National Recreational Water Quality Workshop

April 6-8, 2021

Virtual Workshop

This workshop is funded by the U.S. EPA

The goal for this workshop is to aid recreational water managers, researchers, stakeholders and public health officials at all levels to share information and ideas about implementing and supporting a successful recreational water program. This workshop will focus on two common contaminants: harmful algal blooms and fecal contamination. The workshop will provide information on tools, training and an opportunity to discuss strategies for managing and monitoring HABs and fecal contamination in recreational waters. The workshop will provide opportunities for sharing across programs on management of these issues.

This workshop is funded by the U.S. EPA

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Abstracts

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1. *Integrating Children's Exposure in Risk Assessment*

Authors: Helena Solo-Gabriele, Alesia Ferguson, Maribeth Gidley and Kristina Mena

Topic Area: Risk Assessment

Name of Presenter: Helena Solo-Gabriele

Affiliation: University of Miami, Dept. of Civil, Arch., and Environmental Engineering

Children Activities at Recreational Beaches and Integration with Microbial Risk Assessment

Helena Solo-Gabriele_1, Alesia Ferguson_2, Maribeth Gidley_1 and Kristina Mena_3

1 University of Miami, Coral Gables, FL

2 North Carolina Agricultural and Technical University, Greensboro, NC

3 University of Texas - Houston, School of Public Health, Houston, TX

Quantitative Microbial Risk Assessment (QMRA) requires documentation of activities that impact exposure to environmental contaminants. Such documentation is limited for children's activities in beach settings. The objective of the current study was to gather quantitative data about children's beach activities through: 1) a questionnaire administered to 400 adult beach-goers about their perceptions of child beach play, and 2) participation of 122 children (< 7 years) within a beach study (at two beaches in Miami, FL and two beaches in Galveston, TX) that included several components. The beach study components included: sand adherence studies to document quantities of sand adhered to the hands and body, documentation of abrasions, and a one-hour videotape and translation of the video-tapes to document the child's micro activities. Results show high variability in how children play on the beach, influenced more by age and less by gender. Overall, older children preferred water as compared to younger children with the younger ones preferring dry sand. Sand adherence averaged 10.65 mg/cm2, with higher levels for children with wet hands in comparison to children with dry hands. It was found that 58.2% of children had at least one existing abrasion before playing at the beach, while 8.2% of children had acquired a new abrasion during one-hour of beach play. The results from the beach video-taping activities show that children spent most of their time in seawater (47.9%), followed by the dune ridge area (18.8%), while they spent the most time contacting nothing (24.2%), plastic toys (25.8%) and seawater (18.6%) with the right hand (with similar findings for the left hand). The majority of the time, the mouth was not in contact with anything, however on occasions children ate on the beach (approx. 3 % of time). On occasions, they put items such as toys, sand or seaweed in their mouths. These detailed sand adhereance, abrasion data, contact and time-spent activities improve the accuracy of estimates for dermal, inhalation and ingestion exposures to beach microbial contaminants. Such information can be integrated into QMRA to provide more accurate estimates of exposure to beach microbes. An example of integration of this information into QMRA will be presented.

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2. *Outbreaks Associated with Untreated Recreational Water — United States, 2009-2017*

Michele C. Hlavsa, Mia C. Mattioli, Kayla Vanden Esschert, Aron J. Hall, Elizabeth D. Hilborn, Virginia A. Roberts, Timothy J. Wade

Introduction: Outbreaks associated with fresh or marine (i.e., untreated) recreational water can be caused by pathogens, toxins, or other chemical agents. To help promote healthy swimming in untreated recreational water and advance prevention efforts, we characterized untreated recreational water–associated outbreaks.

Methods: Public health officials in the 50 states, the District of Columbia, and U.S. territories voluntarily report outbreaks associated with recreational water to CDC via the Waterborne Disease and Outbreak Surveillance System.

Results: During 2009–2017, public health officials from 30 states voluntarily reported 98 untreated recreational water–associated outbreaks to CDC. These outbreaks resulted in 4,542 cases. Most outbreaks started during June–August (82 [84%]); most were associated with either a park or beach setting (61 [62%]). Of the 98 outbreaks, 68 (69%) had a confirmed infectious etiology; four (4%) were confirmed to be caused by cyanotoxin. Enteric pathogens caused 64 (65%) outbreaks, resulting in 2,536 cases. Norovirus (17 [17%] outbreaks), *Shiga* toxin–producing *Escherichia coli* (15 [15%]), *Cryptosporidium* (13 [13%]), and *Shigella* (12 [12%]) were the leading confirmed infectious etiologies.

Conclusions: Understanding contamination of untreated recreational water is key to preventing these outbreaks. This, in part, requires engaging and educating the public about healthy swimming before and during June–August. Healthy Swimming messages include heeding posted advisories closing the beach to swimming, not swimming while sick with diarrhea, and not swallowing the water you swim in.

This abstract does not represent EPA policy.

This workshop is funded by the U.S. EPA

3. The One Health Harmful Algal Bloom System (OHHABS)

Author: Virginia A. Roberts [1]; Gabriella E. Veytsel [1, 2]; Marissa K. Vigar[1]; Jonathan Yoder[1]

[1]*Centers for Disease Control and Prevention,* [2] *Oak Ridge Institute for Science and Education*

Topic area: Risks to Recreation, Public health impacts of harmful algal blooms

Name of presenter: Virginia A. Roberts

Affiliation: Centers for Disease Control and Prevention

Harmful algal blooms (HABs) are an emerging public health challenge in coastal and inland waters. Humans and animals can become ill from exposure to HABs and their toxins, however, gaps in current knowledge and research limit identification and understanding of HAB-associated illnesses. Signs and symptoms in humans and animals range from mild to life-threatening, depending on the toxin, dose, and route of exposure. Additional epidemiological, clinical, and environmental data are needed to characterize health outcomes and link them to HAB exposures. To help address data gaps, the Centers for Disease Control and Prevention (CDC) engaged partners to develop the One Health Harmful Algal Bloom System (OHHABS). OHHABS was launched in 2016 to systematically collect data about HAB events as well as cases of human or animal illness associated with HAB exposures. State and territorial health departments can voluntarily report to OHHABS and work with animal health, environmental, and other partners to strengthen public health investigation, detection, and reporting of HAB events and illnesses. OHHABS data will be used to inform and guide public health prevention, response, and mitigation efforts. OHHABS is an example of One Health surveillance. A One Health approach recognizes connections between the health of people, animals, and the environment, and supports collaboration across sectors and disciplines. This presentation will describe how the system works, supporting tools and resources for HAB surveillance, and next steps for sharing data and lessons learned.

This workshop is funded by the U.S. EPA

4. Canine Mortalities in Michigan, Water Exposure

Authors: Susan Peters, DVM, MPH, Michigan Department of Health and Human Services

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Jason Travis, RS, Central Michigan District Health Department

Corresponding Author: Susan Peters, DVM, MPH, Waterborne Disease Epidemiologist, Michigan Department of Health and Human Services.

Introduction

In July 2019, a citizen reported four canine deaths and an additional canine illness to the Michigan Department of Environment, Great Lakes, and Energy. Three dogs had symptoms consistent with poisoning, including vomiting, neurologic signs, and rapid deterioration; two dogs had sudden, unobserved deaths. All dogs were exposed to the citizen's pond before illness onsets. Based on symptoms and exposures, cyanotoxins were suspected as the cause.

Methods

Several state agencies and the local health department conducted owner interviews and site investigations. Pond water collected in July and August was tested for microcystin, anatoxin-a, and cylindrospermopsin. During the second water collection, Chara growth at the pond bottom was disturbed; water was then collected at different depths. The artesian well feeding the pond was tested for arsenic, nitrates, and coliforms. Necropsies were performed on two deceased dogs.

Results

No cyanobacterial blooms were noted. There was no evidence of industrial, environmental, or agricultural contamination or access to toxicants. Pond water from July was negative for cyanotoxins. The artesian well testing was negative except for a slightly elevated arsenic level. Two water samples collected in August from the area of Chara disturbance tested positive for anatoxin-a. Oscillatoria cyanobacteria was identified in the toxin-positive samples. The canine gross necropsy findings were unremarkable; tissues were too autolyzed for additional examination.

Discussion

Oscillatoria is a benthic cyanobacteria known to produce anatoxin-a. The dogs' symptoms were consistent with anatoxin-a exposure. This investigation was the first documented animal toxicosis from benthic cyanobacteria in Michigan and highlighted Michigan's collaborative approach to harmful algal blooms.

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United States Environmental Protection Agency

5. The National Aquatic Resource Surveys: Findings and Applications on Nutrients, Algal Toxins and Pathogens Across the Country

Author: Sarah Lehmann, U.S. EPA Office of Water

Topic Area: Water Monitoring

The National Aquatic Resource Surveys (NARS) are statistical surveys designed to assess the quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands. EPA, states and tribes work together to implement NARS collecting data at more than 1000 sites each year. Using a stratified random design to select sites and consistent sampling protocols, the surveys tell us how widespread water quality problems are across the country, estimate the extent of waters affected by key stressors and track changes over time. Recreational data collected and assessed from surveys to date include microcystins, cyanobacteria, and enterococci. This presentation will present algal and pathogen related findings from the surveys at the national and ecoregional scale. The presentation will also describe upcoming monitoring and assessment plans. Additionally, participants will be asked to consider ways that the NARS data could be leveraged to support state/local needs now and in the future.

This workshop is funded by the U.S. EPA

1. Five Years of Enterococci qPCR in Chicago: Research to Practice

Author: Kendall W. Anderson, MS, MPH

Topic Area: Advances in Monitoring, Approaches and Technology

Chicago Park District
Beach Water Quality Project Manager Chicago Park District

Quantitative polymerase chain reaction (qPCR) is a relatively new method for beach water quality monitoring programs that offers significant advantages over culture-based methods. The biggest advantage of qPCR is that sampling results are available within 2-4 hours as opposed to 18-24 hours with culture-based methods; however, qPCR requires more technical expertise in methods, analysis, and equipment than culture-based methods, making it somewhat difficult to implement with limited resources. In 2015, the Chicago Park District (CPD) began a pilot study of enterococci qPCR as an alternative method to culturable *E. coli* with limited implementation. After two years of the pilot study, the CPD switched exclusively to enterococci qPCR in 2017 for routine beach monitoring and ceased monitoring through culturable *E. coli* for all 27 public beaches. Samples are taken once per day by a university contractor just before dawn between Memorial and Labor Day annually, culminating in over 4,000 samples. During the beach season, results are typically made available to the CPD within four hours of sample collection via email and a real time data pipeline. This allows the CPD to typically activate its notification system by noon the same day. Public notification is facilitated by website posting, a telephone hotline message, email to stakeholders/city council members, lifeguards, physical beach flags, rewritable signage, and Illinois BeachGuard. This presentation will cover lessons learned and components essential to the function and evolution of a rapid monitoring protocol. We hope our experiences can serve as a model to other programs.

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2. Towards a Quantitative Human Fecal Source Identification Recreational Water Quality Management Tool

Orin C. Shanks[1]
[1] U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, USA

Researchers and managers alike recognize the advantages of quantitative human fecal pollution source information to help solve long-standing recreational water quality challenges. Research studies report the use of human-associated microbial source tracking technologies to assess water quality impacts from failing septic systems, leaking sewer lines, combined sewer overflows, and other waste management practices, as well as estimating associated recreational water public health risks. This growing interest in fecal source identification methods signals a potential to transform these experimental tools into mainstream water quality management protocols. As a result, the United States Environmental Protection Agency maintains in active research program focused on the development, validation, and implementation of human fecal source identification methodologies. This presentation will describe the recently released EPA Methods 1696 and 1697 standardized protocols for the characterization of human fecal pollution in water by quantitative real-time PCR and provide an overview of related research activities.

Keywords: Microbial source tracking, human fecal pollution, qPCR, EPA Method 1696

This workshop is funded by the U.S. EPA

3. *Using Next Generation qPCR to Monitor for Toxic Cyanobacteria*

Authors: Laura Webb, Regina Klepikow, Steven Baker, Amy

Shields – EPA Region 7; Heath Mash, Eric Villegas, Jingrang Lu –EPA Office of Research and Development

Topic Area: Emerging Concerns for recreational water quality or Monitoring and rapid assessment

Presenter: Laura Webb, EPA Region 7, Kansas City, KS.

Toxic Cyanobacteria pose a significant threat to freshwater systems, both for drinking water and for recreation. This project evaluated the use of new molecular-based technology to identify the cyanobacterial species that produce toxins and factors that promote toxic blooms. Combined with ongoing monitoring efforts, the data will provide a comprehensive assessment of the development of harmful algal blooms. The EPA Region 7 Monitoring and Environmental Assessment Branch began a 2-year project collecting data from 5 regional lakes to develop molecular techniques to assess harmful algal blooms. Samples were collected weekly at three distances from the shoreline by wading into the lake and then composited. Chemical, physical, and bacterial samples were analyzed by the regional laboratory, EPA's Office of Research and Development (ORD), and Lawrence Berkley Laboratory (LBL). Preliminary data presented here show correlation between land use/land cover and nutrients and chemical parameters. Cyanobacterial abundance and diversity can be matched from microscopic observations and molecular data. Chemical stressors were identified in the data that correlated to cyanobacterial abundance. Molecular data shows application to determine toxicity of the bloom one or two weeks ahead of toxins being detected in the water and promises to be a useful tool to assess recreational water quality.

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4. Derivation of the Equivalent qPCR Value for Escherichia coli to Existing Culture-based Water Quality Standards for Monitoring Beaches in Michigan

Authors: Shannon Briggs[1], Mano Sivaganesan[2], Rich Haugland[2], Shawn Siefring[2], Manju Varma[2], Kevin Oshima[2], Al Dufour[2], Sharon Nappier[3], Brian Schnitker[3]
1. Department of Environment, Great Lakes, and Energy, Water Resources Division, 525 West Allegan Street, Lansing, MI, USA

2. United States Environmental Protection Agency, Center for Environmental Measurement and Modeling, 26 West Martin Luther King Drive, Cincinnati, OH, 45268, USA

3. United States Environmental Protection Agency, Office of Science and Technology, 1200 Pennsylvania Avenue NW, Washington DC. 20460

Topic Areas:

Monitoring and rapid assessment of water quality

State/tribal and local water monitoring (lessons learned, practical applications, new techniques)

Name of Presenter: Shannon Briggs,

Affiliation: Department of Environment, Great Lakes, and Energy, Water Resources Division, 525 West Allegan Street, Lansing, MI, USA;

A quantitative polymerase chain reaction (qPCR) method (Draft Method C) has been developed for *Escherichia coli (E. coli)* by the United States Environmental Protection Agency (USEPA). To implement Draft Method C for monitoring beaches in Michigan, the Department of Environment, Great Lakes, and Energy led a 3-year effort with fourteen labs to share 6,669 water samples from 108 beaches with the USEPA Center for Environmental Measurement and Modeling, (CEMM). Selected beaches were representative of both the upper and lower peninsulas of Michigan with urban and rural locations on inland lakes and the Great Lakes. Samples were analyzed by local labs using a state-approved and USEPA-approved culture method (Colilert) and by both CEMM and the local labs using Draft Method C. Linear relationships between culture and Draft Method C results were determined. Final analysis was based on results from a combined total of 2,092 samples from 39 beaches with at least one exceedance of the Michigan water quality standard by culture, at least 10 paired samples with quantitative estimates for both methods, and a minimum R^2 of 0.6 between the methods per beach. From this analysis, a Draft Method C qPCR value of 1.863 $\log_{10}$ copies per reaction was determined to be equivalent to the Michigan culture standard of 300 *E. coli* per 100 milliliters (ml). The new beach notification value for Draft Method C will be implemented for monitoring Michigan beaches and will improve the protection of public health by providing results in hours instead of the next day.

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5. Predictive Models and Fast Detection of Coliphages for a Paradigmatic Improvement in Rapid Assessment of Water Quality

Anicet R. Blanch, Francisco Lucena and Juan Jofre

Dept. Genetics, Microbiology and Statistics / Water Research Institute (IdRA), University of Barcelona. Spain

Topic area: Monitoring and rapid assessment of water quality

Name of presenter: Anicet R. Blanch

The microbiological quality of recreational water has been significantly improved by the establishment of regulatory guidelines. Quality is assessed mainly through bacterial indicators (*E. coli* and/or enterococci) but this approach does not provide information about viral pathogens, thus risking waterborne viral outbreaks. There is widespread consensus that coliphages are the most helpful indicators of enteric virus contamination. Moreover, coliphages are proving to be useful single indicators of water quality, reducing the need for concomitant application of bacterial indicators.

Any improvement in water quality assessment needs to consider a wide range of fecally contaminated water profiles determined by two factors: space (e.g. small versus large beaches; distance from sewage outfalls or river mouths; diffuse pollution reception, etc.) and weather (e.g. wet versus dry season; sudden storms during the dry season, etc.). Protecting recreational water users involves keeping them informed about the state of fecal contamination. This requires 1) predictive models based on health risk assessment and 2) rapid analysis of the results of water monitoring.

Quality prediction models were applied in accordance with current EU regulations in Barcelona beaches, used by millions of persons during the bathing season. We developed a prediction model based on coliphage analysis, supplying information for modeling in a maximum of 4 hours. Coliphages can be detected within a working-day with methods that are faster than bacterial indicator techniques. Predictive models based on risk assessment and rapid coliphage analysis constitute a significant contribution to water quality assessment, complementing the information obtained by bacterial indicators.

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6. *Portable System for Early Detection of Harmful Algal Bloom Toxins*

Sarah Bickman, Isabella Vinsonhaler and Michael Lochhead

Presenter: Sarah Bickman

Affiliation: MBio Diagnostics

Topic: Advances in Monitoring, Approaches and Technology

Harmful Algal Blooms in freshwater and marine environments are increasing in frequency and duration and constitute a growing public health threat while carrying substantial economic, ecologic, and food supply implications. Recent development of guidelines for microcystin (MC) and cylindrospermopsin (CYN) in drinking and recreational water has increased the need for rapid onsite testing. MBio Diagnostics is developing a transformative platform technology that will enable users in the field to perform laboratory-quality, cost-effective cyanotoxin testing that helps protect human health and provides critical data for ecosystems management. MBio's patent-protected cartridge and reader system provide an unprecedented combination of speed, ease-of-use, quantitation and results multiplexing in a field-portable system. Here, we present results from a one-step, 10-minute duplex assay for microcystin and cylindrospermopsin. With this simple and rapid protocol, 50% inhibition concentrations for both assays are 1 ng/mL. Eleven common MC congeners were measured with cross-reactivities similar to reference tests measured simultaneously. Over 40 natural lake water samples were measured on the MBio assay in comparison to reference testing. Concordance between these methods demonstrates that the MBio assay is not affected by common interferents found in natural water samples. A one-step, 10-minute mechanical cell lysis method enables a fully integrated, field-portable kit.

This workshop is funded by the U.S. EPA

7. Use of Novel Autonomous Technology for Improved Water Quality Monitoring in High Priority Recreational and Shellfish Harvesting Waters

Authors: Carly Dinga[1], *A. Denene Blackwood[1], Thomas Clerkin[1], Everette Newton[2], and Rachel Noble[1]

Topic area: Remote sensing and other technologies

Name of presenter: Denene Blackwood

Affiliations: [1]UNC Chapel Hill Institute of Marine Sciences, 3431 Arendell Street, Morehead City, NC 28557

[2]Duke University Marine Laboratory, Marine Robotics and Remote Sensing Laboratory, 135 Pivers Island Road, Beaufort, NC 28516

Traditional recreational water quality monitoring lacks the capability to provide rapid (<24 hr.) results and to provide data from acute events (foul weather, chemical, or sewage spills) that cause rapid fluctuations in water quality. Autonomous technology can be used for discrete and temporal monitoring at remote locations that cannot be captured with a single grab sample. Beaufort (NC), a coastal town of 4,000 residents with a burgeoning tourist population, is experiencing exponential infrastructure growth in anticipation of a new interstate coming to the region. As the area grows, water quality is expected to degrade due to overburdened septic systems, sewage overflows and increased storm water runoff. With waterways used both recreationally and commercially, contamination events could directly expose the population to human pathogens. Our uniquely designed autonomous boat includes a deployable fluorometer, YSI multi-parameter sonde, and CTD, with geotagged water sample collection along transects at identical points, providing the consistency necessary to make transect-based assessments of microbial contamination. During proof of concept deployments, samples were processed for *Enterococcus, E coli, Vibrio* sp. and human associated molecular markers. Results indicated that enterococcus concentrations increased 3 orders of magnitude following wet weather and Vibrio responded significantly to salinity fluctuations, but not temperature. The use of autonomous technology allowed for improvement of spatial and temporal resolution at this site, enabling managers to better understand the frequencies at which monitoring should occur. Future work will combine autonomous technologies with a near real-time remote sensing monitoring frame work to help identify potential public health risks.

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8. Antimicrobial Resistance in Wastewater Effluent Streams Discharging to Urban Coastal Waters

Joshua A. Steele, Rachel Diner, Madison L. Griffith, Thomas Harper, Jeffrey Chokry, David Wanless, Amy G. Zimmer-Faust, John F. Griffith

Topic Area: Emerging concerns for recreational water quality

Presenter: Joshua A. Steele

Southern California Coastal Water Research Project, Costa Mesa, CA, USA

Antibiotic resistant infections from community-acquired sources have raised concerns about antimicrobial resistant (AMR) bacteria entering the sewer system, being discharged directly into the ocean, rivers, and streams; ultimately making their way to highly populated beaches. Yet, the impact of treatment level and the fate of AMR bacteria and genes after they are discharged into the environment remains understudied. We measured the abundance of AMR bacteria and genes in wastewater from 10 plants in southern California with treatment processes ranging from minimal treatment (primary) to high levels of disinfection (tertiary). Quarterly samples of raw influent and final effluent were collected both for cultivation/isolation and for quantification of resistance genes. AMR bacteria and genes discharged in the environment. Carbapenem Resistant Enterobacteriaciae (CRE); Vancomycin Resistant Enterococci (VRE), and Methicillin Resistant *Staphylococcus aureus* (MRS) were cultivated and quantified in wastewater. Viable AMR bacteria were found in the effluent of every plant with CRE and MRSA detected most frequently across treatments. Concentrations of AMR bacteria lower in effluent (0-10^4 CFU/100ml) compared to influent (1-10^5 CFU/100ml). AMR genes were found at higher concentrations than viable ARB in both influent (10^5-10^7 copies/100ml) and effluent (below detection-10^6 copies/100ml). Higher levels of treatment produced greater reduction in AMR bacteria and gene concentrations being discharged into recreational waters. While the reduction in AMR bacteria and genes following tertiary treatment is encouraging, large quantities of AMR bacteria and genes are being discharged. This presents both a potential to spread resistance and unknown consequences for human or environmental health.

This workshop is funded by the U.S. EPA

1. Beach Report Card and NowCast: Successes and Challenges of Public Water Quality Notifications

Author & Name of Presenter: Luke Ginger

Topic Area: Notification and Risk Communication

Affiliation: Heal the Bay

Heal the Bay has been informing the public about where and when it is safe to get in the water for over 30 years. This has been accomplished primarily through our Beach Report Card program which provides easy-to-understand water quality information for free to the public at over 700 locations across the West Coast. More recently, Heal the Bay has provided water quality predictions alongside grades using our NowCast program, which can predict water quality at more than 20 beaches during summer months. Providing the public with multiple water quality assessments and advisories comes with many challenges. This presentation will touch on methods used to grade and predict water quality. But, the main focus will be on how we overcome the challenges of ensuring effective messaging, awareness, and user comprehension. The presentation will also describe how Beach Report Card and NowCast address differences in regulations across jurisdictions.

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2. Lake Erie Beach Monitoring and Public Notification Database: Beachguard

Jenifer Hassinger, Ohio Department of Health

The State of Ohio monitors beaches along the Lake Erie coastline through USEPA Beach Grant funding. The monitoring surveys and water sample results are documented into the interactive Beachguard database by local and state agencies, where bacterial advisories and harmful algal bloom advisories can be posted for public view and notification by email, phone call, or text message. Water sample results and notification data then can be sent through the newly developed node from the Beachguard application to the US EPA.

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3. Improving the Communication Strategy for the S.C. Beach Monitoring Program

Author: Bryan Rabon, Lindsey Lachenmyer, and Ronnie Martin
Topic area: Communicating water quality conditions to the public and other agencies
Presenter: Lindsey Lachenmyer
Affiliation: South Carolina Department of Environmental Control (DHEC)

South Carolina's Beach Monitoring Program operates from May 1st to October 1st and monitors 123 stations. The sampling system is mainly divided into tier 1 (weekly sampling) and tier 2 (twice a month) beaches based on bacteria contamination risk and the average amount of people using the beach. Currently the public is notified about swimming advisories mainly through posted beach signs and press releases, but the program has been trying to improve its communication strategy. The Department of Health and Environmental Control has been working with local municipalities to develop a more modern communication program that educates the public at the beach and to make an informed decision about entering coastal waters. A new website was created, Checkmybeach.com, to direct people at the beach to check the status of advisories online. A pilot study for tier 1 beaches advertising this website with a QR link was conducted with the help of local municipalities at the end of the 2019 beach season. The web traffic data showed that the QR link and Checkmybeach.com directed an average 30% of the web traffic each day after the project started. South Carolina's Beach Monitoring Program is moving forward with this communication strategy and is developing the website to include more information on beach safety, such as rip currents. The next step of the program is to expand the use of Checkmybeach.com to reach all of the beaches along South Carolina's east coast.

This workshop is funded by the U.S. EPA

4. Monitoring & Public Notification Program for Harmful Algal Blooms in Recreational Lakes

AUTHOR: Matthew Graul and Rebecca Tuden

TOPIC: Monitoring and Rapid Assessment of Water Quality, Communicating to the Public and other agencies

PRESENTER: Matthew Graul

AFFILIATION: East Bay Regional Park District

Over the last two decades, the occurrence of harmful algal blooms in recreational lakes has been increasing in frequency throughout the United States. This presentation will provide participants with guidance on the development of algal monitoring and toxin testing programs to protect public health and discuss strategies for public outreach and notification during harmful conditions. The East Bay Regional Park District manages nine freshwater lakes that provide recreational swimming, boating and fishing opportunities. Since starting a monitoring program in 2014, the Park District experienced more than twenty algal blooms that produced short term toxic conditions in recreational lakes. To safely manage water recreation areas, the Park District developed an extensive algal toxin monitoring program, implemented a public notification strategy, and coordinated with statewide guidelines and local health departments to protect the public. The presentation will identify lessons learned in implementing a monitoring program and key decision points for recreational lake managers to use as guides for their own monitoring, posting and notification program.

This workshop is funded by the U.S. EPA

1. *Tracking Land-based Sources of Nutrients and Microbial Contamination in a Pacific Northwest Estuarine Watershed*

Authors: Amity Zimmer-Faust[1], Cheryl Brown[2], Jim Kaldy[2], TChris MochanCollura[2], Orin C. Shanks[3], and York Johnson[4]

Name of Presenter: Amity Zimmer-Faust

Topic Area: Source tracking

[1]Southern California Coastal Water Research Project, Costa Mesa, CA, USA

[2]U.S. Environmental Protection Agency, Office of Research and Development, Newport, OR, USA

[3]U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, USA

[4]Tillamook Estuaries Partnership, Garibaldi, Oregon 97118

Tillamook Bay (Oregon, USA) often experiences water quality impairments due to low oxygen levels and elevated fecal bacteria counts. Potential pollutant sources in this mixed-use watershed include agricultural (extensive dairy operations in lowlands), wildlife, and human (municipal and onsite wastewater treatment systems) waste, making fecal pollution management challenging. In this study, a multiple water quality metric approach was used to characterize fecal indicator bacteria (FIB), microbial source tracking (MST) genetic markers, and nutrients in surface waters. Water samples were collected from 16 tributary sites, above and below potential anthropogenic pollution sources on each river system draining into Tillamook Bay. Paired measurements of MST markers indicating human (HF183/BacR287 and HumM2), ruminant (Rum2Bac), cattle (CowM2 and CowM3), canine (DG3), and avian (GFD) fecal pollution sources were compared to parallel nitrate isotopic composition ($\delta^{15}N_{NO3}$), nutrient, and *E. coli* (MPMN/100mL) measurements. In tributaries, seasonal and spatial patterns were evident, with cow and human MST marker levels increasing along a downstream gradient. During the wet season, ruminant marker levels were highly correlated with *E. coli* (r^2 = 0.89) and nitrate isotope (r^2= 0.83). Nitrogen load estimates from SPARROW demonstrate that manure and fertilizer explain >80% of the variation in ruminant marker, *E. coli*, and nitrate isotope levels. Results support the utility of using a combined water quality metric approach for tracking land-based pollutant sources in complex watersheds.

This workshop is funded by the U.S. EPA

2. *Ambient Water Quality Thresholds for Human-associated HF183: Effect of Water Temperature, Aging, and Co-contamination with Gull Feces*

Alexandria Boehm, Jeffrey Soller, Kenneth Schiff, and Clint Boschen.

A number of studies have used quantitative microbial risk assessment (QMRA) to derive potential risk-based water quality thresholds (RBTs) for a diverse set of novel water quality indicators. Over time, the QMRA approach has been refined with respect to model inputs and hazard characterization. Recent work considered differential decay of pathogens and indicators, and mixtures of contamination of diverse ages. In the present study, we present a refined ambient water quality RBT for human-associated HF183. The new estimate updates previous work as it specifically considers contamination aging through the inclusion of temperature-dependent organism decay, and the presence of mixtures of human sewage contamination of diverse ages. Based on these analyses, and the local data and conditions considered representative of coastal Southern California recreational waters, we derived an RBT median value of ~500 HF183 copies/100 mL as representative of conditions consistent with those described in the 2012 RWQC (i.e. 32 illnesses/1000). In California's coastal recreational waters, microbial contamination due to gulls is also common. To account for this, we consider the case where human contamination from sewage co-occurs with contamination from gull feces. The resultant proposed median RBTs for HF183 range from 1 to ~500 copies/100 ml and are a function of the amount of gull fecal contamination that is present in the water. The proposed RBT are currently being considered in a regulatory context for the evaluation of coastal water quality.

This workshop is funded by the U.S. EPA

3. MERA – an Integrated, Transdisciplinary Study of Water Quality and Human Health at a Tropical Beach

Authors: Valerie J. Harwood, Erin M. Symonds, Adriana Gonzalez, Mya Breitbart, Maryann R. Cairns

Topic area: Restoring Waters to Recreational Use – Application and Tools

Name of presenter: Valerie J. Harwood

Affiliation: University of South Florida

Microbial water quality at recreational beaches has historically been the purview of environmental microbiologists and environmental regulators. Epidemiology studies in recreational waters have provided some connections between fecal indicators and human health risk, but the number and geographic distribution of these studies has been limited, particularly in less developed countries.

Human cultural practices profoundly affect behavior at beaches, thereby influencing the level of risk experienced by individuals, but ethnography has received little attention in recreational water quality studies. The transdisciplinary MERA study combines sanitary surveys, measurements of fecal indicators, microbial source tracking markers, and pathogens, epidemiology, quantitative microbial risk assessment and ethnography to achieve an integrated understanding of water quality and human health risk at a tropical beach in Costa Rica. Year 1-2 included a pilot study that found evidence of pervasive human sewage contamination and pathogens originating from three rivers that discharge to popular Jacó beach. A prospective cohort study of the health effects of recreational water use in conjunction with an ethnography study of human behaviors and attitudes about the beach was carried out in year 3, along with continued water quality measurements. Over 5,000 beachgoers were interviewed, and > 1000 completed follow-up interviews. Data analysis is ongoing. Pathogen data collected at the beach, including measurements of adenovirus, Norovirus Group I, Salmonella, Giardia and Cryptosporidium, will be used for quantitative microbial risk assessment. We anticipate that this integrative study approach will provide new insights into the complexities of predicting human health risk from recreational water use.

This workshop is funded by the U.S. EPA

4. *EPA's New Sanitary Survey App for Marine and Freshwaters*

Author: Samantha Fontenelle

Topic area: Sanitary Survey (Risk Communication and Tools session)

Name of presenter: Samantha Fontenelle

Affiliation: U.S. Environmental Protection Agency

Sanitary surveys are one of the most widely accepted tools to assess potential sources of pollution that can adversely affect public health. They help state and local beach program managers and public health officials identify sources of beach water pollution. By identifying and mitigating pollution sources, jurisdictions can reduce or eliminate beach advisories and closures.

In 2008, the EPA published the Great Lakes Beach Sanitary Survey and in 2013, the Marine Beach Sanitary Survey. The EPA has now developed a beta version of a data entry app based on the freshwater and marine water sanitary survey forms. This version of the app improves upon the marine beach app released in 2016 and offers several new features. It provides a technically sound and consistent approach to identifying pollution sources and allows jurisdictions to collect electronically the same data previously collected with the paper sanitary survey forms. This information can then be easily transferred to a spreadsheet or database application for analysis. The data collected can also be used for developing predictive tools to ensure same-day swimming advisory decisions at bathing beaches. The EPA's goal for this investment is to encourage broad use of the app by states, tribes, local governments, non-governmental organizations and citizen scientists in coastal and inland waters nationally and water quality programs internationally.

This presentation will cover the beach sanitary survey app development process, discuss new features and capabilities, submitting and accessing data, and app availability.

This workshop is funded by the U.S. EPA

5. The Florida Department of Environmental Protection's MST Toolbox in Action

Authors: David Whiting, Anita Nash, Jasrotia, Puja, Swanson, Cheryl, Espy, Julie, Musson, Curtis

Topic Area: Microbial Source Tracking

Presenter: David Whiting or Co-author

Affiliation: Florida Department of Environmental Protection

The Florida Department of Environmental Protection has implemented a microbial source tracking (MST) methodology that uses a variety of tools, including; microbial DNA markers, chemical tracers, GIS land use layers, and an adaptive sampling protocol to help identify fecal sources and prioritize restoration of fecal-contaminated waters. MST tools are applied proactively, as part of the Department's water quality assessment methodology when determining a water's impairment status, as well as during the restoration phase to more quickly and successfully target fecal sources in impaired waters.

This workshop is funded by the U.S. EPA

6. Lessons Learned on Remediation Options for Harmful Algal Blooms (HABs) in Recreational Lakes

AUTHOR**:** Rebecca Tuden and Matthew Graul
TOPIC: Source Tracking, Remediation/Upgrading Infrastructure Economics and Cost of Remediation
PRESENTER: Rebecca Tuden
AFFILIATION: East Bay Regional Park District

The East Bay Regional Park District is in the eastern side of the San Francisco Bay Area and serves a population of over 25 million visitors per year. It has nine reservoirs that offer swimming, boating and recreational fishing and host summer-long children's' camps. In 2014, the District had its first swimming beach closure due to high toxin levels from HABs and by 2017 the District had over 900 beach closure days due to high toxin levels. In response, the District launched a strategy to actively remediate the HABs for two separate lakes. The strategy included data collection on lake water quality parameters, strategizing with limnologists and regulators and conducting a dredging feasibility study. Each lake has different sizes, depths and issues to address in selecting the remediation effort. This presentation will explain the monitoring data and analysis that East Bay Regional Park District (District) used to identify the probable source of HABs and the discrete steps taken to select and implement HABs remediation methods on two lakes. The remediation methods discussed include vegetation harvesting, algaecide application, alum treatment, dredging, and installation of an oxygenation system.

This workshop is funded by the U.S. EPA

7. *Identifying Septic Pollution Exposure Routes During a Waterborne Norovirus Outbreak -- A New Application for Human-associated Microbial Source Tracking qPCR*

Authors: Mia C. Mattioli[1], Leslie Barclay[3], Catherine E. Barrett[1], Katharine M. Benedict[1], Aron Hall[3], Vincent Hill[1], Amy Kahler[1], Kelly Kline[4], Allison Longenberger[4], Patrick K. Mitchel[4, 5], Jennifer Murphy[1], Orin C. Shanks[2], Sharon Watkins[4], and Andre Weltman[4]

[1] Waterborne Disease Prevention Branch, Division of Foodborne, Waterborne, and Environmental Diseases, National Center for Emerging and Zoonotic Infectious Diseases, Centers for Disease Control and Prevention

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[4] Pennsylvania Department of Health

[5] Epidemic Intelligence Service, Division of Scientific Education and Professional Development, Center for Surveillance, Epidemiology, and Laboratory Services, Centers for Disease Control and Prevention, Atlanta, GA, USA

Topic Area: Restoring Waters to Recreational Use – Application and Tools Session

Speaker: Mia Mattioli[1]

In June 2017, the Pennsylvania Department of Health was notified of multiple norovirus outbreaks at a local campground. Epidemiologic investigations were unable to identify a single exposure route and therefore unable to determine the persistent source of contamination to target for remediation. Norovirus was detected in a recreational water designated for swimming and a drinking water well. Hydrogeologic assessment suggested the campground's septic leach field as a potential contamination source via ground water infiltration. The human-associated microbial source tracking (MST) genetic marker, HF183/BacR287, was used as a microbial tracer to identify a hydrogeological connection between the malfunctioning septic system, drinking water well, and recreational water area. Based on environmental investigation findings, campground management implemented a series of outbreak prevention strategies including discontinuing the use of the contaminated well, providing bottled drinking water to visitors, increasing portable toilet and handwashing station availability, and promoting proper hand hygiene. Despite recent outbreaks and evidence of ground water contamination into the nearby recreational water and drinking water well, no new norovirus cases were reported during a large campground event only a week after initiating prevention practices. This investigation highlights a new application for human-associated MST methods to trace hydrological connections between multiple fecal pollutant exposure routes in an outbreak scenario. In turn, pollutant source information can be used to develop effective intervention practices to prevent future outbreaks.

This workshop is funded by the U.S. EPA

8. Sky Harbor Beach Restoration: Impacts on E. coli Levels over a Three Year Period

Authors: Cindy Hakala, Stephanie Gretsch, and Trisha Robinson
Topic area: Remediation/upgrading infrastructure
Name of presenter: Cindy Hakala
Affiliation: Minnesota Department of Health

Sky Harbor Beach on Superior Bay in Duluth, Minnesota has been monitored since 2003. In 2012, high *E. coli* levels resulted in 42% of monitoring days with a posted advisory. Elevated *E. coli* levels continued to be a problem at the beach, with a high of 57% of monitoring days having a posted advisory in 2014. In response to increased erosion at the site as well as the chronically elevated *E. coli* levels, the City of Duluth developed a green infrastructure project with funding from the United States Environmental Protection Agency.

The City began construction in 2016 with excavation of a rain garden and the installation of boulders to protect the site and prohibit driving on the beach. Rain gardens, live willow staking, and native plant gardens were added in 2017 and 2018. Changes in plant height and the installation of an earthen berm have helped to deter geese and gulls from loafing in the area. In addition, across the street lawn has been left to grow without mowing, resulting in approximately 2.5 acres of meadow. The initial work of this restoration appears to have resulted in water quality improvements; between 2017 and 2019, 17% of monitoring days had a posted advisory compared to 36% between 2012 and 2016. The length of advisories have also decreased.

This presentation will include a discussion of restoration work, local and state agency cooperation, as well as water quality findings over time at this beach.

This workshop is funded by the U.S. EPA

Building Partnerships in Recreational Water Monitoring and Remediation – Session 5

1. Utah's Joint Harmful Algal Bloom and E. coli Recreational Water Quality Advisory Program

Author: Kate Fickas
Topic area: Risk Assessment/ State local monitoring /Evaluating the effectiveness of recreational water programs / Predictive models/forecasting/remote sensing Name of presenter: Kate Fickas
Affiliation: Utah Division of Water Quality

The Utah harmful algal bloom (HAB) recreational advisory program was born out of a collaboration with Utah Division of Water Quality (UDWQ) and Utah Department of Health (UDOH) in 2016 to protect recreators from cyanobacteria related health effects after a widespread bloom on Utah Lake. Since then, the advisory program has continued to grow and evolve into an efficient and trusting partnership with local health departments. With increased effort towards prioritized monitoring using novel remote sensing analysis, state beneficial use classifications, and guidance from local agencies, the program has doubled the number of lakes on advisory each year since 2016.

As a recreational water quality health risk, *Escherichia coli* (*E. coli*) presents both similar and divergent approaches as HABs in a recreational health advisory program. Past attempts to replicate the HAB advisory process in the *E. coli* advisory program have had little success and led to local health departments averse to participate. Here we present how UDWQ and UDOH have overhauled the Utah *E. coli* water quality health advisory program by identifying strategy deficiencies such as a lack of site prioritization, harmony with the Clean Water Act 303d program, data sharing, and signage. We will illustrate our strategy going forward and new tools for site prioritization such as remote sensing analysis to identify potential *E. coli* hot spots and molecular source tracking to identify contamination source. Lastly, we will discuss how we have merged the HAB and *E. coli* advisory programs into a single Recreational Water Quality Advisory Program.

This workshop is funded by the U.S. EPA
United States Environmental Protection Agency

2. *Integrating HAB Detection Technologies with a Regional Observing System in the Great Lakes*

Author: Tim Davis

Affiliation: Bowling Green State University

The goal of this is to fully validate and integrate a rapid, portable, quantitative, multiplexed cyanotoxin detection technology into routine monitoring programs, citizen science groups, recreational beach management, and water treatment plants throughout the western Lake Erie to provide water managers with on-the-spot testing of MC and CYN. We will use a commercially-available MC/CYN HAB Toxin Detection System has been developed by industrial partner, MBio Diagnostics, Inc., for a rapid detection of MC as well as CYN. To fully validate the MBio MC/CYN HAB Toxin Detection System, four programs, University of Michigan Cooperative Institute for Great Lakes Research, University of Toledo, The Ohio State University (OSU), and Bowling Green State University, will incorporate the MC/CYN HAB Toxin Detection System into their routine CHAB monitoring programs. Furthermore, the MC/CYN HAB Toxin Detection System will be evaluated by Toledo and Port Clinton water treatment plant operators. This technology will also be assessed by NOAA's Phytoplankton Monitoring Network for western Lake Erie and the Lake Erie charter boat captain citizen science initiative that OSU has been leading since 2013. Lastly, Maumee Bay State Park beach managers will integrate the MC/CYN HAB Toxin Detection System into their routine beach monitoring program. These coordinated, concurrent validation efforts will provide robust data to not only validate the MBio instrument against a recognized 'gold standard' method, but also to assess the ease of use for water management professionals and citizen scientist organizations. Moreover, to understand how various MC congener ratios may affect the accuracy of the instrument, a subset of field samples will be analyzed using LC-MS/MS. This comparison will provide critical assessment of the MBio instrument's range of sensitivity for the most common MC congeners. Finally, a data management system will be developed to provide an easy method for the aforementioned monitoring groups to upload their data through a user-friendly smartphone 'app' to a common database system and ultimately to an end-user website, providing a centralized location accessible by other researchers, water plant managers, and the general public.

This workshop is funded by the U.S. EPA

3. Development of a Multifaceted Statewide Strategy for the Monitoring and Assessment of Freshwater Harmful Algal Blooms in California

Authors: Jayme Smith[1], Keith Bouma-Gregson[2], Marisa Van Dyke[2], Martha Sutula[1]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA

[2]State Water Resources Quality Control Board, Sacramento, CA

Freshwater harmful algal blooms (FHABs) are a challenging water quality issue in recreational waters because they can reduce aesthetics, lower dissolved oxygen concentrations, cause taste and odor problems, and produce potent toxins. In California, cyanobacteria and their toxins have been a recurring and escalating issue, particularly in recent years. A key need in California was a strategy for field assessment and ambient monitoring program for FHABs to both understand the extent and magnitude of the FHABs in the state and protect human recreational uses. To fill this need, a FHABs ambient monitoring framework was developed that strategically integrates state-wide field assessments with voluntary waterbody specific ambient monitoring programs and remote sensing monitoring approaches. Here we present the approach used to develop the ambient monitoring framework and the key elements of the program. The process to develop the monitoring framework was conducted in conjunction with a technical advisory committee (TAC) that included academic scientists, state and regional water board staff, local agency staff, and NGO staff to ensure the final product addressed the diverse needs of stakeholders across the state. The key management questions to be addressed by the program were identified and vetted by the TAC and through extensive outreach to stakeholders. The monitoring framework identified priority FHAB indicators to address the defined management questions and highlighted information/infrastructure gaps required to implement the framework. Key programmatic elements developed for the framework were approaches to integrate and standardize data from state and local government, tribal and NGO monitoring efforts.

Presenting author: Jayme Smith

Presenting author affiliation: Southern California Coastal Water Research Project

Topic: Building Partnerships in Recreational Water Monitoring and Remediation

This workshop is funded by the U.S. EPA

4. Citizen Science at the EPA: Streamlining Water Quality Testing and Future Visions

Jay Benforado and Demi Gary
Citizen Science
Jay Benforado
Office of Research and Development, US EPA

Using volunteers in water quality monitoring has huge potential to increase the breadth and scope of data collection projects. Citizen science, or the involvement of the public in scientific research, presents opportunities and challenges for use in environmental programs at in federal, state, tribal, and local agencies. Citizen science projects can have valuable applications including improved data for bacteria and HABS and more traditional water quality monitoring. The challenges include ensuring proper data quality and management. EPA is drafting a comprehensive vision for using citizen science with principles to guide individual projects. In March 2019, EPA issued a QA assurance handbook to help citizen science organizations prepare QA project plans. EPA is also developing a data management action plan that will improve data infrastructure, encourage adoption of data standards, and promote accessibility and transparency of data. Citizen science projects can yield multiple benefits including actionable information, engaged communities, and environmental literacy. Well-designed projects can also result in cost savings and efficiency in environmental monitoring and protection programs. For example, current citizen science projects include monitoring of water quality in rural drinking wells, coastal acidification, monitoring for bacteria in recreational waters, and tracking harmful algal blooms. Building on the efforts of thousands of volunteer water monitoring groups across the US, EPA envisions a future where citizen science data are abundant, accessible, and useful for environmental decision making. This future is possible through strong partnerships with states and tribal agencies, NGOs, academic institutions, and the public.

This workshop is funded by the U.S. EPA

5. Citizen and Community Evolvement to Make a More Swimmable California

AUTHOR: Erick Burres

TOPIC AREA: Partnering/Citizen Science

PRESENTER: Erick Burres

AFFILIATION: Clean Water Team - California State Water Resources Control Board

Safe to Swim Network - California Water Quality Monitoring Council

The people of California enjoy recreating in its waters and many are willing to engage in the science that ensures are water quality is swimmable. Community organizations (NGO's, Tribes, Colleges…) are conducting or engaging via partnerships the sampling for FIBs or HABs, conducting sanitary surveys, source tracking, communicating water quality conditions and generating predictive forecasts. The State's Clean Water Team helps many of these organizations with training, loans of equipment, and assistance with monitoring and quality assurance plans so that data generated is actionable.

This workshop is funded by the U.S. EPA

6. A Water Quality Standards Perspective on Swimming in an Urban Waterway—The Anacostia River

Authors: Ed Dunne, George Onyullo, Amir Sharifi, Rebecca Diehl, and Gretchen Mikeska

Topic area: Communicating water quality conditions to the public and other agencies; partnering/citizen science, monitoring and rapid assessment of water quality

Name of presenter: Ed Dunne

Affiliation: District of Columbia, Department of Energy and Environment

Would you swim in a historically contaminated urban river if there was a temporal window when water quality criteria for primary recreation were met? A similar question was posed in an Anacostia River Use survey. Over 80 percent of respondents said they would swim at least once a month. Anacostia river conditions are changing. For example, combined sewer overflows are reduced by 90 percent (March 2018 through November 2019) as a result of DC Water implementing their Long-Term Control Plan. DC Department of Energy and Environment is leading a remedial plan to remove contaminated river sediments, which is the result of a river-wide feasibility study. Long-term (2008-2019) ambient river water quality data show that annual average *E*. coli ranged between 670 and 271 MPN/100 ml. In 2019, both the annual average and the within year variability of *E*.coli decreased. Contributing factors may include rainfall and the reduction of combined sewer overflows. The District has two *E.*coli water quality criteria for primary contact recreation—swimming. A 30-day geometric mean of 126 MPN/100 ml and a single sample value of 410 MPN/100 ml. Swimming is currently prohibited in the District of Columbia. There are, however, regulatory provisions to allow special swimming events. The objective of this presentation is to: (1) share how we currently implement special swimming events, which consider water quality standards, and (2) ask workshop participants about ideas to implement an updated approach to provide for recreation in and on the Anacostia River and other District of Columbia waters.

This workshop is funded by the U.S. EPA

7. *Building Partnerships to Enhance Public Health Protection at the Beach through the Surfrider Foundation's Blue Water Task Force*

Author & Presenter: Mara Dias, Surfrider Foundation

Topic area: Partnering/Citizen Science

Affiliation: Surfrider Foundation

For 25 years, the Surfrider Foundation's Blue Water Task Force citizen science program has been testing beaches and recreational waters for fecal indicator bacteria to provide coastal communities with information on where it's safe to surf, swim and play in the water. With over 50 Blue Water Task Force water testing programs located in coastal states across the country, Surfrider volunteers have established many successful collaborations with other NGOs, academia, and government agencies to enhance the coverage and effectiveness of beach monitoring programs.

These citizen/agency partnerships help stretch limited government resources to expand the coverage and prioritize the focus of state and local beach programs. Surfrider chapters also help increase community awareness and consumption of local water quality information by sharing agency and volunteer-generated data with the public through conventional and social media platforms. By developing a trained and committed volunteer workforce and established modes of communication between agencies and community groups, these partnerships can be particularly valuable during off-season months when agency staff is limited or in times of critical need following natural disasters, outbreaks of Harmful Algal Blooms and other emergencies.

Examples of successful collaborations between Surfrider volunteers, agencies and community partners in several coastal states and territories including New York, California, Washington and Puerto Rico will be presented with key benefits and workable strategies discussed.

This workshop is funded by the U.S. EPA

What's next? Emerging Concerns – Session 6

1. *How well do Coliphages Predict the Presence and Concentrations of Human Enteric Viruses in Water and Wastewater?*

Author: Mark D. Sobsey

Topic area: Monitoring and rapid assessment of water quality

Name of presenter: Mark D. Sobsey

Affiliation: University of North Carolina

Human enteric viruses are widely present in wastewater and water, relatively persistent in aquatic environments and resistant to wastewater and water treatment processes, including disinfection. Human enteric virus pathogens are difficult to detect and quantify rapidly for their infectivity, making it impossible to acquire relevant virus pathogen data for timely management of wastewater discharges and recreational water quality. Newer nucleic acid-based molecular methods make human enteric virus detection more rapid and potentially more sensitive, but these methods do not reliably predict the presence and concentrations of infectious viruses. Hence, data on the presence and concentrations of infectious human enteric viruses in wastewater and water is quite limited in the USA, making it difficult to predict their human health risks from water exposures. Therefore, greater efforts and improved methods are needed to detect and quantify infectious human enteric viruses in such samples for human health risk assessments.

Fecal indicator viruses, such as coliphages are widely and consistently present at relatively high concentrations in wastewaters and fecally contaminated waters and they easier to detect by infectivity methods more rapidly than are human enteric viruses. Several different candidate methods are available for simple and potentially rapid coliphage detection, including self-contained, commercially available kits. However, the extent to which coliphage detection predicts the presence and concentrations of infectious human enteric viruses in raw and treated wastewaters and in ambient waters such as those used for primary contact recreation is still uncertain and remains problematic. Furthermore, the taxonomic diversity of coliphages and the extent to which the different ones predict the presence and concentrations of infectious human enteric viruses in wastewaters and waters and their health risks also remains uncertain and problematic. Therefore, greater efforts are needed to determine the extent to which different infectious coliphages predict the presence, concentrations and health risks of human enteric viruses.

The results of our recent studies indicate that treated wastewaters, including those highly treated by multiple processes, can still contain relatively high concentrations of infectious human enteric viruses, even when coliphages and fecal indictor bacteria have been extensively reduced. This presentation reviews these issues and recommends ways forward to improve what we must know for informed virus risk assessments and reliable management decisions.

This workshop is funded by the U.S. EPA
EPA United States Environmental Protection Agency

2. *Risk-based Water Quality Threshold for Coliphage in Surface Waters of Different Temperatures*

Alexandria Boehm

This study investigated the risk of gastrointestinal illness associated with swimming in surface waters with aged sewage contamination using quantitative microbial risk assessment (QMRA). The QMRA used F+ and somatic coliphage as indices for the amount of sewage present and thereby provided insight into how risk relates to coliphage concentrations in surface water. We compiled data on temperature-dependent pathogen and coliphage decay rate constants in surface waters using a systematic review and subsequent meta-analysis. The compiled decay rate constants allowed for us to account for differential decline in pathogen and coliphage concentrations as they age in the surface water in the QMRA model. Because exposure to norovirus contributed the majority of risk, and coliphage decay rate constants are greater than norovirus decay rate constants, the risk associated with exposure to a fixed coliphage concentration increases with the age of contamination. A risk-based water quality threshold for coliphage in surface waters that takes into account uncertainty in contamination age, and water temperature is derived. This framework can be applied to assessing risk associated with indicators from other single microbial pollutant sources including treated wastewater and agricultural runoff. The framework can also be applied to a pollution scenario where there are multiple pathogen sources (for example, a mixture of gull feces and raw sewage).

This workshop is funded by the U.S. EPA

3. *EPA's Development of Recreational Water Criteria for Coliphage*

Authors: Lesley D'Anglada, U.S. EPA & Kaedra Jones, ICF

Presenter: Kaedra Jones

In 2012, EPA issued current recreational water quality criteria (RWQC) recommendations for ambient waters, reflecting the latest scientific knowledge, public comments, and external peer review. The criteria are designed to protect the public from exposure to harmful levels of pathogens in all water bodies designated for primary contact recreational uses, such as swimming, wading, and surfing. Low concentrations of human pathogens in ambient waters, most of which originate from fecal sources, are often difficult to detect but can result in elevated risks of human illness while recreating. EPA researchers are investigating the potential use of coliphage as a viral indicator for RWQC applications. Viruses cause many illnesses associated with primary contact recreation in surface waters. Compared to bacteria, viruses are typically much smaller and more persistent through wastewater treatment and in environmental waters. Coliphages may be useful for evaluating surface water quality because they may exhibit numerous desirable indicator characteristics. Therefore, the development of coliphage as a viral indicator could represent a major improvement for future RWQC and the protection of human health. However, the smaller size and lower concentrations of coliphage in ambient waters have necessitated the development of improved concentration and detection methods. Research activities include (1) the development of a method for the concentration and quantification of F-specific and somatic coliphage in fresh and marine waters, and (2) the characterization of relationships between coliphage and other fecal indicators in recreational waters.

This workshop is funded by the U.S. EPA

4. *Large-scale Patterns of Antimicrobial Resistance Genes and Fecal Indicator Bacteria in United States Rivers and Streams*

Authors: SP Keely, NE Brinkman, E Wheaton, MA Jahne, S Siefring, M Varma, RA Hill, SG Leibowitz, R Martin, J Garland, R Haugland
Topic area: Emerging concerns
Name of Presenter: Scott Keely
Affiliation: US EPA Office of Research and Development

Collaborating with States and Tribes, the United States Environmental Protection Agency (EPA) conducts periodic and rotating, probabilistic surveys of: U.S. rivers and streams; estuarine and Great Lakes nearshore coastal waters; lakes and ponds; and wetlands from the lower contiguous 48 states. These studies, collectively referred to as the National Aquatic Resources Surveys (NARS), are performed to provide the public and decision makers with nationally consistent and representative information on the condition of all the nation's waters. Among the numerous parameters investigated in these surveys, EPA has determined enterococci fecal indicator bacteria (FIB) concentrations in rivers and streams from PCR analyses since 2008-2009 for comparisons with EPA national recreational water quality criteria. *E. coli* FIB and total bacteria were also determined from estimates of ribosomal RNA gene concentrations in the 2013-2014 rivers and streams survey samples. EPA also collected data from the 2013-2014 River and stream samples to examine the environmental heterogeneity of the class I integron integrase gene (intI1) and several antimicrobial resistance genes (ARG). Estimates of FIB, intI1 and ARG concentrations were greater in the southern, temperate, and coastal plains, as well as in the Appalachians; and lower in the Xeric and Western Mountains. Stressed ecosystems also showed higher concentrations of Int1 and ARG when compared to watershed integrity and reference sites. US Rivers and streams represent new information that will aid in understanding the role of the environment in transmission of antibiotic resistant bacteria to humans and animals.

This workshop is funded by the U.S. EPA

5. *Pathogenic Vibrio Species in Southern California Coastal Waters*

Author: Rachel E. Diner, Joshua A Steele, Andrew E. Allen, John F. Griffith

Topic area: Emerging concerns for recreational water quality

Name of presenter: Rachel E. Diner

Affiliation: Southern California Coastal Water Research Project and the J. Craig Venter Institute

Many species of coastal *Vibrio* bacteria can infect humans, representing an emerging health threat in recreational waters linked to increasing seawater temperatures. The abundance, ecology, and environmental drivers of these species, however, are poorly understood in areas with potentially high human health risk. We present the first quantification and ecological analysis of pathogenic *Vibrio* spp. in the Southern California region, an area of emerging risk due to warm coastal seawater temperatures, high recreational water use, and seafood cultivation. We quantified pathogenic *Vibrio* spp., including *V. cholerae*, *V. parahaemolyticus*, and *V. vulnificus*, and two virulence-associated genes for one year at five coastal sites using digital droplet PCR. We then profiled associated prokaryotic and eukaryotic communities using next-generation sequencing to investigate co-occurring organisms and probe *Vibrio* diversity. *Vibrio* spp. inhabited species-specific environmental niches driven by temperature and salinity and were abundant during warm summer months, a finding consistent with other geographic regions. Particularly high abundances (e.g. *V. cholerae* >2,500 cells/mL) corresponded to low salinity and urban freshwater accumulation caused by lagoon closure. Several co-occurring chitin-producing eukaryotes, including diatoms and copepods, were positively associated with pathogenic species suggesting potential environmental reservoirs. Furthermore, *Vibrio*-specific communities were highly diverse (>20 species) including additional potential pathogens. Our findings elucidate potential health risks in Southern California and establish methods for detecting and quantifying *Vibrio* species of interest and characterizing community associations to assess emerging water quality concerns in a wide range of recreational waters.

This workshop is funded by the U.S. EPA

6. *International Comparison of Antibiotic Resistance Genes and Microbial Communities from Wastewater Treatment Plant Final Effluents and Receiving Environments*

Authors: Ayella Maile-Moskowitz [a], M. V. Riquelme[a], E. Garner[a], D. S. Aga[b], I. Nambi[c], J. Larsson[d], H. Burgmann[e], T. Zhang[f], A. Pruden[a] and P. J. Vikesland[a]

Topic area: Emerging concerns for recreational water quality

Name of presenter: Ayella Maile-Moskowitz

Affiliation: Virginia Tech

Antibiotic resistance (AR) is a global challenge to public health and wastewater treatment plants (WWTPs) have been identified as potential disseminators of AR to the environment. As part of a global survey of WWTPs to characterize and mitigate dissemination of AR to the environment, samples were collected from two WWTP plants in each of the following countries: India, Sweden, Switzerland, and the United States. From each WWTP, final effluent was sampled, as well as water upstream and downstream of the effluent-receiving environment. Select antibiotic resistance genes (ARGs) (including, *sul*1, *bla*TEM, and *van*A) of interest due to their environmental prevalence and clinical relevance were quantified using qPCR. Total bacterial counts (approximately by 16S rRNA genes) and the class 1 integron integrase gene, *int*I1, were also quantified via qPCR. To provide a deep characterization of ARG profiles, metagenomic sequencing was conducted for select samples. Results will provide insight as to the total loading of all known ARGs being discharged into the environment via WWTPs and how receiving environments are impacted. Differences among international sampling sites will also be compared to better understand the global variation in WWTP effluent quality and receiving environment water quality. The results of this study will be used to identify the relative contribution of WWTP effluent in disseminating ARGs to the environment when different treatment methods, antibiotic regulatory policies, and cultural expectations of antibiotic use differ across sampled locations.

This workshop is funded by the U.S. EPA

Thank you!

The 2021 National Recreational Water Quality Workshop brought together a wide range of perspectives on two key concerns in recreational water quality—fecal contamination and harmful algal blooms.

The workshop and the body of work that underlies it is a testament to the commitment of water quality professionals from across the research, regulatory and technical specialties who have spent countless hours in the water, in the lab, or in the office to safeguard our nation's recreational waters and share their insights with us.

The COVID-19 pandemic turned this workshop—like countless others—into a virtual event. The bright side of that change in plans was our ability to connect more people to this year's presentations, regardless of their location, position or travel budget.

To our presenters, a big thank-you for sharing your time and expertise. To our organizers, thank you for setting the course and maintaining the focus of the workshop. And to you and all our participants, thank you for your interest in the workshop and for all you do to make America's recreational waters safer and healthier.

This workshop is funded by the U.S. EPA

Notes

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