Are Existing Bacterial Indicators Adequate for Determining Recreational Water Illness in Waters Impacted by Nonpoint Pollution?

Kellogg J. Schwab

Tens of millions of persons swim in coastal waters in the United States each year. In many instances, these waterways are contaminated with fecal pollution that can contribute to recreational water illness.[1] Unfortunately, monitoring recreational waters for disease-causing microorganisms is not as straightforward as it would seem. In addition to the well-known pathogenic bacteria such as *Escherichia coli*, *Salmonella*, and *Shigella,* protozoa including *Cryptosporidium* and *Giardia* and viruses, in particular noroviruses and adenoviruses, are also major contributors to recreational water illness. Protozoa and viruses persist in the environment for much longer periods of time than do bacteria, and virus transport through surface and subsurface water is both faster and farther than that of bacteria. The great diversity in pathogenic microorganisms that can be transmitted by water and the difficulty in developing and implementing detection strategies for all possible microbes has resulted in the selection of a few indicator organisms to determine the presence and magnitude in a waterway of microorganisms causing recreational water illness. These "classic" indicators include total coliforms, fecal coliforms, *E. coli,* and enterococci, many of which have been used as indicators for over 100 years.

Several studies have shown a strong correlation between conventional bacterial indicators and human illness resulting from recreation in water contaminated by human sewage outfalls.[2] However, nonpoint pollution is also a major source of contamination of marine and fresh water recreation areas, and other studies have concluded that there is a poor correlation between levels of classic bacterial indicators and the presence of sources of nonpoint pollution. Compared with point source pollution, nonpoint pollution sources are diffuse and heterogeneous, and they typically include agricultural runoff, malfunctioning or poorly maintained septic tanks, leaking sewer infrastructure, as well as waste from wildlife such as deer and birds. In many instances, animals shed high numbers of bacteria, many of which are not of human health concern, resulting in false-positive interpretation of the magnitude of health risk when relying on classic bacterial indicators. Importantly, nonpoint pollution can also contribute to high levels of unmeasured potentially pathogenic protozoa and viruses that can result in false-negative interpretations of the risk to human health when only bacteria are used to evaluate microbial water quality. Thus, a major challenge in assessing the risk to swimmers posed by nonpoint pollution is selecting appropriate indicators. One microbial group that shows considerable promise as a potential viral indicator are bacteriophage. Bacteriophage are viruses that infect bacteria. Although they do not cause illness in humans, many bacteriophages are similar in size, shape, and environmental persistence as human enteric viruses. In particular, male-specific coliphage show considerable promise as a more reliable indicator of viral pollution.

Climatic events also are a major factor in assessing the level of risk to bathers of recreational water illness. After as little as 1 to 2 cm of rainfall, the levels of microorganisms in water can increase by several orders of magnitude.[3] Conventional sample analysis of water for classic indicators can take 24 to 48 hours. This delay in the

From The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD.
Correspondence: Kellogg J. Schwab, The Johns Hopkins University, Bloomberg School of Public Health, 615 N. Wolfe Street, Room #6620, Baltimore, MD 21205. E-mail: kschwab@jhsph.edu

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availability of microbial data presents a considerable challenge for public health officials who must rapidly decide on beach closures, especially after rainfall. Inappropriately closed beaches can cause economic hardship to the surrounding community, whereas leaving contaminated beaches open can result in morbidity or even mortality.

The efficacy of any new public health monitoring tool must be evaluated through epidemiologic studies that identify relationships with the incidence of recreational water illness. In this issue, researchers report on the incidence of such illness in a prospective cohort of over 8700 beachgoers at Mission Bay, California.[4] Beachgoers were assessed for multiple health outcomes, including gastrointestinal, skin rash, eye irritation, earache and discharge, fever, and respiratory symptoms after contact or ingestion of water. Mission Bay is unusual in that most of the water contamination results from nonpoint sources with no major point source human waste contamination. Over 1800 water samples were concurrently collected and analyzed for enterococcus, total coliforms, and fecal coliforms as well as nontraditional indicators, including *Bacteroides*, somatic bacteriophage, and male-specific bacteriophage. The presence of the frank human adenovirus and noroviruses pathogens was also investigated.

An increase in diarrhea and skin rash was observed among persons having any water contact. For those persons who reported having swallowed water, cramps and eye irritation were also increased. Interestingly, unlike most previous epidemiologic studies of marine recreational activities, the current study did not detect a correlation between the risk of illness and increased levels of classic water quality indicators. This lack of correlation persisted even when exposure to indicator measures was above California state water quality thresholds. The authors also reported that increasing concentrations of male-specific coliphage were correlated with increased incidence of several health outcomes, including highly credible gastroenteritis, nausea, cough, and fever. The number of individuals exposed to the water during detection of higher levels of bacteriophage was low and thus the results should be interpreted with caution. It should be noted that all sampling was conducted during dry weather and no wet weather events were captured during the sampling timeframe. Thus, although these data are of considerable interest, as acknowledged by the authors, additional research on recreational sites impacted by nonpoint pollution, especially after rain events, is needed before extrapolating the results to other beaches.

ABOUT THE AUTHOR

KELLOGG J. SCHWAB is an Associate Professor at the Johns Hopkins Bloomberg School of Public Health. His research focuses on the fate and transport of indicators and pathogens in the environment. This work involves developing molecular detection methods with subsequent application of these methods in field-based investigations. Data gathered during these studies are then integrated into exposure assessments for risk analysis.

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