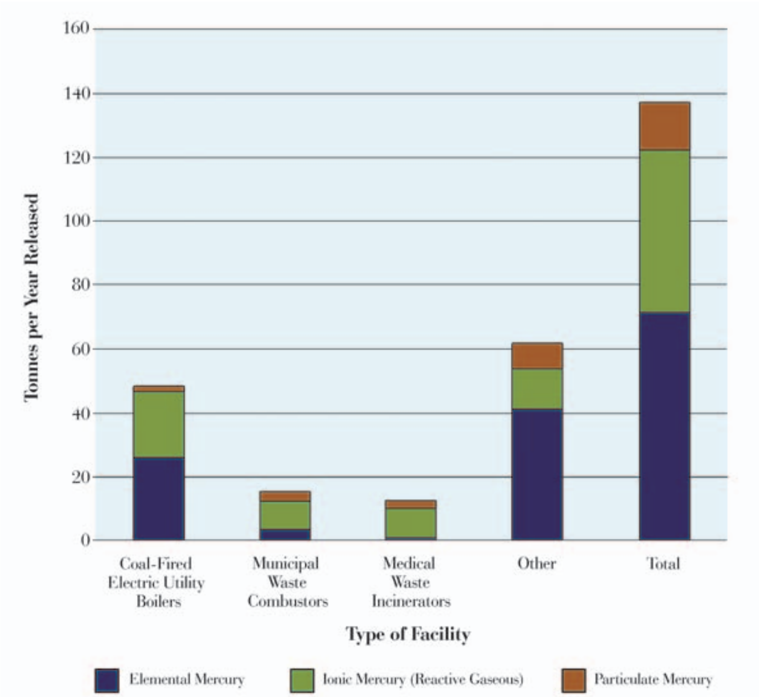


Figure 4. Emission Profile of Mercury Releases — 1999

(Anne Pope, U.S. EPA, 1999 U.S. Natural Emissions Inventory Draft)

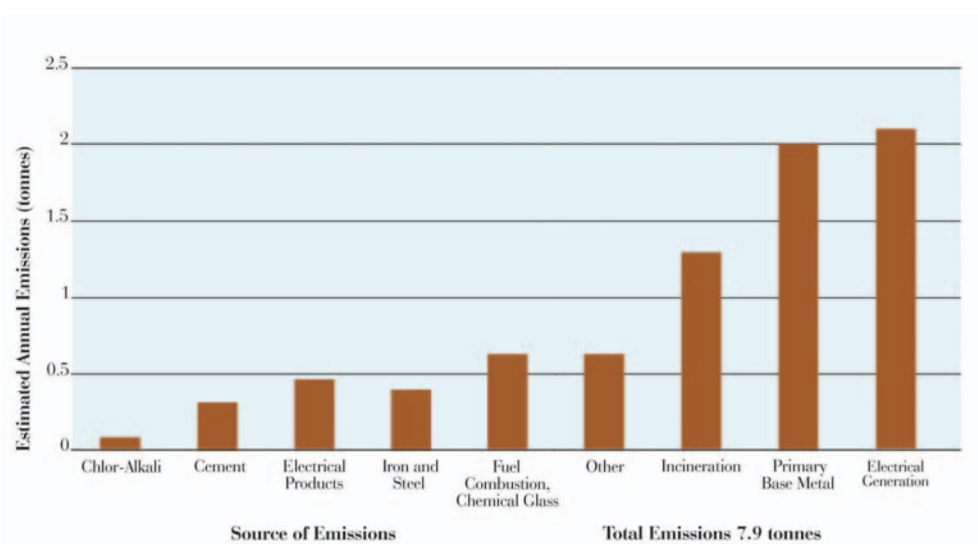


Figure 5. Preliminary Mercury Emissions in Canada — 2000

(Marc Deslauriers, Pollution Data Branch, Environment Canada) will result in "co-benefits" of reductions in mercury emissions and fine particulate matter. The U.S. Environmental Protection Agency has also proposed alternatives for ways to reduce mercury emissions from utilities. These alternatives include creating a market-based "cap and trade" program to reduce mercury emissions in a two-phased approach, and requiring utilities to install controls known as "maximum achievable control technologies" (MACT).

The Canadian Council of Ministers of the Environment has committed to develop a Canada-wide standard to reduce mercury emissions from the coal-fired electric power generation sector by 2010 (with variance in provincial application of the national target or standard), to explore the national capture of mercury from coal burned in the range of 60-90% (including all efforts to reduce mercury releases, from pollution prevention through emissions control), and to align with U.S. standards for mercury. The standard will apply to existing and new plants.[30] As well, Canada-wide standards for mercury-containing fluorescent lamps and dental amalgam waste will assist in meeting the Canada-Ontario Agreement (2002) commitment to reduce mercury releases by 90% by 2010 compared to 1988. Jurisdictions are required to develop an implementation plan which describes what actions will be taken to implement a Canada-wide standard and achieve compliance by the deadline set for the standard, except that as Quebec is not a signatory to the Canada-wide Accord on Environmental Harmonization nor the Canada-wide Standards, it is not required to develop an implementation plan;[31] however, the principal mercury sources from Quebec are included in the National Pollutant Release Inventory.

With respect to the lower Great Lakes, information provided by the Commission's International Air Quality Advisory Board in the 2001-2003 Priories Report shows that there are significant regional and local sources of mercury emissions. The Board's report shows that 40% of the mercury emission from coal-fired generation facilities in that region is in the more biologically-available reactive form. The waters of the Great Lakes also continue to receive mercury from previously contaminated sediments. In addition, contaminated groundwater and wastewater discharges contribute to the local mercury burden, especially in Areas of Concern. Because the U.S. and Canadian governments can control emissions from sources within their jurisdictions more effectively than some global emissions, and because reactive gaseous mercury is more biologically available, governments should substantially reduce the deposition of reactive gaseous mercury in the Great Lakes region.

The combined impacts of mercury contamination in Canada are difficult to quantify,[32] and the exact proportion of the impact which can be ascribed to natural mercury and to past and present anthropogenic releases cannot presently be quantified.[33] The U.S. Environmental Protection Agency cited a plausible link between mercury from industrial combustion sources and methyl mercury in fish, but noted that it was not possible to quantify how much of the methyl mercury in fish consumed by the U.S. population is contributed by U.S. emissions relative to other sources of mercury (such as natural sources and re-emissions from the global pool).[34] A recent study in the Florida Everglades estimated how quickly fish tissue levels respond to decreased regional mercury emissions. Reductions in total mercury emissions of approximately 90% since the late 1980's have been paralleled by a reduction in average fish tissue methyl mercury of about 80%.[35] However, more definitive information, ideally through studies focused on the Great Lakes, would be helpful in exploring linkages between mercury emissions and deposition, and biologic uptake and effects.

Conclusions

Mercury provides a case study for chemical integrity. Much is known about mercury's toxic effects at higher doses, and there is a growing body of knowledge concerning effects at lower doses. At sufficient levels of accumulation of methyl mercury compounds, toxic effects occur, including neurotoxicity (brain and nerve tissue damage) and nephrotoxicity (kidney damage).

The Commission recognizes that both governments are currently considering proposals for further reductions in mercury emissions. The Commission encourages both governments to adopt and implement initiatives that will further reduce the release of mercury to the environment, including atmospheric emissions.

The effects of past mercury emissions, compounded by continuing emissions, will remain an issue for decades to come. Associated risks must be effectively communicated. While both governments have compiled and disseminated fish advisories, difficulties remain in reaching those most at risk and in effecting changes in behavior that would reduce that risk.

Significant gaps in knowledge remain about the processes by which mercury moves from source to water body, to fish and wildlife, to humans, and about the effects of low doses of mercury on human health. Scientists continue to explore plausible connections and build on the knowledge base. In addition to general studies of this nature, specific focused studies on mercury deposition and its effects on the Great Lakes are required.

Recommendations

The Commission recommends that the two federal governments, in conjunction with the states and provinces and institutions:

- Undertake retrospective and prospective epidemiological studies, in Areas of Concern and other pertinent locations of the Great Lakes basin, to better understand potential neuro-developmental effects associated with methyl mercury and PCBs.

- Make fish advisories clear, simple, and consistent, and ensure that they are reaching the intended audiences.

- Select and promptly implement programs in both the United States and Canada that would substantially reduce the deposition of mercury in its reactive gaseous form in the Great Lakes region; and also pursue multi-lateral strategies for further control of this persistent toxic substance on a global basis.

Chapter Four

ECOSYSTEM INTEGRITY: THE CHANGING LAKE ERIE ECOSYSTEM

Introduction

Environmental problems in the Lake Erie ecosystem function as early warning signals for the other Great Lakes. As the shallowest of the lakes, Lake Erie has the shortest water retention time (less than three years), but it also has the largest watershed relative to its size, the highest human population density, the most farm land, and the largest number of major cities. These factors converge to make Erie the Great Lake where ecological disruption often shows up first. If we can develop a detailed understanding of ecological disruption symptoms on Lake Erie, we can perhaps avoid similar problems on the other Great Lakes.

Rapid ecological changes are in fact occurring in the Lake Erie ecosystem, some as puzzling as they are troubling. Evidence now suggests that these changes involve complex and often poorly understood interactions between many factors related to the lake's chemical, physical and biological integrity. From what we know now about the suite of possible problems and their causes, achieving ecosystem integrity in Lake Erie and the other Great Lakes will require greater recognition of the need to address chemical, physical and biological integrity as parts of a unified whole.

Past Successes

Programs created by both countries in response to *Annex 3: Control of Phosphorus* of the *Great Lakes Water Quality Agreement* led to a sharp reduction of phosphorus entering Lake Erie during the late 1970s and the 1980s. These programs, especially those involving improved sewage treatment plants and reformulated laundry detergent, led to a reversal of the lake's eutrophication[1] and water quality improved significantly.[2] The U.S. and Canadian Governments achieved further reductions in phosphorus in subsequent years through a variety of control measures, as recommended by the Commission's Pollution From Land Use Activities Reference Group in 1978. These measures focused on direct or "point" sources of pollution – such as discharge pipes from factories and sewage treatment plants – as well as "nonpoint" sources such as storm water runoff from farm fields or parking lots. The control of eutrophication in Lake Erie is recognized worldwide as a successful model of transboundary cooperation that linked scientific findings with monitoring, resource management, and policy formulation and application.

Recent Trends and Possible Causes

Trends in Lake Erie water and ecosystem quality since the early 1990s are not well understood. Recent research paints a confusing picture of simultaneously positive and negative trends in water and ecosystem quality (Table 5). Considerable year-to-year variations in scientific observations also inhibit identifying cause-and-effect linkages that can guide resource management and policy decision-making. For example:

- Springtime phosphorus concentrations have begun to increase and summertime levels of dissolved oxygen are depleting in the lake's central basin, even though there is no firm evidence of increases in external phosphorus loading.[3] Recent calculations suggest minimal increases of phosphorus from point sources. However, as noted in the Commission's Tenth Biennial Report, uncertainty exists about phosphorus discharges into tributaries because of cutbacks in monitoring programs and less sensitive detection limits of phosphorus in sewage treatment plant discharges.[4]
- An increase in phosphorus should stimulate the growth of phytoplankton (tiny, free-floating plant life), which is a key component of the food web. However, phytoplankton concentrations generally remain low in offshore waters.[5]
- Invasive species continue to enter and become established in Lake Erie, causing economic damage and ecosystem disruptions. Scientists suspect that zebra and quagga mussels and the round goby (Fig. 7) are causing major changes in the Lake Erie ecosystem, perhaps including the springtime increases in phosphorus in lake waters. Non-native species may in

fact be altering the way the natural ecosystem functions, as changes in the food web and rising phosphorus concentrations have coincided with the arrival and population boom of non-native zebra and quagga mussels. Whether there is a relationship between these events or if they are mere coincidences remains unclear.

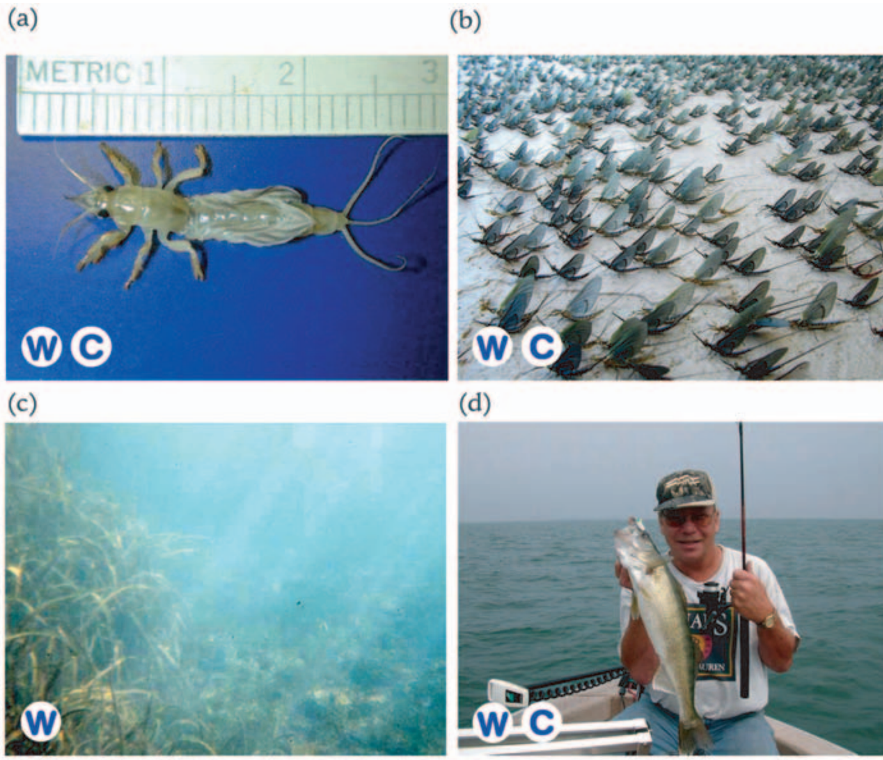
- The walleye population recovered dramatically during the 1980s and developed into one of the most financially important sport fisheries in North America (Fig. 6). However, walleye and other fish populations (such as rainbow smelt) have declined in recent years, raising concerns among sport fishers and the fishery management community that changes in phosphorus and the food web may be responsible.[6] Again, the causes for these changes are unclear.

Table 5. Summary of Recent Trends in Lake Erie Ecosystem Quality

Positive Trend
Increased water clarity
Re-establishment of rooted aquatic plant communities
Burrowing mayfly recovery
Walleye recovery
Lake whitefish recovery - central basin

Negative Trend
Lake whitefish decline - eastern basin
Phosphorus increase in water column
Phytoplankton decline in offshore waters
Blue-green algae blooms
Cladophora shoreline accumulations
Establishment of invasive species
Diporeia decline
Fish and wildlife die-offs from botulism

Figure 6. Positive Changes in Lake Erie Ecosystem Quality, and Lake Erie Map



(a) Aquatic and (b) adult burrowing mayfly, *Hexagenia*; (c) rooted aquatic plants improve habitat diversity; and (d) walleye

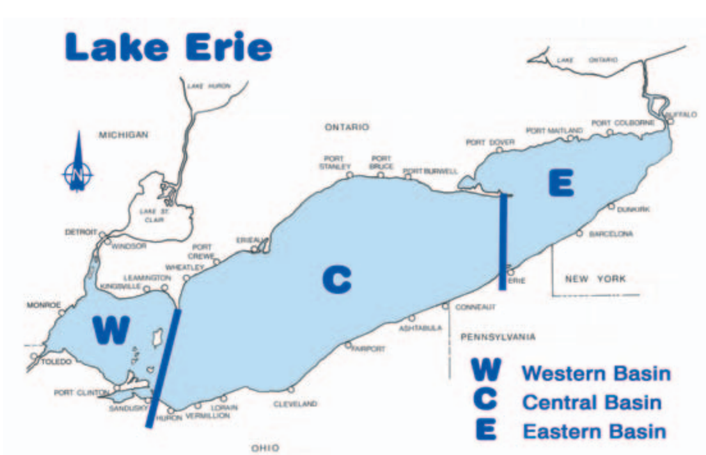
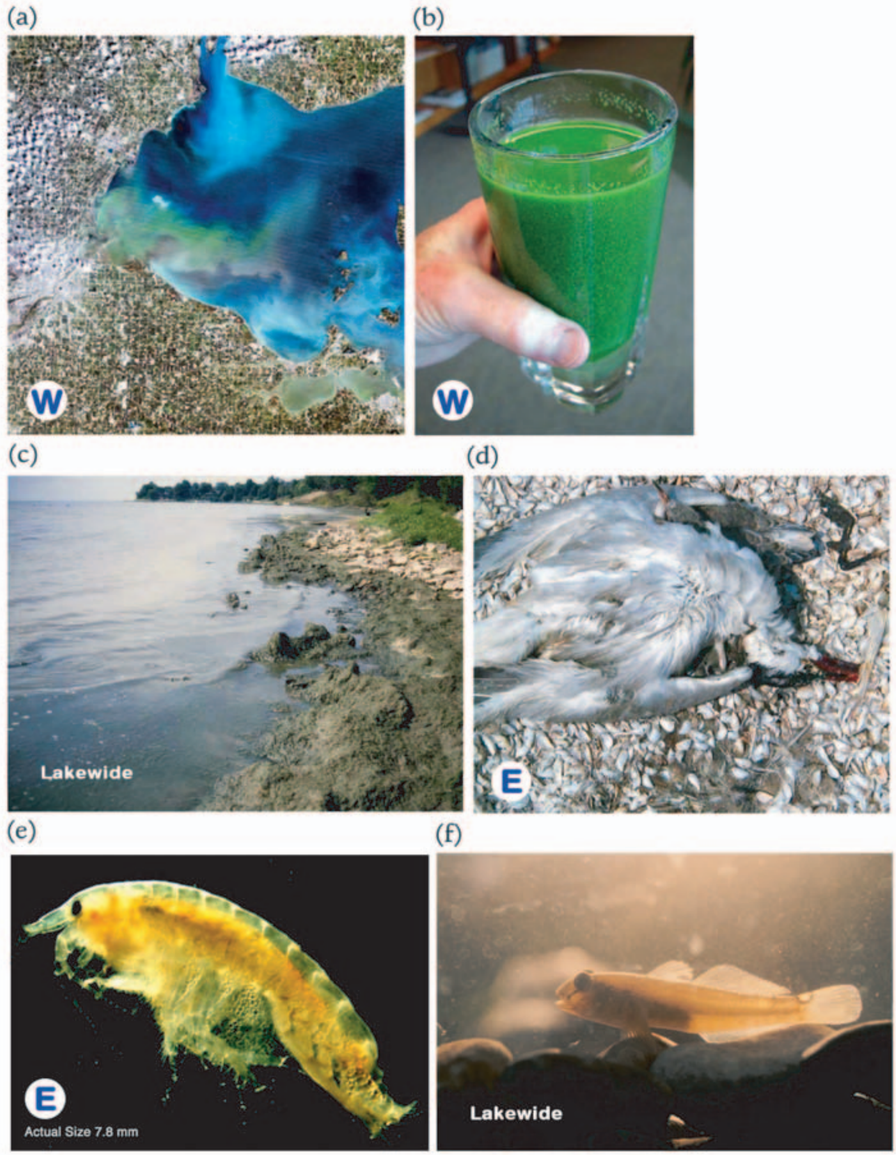


Figure 7. Negative Changes in Lake Erie Ecosystem Quality, and Lake Erie Map



(a) and (b) Blue-green algae blooms; (c) the macro-algae, *Cladophora*, fouling beaches; (d) fish and fish-eating birds dying of botulism poisoning; (e) the declining native invertebrate, *Diporeia*; and (f) another invasive species, the Round Goby

- In some nearshore waters, especially around the western Lake Erie islands, greater water clarity has resulted in a dramatic increase in rooted aquatic plants.[7] This has improved habitat diversity for such fish as the smallmouth bass. (Fig. 6)[8] Concurrently, blue-green algae (cyanobacteria) blooms periodically erupt in the open waters of western Lake Erie, causing a soupy, green scum on surface waters. Closer to shore, sheets of *Cladophora*, macro algae, are growing at excessive rates on rocks and other hard surfaces, sloughing off in wind and waves, then dying and rotting on beaches. (Fig. 7)[9] These conditions prevailed when eutrophication was at its worst in the late 1960s and early 1970s, yet phosphorus levels in the western Lake Erie basin do not suggest eutrophication is occurring.[10]
- *Hexagenia*, a large burrowing mayfly, serves as an important indicator of high water and sediment quality. This once-abundant insect spends its immature (nymph) stage in the lake and emerges only briefly as an adult, when it serves as a food source for many fish. This species disappeared from the lake during the 1950s, presumably due to oxygen depletion, but has recovered dramatically in the western and near shore portions of the central and eastern basins of Lake Erie since the early 1990s. Its reappearance after four decades — sometimes in great clouds of adults — can be hailed as an indicator that the Lake Erie ecosystem is recovering. (Fig. 6)[11]
- The predominant bottom-dwelling organism in the deeper, colder waters of the eastern basin of Lake Erie has been the deepwater amphipod, *Diporeia*, a small shrimp-like organism. It also is an indicator of good water quality and an extremely important food source for fish. *Diporeia* populations declined dramatically in the late 1990s (Fig. 7), and the species is now virtually absent.[12] The lake whitefish, once the mainstay of the Lake Erie fishery during the 19th and early 20th centuries but a minor part of the fish community for decades thereafter, had undergone a recovery in the eastern basin during the 1990s. One of its main sources of food is *Diporeia*, and as that prey species declined, so did the short-lived recovery of the lake whitefish in the eastern basin. However, the lake whitefish population is still rebounding in the central basin and occurs in the western basin during the colder months of the year.[13]
- Episodic die-offs of bottom-feeding fish and fish-eating birds from botulism poisoning are being reported, mainly in the eastern basin of Lake Erie, with lesser outbreaks noted in the western and central basins as well as in lakes Huron and Ontario. During and after the die-offs, rotting fish and bird carcasses litter beaches and shorelines (Fig. 7). Toxins from the

bacterium *Clostridium botulinum* and specifically Type E botulism, which is found in fish-eating birds in the Great Lakes, cause these die-offs. Type E botulism is one of seven botulism types identified with the letters A through F, each characterized by the neurotoxin it produces. The last substantial Type E botulism outbreak occurred in Lake Michigan during the 1960s. The neurotoxin is produced in the absence of oxygen and with suitable temperature and nutrient conditions. It remains unclear which factors trigger the bacterium to produce the neurotoxin and the ensuing fish and wildlife die-offs. However, Type E botulism outbreaks have occurred as the round goby population, another invasive species, has increased. Researchers are looking for clues that triggered the botulism outbreak in Lake Erie, the source of the toxin, and its transfer among fish and other aquatic organisms, waterfowl, and fly maggots on carcasses.[14]

- Two other factors may be influencing or contributing to Lake Erie's ecosystem alterations, perhaps in similar or different ways on the other Great Lakes. Both short-term storms and long-term climate change may be influencing the ecosystem's dynamics. As already discussed in previous chapters, the same changes in land use, shoreline hardening from buildings, roads and parking lots, and wetland loss also may be triggering changes.

Understanding Lake Erie's Complexity

Because of their complex nature, addressing the overlapping and interacting issues affecting Lake Erie today requires a greater level of binational communication and cooperation than ever before.

Nevertheless, significant information gaps remain, making it difficult for policymakers to determine what actions can and should be taken to improve the lake's ecological integrity. Because the ecosystem is undergoing dynamic changes, scientists need to conduct more comprehensive biological investigations, including the effects of aquatic invasive species, climate change and other factors, as well as improve measurements of phosphorus loading. These investigations must clarify whether observed environmental changes result from increased phosphorus loadings from outside the lake or as a result of changes in phosphorus cycling within the lake, which could be due to zebra and quagga mussels, environmental changes, or other factors.

Thus, the Governments should:

- Improve phosphorus monitoring from point and nonpoint sources to determine relative contributions of external loadings versus internal cycling;
- Improve research to resolve questions about cause-and-effect linkages between observed ecosystem changes and various stressors. The complexity of this issue requires a collaborative approach between water quality research and fisheries research, including linkages with watershed land use issues; and
- Ensure that these research and monitoring improvements employ an ecological modeling framework that enables the most cost-effective and ecologically meaningful programs to be developed and implemented. Doing so would provide the greatest value to resource management and policy.

Unraveling the complexity of the issues requires new research and monitoring studies under the umbrella of a modeling framework, as recommended by the Commission's Council of Great Lakes Research Managers.[15] The Parties should also develop a Great Lakes ecological observation and forecast network. Such a system of automated buoys and remote sensors would supplement traditional shipboard and shore-based sampling to provide simultaneous records at multiple locations, help us to observe large-scale patterns, test models and predictions, and to increase our understanding of ecosystem and species variability.[16]

Eutrophication was the predominant environmental issue in Lake Erie during the 1960's and 1970's, toxic contaminants in the 1980's, and invasive species in the 1990's. In the new millennium, scientists are recognizing that all of these issues and others, such as habitat loss and degradation, climate change and botulism, are occurring concurrently. The Commission commends the Parties for their rapid action to initiate a comprehensive study of the lake in 2002, with a large portion of the work coordinated and communicated through the Lake Erie Millennium Network. This network of scientists, managers and policymakers is playing a vital and increasingly important role to identify the issues and research priorities, obtaining the necessary data, and providing the binational forum for exchange of information and reporting. For the botulism issue, the Pennsylvania Sea Grant program and the New York Sea Grant program are providing a similar communication and coordination role.

Recommendation

The Commission recommends that Governments continue to fund bi-national research efforts begun in 2002 and 2003 to better understand changes in the Lake Erie ecosystem. The institutional model provided by the Lake Erie Millennium Network should be considered for adaptation and adoption on the other Great Lakes to foster enhanced binational cooperation and communication.

Signed this fourteenth day of September, 2004
as the Twelfth Biennial Report
of the International Joint Commission
pursuant to the
Great Lakes Water Quality Agreement of 1978

Herb Gray *Chair, Canadian Section*	*Dennis L. Schornack* *Chair, U. S. Section*
Robert Gourd, Commissioner	*Irene B. Brooks, Commissioner*
Jack P. Blaney, Commissioner	*Allen I. Olson, Commissioner*

Glossary of Terms

Anthropogenic: Made by people or resulting from human activities. Usually used in the context of emissions that is produced as a result of human activities.

Benthic: Located on the bottom of a body of water or in the bottom sediment, or pertaining to bottom dwelling organisms.

Best Management Practices: Effective, feasible (including technological, economic, and institutional considerations) conservation practices and land- and water-management measures that avoid or minimize adverse impacts to natural and cultural resources. www.nps.gov/yose/planning/yvp/seis/vol_Ib_p2/gloss_1.html

DNA Fingerprinting: DNA fingerprints are sequences of DNA molecules (genetic material) that are unique to each individual organism.

Eutrophication: The natural or artificial process of nutrient enrichment whereby a water body becomes filled with aquatic plants and low oxygen content. The low oxygen level is detrimental to fish.

Groundwater Recharge: Inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge.

Lake Erie Millennium Network: The Lake Erie Millennium Network is a cooperative approach, benefiting from the expertise and concerns of the public, regulatory agencies and the academic community. The goal is to define and understand Lake Erie's most pressing problems, propose solutions, and track the changes. http://zeus.uwindsor.ca/erie2001/working.html

NOBOB: Vessels with 'no ballast on board'.

Pervious: Pervious materials permit water to enter the ground by virtue of their porous nature or by large spaces in the material.

PLUARG: The Commission's Pollution from Land Use Activities Reference Group (**PLUARG**) was established under the 1972 Agreement to determine the cause and extent of pollution originating from land use activities, and to recommend appropriate actions. PLUARG reported its findings to the Commission in 1978, and the Commission forwarded a set of recommendations to the U.S. and Canadian governments in 1980.

Persistent Toxic Substances: Any toxic substance with a half-life in water greater than eight weeks.

Uncertainty Factor: A safety factor such as is used in the development of the reference dose for the protection of human health.

Endnotes

Executive Summary and Introduction

[1] Best Management Practices: see glossary of terms
[2] Lake Erie Millennium Network: see glossary of terms
[3] http://www.ijc.org/php/publications/html/aoc_rep/english/report/index.html
[4] http://www.uscg.mil/d9/wwm/rrt5/docs/CANUSLAK-1999.pdf

Chapter One
Physical Integrity

[1] Northeastern Illinois Planning Commission, 2002; SOLEC, 1996; SOLEC, 2002
[2] Environment Canada, 2001
[3] Groundwater Recharge: see glossary of terms
[4] Pitt., et al., 1999
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