WISCONSIN MEDICAL JOURNAL

# Protecting the Waters of Wisconsin from Microbiological Threats

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## ABSTRACT

Wisconsin is blessed with an abundance of high quality water that has played a significant role in the economic and social development of the state. The quality of life for Wisconsinites is often at least partially defined by pristine inland lakes, a portion of the Great Lakes shoreline, or great-tasting well water. While no one likes to associate water with disease, especially waters like those we enjoy in Wisconsin, the historical reality is that there is a strong connection. Until the 1920s, intestinal diseases such as typhoid fever and cholera often spread through water and were a leading cause of death in the United States. While easy access to modern medical care combined with improved water treatment technologies have greatly decreased waterborne disease, the microbiology of Wisconsin's waters still deserves continued vigilance and attention. The World Health Organization currently estimates that, on a global basis, 4 billion annual cases of waterborne diarrhea result in more than 2 million deaths per year[1]—the equivalent of 20 jumbo jet crashes per day. Most of these deaths are in children under 5 years of age. The daily global death toll from waterborne disease is at least 1000 times greater than from the Severe Acute Respiratory Syndrome epidemic that recently made headline news. Waterborne disease is not just a problem in underdeveloped countries. Scientists who study disease transmission believe that 10%-30% of the vomiting and diarrhea illness in North America, including Wisconsin, may be acquired from water.


## INTRODUCTION

The University of Wisconsin (UW) had an early presence in the field of bacteriology that emerged from Victorian Europe during the late 1800s.[2] Wisconsin bacteriology pioneers, such as E.A. Birge, H.L. Russell, and C.A. Harper, spent time training in the laboratories of the European luminaries Louis Pasteur and Robert Koch and subsequently brought their new knowledge back to Wisconsin. By 1903, these Wisconsin bacteriologists saw the need for government to be involved with testing to protect public health and convinced Governor Robert M. LaFollette and the legislature to fund a State Board of Health laboratory. One of the first issues of the *Wisconsin Medical Journal* contained an impassioned editorial written in support of starting a public health laboratory.[3] The first argument presented in this editorial was the need to have the capability to test water in order to stop the common occurrence of waterborne outbreaks being experienced in Wisconsin. Later that year, when the laboratory was actually set up, 1 of the primary functions was to test drinking water for contamination. In 1908, laboratory director Dr Mazyck Ravenel used the laboratory to exonerate the University's water and food as a source of a campus typhoid epidemic that claimed 7 lives. The sentinel case source turned out to be a student coming to campus from a small rural community.

The early history of the Wisconsin State Laboratory of Hygiene (WSLH) demonstrated that the Wisconsin Idea was adopted by using existing university laboratories and expertise to address the issue of waterborne disease in Wisconsin. Microbiological testing of drinking water has remained a cornerstone of WSLH activities throughout the laboratory's history. In 1947, Wisconsin Statute 36.225, which redefined WSLH priorities, listed the examination of water supplies for domestic use as the first of 4 public activities to be carried out. Dr M. Starr Nichols, the Assistant Director, who had a joint academic appointment with the WSLH and the UW Department of Civil Engineering, focused much of his work on waterborne disease issues. His research interests included swimming pool disinfection, activated sludge treatment of wastewaters, and treatment of algal blooms in swimming beaches.

## WISCONSIN PROGRAMS TO INSURE SAFE WATER

Ever since its inception, the WSLH has had a strong

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working relationship with other state agencies including the Board of Health, the Conservation Department, and later, the Department of Natural Resources and the Department of Health and Social (Family) Services. Employees from these agencies were actually assigned to office and laboratory space at the WSLH. These agency employees worked side-by-side with WSLH microbiologists on sample testing, training, regulation writing, and laboratory evaluation. These relationships resulted in highly-effective waterborne disease control programs. For example, testing procedures for the detection of coliform bacteria and *E. coli* (indicators of fecal pollution) have been continuously updated, providing competent analysis of public water supplies and privately owned wells. The training and laboratory evaluation efforts have resulted in the performance of uniform testing procedures even by the smallest laboratories in remote areas of the state. In the regulatory arena, these cooperative monitoring and research efforts have resulted in a uniform well drilling code ensuring microbiologically safe water for most Wisconsin residents. This code has been copied and implemented by a majority of the other states. Responsive evaluation of waterborne disease outbreaks is another positive aspect of collaboration with other public health agencies.

WSLH water microbiologists have also been active participants in committees and groups setting national policy and standards. A number of WSLH scientists have served on the editorial board of "Standard Methods for the Examination of Water and Wastewater," published jointly by the American Water Works Association (AWWA) and the American Public Health Association.[4] This reference manual is updated every few years and serves as the major reference for determining how water testing must be performed. WSLH microbiologists also serve on regulatory committees formed by the United States Environmental Protection Agency (US EPA) and the AWWA charged with formulating legislation for protection of citizens from waterborne disease.

## PROGRAM CHANGES IN WATER MICROBIOLOGY

Beginning in the 1970s, the focus of the water microbiology program at the WSLH began to shift. In addition to the routine indicator bacteria testing done in support of regulatory programs aimed at protecting people from waterborne disease, the laboratory began to take a more active role in waterborne disease research. For example, in 1977, a UW student nearly died after acquiring an *Aeromonas hydrophila* infection from a swimming-related trauma. Water Microbiologist Jon Standridge teamed with UW physicians in linking the infection to high concentrations of the organism in Lake Mendota.[5]

Much of the research in the 1970s and 1980s was focused on improving testing methods for indicators of waterborne disease. In 1981, as the Wisconsin Department of Natural Resources (WDNR) began requiring disinfection and testing of most wastewater effluents, the laboratory published a simple technique for detecting fecal coliform bacteria that could readily be employed by wastewater treatment plant laboratories.[6] Other test method-related research focused on method improvements, dealing with sample matrix problems and transport conditions of samples prior to laboratory analysis.[7-9] In conjunction with US EPA and other collaborators in the early 1980s, a rigorous evaluation of a new enzyme-based technology for simultaneous detection of total coliforms and *E. coli* in water samples resulted in the approval of this technology for routine use. The enzyme-based method now accounts for more than 80% of the coliform testing performed worldwide.[10]

In 1994, the WSLH participated in a cooperative project with 9 midwestern states and the Centers for Disease Control and Prevention to determine the prevalence of coliform bacteria in private wells. A grid pattern was drawn on maps of all 9 states at 10-mile intervals. The private well closest to the 10-mile grid-line intersections on the map was then sampled and tested. Partially because of the protected nature of our groundwater resource and partly because of the success of the programs and partnerships outlined above, Wisconsin is among the states with the lowest rates of private well contamination (Table 1).[11]

In addition to the indicator testing methods research, the laboratory has also been involved in research in the detection of specific pathogens. This shift in emphasis was prompted by the re-focusing of the WSLH's mission on disease outbreak response readiness and capability. The 1993 Milwaukee *Cryptosporidia* outbreak that caused severe illness in 402,000 residents and killed more than 100 people elicited a flurry of research that resulted in several large studies.[12] These studies, funded by the WDNR, the AWWA, the Water Environment Research Foundation, and the US EPA, included investigations regarding the occurrence and prevalence of this agent in Wisconsin source water and drinking water as well as pioneering work in the methods for detecting the organism in water.[13-15] The laboratory continues as a premier water parasitology research center.

Much of the specific pathogen work is driven by the US EPA's creation of the Contaminant Candidate List of known and emerging pathogens that may pose a threat as drinking water pathogens (Table 2).[16] The US

**Table 1.** Coliform Positivity in Well Waters Summarized by State

| State | % Total Coliform Positive | % *E. coli* Positive |
|---|---|---|
| Illinois | 46 | 15.3 |
| Iowa | 58.2 | 20.8 |
| Kansas | 49.2 | 16.9 |
| Minnesota | 26.8 | 4.3 |
| Missouri | 57.1 | 22.7 |
| Nebraska | 37.4 | 2.6 |
| North Dakota | 35.6 | 8.2 |
| South Dakota | 39.7 | 8.0 |
| Wisconsin | 23.3 | 2.4 |

**Table 2.** The Drinking Water Contaminant Candidate List

| Microbiological Contaminants |
|---|
| Acanthamoeba (guidance expected for contact lens wearers) |
| Adenoviruses |
| *Aeromonas hydrophila* |
| Caliciviruses |
| Coxsackieviruses |
| Cyanobacteria (blue-green algae), other freshwater algae, and their toxins |
| Echoviruses |
| *Helicobacter pylori* |
| Microsporidia (Enterocytozoon and Septata) |
| *Mycobacterium avium intracellulare* (MAC) |

EPA prepares this list based on expert opinion. *Helicobacter pylori*, the causative organism of gastric ulcers, is included. This fastidious bacteria is very difficult to grow in culture and subsequently no methods existed to detect it in water. Epidemiological evidence points to the possibility of the disease being waterborne. Thus, a culture method for detection in water was needed. A grant from the WDNR enabled WSLH water microbiologist Alan Degnan to develop and publish an effective plating media for detecting the organism in water.[17]

For more than 3 decades, the Water Microbiology Unit has been involved in research on blue-green algae (cyanobacteria) capable of producing potent toxins. The laboratory has been asked on numerous occasions to test for the presence of algal toxins following deaths of dogs and livestock related to ingesting water contaminated with blue-green blooms. These investigations prompted a study on the occurrence of these toxins in Wisconsin waterways and another on the possible long-term effects of chronic exposure to these toxins.[18,19]

## CONCLUSIONS

The control of waterborne disease continues to be a cornerstone of public health activity. The Water Microbiology Unit of the WSLH has been involved throughout its 100-year history with improving test methods and then using these methods to monitor drinking water, wastewater, and recreational waters. The WSLH is poised to continue participating in emerging areas such as the development of real-time pathogen detection devices and water as a source of antibiotic-resistant bacteria.

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