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RAPID HEALTH-BASED METHOD FOR MEASURING MICROBIAL INDICATORS OF RECREATIONAL WATER QUALITY

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LTG 1 Poster 09

Science Questions

How can stressor levels, biological-response relationships, classification schemes, bioassessment methods, ecological risk assessments, and indicators be applied across U.S. surface waters to set criteria for identifying/restoring impaired water and maintaining designated uses?

How Research Addresses the Water Quality MYP Goals

Because the current approved cultural methods for monitoring recreational water require 24 hours to produce results, the public may be exposed to potentially contaminated water before the water has been identified as hazardous. Therefore, this project was initiated to find one or more rapid, health-based methods that could obtain results the same day water was tested. The results of this study will be communicated to the USEPA Office of Water in support of their efforts to develop new state and/or federal guidelines and limits for water quality indicators of fecal contamination. The new method(s), criteria, and guidance will allow the beach managers and public health officials to post warning signs or flags at the beaches or to close them in a timely manner in order to protect the public from exposure to unsafe water.

Research Objectives

- To evaluate rapid state-of-the-art measurement methods for bacteria that may indicate the presence of fecal pollution in recreational waters (beaches).
- To obtain, jointly with another EPA laboratory (NHEERL), a new set of water quality data and related health effects data at a variety of beaches across the U.S. in fresh, estuarine, and marine waters.
- To analyze the research data set to evaluate the utility of the tested rapid measurement method(s), used with the new EMPACT water sample collection protocol and the swimmer health survey, in order to establish a relationship between measured pathogen indicator organisms and observed health effects.
- To communicate the results to the USEPA Office of Water in support of their efforts to develop new state and/or federal guidelines and limits for water quality indicators of fecal contamination, so that beach managers and public health officials can alert the public about the potential health hazards before exposure to unsafe water can occur.

Research Methods & Collaboration

The beach epidemiological water study [National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study] consists of a water quality study of beaches waters using a rapid, same-day method to determine *Enterococcus* concentrations and a swimmer health survey of illness outcomes after exposure of the swimmers to the water.

Beach Sites



The NEEAR Water Study was conducted in 2003 and 2004 at four freshwater Great Lakes beaches that were influenced by point sources of wastewater.

- West Beach, Indiana Dunes National Lakeshore, Porter, Indiana.
- Huntington Beach, Bay Village, Ohio.
- Washington Park Beach, Michigan City, Indiana.
- Silver Beach, St. Joseph, Michigan.

2003 Beach Sites
2004 Beach Sites

1. Swimmer Health Survey (NHEERL)

Swimmer Health Survey Outcomes:

- Gastrointestinal illness (GI) – defined as any of the following:
 - Diarrhea – 3 or more loose stools in a 24-hour period.
 - Vomiting, nausea, and stomachache.
 - Cramp on activity and either nausea or stomachache.
- Upper Respiratory Illness (URI) – defined as any of the following:
 - Sore throat, cough, runny nose, cold, fever.
 - Skin rash.
 - Eye ailment – eye infection or watery eye.
 - Earache.

Definitions:

- Swimmer – a person who immersed his/her body in the water with or without head immersion.
- Non-Swimmer – a person who did not wade, swim or play in the water.
- Swimming-Associated Illness – the difference between the probability (or incidence) of illness among swimmers and the probability (or incidence) of illness among non-swimmers.
- Risk Ratio – the ratio of the probability of illness in the exposed group and the probability of illness in non-exposed group. The risk ratios, shown in Table 1, quantify the overall risk of swimming for the health outcomes studied.



NEEAR Study Design

- Two methods: QPCR and EPA Method 1600.
- Four freshwater Great Lakes beaches.
- Six sample locations (or nine at Huntington Beach).
- Three sample visits per day at 8 AM, 11 AM, and 3 PM.
- Saturdays, Sundays, and holidays.
- 8-12 weekends per beach.
- Concurrent survey of swimming-associated illnesses at each beach.
- Ancillary measures for each water sample, including beach, water, and weather conditions, pH and turbidity.



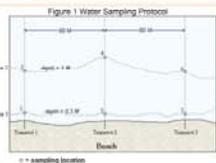
Research Results

- Results from the QPCR method were detected in the Smart Cycler Instrument (Cepheid) in "real-time" (i.e., ≤ 2 hours) and were correlated with the number of DNA copies.
- Enterococci* concentrations, obtained using the QPCR method, were significantly correlated with swimming-associated gastroenteritis (i.e., As the concentrations of *Enterococci* increased, the risk of gastroenteritis also increased) (See Figure 2).
- The incidence of GI illness was higher in children than in adults. Swimmers experienced an elevated incidence of gastrointestinal illness, rash, and earache compared to non-swimmers (See Table 1).
- The detection limit of the QPCR method is ~ 2 cells per sample.
- Inhibition was not a major problem with the QPCR method, as $< 5\%$ of sample extracts required additional dilutions.
- QPCR results were also correlated with the current EPA-approved Method 1600, especially at high pollution levels (See Figure 3).
- The "deep" sample was a slightly better predictor of GI illness than the "shin-deep" sample, but the overall average was more strongly associated with GI illness than the specific depth averages.

2. Water Quality Study and Rapid Method Evaluation (NERL)

Water Sample Collection:

Six water samples were collected three times a day at all beaches, except Huntington Beach along each of three transects perpendicular to the beach shoreline, one in waist-high water (i.e., 1 meter deep) and one in shin-high water (i.e., 0.3 meter deep) (See Figure 1), for a total of 18 samples per day. Because the rock piers/jetties at Huntington Beach prevented free circulation of water, three additional shin-high samples (9 samples three times a day, for a total of 27 samples per day) were collected at each visit using a modified sampling scheme to properly characterize the beach.



Microbiological Methods:

- USEPA Method 1600 – Membrane Filter Method for the Detection of *Enterococci* in Recreational Water.
- Quantitative Polymerase Chain Reaction (QPCR) for the Same-Day (≤ 2 hours) Detection of *Enterococci*.

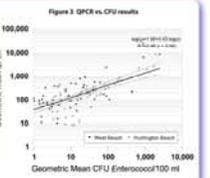
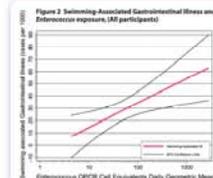
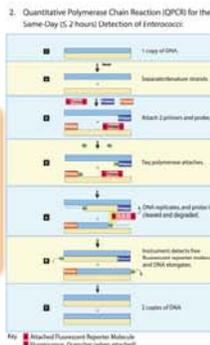


Table 1. Swimming and Illness

Great Lakes Region	Illness	Risk Ratio for Type of Illness	95% CI
Indiana	Swimming	1.21	0.81 - 1.81
Michigan	Swimming	1.31	0.91 - 1.91
Ohio	Swimming	1.41	1.01 - 2.01
Michigan	Non-Swimming	1.11	0.71 - 1.71
Ohio	Non-Swimming	1.21	0.81 - 1.81
Michigan	Non-Swimming	1.31	0.91 - 1.91
Ohio	Non-Swimming	1.41	1.01 - 2.01
Michigan	Non-Swimming	1.51	1.11 - 2.11
Ohio	Non-Swimming	1.61	1.21 - 2.21
Michigan	Non-Swimming	1.71	1.31 - 2.31
Ohio	Non-Swimming	1.81	1.41 - 2.41
Michigan	Non-Swimming	1.91	1.51 - 2.51
Ohio	Non-Swimming	2.01	1.61 - 2.61
Michigan	Non-Swimming	2.11	1.71 - 2.71
Ohio	Non-Swimming	2.21	1.81 - 2.81
Michigan	Non-Swimming	2.31	1.91 - 2.91
Ohio	Non-Swimming	2.41	2.01 - 3.01
Michigan	Non-Swimming	2.51	2.11 - 3.11
Ohio	Non-Swimming	2.61	2.21 - 3.21
Michigan	Non-Swimming	2.71	2.31 - 3.31
Ohio	Non-Swimming	2.81	2.41 - 3.41
Michigan	Non-Swimming	2.91	2.51 - 3.51
Ohio	Non-Swimming	3.01	2.61 - 3.61
Michigan	Non-Swimming	3.11	2.71 - 3.71
Ohio	Non-Swimming	3.21	2.81 - 3.81
Michigan	Non-Swimming	3.31	2.91 - 3.91
Ohio	Non-Swimming	3.41	3.01 - 4.01
Michigan	Non-Swimming	3.51	3.11 - 4.11
Ohio	Non-Swimming	3.61	3.21 - 4.21
Michigan	Non-Swimming	3.71	3.31 - 4.31
Ohio	Non-Swimming	3.81	3.41 - 4.41
Michigan	Non-Swimming	3.91	3.51 - 4.51
Ohio	Non-Swimming	4.01	3.61 - 4.61
Michigan	Non-Swimming	4.11	3.71 - 4.71
Ohio	Non-Swimming	4.21	3.81 - 4.81
Michigan	Non-Swimming	4.31	3.91 - 4.91
Ohio	Non-Swimming	4.41	4.01 - 5.01
Michigan	Non-Swimming	4.51	4.11 - 5.11
Ohio	Non-Swimming	4.61	4.21 - 5.21
Michigan	Non-Swimming	4.71	4.31 - 5.31
Ohio	Non-Swimming	4.81	4.41 - 5.41
Michigan	Non-Swimming	4.91	4.51 - 5.51
Ohio	Non-Swimming	5.01	4.61 - 5.61
Michigan	Non-Swimming	5.11	4.71 - 5.71
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Michigan	Non-Swimming	5.91	5.51 - 6.51
Ohio	Non-Swimming	6.01	5.61 - 6.61
Michigan	Non-Swimming	6.11	5.71 - 6.71
Ohio	Non-Swimming	6.21	5.81 - 6.81
Michigan	Non-Swimming	6.31	5.91 - 6.91
Ohio	Non-Swimming	6.41	6.01 - 7.01
Michigan	Non-Swimming	6.51	6.11 - 7.11
Ohio	Non-Swimming	6.61	6.21 - 7.21
Michigan	Non-Swimming	6.71	6.31 - 7.31
Ohio	Non-Swimming	6.81	6.41 - 7.41
Michigan	Non-Swimming	6.91	6.51 - 7.51
Ohio	Non-Swimming	7.01	6.61 - 7.61
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Ohio	Non-Swimming	8.01	7.61 - 8.61
Michigan	Non-Swimming	8.11	7.71 - 8.71
Ohio	Non-Swimming	8.21	7.81 - 8.81
Michigan	Non-Swimming	8.31	7.91 - 8.91
Ohio	Non-Swimming	8.41	8.01 - 9.01
Michigan	Non-Swimming	8.51	8.11 - 9.11
Ohio	Non-Swimming	8.61	8.21 - 9.21
Michigan	Non-Swimming	8.71	8.31 - 9.31
Ohio	Non-Swimming	8.81	8.41 - 9.41
Michigan	Non-Swimming	8.91	8.51 - 9.51
Ohio	Non-Swimming	9.01	8.61 - 9.61
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Ohio	Non-Swimming	9.21	8.81 - 9.81
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Michigan	Non-Swimming	9.51	9.11 - 10.11
Ohio	Non-Swimming	9.61	9.21 - 10.21
Michigan	Non-Swimming	9.71	9.31 - 10.31
Ohio	Non-Swimming	9.81	9.41 - 10.41
Michigan	Non-Swimming	9.91	9.51 - 10.51
Ohio	Non-Swimming	10.01	9.61 - 10.61

* Risk Ratio are statistically significant at $p < 0.05$.

Research Conclusions & Future Directions

- Enterococcus* QPCR cell equivalents were associated with gastrointestinal illnesses at freshwater Great Lakes beaches, influenced by point sources of wastewater.
- The 8 AM water sample analyses were predictive of illness the same day.
- None of the other illnesses studied produced relationships with the QPCR cell equivalents supportive of swimmer protection and criteria development.
- Results from this study may lead to the development of new criteria for beach closings based on same-day measurements.
- Use of the QPCR method, which is capable of producing "real time" results in ≤ 2 hours, will allow beach managers and public health officials to alert the public in a timely manner about potential health hazards at Great Lakes beaches, thereby reducing waterborne illness.
- This research reported the results obtained at the freshwater, Great Lakes beaches studied in 2003 and 2004. In 2005, the first marine water beach (Edgewater Beach, Biloxi, Mississippi) was studied, and an estuarine beach, Goddard Memorial State Park Beach, Warwick, Rhode Island, is being considered for the summer of 2006. Other estuarine and marine beaches will be studied in the future.

Interactions with Customers

- The USEPA Office of Water:
 - The Office of Research and Development and the Office of Water jointly developed the Action Plan for Beaches, which outlined the research needed for preparing a criteria document for recreational waters.
 - The Office of Research and Development has included staff from the Office of Water on all Peer Review Panel meetings.
 - The Office of Research and Development has maintained a close liaison with the Office of Water during the course of the NEEAR study, informing them of the progress of the study on a routine basis.
- Stakeholders (Includes state and local beach authorities, beach managers, public health officials, USEPA Regions, the scientific community, and the public):
 - The Office of Research and Development participated in five regional beach conferences, which provided a platform for informing stakeholders of the progress of the NEEAR study and also for presenting preliminary data from the study.
 - USEPA Regional personnel and some Office of Water Staff assisted with the field studies.
 - Presentations have been made at workshops and other scientific meetings in various parts of the United States to groups that have an interest in recreational water and public health safety in order to keep them aware of the U.S. Environmental Protection Agency's research efforts in this area.
 - Data developed during the course of this study have been published in peer reviewed journals.

How Research Contributes to Outcomes

The data from this research study will be used by the USEPA Office of Water to develop new health-based criteria and guidelines for recreational water quality. The rapid QPCR method provided by this study is capable of producing results within 2 hours of sample analysis and will allow beach managers and public health officials to alert the public before they are exposed to potential health hazards, thereby reducing waterborne illness.