USGS
science for a changing world

Understanding Beach Health Throughout the Great Lakes—Entering a New Era of Investigations

Water recreation and associated tourism provide wide-ranging economic opportunities and societal benefits to the Great Lakes Region. Unfortunately, coastal areas can become contaminated with pathogens (disease-causing microorganisms) of fecal origin that threaten the health of people who swim in coastal waters. Beach advisories and closures are intended to protect swimmers from illness caused by fecal contamination; however, several problems face beach managers who issue advisories or closures or try to solve contamination problems:

- *Traditional lab analyses for beach water quality take too long.* Current beach water-quality monitoring relies on culturing of fecal-indicator bacteria, such as *E. coli* or enterococci. Although not necessarily pathogenic, these bacteria are considered to be indicators of contamination from human and (or) animal waste. Unfortunately, results aren't available until at least 18–24 hours after sampling, so bacteria counts may have changed by the time management decisions are made. Too often, beaches are closed or placed under advisory too late to protect visitor health or are closed unnecessarily, which keeps visitors out of relatively safe water. **Rapid assessments are needed to improve the timeliness and accuracy of beach closures and advisories.**

- *Sources of fecal contamination in recreational waters are often unknown.* This makes it difficult to assess the extent of fecal contamination and take remedial actions. **Relations between coastal processes, such as sediment transport and wave action, and bacteria concentrations from nonpoint sources need to be comprehensively studied in the Great Lakes. Methods that can distinguish between human and animal fecal contamination also need to be developed and applied to help identify risks associated with contaminated recreational waters.**

- *Recreational waters are seldom monitored for actual pathogens.* Fecal indicator bacteria do not necessarily have the same transport and survival properties as all pathogens. **Beach managers need data on the types of potential pathogens present, the relation of the pathogens to indicator-organism concentrations, and options for other parameters—such as environmental conditions—that correlate well with pathogens and potential swimming-related illness at their beaches.**

- *Data used in the study of recreational waters are sometimes inconsistent between beaches because data currently are compiled by numerous agencies and in a wide variety of formats.* Improved Great Lakes-wide data reporting, data consistency, and data accessibility are needed to better facilitate analysis, interpretation, and communication among those who monitor, evaluate trends, or do research at beaches.

Key Questions for USGS Research

- Are there better ways to inform the public whether they can use a beach without risking their health?
- How do new rapid analytical methods compare to traditional methods for determining concentrations of fecal-indicator bacteria at beaches?
- Are pathogens present at beaches? If so, how do they get to the beach, and what is their source?
- How do sand movement and wave action on the beach affect fecal-indicator-bacteria and pathogen concentrations in the lake water?
- What are the best indicators of pathogenic microorganisms?
- With so many potential sources of fecal contamination at a beach, what methods can be used to distinguish the contributions from humans?
- What characteristics of beaches contribute most to influencing bacterial indicator and pathogen concentrations in beach sands and groundwater?

Overall Mission

For over a decade, the U.S. Geological Survey (USGS) has been a leader in the science of beach health. **The overall mission of this work is to provide science-based information and methods that will allow beach managers to more accurately make beach closure and advisory decisions, understand the sources and physical processes affecting beach contaminants, and understand how science-based information can be used to mitigate and restore beaches and protect the public.** The work consists of four science elements—real-time assessments; pathogens and microbial source tracking; coastal processes; and data analysis, interpretation, and communication—which are described in the remainder of this fact sheet.

Real-Time Assessments

Real-time assessments can be done by means of predictive models and (or) rapid analytical methods. Predictive models use easily measured environmental and water-quality variables, such as rainfall amounts and water clarity (turbidity), to estimate current recreational water-quality conditions, thus allowing the beach manager to evaluate the need for an advisory or closing. Nowcast systems, based on predictive models, are used to provide model results to the public (for example, *www.ohionowcast.info*; see box below). Rapid analytical methods such as quantitative polymerase chain reaction (qPCR) and immunomagnetic separation/adenosine triphosphate (IMS/ATP) can provide analytical results within 2–3 hours.

USGS researchers are working to further develop and expand functional real-time assessments to more locations around the Great Lakes and provide assessment tools and training to beach managers. Current activities include the following:

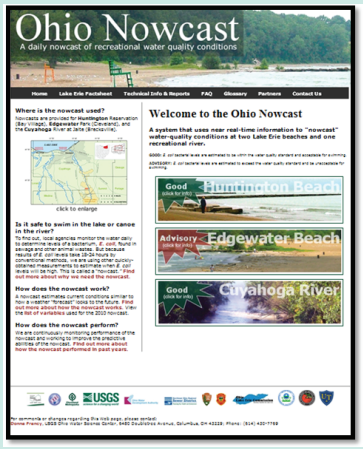
- Exploring the use of new variables that explain physical and biological processes affecting fecal-indicator bacteria concentrations.
- Testing alternative statistical techniques to improve the accuracy of model predictions.
- Providing an automated modeling system to better enable technology transfer to beach managers.
- Providing training and technology transfer to beach managers to apply and evaluate rapid analytical methods.

Nowcasting at Great Lakes Beaches

A nowcast is a system that uses environmental and (or) water-quality "variables" (such as turbidity and rainfall amounts) measured in real time to estimate recreational water quality. The USGS is working with local agencies in Illinois, Indiana, Ohio, Pennsylvania, Michigan, New York, and Wisconsin to establish nowcast systems at over 25 Great Lakes beaches.

The Ohio Nowcast (*www.ohionowcast.info*) is an operational system for two Lake Erie beaches—Huntington in Bay Village and Edgewater in Cleveland. The Ohio Nowcast provides the probability (in percent) that the Ohio bathing-water standard of 235 colony-forming units per 100 milliliters for *E. coli* will be exceeded. A threshold probability is established on the basis of historical data; when the probability is above the threshold, the beach is posted with an advisory.

Since the Ohio Nowcast began operation in 2006, the nowcast models have provided more accurate estimates of water-quality conditions than have the use of the previous day's *E. coli* concentration (the current method used by most beach managers) (Francy and others, 2009). Most importantly, using the models, beach managers were better able to predict when the *E. coli* standard was exceeded and issue advisories to the public. The USGS continues to work with local agencies to improve the accuracy of the Ohio Nowcast.



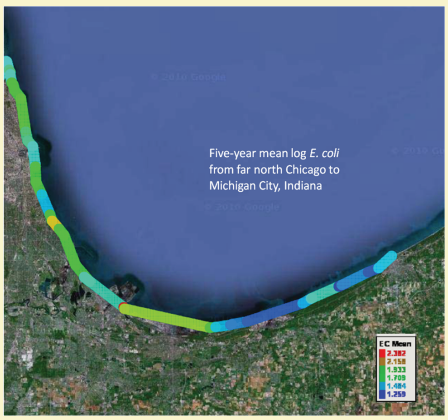
Pathogens and Microbial Source Tracking

USGS researchers are working to determine the occurrence of microbial source tracking (MST) markers and pathogens of concern for human health at beaches susceptible to various sources of fecal pollution. Methods for identifying or enumerating pathogens include laboratory culture for bacterial pathogens and molecular methods, such as qPCR, for all types of pathogens. MST molecular markers—segments of genetic material that can be used to indicate potential sources—have been used to link fecal contamination in the environment back to humans or animals as sources. MST techniques can also be applied to identify contaminant sources at beaches. Current activities include the following:

- Developing and applying sampling strategies and analytical methods for MST markers and bacterial, protozoan, and viral pathogens.
- Identifying the relationship between fecal-indicator bacteria concentrations and pathogen or MST marker detections or concentrations.
- Identifying environmental conditions that are associated with pathogen occurrence, such as rainfall, wave frequency and magnitude, and contributions from streams that empty into coastal waters.
- Identifying whether sand or algae are reservoirs for enteric organisms and may release pathogens to the water column and affect recreational water quality.
- Developing a categorization of beach types using bacterial indicators, pathogens, and MST markers as criteria. These categories can then be used by researchers to help design a pathogen- and MST-monitoring strategy.

Determining Regional Influences on *E. coli* Fluctuations

Previous studies by the USGS (Nevers and Whitman, 2008; Whitman and Nevers, 2008) have determined that a persistent background concentration of *E. coli* in the nearshore waters of Lake Michigan affects multiple beaches. The background *E. coli* combines with local



Coastal Processes

Coastal processes that may influence bacteria concentrations include longshore currents and sediment transport, surface-water contributions, turbulence associated with currents and wave action, changes in lake and groundwater water levels, and seiches. Beach sand and *Cladophora* (a filamentous green algae) potentially accumulate bacterial indicators and pathogens for release into lake waters.

USGS researchers are working to characterize the transfer of bacterial indicators, pathogens, and MST markers to the nearshore waters, sediments, groundwater, and lake water. Current activities include the following:

- Determining the role of groundwater as a source of bacterial indicators and pathogens to lake water.
- Evaluating the role of surface and buried beach debris and algae on concentrations of bacterial indicators in foreshore beach sands and submerged sediments.
- Determining the relations between various environmental conditions and sediment dynamics.
- Expanding the geographic extent of studies of coastal processes over a range of beach types.

sources at specific beaches, and these local and background sources influence overall *E. coli* concentrations and therefore beach-monitoring results. The co-occurrences of *E. coli* concentrations with other fecal indicators and markers of various types of contamination are being explored so that immediate and persistent sources can potentially be eliminated. To examine bacterial transport in the region, water samples from representative beaches along the southern coast of Lake Michigan are being analyzed, and instruments to measure water and current conditions are being deployed at advantageous locations. Future research will expand the region of focus and increase the number of genetic and fecal markers analyzed so that the influence of large-scale lake processes on beach water quality can be determined.

Coastal Processes at Great Lakes Beaches

Coastal processes that affect fecal-indicator bacteria and pathogen concentrations at Great Lakes beaches are not well understood. At one Lake Erie beach—Edgewater, Cleveland, Ohio—past studies indicated that shallow groundwater and waves influence the storage and accumulation of *E. coli* in foreshore sands (Francy and others, 2006). Work was done during the recreational season of 2008 to help researchers better understand this phenomenon.

Six piezometers (shallow water wells) were installed. Four were buried at 2, 4, 7, and 10 feet from the swash zone (the zone of the shoreline that is constantly washed by waves or tides), and two were installed at 20 and 80 feet from the swash zone. Pressure transducers were installed in two of the piezometers. Data on water levels, water temperature, specific conductance, pH, turbidity, enterococci, and *E. coli* concentrations were collected 4 days a week from June 6 through August 14, 2008.

Over 150 groundwater and lake water samples were collected. Enterococci and *E. coli* concentrations greater than 100,000 colony-forming units per 100 milliliters (CFU/100 mL) were found on multiple days in groundwater samples, but the highest concentrations in lake water were only 1,300 and 1,400 CFU/100 mL, respectively.

Bacterial Pathogens at Beaches

Health effects associated with swimming and the handling of sand have been identified by epidemiological studies at Great Lakes beaches (Wade and others, 2008; Heaney and others, 2009). In recreational waters, pathogens implicated in waterborne human disease include several bacteria transferred among humans and animals, as well as human enteric viruses. A recent U.S. Environmental Protection Agency review (2009) notes that much remains to be learned about occurrence, sources, and human-health significance of pathogens in recreational waters where human waste is not a major contaminant source. As a follow-up to preliminary studies at two Great Lakes beaches, the USGS has begun a comprehensive study evaluating the presence of key bacterial pathogens and MST markers at 12 beaches across the Great Lakes. The 12 beaches were selected to represent a wide array of potential sources and typical Great Lakes environmental settings. Results of over 400 samples being analyzed in 2010 will provide data on sources of fecal contamination, help to identify human health risk, and facilitate the relation of pathogen occurrence to fecal-indicator bacteria concentrations and environmental factors.

Improving Great Lakes-Wide Beach-Data Analysis, Interpretation, and Communication

USGS researchers are working to compile recreational-water-quality data on Great Lakes beaches into comprehensive databases and a Geographic Information System (GIS) that will facilitate the assembly of USGS data and enhance the communication of this information to beach managers and the public. The GIS could encompass multiple scales of analysis, enabling beach-pollution factors (such as tributaries or stormwater outfalls) and land-use factors to be represented in spatial models of beach-bacteria dynamics. A multiagency database could be used to incorporate data into predictive models and other diverse research activities. Current activities include the following:

- Developing a publicly accessible, Web-based, interactive GIS that allows visualization of Great Lakes-wide water-quality and environmental data associated with beaches.
- Developing a comprehensive database to assemble environmental data collected at Great Lakes beaches.
- Developing a comprehensive database that integrates real-time data (such as rainfall) from additional sources, such as the National Oceanic and Atmospheric Administration, with beach-collected data.
- Exploring ways to use an integrated, central database in development of predictive models.

Development of a Geographic-Information-System-Based Beach Visualization and Analysis Tool

USGS has initiated the first comprehensive assembly of Great Lakes beach and coastal data. A wide array of spatially referenced beach information, including bacterial beach-monitoring data for 2007 through 2009, has been incorporated into a Geographic Information Systems (GIS)-based internet mapping application called the Great Lakes Beach Analysis Tool. The tool enables users to view Great Lakes beach monitoring data, examine the physical setting (land cover, topography, geology, and so forth), link to sites that serve relevant real-time data (wind velocity and direction, wave height, rainfall, and so forth), and potentially visualize patterns of beach bacterial water quality around the Great Lakes. The tool is being developed as an example, and perhaps a template, for assembling and communicating Great Lakes beach data. It is currently (August 2010) in beta-version review by numerous potential users of the final product, and their input will guide further development.

Program Information

Funding for USGS beach projects and research in the Great Lakes comes from a variety of sources including the Ocean Research Priority Plan, the USGS, the Great Lakes Restoration Initiative, the U.S. Environmental Protection Agency (USEPA), and many state and local partner agencies and organizations throughout the region.

Contact

James R. Morris, Director
USGS Ohio Water Science Center
6480 Doubletree Avenue
Columbus, OH 43229-1111
614-430-7700
dc_oh@usgs.gov

http://greatlakesbeaches.usgs.gov/

References

Francy, D.S., Bertke, E.E., and Darner, R.A., 2009, Testing and refining the Ohio Nowcast at two Lake Erie beaches—2008: U.S. Geological Survey Open-File Report 2009–1066, 20 p., accessed August 19, 2010, at *http://pubs.usgs.gov/of/2009/1066/*.

Francy, D.S.; Bertke, E.E.; Finnegan, D.P.; Kephart, C.M.; Sheets, R.A.; Rhoades, John; and Stumpe, Lester, 2006, Use of spatial sampling and microbial source-tracking tools for understanding fecal contamination at two Lake Erie beaches: U.S. Geological Survey Scientific Investigations Report 2006–5298, 29 p.

Heaney, C.D., Sams, E., Wing, S., Marshall, S., Brenner, K., Dufour, A.P., and Wade, T.J., 2009, Contact with beach sand among beachgoers and risk of illness: American Journal of Epidemiology, v. 170, no. 2, p. 164–172.

Nevers, M.B., and Whitman, R.L., 2008, Coastal strategies to predict *Escherichia coli* concentrations for beaches along a 35 km stretch of southern Lake Michigan: Environmental Science & Technology, v. 42, p. 4454–4460.

Wade, T.J., Calderon, R.L., Brenner, K.P., Sams, E., Beach, M., Haugland, R., Wymer, L., and Dufour, A.P., 2008, High sensitivity of children to swimming-associated gastrointestinal illness—Results using a rapid assay of recreational water quality: Epidemiology, v. 19, no. 3, p. 375–383.

Whitman, R.L., and Nevers, M.B., 2008, Summer *E. coli* patterns and responses along 23 Chicago beaches: Environmental Science & Technology, v. 42, p. 9217–9224.