Indiana Strategizes with Partners to Protect Vulnerable from Private Well Water Risks

by Mary Hagerman, MS, chemistry division director, Indiana State Department of Health Laboratories and Sarah Wright, MS, manager, Environmental Laboratories, APHL

In 2014, APHL partnered with the US Centers for Disease Control and Prevention (CDC) National Center for Environmental Health Environmental Hazards and Health Effects Division to provide funding for laboratories to develop and host a meeting of their environmental health system partners. In fall 2017, APHL issued a request for proposals for laboratories to apply for up to $15,000 for meeting support. Indiana was a funding recipient and hosted its meeting in October 2018.

Indiana has over 600,000 private, unregulated wells used for drinking water, and most are not tested to determine if the water is safe. Arsenic is estimated to be found in more than 10% of private drinking water wells in the state with levels in excess of the US Environmental Protection Agency (US EPA) Safe Drinking Water Act limit of 10 µg/L. Maternal arsenic exposure has been linked to gestational diabetes, lower infant birth weights and infant mortality.

In light of the high prevalence of naturally-occurring arsenic in Indiana’s well water, the Indiana State Department of Health (ISDH) laboratory was concerned about exposure of expectant mothers and small children to untested and untreated drinking water. Were healthcare providers asking expectant or new mothers about their drinking water source? Were clinicians recommending well water testing?

ISDH staff decided they needed answers. With APHL meeting support, the laboratory planned a meeting that brought together environmental health laboratory scientists, environmental health specialists and clinicians—public health nurses, OB/GYNs, pediatricians and others—to discuss actions to protect mothers and young children from the effects of contaminated well water.

Featured on the agenda were two nationally-known experts on the relationship between well water and health. Steve Wilson, an expert on
private wells, explained the importance of health professionals in promoting water testing. Dr. Susan Buchanan, director of the Great Lakes Center for Children’s Environmental Health in Chicago, discussed children as “the canaries in the coal mine” of environmental health and addressed the effects of contaminant exposures in pregnancy and early childhood.

From Meeting to Action
The meeting demonstrated the value of laboratory outreach to the environmental health community, and notably to clinicians. Participants contributed creative ways to reach mothers with information on well water testing. For example, they suggested that information be included on immunization schedules for young children and obstetricians’ checklist for safe pregnancy. The ISDH laboratory will pursue these leads with support from the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and the Indiana section of the American Congress of Obstetricians and Gynecologists (ACOG).

The ISDH laboratory is now working with the Indiana Health Commissioner to explore how the state can enlist pediatricians to promote well water testing for mothers and young children, thereby becoming a model for other states. Other plans include:

1. An update to Indiana’s pregnancy mobile phone app to allow users to find recommended well water tests and testing schedules, certified laboratories and information on treatment of unsafe well water, and

2. A regular meeting of state environmental health representatives with private well water issues on the agenda.

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PRIVATE WELL WATER QUALITY TESTING REGULATIONS AND GUIDANCE: A LABORATORY LENS

By Allison Schneider, project specialist, National Environmental Health Association

The water that most Americans drink every day from public water systems is required to be tested for more than 90 contaminants under the Safe Drinking Water Act, and some states require additional water quality standards (US Environmental Protection Agency, 2017). Unfortunately, one in nine Americans drinks water that is not regulated at the federal level and might not be regulated, or tested, at all (US Centers for Disease Control and Prevention, 2018). More than 13 million households rely on private wells as their primary source of drinking water (US Environmental Protection Agency, 2018), for which there are no federal water quality requirements, and most states do not regulate private well water. This leaves testing the well water and making sure that it is safe to drink largely up to the homeowner.

State and local regulations and the testing guidance provided to well owners vary widely across the country, making it difficult to identify trends, including successful program elements and common areas of need. To address this shortfall, in 2018 the National Environmental Health Association (NEHA) conducted an assessment to identify private well water quality testing regulations by state and understand the resources that are available, including the role of laboratories where well owners test their water. Methods included an online search of state and local agency websites using the following search terms: private well, private well testing, and well regulation. Additionally, telephone interviews were conducted by NEHA with 65 environmental health professionals from state and local agencies and university extensions. A standard interview protocol was used.

Results of the online search show that, as of 2018, only 18/50 states have requirements at the state level or in the majority of localities for well water quality testing. Of these, most states require testing after well construction (n=8) or after well construction and repair (n=7). Other, less frequent policies under which testing is required can be seen in Figures 1 and 2. All 18 states require mandatory testing to be done through either state or local laboratories, university extension laboratories, or private accredited laboratories.

Based on interviews with environmental health professionals from state and local agencies and university extensions, common resources that are provided to well users included online testing schedules, free testing events or programs, targeted testing awareness campaigns, and other materials. Interview participants from state and local agencies identified bacteria (e.g., total coliform and *E. coli*), nitrate, and arsenic as contaminants about which they provide guidance or frequently receive questions. Respondents identified a variety of other sources from which well owners receive guidance about testing which included university extensions, non-profit organizations, federal agencies, and accredited laboratories. Although accredited and state and local laboratories make up a relatively small percentage (3%) of the organizations identified as partners, these laboratories can play a critical role in determining the safety of well water through the resources provided to well owners, regardless of the state’s regulatory status.

According to the interviews, most well owners are recommended or required to use state or local and private accredited labs for well testing (n=18), followed by solely private accredited labs (n=13; figure 3).

While the use of state or local laboratories and accredited private laboratories are both common, the educational information well users receive after having their water tested varies. In over 30 states, if well water quality testing is done through a state or...
local laboratory, state or local agencies often call the well owner to follow up on any alarming contaminant levels and provide educational information. In 13 states, state or local laboratories may follow up with well owners individually. University extension laboratories may also provide educational information to well owners in several states. Accredited private laboratories, however, provide varying educational information. Some provide well users with resources to address their water quality concerns or put them in contact with a state agency, while others do not address the health issues families’ face drinking well water.

State and local laboratories play an important role in sharing well water quality data and educating well owners. Providing well owners with more information about their water quality may improve awareness and help well owners take steps to improve their water quality. Furthermore, state and local laboratories share data with state and local agencies, helping to assess contamination throughout the state and serve well users by offering:

- Biomonitoring programs that allow residents to test their water for metals and provide information on the health effects of contaminants in well water
- Onsite testing and follow-up meetings with well owners or mailing detailed fact sheets listing treatment options
- Financial assistance programs for low-income residents using well water
- Provision of free testing fairs or educational programs

Figure 2. States with at least one well water testing regulation, 2018 (below & right).
Note: Only states with requirements that are enforced in most or all localities are included here. Some states may have other regulations, such as a regulation to inform homeowners on the importance of testing, to allow state agencies to request a water quality test or to require testing in only known contaminant zones.

* Goes into effect in 2019

<table>
<thead>
<tr>
<th>State</th>
<th>After Well Construction</th>
<th>After Well Repair</th>
<th>Prior to Real Estate Transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delaware</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Illinois</td>
<td>X</td>
<td></td>
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<tr>
<td>Iowa</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Kentucky</td>
<td>X</td>
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<tr>
<td>Maryland</td>
<td>X</td>
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<td>Massachusetts</td>
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<tr>
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<td>X</td>
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</tr>
<tr>
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<tr>
<td>Oregon</td>
<td>X</td>
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<td></td>
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<tr>
<td>Rhode Island</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>South Dakota</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vermont</td>
<td>X*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virginia</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Recommended or required well water quality testing laboratory types in each state, 2018 (n=50)
Despite these strengths, some states do not have the capacity to run large well programs or fund state and local laboratories. As a result, well owners might not have access to the same quality of resources in different states. Even in states that do have strong well programs, many well owners do not test their well water on a regular basis because they lack information about available resources (Paul et al., 2015). Educating policy makers on the importance of state and local laboratories, sharing examples of ways laboratories successfully serve well owners, and disseminating more information on available programs are a few ways to support state and local laboratories as they improve public health and understanding across the United States. The research NEHA conducted will inform future program work by highlighting the variability in well water quality testing programs, including differences in state and local regulations, guidance, and resources, and the role of laboratories in ensuring well owners are educated about their water quality.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

References


INFECTIONOUS DISEASE AND THE ENVIRONMENT—A TWO-WAY STREET

By Kelly Lenox

Chemical exposures may prime the immune system for more extreme responses to infection, and infectious diseases influence the body’s response to exposures. The need to study this interplay is urgent, according to experts who joined a National Academy of Science, Engineering, and Medicine (NASEM) workshop January 15-16, 2019 in Washington, DC. The meeting was sponsored by the NASEM Emerging Science for Environmental Health Decisions.

During her opening remarks, National Institute of Environmental Health Sciences (NIEHS) and National Toxicology Program Director Linda Birnbaum, PhD, pointed out that the 2018-2023 NIEHS Strategic Plan emphasizes interaction between the institute’s research and its other programs. An interdisciplinary approach is crucial for gaining insights into how environmental health and infectious disease management can interact.

“Exposure to environmental contaminants can alter the immune response to pathogens, and, of course, the pathogens can alter the response to the toxicants as well,” she told the audience. “So we have a two-way street we have to look at.”

For example, in a 1996 paper, Birnbaum reported that exposures to 2,3,7,8-tetrachlorodibenzo-p-dioxin altered the immune response of mice to the influenza virus and resulted in increased mortality. “This response has now

Birnbaum observed that the themes of the NIEHS strategic plan overlapped with the themes of the workshop, namely, basic science, translation, training, involving people and increasing scientific literacy. (Photo: NASEM)
been shown for things like air pollution, [which] can impact the response not just to influenza, but to staph and strep infections,” she said.

**Entryways and the Microbiome**

According to several other speakers, the body’s microbiomes—especially the one in the gut—are likely suspects in the search for agents of this change because of their important roles in immune responses. Rodney Dietert, PhD, from Cornell University, pointed out that toxicological routes of exposure involve the same entryways, such as the skin, airway and the gastrointestinal tract, that allow access to infectious agents.

“They are also the physical locations where the majority of the human microbiome is housed,” he noted. He listed the range of responses microbes might have to chemicals, drugs, foods, and other substances that come their way:

- **Sequester**—if it is something they want.
- **Avoid**—to keep it out.
- **Metabolize**—generating products that affect the host.
- **Signal**—among microbes and to the host.
- **Die**—“If it is a keystone bacteria with a unique function that you have to have, that is bad,” he noted.

“At some point environmental health became toxics health,” observed Carlos Santos-Burgoa, MD, PhD, from George Washington University. “Somewhere, we lost track of [the fact that] the microbial world and chemical world are the same world.”

**An Example: Mercury**

Several speakers addressed the complex challenges of studying contaminants, infections and the microbiome. Jennifer Nyland, PhD, from Salisbury University, discussed mercury’s role in provoking an inflammatory response in parts of the body, such as the brain and gut.

People are exposed to different forms of mercury, both organic and inorganic, she pointed out. “[These forms] affect the immune system,” she said. “They do not affect the immune system all in the same way. They do not have the same level of toxicity. And they are not metabolized in your system the same way.”

Her viral studies in mice found increased inflammatory responses and decreased anti-inflammatory action. But the responses were not seen with mercury alone. They were triggered only in the presence of a virus.

**Calling on Diverse Disciplines**

One theme of the workshop was that interdisciplinary, multidisciplinary and transdisciplinary research approaches (see sidebar) are needed to uncover the interplay between pathogens and toxicants. This task calls on such disciplines as global health, epidemiology and immunotoxicology, as well as sectors as diverse as agriculture,
housing, health care and transportation, to do this research.

John Balbus, MD, NIEHS senior medical advisor and member of the workshop’s organizing committee, underscored the importance of an integrated approach. He highlighted the NASEM Environmental Health Matters Initiative as a potential avenue for continuing the discussion about new ways of doing things. NIEHS is one of the sponsors of that initiative.

Participants in the NASEM workshop included organizing committee member Josh Rosenthal, PhD, from the Fogarty International Center, and several NIEHS grantees.

References

ELITE CERTIFICATION EXPANDS WATER TESTING OPPORTUNITIES FOR MILWAUKEE HEALTH DEPARTMENT LABORATORY

By Julie Plevak, program assistant; Dr. Trivikram Dasu, deputy laboratory director; Dr. Sanjib Bhattacharyya, laboratory director; Milwaukee Health Department Laboratory

The City of Milwaukee Health Department Laboratory (MHDL) has recently achieved certification through the US Centers for Disease Control and Prevention (CDC)’s Environmental Legionella Isolation Techniques Evaluation (ELITE) Program, allowing MHDL to identify Legionella isolates from environmental samples and greatly increasing their ability to support public health investigations and improve water quality in Wisconsin.

Legionella Incidence and Testing in Wisconsin

Testing for Legionella in environmental laboratories plays a crucial role in the risk assessment of water system-related disease transmission. Legionella species have been recovered from a wide variety of domestic water systems and are common in freshwater environments. Aerosolized waters from fountains, cooling towers, saunas, evaporative condensers, showers and humidifiers have been identified as sources of Legionella infection, which can result in Legionnaires’ disease, a serious type of pneumonia, or a milder illness called Pontiac fever. In 2018, there were 298 laboratory-confirmed cases of Legionnaire’s disease in Wisconsin, compared to 181 cases in 2017 (WI Department of Health Services).

Investigation of Legionnaires’ disease cases and outbreaks requires comparing Legionella isolates grown from patient samples to Legionella from environmental water samples. To identify Legionella isolates from environmental samples, laboratories must be certified through CDC’s ELITE Program.
ELITE Laboratories Assure Legionella Data Quality

To become ELITE certified, laboratories are required to successfully complete proficiency testing panels following ELITE protocols. These panels, produced and distributed by the Wisconsin State Laboratory of Hygiene (WSLH), consist of lyophilized test samples and are collected twice a year from the enrolled programs.

“The strength of this program lies in ELITE laboratories following standardized water quality enumeration procedures for Legionella in potable, industrial, waste and natural waters, as well as biofilms and sediments. This assures sample submitters they will receive quality test results from Legionnaires’ disease individual case and outbreak investigations,” said Dr. Trivikram Dasu, MHDL’s deputy laboratory director. ELITE laboratories also have access to individualized performance reports, the latest CDC policies and guidelines, and assistance from subject matter experts to help optimize isolation procedure.

Expanding MHDL’s Legionella Testing Capabilities, Opportunities

MHDL, along with the Milwaukee Health Department Disease Control and Environmental Health division, began exploring ELITE certification in 2017 in light of new US Centers for Medicare and Medicaid Services (CMS) guidelines for healthcare facilities to implement water management policies. The new CMS requirements mandate that healthcare facilities have water management policies and procedures aligned with CDC and American Society of Heating, Refrigerating and Air-Conditioning Engineers guidelines, and to implement plans to reduce Legionella and other pathogens in their water systems.

“We plan to have dialogs with local healthcare agencies soon and hope to open up opportunities for environmental water testing as soon as we have logistics in place,” says Sanjib Bhattacharyya, director of MHDL. “At MHDL, we are also working on an algorithm potentially integrating Legionert (IDEXX) that detects Legionella pneumophila, real-time PCR, and Legionella species nucleotide sequencing to detect and differentiate causative agents of Legioniannes’ disease to improve water management practices.”

With their new ELITE site designation, MHDL is now one of only two ELITE laboratories in the state of Wisconsin capable of growing and identifying Legionella from a water sample using standardized microbiological culture techniques (the other being the Wisconsin Occupational Health Laboratory at WSLH). MHDL’s ELITE certification will also allow them to consult with local healthcare facilities as they plan to implement CMS-mandated water management policies and procedures in their jurisdiction, improve future investigations of Legionella clusters or outbreaks related to facility water systems, and may open up the laboratory’s revenue opportunities.

Water samples containing legionellae after culture (Photo: CDC):

1. Buffered charcoal yeast extract (BCYE) agar with numerous non-Legionella bacteria and a few Legionella (white) colonies.
2. BCYE + polymycin B, cycloheximide, vancomycin (PCV) agar with numerous Legionella colonies and other bacteria.
3. BCYE + glycine + PCV (GPCV) agar for inhibition of microflora with Legionella; few, if any non-Legionella bacteria are present.
4. PCV-without cysteine agar with some non-Legionella bacteria; no legionellae present (negative control medium).
ACCREDITED ENVIRONMENTAL PUBLIC HEALTH LABORATORIES CAN HELP MANAGE RISK OF LEGIONNAIRES’ DISEASE

Patsy Root, regulatory affairs manager; Kristin Majeska, senior manager, Strategic Initiatives; IDEXX Water

Legionnaires’ disease cases and outbreaks have risen dramatically over the past few years and the causative agent, *Legionella pneumophila*, is recognized nationwide as the most dangerous waterborne pathogen of our time. To help reduce the risk of exposure to *L. pneumophila*, building owners, healthcare facilities and others should implement water safety management (WSM) plans.

The guidance typically used in the US to develop effective WSM plans comes from either the American Society of Heating, Refrigerating and Air-Conditioning Engineers standard (ASHRAE Standard 188) or the US Centers for Disease Control and Prevention (CDC) *Legionella* toolkit. Both documents reference a seven-step WSM plan development process that culminates in routine validation testing to ensure the plan is effective at controlling the risk of *L. pneumophila* exposure. Both documents are also recommended resources for compliance with water safety management planning per the US Centers for Medicare and Medicaid Services rule.

A WSM plan is usually validated by testing routine water samples at various locations within a building, including its cooling towers, to ensure the level of *L. pneumophila* is within an acceptable range and below any pre-established action limit, as determined by the WSM plan team. Choosing the right environmental laboratory for WSM validation testing is extremely important because these routine validation test results determine whether any additional or different action must be taken to improve the management of the water and minimize *L. pneumophila* risk. But what criteria should be used when choosing a laboratory to perform routine validation testing?

It is good to bear in mind that microbiological water testing has been an integral part of the strategy to ensure water safety in the US for decades. In addition to stringent and well-established requirements for water treatment, the US Environmental Protection Agency (EPA) also requires routine testing of drinking water to ensure this treatment is working and to enable a quick response when testing results show a system is out of control. To ensure testing data is reliable, the EPA requires the use of accredited laboratories for this microbiological water testing. Indeed, the vast majority of public health environmental laboratories are accredited to provide drinking water testing data to the EPA. The ASHRAE Standard 188 Annex C guidance also recommends contracting with a laboratory accredited to standards nationally recognized by the American National Standards Institute or International Standards Organization (ISO). The interdisciplinary teams charged with developing WSM plans in any community are encouraged to use the same principle: engage an accredited laboratory for routine WSM plan validation testing to ensure reliable data with which to make water management decisions.
Accreditation options include, but are not limited to: ISO 17025, AIHA/EMLAP or the TNI Standard. Additionally, each state offers accreditation to environmental laboratories. To gain accreditation, environmental laboratories must be able to demonstrate proficiency in enumerating the bacteria of interest—which, in the case of validating WSM plans, should include \textit{L. pneumophila} testing.

Laboratory accreditation covers all aspects of the technical, managerial and contractual operations of a laboratory. An accredited laboratory is subjected to third-party audits to ensure all portions of the laboratory's quality system are complete, being followed and documented. Sample receipt, chain of custody, having analytical methods in standard operating procedures, documented performance training for all analysts, vendor and customer contract processes, quality control testing, and data results reporting are just a few of the requirements an accredited laboratory must meet. All of these requirements help ensure the laboratory is consistently supplying its users with data of known and documented quality.

Some may ask: Why not use a CDC Environmental \textit{Legionella} Isolation Techniques Evaluation (ELITE) laboratory for routine validation testing of WSM plans? The CDC ELITE program issues participating environmental laboratories a certificate, but is not a national or recognized accreditation program in and of itself, which is a recommendation in ASHRAE Standard 188. That being said, many ELITE program laboratories are accredited for water testing by EPA or their designee, but they are not guaranteed to be so.

In summary, a water safety management plan should include routine validation testing to ensure it is effectively controlling the risk of exposure to \textit{L. pneumophila}. For greatest confidence in their decision-making data, and the effectiveness of their plan, WSM plan teams should consider the recommendation of ASHRAE Standard 188 and the CDC toolkit and consider the use of an accredited laboratory when routine \textit{Legionella} testing is implemented for WSM plan validation.

**MANAGING LEGIONELLA RISK IN RECLAIMED WATER SYSTEMS**

by Megan Karklins, content manager, Water Research Foundation

**Legionnaires’ Disease on the Rise in the US**

From 2000 to 2015, there was a greater than five-fold increase in cases of disease caused by \textit{Legionella} spp. (Berkelman and Pruden 2017). Interestingly, the US Centers for Disease Control and Prevention (CDC) found that only 4% of confirmed Legionnaires’ disease cases were tied to a known outbreak (Hicks et al. 2011). This underlines the importance of not relying simply on outbreak detection and control as the chief prevention strategy (Garrison et al. 2016).

There are several reasons, both demographic and environmental, why Legionnaires’ disease is on the rise. People aged 50 years or older are at higher risk from Legionnaires’ disease, and the aging population in the US is growing. In addition, the use of immunosuppressant drugs is increasing and there is a higher incidence of comorbid conditions. Environmental factors include increased reliance on heating, ventilation and cooling systems. As technology and design advance, large buildings also have increasingly complex indoor plumbing systems (Berkelman and Pruden 2017).

In commercial, industrial and institutional buildings, water conservation, on-site reuse technologies and high-volume water storage can all result in increased water age and lowered disinfectant residuals. “Low flow” water-conserving fixtures could have the undesired side effect of not flushing out biofilms and other particulates conducive to \textit{Legionella} spp. growth (Berkelman and Pruden 2017).

**Researching Legionella Risk in Reclaimed Water Systems**

Earlier research on \textit{Legionella} focused mostly on its incidence in potable water systems, but there are crucial differences between potable and reclaimed water systems. The most important distinction is the higher level of nutrients in reclaimed compared to drinking water. How might this impact \textit{Legionella} occurrence and risk? In 2013, the WateReuse Research
Foundation (one of two past organizations that combined to form the Water Research Foundation) launched the project, Development of a Risk Management Strategy for Legionella in Reclaimed Water Systems (Bukhari et al. 2018) to answer these questions.

First, the research team conducted a comprehensive literature review to understand Legionella occurrence in environmental matrices, impacts of various treatment processes on inactivation and removal, status of Legionella detection methods and potential human health risks.

Quarterly monitoring of six reclaimed water utilities—representing different treatment processes, storage conditions and distribution system sizes—was performed in four states: California, Florida, Texas and Arizona. Grab samples from each utility were taken at five locations: plant effluent, reservoir and three points within the distribution system (see Table 1).

Legionella in biofilms was also measured at two facilities using experimental pipeloops configured to allow for evaluation of several disinfectants in parallel. The disinfectants studied were chlorine, monochloramine and peracetic acid. After 48 hours of treatment, bulk water and biofilm samples were analyzed for Legionella, protozoa, disinfectant residual and a variety of other water quality parameters.

Previous research has shown that viable and dead Legionella cells can co-occur in water samples. If researchers do not differentiate between the two, overestimation of Legionella risk can occur. Therefore, while analyzing samples for this project, the research team differentiated between viable and membrane-compromised Legionella cells through pre-treatment with an intercalating dye—ethidium monoazide (EMA). This dye penetrates dead or damaged cells, but not viable cells with intact cell membranes.

Table 1. Characteristics of the six reclaimed water systems sampled during the detailed survey (Bukhari et al. 2018)

<table>
<thead>
<tr>
<th>Utility</th>
<th>Treatment Process</th>
<th>Production Capacity (MGD)</th>
<th>Disinfectant</th>
<th>Storage</th>
<th>Length of Distribution System (mi)</th>
<th>Average Residence Time (hours)</th>
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</thead>
<tbody>
<tr>
<td>AZ - 33</td>
<td>Activated Sludge, BNR, tertiary anthracite filtration</td>
<td>10</td>
<td>Chlorine</td>
<td>Closed</td>
<td>130</td>
<td>5, 10, 24</td>
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<td>CA - 4</td>
<td>Trickling Filter with tertiary sand filtration</td>
<td>0.24</td>
<td>Chlorine</td>
<td>Open</td>
<td>0.3</td>
<td>2, 4, 5</td>
</tr>
<tr>
<td>CA - 32</td>
<td>Activated Sludge, tertiary anthracite filtration</td>
<td>40</td>
<td>Chloramine</td>
<td>Closed</td>
<td>100</td>
<td>1, 24, 48</td>
</tr>
<tr>
<td>FL - 30</td>
<td>Secondary clarification, sand filtration</td>
<td>7</td>
<td>Chlorine</td>
<td>Open</td>
<td>36</td>
<td>0.25, 10, 29</td>
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<tr>
<td>FL - 31</td>
<td>Activated Sludge, cloth filtration</td>
<td>14</td>
<td>Chlorine</td>
<td>Closed</td>
<td>10</td>
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<tr>
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<td>Activated Sludge, tertiary sand filtration</td>
<td>27</td>
<td>Chlorine</td>
<td>Closed</td>
<td>16</td>
<td>24, 55, 127</td>
</tr>
</tbody>
</table>

Study Findings and Recommendations

Traditionally, scientists and utilities have relied on culture-based procedures to identify the presence of Legionella and other pathogens. This research found that indicator bacteria, or heterotrophic plate counts (HPCs), did not always correlate with Legionella presence (Figure 1). Legionella grows slowly in cultures such as buffered charcoal yeast. Utilities and other environmental health laboratories are therefore encouraged to supplement the use of cultures with molecular methods. Analysis speed and sensitivity can be improved by incorporating quantitative polymerase chain reaction (qPCR) with an EMA pretreatment. However, caution must be exercised when interpreting the significance of viability data generated with EMA following Legionella disinfection. EMA is best suited for systems using chemical disinfectants (i.e., chlorine, chloramine, peracetic acid) rather than UV disinfection. EMA can be a valuable tool for monitoring system performance when controlling Legionella, but a more complete risk determination should be based on identification of Legionella pneumophila through culturing.
For any system seeking to control Legionella proliferation, maintaining an adequate disinfectant residual in the distribution system is crucial. Previous research showed that system conversion from free chlorine to monochloramine can significantly reduce Legionella spp. (Pryor et al. 2004 and Flannery et al. 2006). In this study, one participating California utility (CA-#32) was the only system that used monochloramine as a disinfectant. The percentage of viable Legionella in this system, as measured by the EMA-qPCR method, was the lowest of any utility. The California utility had generally low concentrations of protozoa and most of them were in cyst form, in which protozoa are able to survive extreme environmental conditions but are unable to host and protect Legionella and other bacteria. This data suggests that a possible control strategy for protozoa—and, indirectly, Legionella—could be to use monochloramine to transform the trophozoites into cysts rather than attempting to keep free chlorine residuals unrealistically elevated.

Disinfectant residuals, when present, were effective at controlling Legionella growth. For total chlorine (free chlorine plus chloramines), the minimum threshold to achieve adequate disinfection was determined to be 1 mg/L. Samples with at least 1 mg/L of total chlorine had, on average, seven times less Legionella, regardless of sampling location. Samples with a free chlorine minimum threshold of 0.2 mg/L had on average six times less Legionella.

Organic carbon was shown to be an indicator of Legionella occurrence. High levels of organic carbon were present in the samples containing elevated levels of Legionella. Samples that had more than 1,000 μg/L of assimilable organic carbon (AOC) and/or more than 10 mg/L of total organic carbon (TOC) had over 70% more Legionella than samples with AOC and TOC below these thresholds. Treatment strategies that improve removal of particulate and dissolved organic carbon (e.g., longer solid retention times, implementation of biologically activated carbon filtration, application of membrane filtration or other advanced treatments) are likely to be beneficial.

CDC has reported that Legionella accounted for 66% of the US’ waterborne disease outbreaks from 2011–2012. L. pneumophila serogroup 1 was responsible for most of those infections; thus, detection methods should focus on this species. Over half (64%) of the identified organisms in this study were L. pneumophila, which was detected in 96 samples. The other most-identified species included L. oakridgensis (n=12), L. moravica (n=9), L. longbeachae (n=8) and L. hackeliae (n=8). All the species identified (n=16) are capable of causing human disease, except for L. moravica, which was found in the effluent and distribution system samples of three utilities. Utilities concerned about Legionella infection should carefully select their final disinfectant, optimize disinfectant residuals, minimize nutrient loading and monitor for the presence of L. pneumophila directly. Legionella occurrence can be influenced by complex ecological interactions. To manage this risk, utilities must recognize the lack of correlation between Legionella and common microbial indicators such as HPCs, acknowledge the need for adapting adequately sensitive detection methods to enable successful monitoring, maintain disinfectant residual in distribution systems, and manage nutrients (particularly organic carbon and nitrogen) in upstream treatment processes to minimize system regrowth.
Utilities should also clean and flush their systems to inactivate *Legionella* and protozoa trophozoites.

It is important to realize that the risk models utilized in this study are complex and scenario-dependent. The models can vary widely depending on the assumed conditions. The models are not intended to describe safe or unsafe levels of *Legionella*, but rather provide a comparative analysis of factors that contribute to the risk of infection. The sensitivity analysis of the quantitative microbial risk assessment models all pointed to the importance of reducing *Legionella* concentrations as a means of reducing risk. Even though no outbreaks of Legionnaires’ disease have been reported from reclaimed water systems, utility operators are still advised to address *Legionella* to lower risk and protect public health.

Please contact Megan Karklins with questions.

References


Water Research Foundation Recorded *Legionella* Webinars

**Understanding Analytical and Monitoring Methods for *Legionella* in Building Water Systems**

The presence of *Legionella* in building water systems has continued to grow in significance as a public health concern. However, the ability to provide reliable, sensitive and quantitative detection and differentiation of live and infectious pathogens remains a significant challenge. This webcast focuses on the current analytical and monitoring techniques for *Legionella* and explains considerations for method selection. Presented by:

- Janet Stout, PhD, president and director, Special Pathogens Laboratory and research associate professor, University of Pittsburgh Swanson School of Engineering
- Laura Boczek, microbiologist, US EPA–ORD
- Joseph Cotruvo, PhD, Joseph Cotruvo & Associates, LLC

**Management Technologies for Prevention and Mitigation of *Legionella***

There are several management technologies that can help control *Legionella* in building water systems. Many technical and practical considerations are necessary to choose the appropriate mitigation strategy for a particular site. This webcast explores the current understanding of prevention and mitigation technologies for *Legionella* management. Presented by:

- Frank Sidari, PE, BCEE, technical director, SPL Consulting Services
- Sheldon Masters, Corona Environmental Consulting, LLC
- Joseph Cotruvo, PhD, Joseph Cotruvo & Associates, LLC

**Legionella Management and Guidelines**

The risk of *Legionella* growth and transmission in building water systems can be reduced through the implementation of water management programs. This webcast covers current guidance for prevention of Legionnaires’ disease through effective water management. Presented by:

- Laura Cooley, Centers for Disease Control and Prevention
- David Dziewulski, New York State Department of Health
- Mark LeChevallier, Dr. Water Consulting, LLC
- Claressa Lucas, Centers for Disease Control and Prevention
- Bill Pearson, ASHRAE SSPC 188