Great Lakes Water Quality

AGREEMENT

PRIORITIES 2007-09 SERIES

Work Group Report on Beaches and Recreational Water Quality

What is a "Priority?"

Because the Great Lakes Water Quality Agreement (GLWQA) focuses on a wide variety of water-quality issues facing the Great Lakes Basin Ecosystem, the Commission created a GLWQA "Priority" setting process to focus on what it considers the most pressing issues. The Commission and its advisory bodies review and revise these Priorities as needed every two years. After receiving input from the public on its Priorities work, the Commission prepares Biennial Reports to governments on the status of Great Lakes water quality.

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"Can I swim at the beach?"

Beaches and recreational waters provide enjoyment for humans and habitat for local wildlife. Along the thousands of miles of Great Lakes shoreline are more than 800 monitored beaches, but not all places where people swim are monitored and others are only monitored sporadically.

The availability of clean recreational water brings both tourists and locals to our shorelines, helps to create a stable, healthy economy in the area and improves our quality of life. Conversely, impaired beaches and recreational water quality can seriously degrade our quality of life and the economy of the Great Lakes basin.

Understanding the underlying causes of problems and finding appropriate solutions is challenging in our binational, multi-jurisdictional basin. Cooperation, consistent standards and innovative rapid-detection methods will be required to improve the swimmability of our Great Lakes.

This workgroup report synthesizes available information about ecological and source-tracking methods and makes recommendations toward consistent sampling methods, standards and beach advisories. The report is based on a series of 'white papers' on fecal indicator monitoring, inconsistent water quality criteria used at Great Lakes beaches, local economic effects of impaired recreational water quality, the burden of human illness from impaired recreational water quality, policies and practices for beach monitoring and on protecting beach visitor health.

In addition to preparing this report, the work group will host a session on Beaches and Recreational Water Quality on Wednesday, October 7, 2009 at the GLWQA Biennial Meeting in Windsor, Ontario. Using the work group report as background material, work group members will present findings and discuss the issue with the public to elicit various perspectives and to inform the Commission's 15th Biennial Report.

Work Group Report on Beaches and Recreational Water Quality

Great Lakes Water Quality Agreement Priorities 2007–09 Series

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Introduction

Great Lakes beaches and recreational waters add great value to the resource by providing enjoyment for humans and habitat for wildlife. These nearshore environments contribute to ecosystem biodiversity and provide breeding grounds and cover for fish, birds, aquatic invertebrates and other wildlife. When beaches are clean and healthy, they attract large numbers of local residents and visiting tourists. Not all locations where people swim are monitored. However, along the many thousands of miles of shoreline, there are approximately 822 monitored beaches in the Great Lakes Basin. Only those classified as designated recreational areas are monitored. The recreational opportunities provided by the waters and beaches in the Great Lakes are very important to a healthy economy in the area. Unfortunately, the stigma of contaminated waters and beaches hurts both the quality of life and the economy of the region, as well as presenting risks to human health. Understanding the nature, extent and causes of the problems, as well as finding the solutions, is an important challenge that must be met by all those who care about the Great Lakes.

Study Objectives

This collaborative study addresses significant Great Lakes Water Quality Agreement (GLWQA) recreational water quality issues related to "swimmability" in the Great Lakes basin. Topics of discussion include the current status of beach standards and practices across jurisdictions, as well as reasons for and effects of impaired beach quality on human health and economics.

This Work Group report synthesizes available information about ecological and source tracking methods and makes recommendations toward consistent sampling methods, standards and beach advisories. Overall, it is clear that healthy recreational waters benefit everyone and everything around them. It is in our best interest, therefore, to protect them and ensure that future generations get a chance to fully appreciate them.

Sources of Contamination

There are various point and non-point sources of recreational water contamination. With reductions and better management of point sources, such as industrial and municipal effluents, non-point sources have become a better recognized factor in the contamination of Great Lakes recreational waters. These include faulty On-Site Waste Treatment Systems (OWTSs), sewer overflows, Confined Animal Feeding Operations (CAFOs), wildlife and agricultural runoff. A CIWR research study shows that the most prominent input into surface water came from agricultural runoff (Chambers et al., 2008).

Much of the lower Great Lakes Basin is highly urbanized with extensive and aging infrastructure. Leaking municipal sewer lines are of significant concern to groundwater and recreational water quality in the Great Lakes Basin (Dorfman and Sinclair-Rosselot, 2008) (Dorfman and Sinclair-Rosselot, 2009). Recent reports indicate that by 2020, 45% of U.S sewers will be categorized as being in poor or worse condition, and 85% will have reached the end of their useful/designated life. In the upper Great Lakes, the most attractive sites for waterfront homes and cottages have high water tables for part of the year and soils that are not suitable for OWTPs . Poor OWTP maintenance is also an issue.

Southwestern Ontario has about 2 million hogs which produce as much raw sewage as the province's human population – each pig produces about four times the waste of humans. Common Confined Animal Feeding Operation (CAFO) pollutants that can affect recreational water quality include nutrients (N and P), which can produce eutrophication, and pathogens (parasites, bacteria and viruses).

In some parts of the basin liquefied manure is sprayed on 'tile-drained' fields and often at rates far beyond the assimilative capacity of the crops and pastures. The drains are situated about a meter below land surface with the expectation that contaminants will be filtered out before reaching the drain and nearby receiving waters. Often, however, desiccation cracks, animal burrows and other conduits can divert the unfiltered waste directly to the underlying drain.

In a recent study of recreational water contamination in southeastern Lake Huron, the researchers sampled both On-Site Waste Treatment Systems (OWTSs) and CAFO sewage lagoons (Kon et al., 2009). The results demonstrated that the dominant source of E.coli in lake water samples was agriculture, which supplied about 60% of the bacteria to the lake, whereas human sources provided only about 3%. The researchers noted that the farmland of the study region is extensively tile-drained and that cattle and swine manure is abundant and routinely applied to the fields as fertilizer. Also of note in the report is the fact that public beaches in the area have been

periodically posted as unsafe for swimming because of elevated E.coli numbers in the water. The NRDC document Testing the Waters, 2008 quotes the EPA that agricultural runoff is responsible for 70% of identified water quality problems in the U.S.

Given the range of possible causes for contamination of recreational waters, there is great interest in microbial source tracking (MST) methodologies to distinguish between the various potential factors which contribute to contamination of recreation waters (Stoeckal and Harwook, 2007).

As climate change becomes more prevalent in the Great Lakes basin more frequent and more severe storms, like Hurricane Ike in 2008, are anticipated to have an impact on Great Lakes beaches and recreational water quality (Figure 1). These include short but intense precipitation events ("micro-bursts") which have the potential to erode beach heads, mobilize materials within the watershed and impair water quality. These storms bring with them large amounts of precipitation, which often leads to sewer overflows. These overflows allow raw or partially treated sewage to be released into the lakes and rivers, leading to elevated E.coli counts and subsequent beach postings.

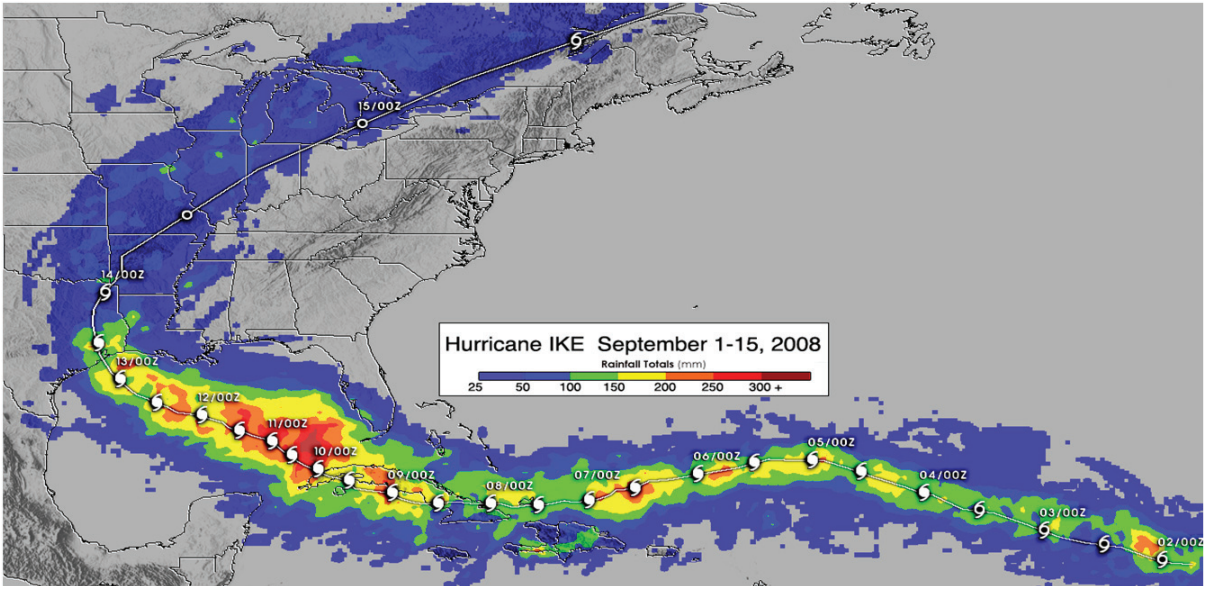

Figure 1

The City of Racine has been particularly successful in almost completely eliminating beach advisories after experiencing levels as high as 65%. They have used storm water management improvements, a constructed wetland, changes in beach grooming and other strategies, which are now being adopted in other cities (Kinzelman and McLellan, 2009).

Current beach testing methodologies take 24 hours or more prior to posting beaches as unsafe for swimming. As metropolitan areas continue to grow in the Basin, larger numbers of people will be using nearby beaches. An efficient and timely testing method is urgently needed to advise the public about recreation water quality at busy beaches to prevent water-based illnesses.

Great Lakes Surveillance and Monitoring Standards

BACKGROUND

The GLWQA (Annex 1, III) identifies microbiological performance criteria as a Specific Objective, and, as a result, beach closures are identified as an index of impaired beneficial use for all Remedial Action Plans (RAPs). Accurate evaluation of the extent to which this objective has been achieved requires both that (a) spatiotemporal trends in beach advisories accurately reflect spatiotemporal trends in pathogenic bacteria, fungi and viruses; and (b) decisions about beach closures are made according to criteria that accurately reflect contemporaneous health risks. Criterion (a) in turn implies consistent (or at least comparable) basin-wide monitoring protocols, while (b) implies that endpoints used for decision making accurately reflect contemporaneous human health risks.

METHODS AND FINDINGS

The current status of Great Lakes monitoring, surveillance, standards and prediction was reviewed and summarized in a series of reports completed on behalf of the working group (Robertson, 2008; Whitman and Nevers, 2008; Giroud-Bougard, 2009). Surveillance/monitoring protocols around the Great Lakes show substantial variability (Whitman and Nevers, 2008):

- Depth of sample collection varies from knee-deep to chest-deep despite evidence that, generally, sampling in shallower water or in the "swash zone" results in higher E. coli counts than in deeper water. Differences in the depth of sample collection may therefore result in a difference in the number of beach advisories despite overall similar water quality between the beaches.

- Despite evidence that Fecal Indicator Bacteria (FIB) concentrations tend to decrease throughout the day with increasing solar intensity, time of sample collection is highly variable.

- Although high spatiotemporal variability in FIB concentrations even at a single beach indicates that considerable within-beach replication is required to adequately characterize bacterial levels, many beach monitoring programs take only a single water sample.
- Frequency of FIB collection varies from daily to as little as once a month at Great Lakes beaches.
- Across the Great Lakes, samples are analyzed using different laboratory analysis techniques that result in similar estimates of mean FIB concentration but have different confidence intervals

Criteria for swimming advisories or beach postings also vary widely across Great Lakes beaches, even within local or regional jurisdictions. In the US, beaches are considered unsafe for swimming if E. coli levels are above 235 colony forming units (cfu) per 100 ml in a single sample maximum (SSM), with a maximum geometric mean (GM) of 126 cfu/100ml based on 5 samples over 30 days. By contrast, most Canadian beaches use a less conservative SSM such as 400 cfu/100ml and a 200 cfu/100mL GM, also based on 5 samples collected over 30 days (Health and Welfare Canada, 1992). In Ontario, however, the Provincial Water Quality Objective is based on the GM of levels of E. coli determined from a minimum of 5 samples per site taken within a given swimming area and collected within a one-month period (OMOE, 1994), but postings are considered when the daily geometric mean of the samples from a beach exceeds 100 E. coli per 100 ml. water (Ontario Ministry of Health, 1998).

In addition to substantial variation in beach monitoring protocols, FIB assays and criteria for advisories and postings, there are substantive concerns about the reliability of E. coli, which is the standard FIB for Great Lakes beach monitoring since it is present in numerous natural settings (e.g., in beach sand, forest soil and on beach algae) suggesting occurrence independent of recent human fecal contamination (Whitman and Nevers, 2004, Byappanahalli et al., 2003, Byappanahalli et al., 2006).

Another challenge to current monitoring protocols is the interval between sample collection and the availability of results (typically 24-48 hours), which means that any management actions are invariably carried out after bathers have been exposed to the contamination. Alternative and more rapid test methods have been developed and investigated including Quantitative Polymerase Chain Reaction (QPCR), which has an analysis time of three hours or less. Alternative indicators have been suggested, including the use of chemical and biological tracers of human fecal pollution such as human viruses and fecal sterols. Methodological issues, however, limit their utility for widespread, routine beach monitoring. There is a research need to develop reliable indicators

of human fecal contamination that can be used as part of a tiered approach to determine human risk and to identify sources of the contamination (Whitman and Nevers, 2008).

The time delays associated with Fecal Indicator Bacteria (FIB) assays have led to the widespread use of so-called "persistence" models to estimate current FIB levels based on levels measured 24 hours previously. Unfortunately, the predictive value of persistence models for E. coli is generally low, simply because bacterial concentrations at the same location can fluctuate dramatically over short time periods (Olyphant and Whitman, 2004; Whitman and Nevers 2004). As an alternative, attention has turned to FIB nowcasting and forecasting using statistical modeling approaches that incorporate both local and more regional predictors such as wave height, turbidity and precipitation to predict conditions when FIB levels are likely to exceed benchmarks for beach posting. A key issue, therefore, is the ability of existing models to predict current FIB levels based on other more easily obtainable predictors (nowcasting) or levels at least 24 hours in the future (forecasting).

A systematic review of published nowcasting/forecasting studies in the Great Lakes basin employing various predictive models indicated that:

- In the set of 11 published studies examined, 38 candidate predictor variables were identified, with statistical models being developed for 51 different beaches, including beaches with and without one or more (known) nearby urban sewer or stormwater outfall or agricultural drain.

- The most common candidate predictor variables overall were rainfall, turbidity, wave height, water temperature, wind speed and wind direction. Wave height, turbidity and precipitation were retained in over half of all final models; by contrast, the remaining 35 predictors appeared in fewer than 15% of final fitted models. For beaches with known point sources, final models almost invariably included attributes of these sources, including turbidity, source height and source flow.

- Bona fide unbiased tests of predictive ability were almost invariably lacking. In most cases, predictive value was adjudged by the coefficient of determination (R2) based on model fit to the entire data set. In the sample, adjusted R2 ranged from 0.23 to 0.73, with fewer than half the models achieving R2 > 0.50.

- In the very few "head to head" comparison with persistence models, predictive nowcasting models have substantially higher predictive value, although at best now/forecasting models achieve moderate predictive accuracy.

There is increasing interest in the use of a preventive risk management approach to minimize risks of gastrointestinal illness among bathers (Robertson, 2008) as has,

for example, been adopted by the World Health Organization (WHO, 2003). The WHO approach incorporates classification of beaches based upon an assessment of principal sources of fecal contamination (sanitary inspection) and microbiological quality commonly referred to as the Annapolis protocol (WHO 1999). Beaches can be re-classified if remedial measures are put into place to reduce exposures at times or locations of increased risk. The Annapolis protocol and preventive risk management strategies may well serve as a useful basis for monitoring of Great Lakes beaches.

Water quality monitoring protocols are highly variable for microbiological sampling, analysis and interpretation among individual state and provincial jurisdictions. The lack of a basin-wide coherent, systematic yet adaptive monitoring scheme, combined with different criteria for beach advisories among different jurisdictions, severely restricts the utility of beach advisories as indicators of spatiotemporal trends in recreational water quality and leads to uneven public health protection and perception. Development of rapid assays and refinement of predictive methods are required. These findings point to the need for a consistent basin-wide monitoring protocol for Great Lakes beaches that incorporate a preventive risk assessment approach.

Health Problems from Recreational Water in the Great Lakes Area

The definition of recreational activities used in the report includes "all recreational activities in which there is intentional, probable or accidental direct contact with natural water" (Dewailly et al., 1986). Those 'at-risk' include not only swimmers and boaters, but also windsurfers, those water skiing or tubing behind power boats, sport fishermen, scuba divers and kayakers.

GREAT LAKES OUTBREAKS

There has only been one reported recreational water related outbreak in the Great Lakes. Persons swimming at a Lake Michigan beach in Wisconsin exhibited symptoms consistent with norovirus infection; the outbreak was attributed to S. sonnei and Cryptosporidium, as well as norovirus (Yoder et al., 2004). There were 44 primary and 22 secondary cases of illness. Water samples collected prior to the outbreak were below the EPA's single-sample maximum guideline of 235 E. coli CFU/100 mL; however, tests during the outbreak demonstrated a large surge in E. coli levels to 2,419 CFU/100 mL. The same beach was posted on five occasions during the same summer, always after heavy rainfall events.

PRESENCE OF HUMAN PATHOGENS IN BEACH WATER SAMPLES

The majority of epidemiological studies have been conducted at beaches primarily influenced by point source contamination, and these were used by the US EPA to develop beach standards (Whitman and Nevers, 2008). These standards may not apply to contaminated beaches with non-point sources. With little information available about the risks associated with non-point sources of contamination (Calderon et al., 1991, Colford et al., 2007), researchers have attempted to determine where fecal indicator bacteria originate and also if pathogens harmful to humans are ubiquitous with non-point source contamination.

Studies of inner-city beaches on Lake Ontario in Hamilton and Toronto, Ontario, used microbial source tracking methods to demonstrate that the main source of E. coli in nearshore beach water was wild birds (Edge and Hill, 2007; Edge et al., 2007), which has an unknown illness risk for humans (Field and Samadpour, 2007). A study of pathogens in gull feces from two beaches on Lake Michigan found that samples from Racine, Wisconsin, contained Salmonella (0.4%), Campylobacter (22.7%) and Aeromonas hydrophila (0.4%), a cause of bacterial skin rash in humans (Kinzelman et al., 2008). Results from the Milwaukee beach were much different, with salmonella absent and Campylobacter in only 0.4% of fecal samples. In contrast, a beach on Lake Huron impacted by agricultural runoff had E. coli found mainly in cattle and pig manure (Kon et al., 2009). A study of the enterococcal surface protein (esp) as an indicator of sewage contamination at Lake Michigan beaches has been discontinued, as it was widely found in environmental samples including beach sand, algae and stream water (Byappanahalli et al., 2008). Further research is needed to determine what methods are optimal for definitive source tracking and whether natural and non-point sources of indicator bacteria present a threat to human health.

EPIDEMIOLOGICAL STUDIES OF RECREATIONAL WATER ILLNESS

Early prospective studies from Great Lakes beaches in Ontario found higher rates of respiratory, gastrointestinal, ear and skin symptoms in swimmers than in non-swimmers using the beach the same day, during a 7- to 10-day phone follow-up (Seyfried et al., 1985). Illness rates in swimmers were highest in the 0-5 and 16-20 age groups (12.2% and 11.3 %, respectively). Water samples taken found the geometric mean of fecal coliform counts in water was well below the then Ontario swimming standard of 100 coliforms per 100 ml water.

Two systematic reviews of epidemiologic studies on uncontrolled waters (i.e., lakes, rivers, sea) outside the Great Lakes found a dose-response relationship between gastrointestinal (GI) illness and recreational water quality, as measured using indicator bacteria (Pruss, 1998; Wade and Pai, 2003).

Recent studies on illness in swimmers use monitoring methods that allow same-day results to be available for decision making. One study of two Great Lakes beaches (one on Lake Erie and one on Lake Michigan) showing that levels of Enterococcus using a quantitative polymerase chain reaction (QPCR) method were predictive of GI illness (Wade and Calderon, 2006) . Another study of four Great Lakes beaches (Huntington Beach on Lake Erie and West Beach, Silver Beach and Washington Park Beach on Lake Michigan) found that Enterococcus PCR cell equivalents were positively associated with swimming-related GI illness particularly in children aged 10 years or younger: OR=1.7 (95% CI:1.1-1.5) (Wade and Calderon, 2008).

Few experimental studies have been conducted so far. An experiment at a windsurfing competition near Quebec City found the relative risk (RR) of any illness for windsurfers was 2.9, and the RR for gastrointestinal illness was 5.5 (Dewailly et al., 1986). The number of falls into the water correlated positively with the development of illness. A large experimental study in Germany randomized 2,196 subjects to swim or not swim at five freshwater beaches. At one- and three-week follow-ups, swimmers had more gastrointestinal illness and skin problems than non-swimmers (RR 1.8-4.6) (Wiedenmann et al., 2006). An increased number of head immersions in contaminated water increased illness risk.

Socioeconomic Issues

With more than 10,000 miles of shoreline, the Great Lakes coast offers a wide variety of recreational opportunities. In fact, tourism contributes more than $6 billion annually to the regional economy. More than 60 million people visit Great Lakes Region provincial and state parks every year (www.epa.gov/glnpo/monitoring). Visitors spending a day or week at the beach are often the engine fueling the local economy. While studies and research focus on the causes and frequency of advisories and postings, there is little documentation of the cost to the local and regional economy.

The socioeconomic costs associated with beach advisories and postings include trip-related expenses like travel, lodging, food and fuel. Economists estimate that the cost of a "typical swimming day" at one beach is $30.84 per person (Dorfman and Sinclair-Rosselot, 2008). A survey undertaken in Ohio looked at two popular beach destinations and estimated that expenditures in local municipalities near the beach could range from $3.3 to $6.2 million per bathing season. The study also concluded that individuals spend only 26% - 30% of these dollars on travel expenses, with the

remaining 70% going into the local economy (Ohio Sea Grant, 1999). Impaired recreational water quality may result in a loss of at least a portion of those dollars. Additionally, people most likely change vacation and free time plans due to beach postings, which result in a loss of revenue associated with other recreational activities like bird watching, fishing, camping and hiking. Beach postings due to bacterial contamination or nuisance algae are also known to decrease lakefront property values. Economic impacts also may occur where ignoring postings results in lost work or sick days as well as medical costs for doctor visits and pharmaceuticals. In an Ontario study the estimated mean cost for each case of gastroenteritis was $1,089 per person (Majowicz, 2006). A recent cost benefit analysis concluded that reducing the number of beach advisories would result in a $3 billion benefit to the region (Austin et al., 2007).

As discussed earlier, current monitoring and modeling show relationships between storm and wind events with beach postings and advisories due to bacterial contamination. Climate change scenarios predict more intense storm events, warmer water temperatures and fewer months of ice cover on the lakes, all which may contribute to an increase in the frequency and duration of beach postings. The negative impact on the local and regional economy could result in substantial losses of tourism related spending.

Beach Management and Communications

Effective management of beaches across the Great Lakes and St. Lawrence is complicated by a number of factors, one of the most significant being the many United States and Canadian federal, state/ province and local authorities involved in managing the resource. This creates a difficult challenge in having consistent approaches to the multiple management issues of monitoring, analysis, advisories, corrective measures and others. The situation is complicated by the varying recreational water quality standards and criteria in the U.S. and Canada.

Another difficult issue is the protocol for when to issue a beach advisory when water quality samples show elevated levels of E.coli bacteria. There appears to be significant variation from one jurisdiction to another as to when an advisory is issued, when swimming at a beach might be closed completely and in reporting illnesses resulting from exposure to contaminated waters.

Recent actions may be moving things in the right direction on these issues. First, under the Great Lakes Regional Collaboration on the U.S. side, there has been a beach initiative which has included expanded use of predictive models to provide more timely

advisory information and broad use of a standardized sanitary survey which has led to a more systematic approach to finding and correcting beach contamination problems. On the Canadian side, mayors from Ontario recently called for establishment of a beach office at the provincial level, and the Ministry of Natural Resources has agreed to take the lead in this effort. What would help further would be the designation of a focal point on the U.S. side and the Canadian side, each of whom could pull together what is happening on the local, regional, state, provincial and federal levels.

The Michigan Department of Environmental Quality along with similar state agencies in Wisconsin and Minnesota have public beach data sites that list how often beaches are tested, who tests them, what the latest and historical testing results are for each beach and the beach's history of postings. Additionally, U.S. EPA has a "beach cast" site for the entire country and all eight Great Lake states and Ontario have a Web page: great-lakes.net/beachcast/XX, where XX is the two digit state code.

Beach Activities Matrix (Appendix 1)

Throughout the Great Lakes Region many initiatives are being taken by both Canadian and U.S. agencies and jurisdictions regarding recreational water quality, beach monitoring and forecasting. This matrix aims to organize and display various modeling, forecasting, research and information-soliciting programs and organizations. The information presented only represents a small portion of the programs related to recreational water quality in the Great Lakes states and provinces. During compilation of the matrix it became clear that a large portion of beach and recreational water research and monitoring initiatives are taking place solely in the United States, in part due to the implementation of the Beach Act.

Government Accountability Office Recommendations (Appendix 2)

The Beach and Recreational Water Quality Work Group was asked to review, and comment on, the recommendations included in the May 2007, Government Accountability Office Report on Great Lakes beaches. These recommendations and Work Group comments are included in Appendix 2.

Appendices URL

Appendix 1 and Appendix 2 are available at:
http://www.ijc.org/en/priorities/2009/beach-quality/appendix

Recommendations

The Work Group encourages the International Joint Commission to recommend to the Parties:

1. Research to determine sources of contamination, especially non-point sources, the human versus non-human contributions and the resulting risk to human health.

2. Research is also needed to develop novel indicators of human fecal contamination that are rapid and reliable to increase the efficiency of the decision-making process for beach advisories.

3. Undertake a head-to-head comparison of the true predictive value of a suite of now/forecasting models versus the persistence model at a set of Great Lakes beaches that span the full range of ambient conditions.

4. Develop binational, standardized basin-wide surveillance and monitoring protocols in conjunction with preventive risk management strategies.

5. Adopt binational standardized criteria for beach postings.

6. Develop a binational, systematic, centralized and timely way to evaluate and report waterborne illness in the Great Lakes and track what is happening on the local, regional, state, provincial and federal levels.

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