*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.

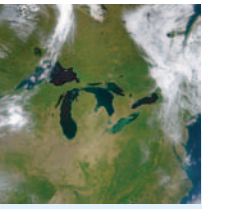
- The International Maritime Organization adopted the Convention for the Control and Management of Ships' Ballast Water and Sediments in February 2004. This United Nations agency, responsible for the safety and security of shipping and preventing marine pollution by ships, is to be commended for their 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 cooperation 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]

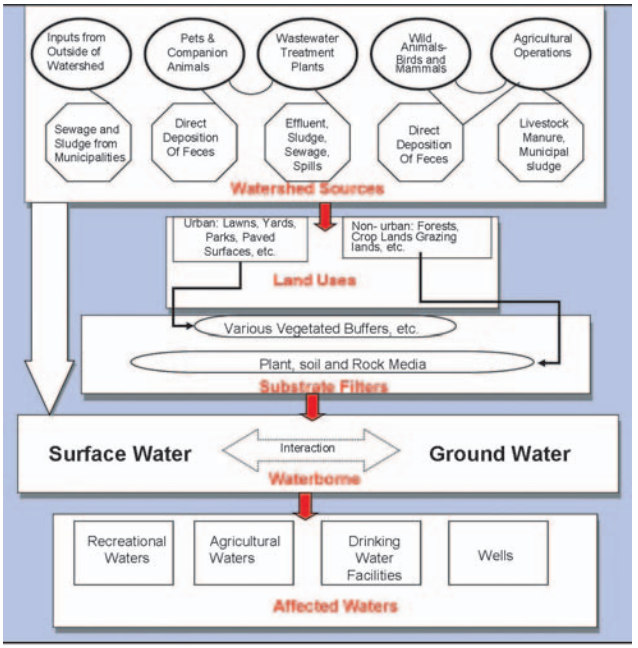



Figure 2. Potential Pathways for Waterborne Pathogens

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<br>• More runoff from hardened surfaces | • High loads of pathogens, bacteria, parasites, and viruses<br>• More users of urban beach<br>• 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.

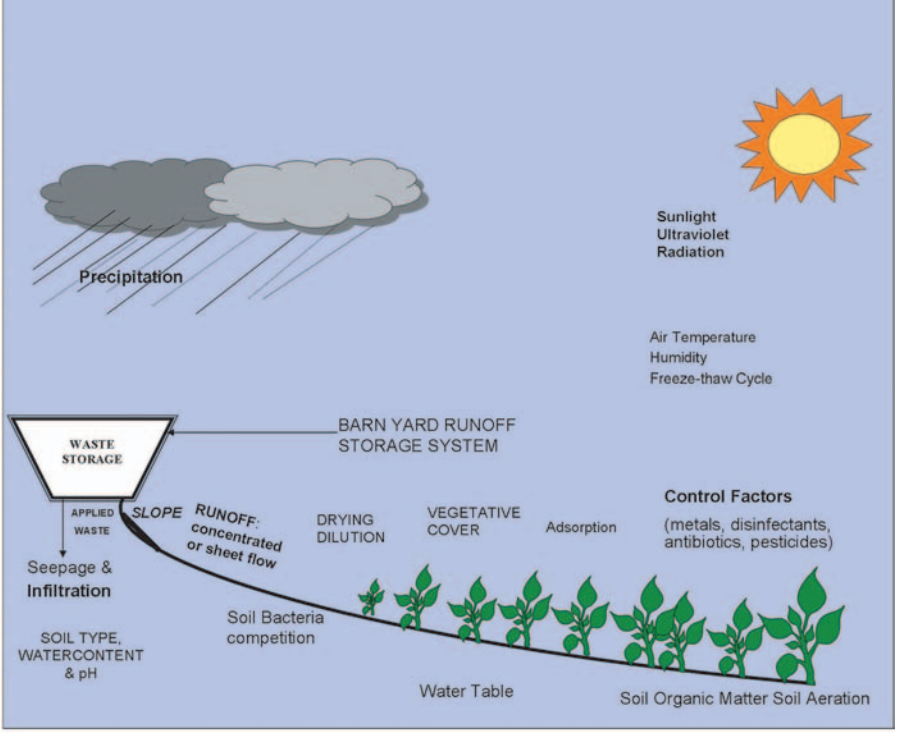



Figure 3. Factors Affecting Viability Along Transport Pathways

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.