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## Research Article

# Guidance on Developing a Legionella pneumophila Monitoring Program for Utility Distribution Systems

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## Abstract

Despite recommendations for water utilities to “validate treatment performance by routine monitoring for *L. pneumophila*,” little guidance is available on how exactly to accomplish this goal. The objective of this study was to outline a process by which water utilities can plan and implement such a monitoring program. The guidance is based on the experience gained through several prior research studies and input from several state public health authorities. Unfortunately, there is no such guidance from U.S. federal agencies. The seven step process guides utilities to consider program objectives, key internal and external stakeholders, monitoring protocols and training, communications, support for testing and reporting, pilot testing and program documentation. There are a number of commercially available tests for *L. pneumophila*, although some have been more widely evaluated by third-party entities than others. In all cases, it is important for utilities to consider how program results will be communicated and to solicit input on the process from relevant stakeholders. In all cases, it is important for utilities to consider how that program results will be communicated and to solicit input on the process from relevant stakeholders. Finally, program documentation and sharing of the results with the public and other utilities is encouraged to help other water utilities navigate the same path and demonstrate industry leadership.

**Keywords:** Legionella pneumophila, monitoring, distribution system, stakeholders, communications

## Introduction

The national Academies of Science and Medicine recommended in their 2019 report entitled Management of Legionella in Water Systems that drinking water utilities maintain “a disinfectant residual throughout public water systems and validate the treatment performance by routine monitoring for Legionella pneumophila from water samples representative of the distribution system” [1]. The rationale for the recommendation is that water entering domestic and public buildings should be of the highest quality possible. Currently, the federal regulations allow for no detectable residual to be possible in 5 percent of the measurements in distribution systems that use surface water [2], and the federal law does not require groundwater systems to maintain any disinfectant residual within their distribution systems. There are no national guidelines, however, to help utilities develop a monitoring program for distribution systems.

Surprisingly, there are relatively few studies of Legionella occurrence in the portion of the distribution system managed by

water utilities. Wang et al. [3] detected Legionella spp. using quantitative PCR (qPCR) in two chloraminated drinking water distribution systems, although *L. pneumophila* was detected in only 5.6 percent of samples and Legionella spp. concentrations were reduced 45-fold after tap samples were flushed for 3 minutes. Lu et al. [4] examined large volume (90 L) ultrafiltration concentrates from six sites within a distribution system and frequently (57 percent) detected Legionella spp. by qPCR at an average concentration of 85 cell equivalents per liter. *L. pneumophila* was detected, but at low frequency (6 percent). Concentrations of Legionella spp. were 0.4 to 78-fold higher in the distal sections of the distribution system compared to the entry point, suggesting growth within the distribution system.

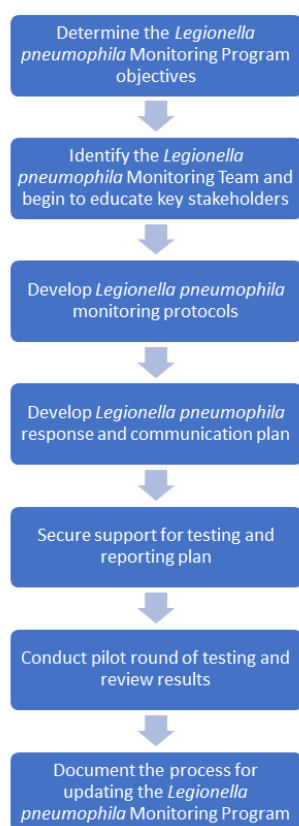
LeChevallier [5,6] detected *L. pneumophila* in six of 12 (50%) drinking water distribution systems at rates ranging between 0.17 to 2.4%. The average concentration of *L. pneumophila* during periods of warm water in free chlorinated systems (n=317) was 3.04 MPN/100 mL but were 0.02 MPN/100 mL in chloraminated systems (n=258). For

the studies, the utility participants collected and analyzed the water samples for *L. pneumophila* and the lessons learned from these trials along with discussions with other utilities formed the basis of the recommendations outlined in this paper. These suggestions are offered to water utilities to help them plan and implement a voluntary *L. pneumophila* monitoring program. Should requirements be developed by regulatory agencies, of course such regulations would take precedence.

## Program Development

### Setting program objectives

Figure 1 provides an overview of the seven steps recommended in developing a *L. pneumophila* monitoring program. The first step is to determine the program objectives. Clarity on the objectives of the *L. pneumophila* monitoring program is important so that a consistent message can be presented to all stakeholders. These objectives can have multiple reasons and can have different aims. Table 1 shows the actual objectives that utilities have listed as reasons for starting a *L. pneumophila* monitoring program [5]. Water utilities want to be confident that the water they serve meets or surpasses all state and federal standards. Monitoring for *Legionella* can give them the confidence that their treatment processes are adequately controlling this organism. In one case study [6], a utility detected *L. pneumophila* in an area of the distribution system with low chlorine residual and redirected their capital program to improve mixing in storage tanks to maintain their internal goal of >0.3 mg/L free chlorine throughout their distribution system.



**Figure 1.** Seven Steps in Developing a *L. pneumophila* Monitoring program

**Table 1.** Possible Objectives for the *L. pneumophila* Monitoring Program

- To understand the adequacy of existing treatment to control *Legionella* in the distribution system
- To be able to better communicate with stakeholders on *Legionella* management
- To become familiar with methods for *Legionella* monitoring
- To be proactive in advance of any future regulations
- To be consistent with internal water quality goals

Increasingly, public buildings are implementing water management plans for control of *Legionella* and other opportunistic pathogens and may contact their utilities for help and information. Masters et al. [7] reported that water utility commercial customers had a high awareness of *Legionella* with over 50% surveyed having a water management plan being led by hospitals and health care facilities (81%), but also commercial and industrial customers (41%) and multi-dwelling facilities (29%) having implemented such plans. By having a *L. pneumophila* monitoring program the utilities can communicate their activities to ensure high water quality with these customers.

With the availability of commercially-available tests for *L. pneumophila*, utilities are interested in becoming familiar with the assays. When utilities were asked why they would monitor for *Legionella* in their treated water, 36% indicated that they wanted to have experience with methods for *Legionella* detection [5]. Additionally, 9% indicated that they wanted to have information on *Legionella* occurrence in advance of any possible USEPA regulations [5].

### Identify monitoring team and stakeholders

With It's important that all the key stakeholders are aligned on the objectives and benefits of the testing program. Valid questions will arise and must be addressed. Table 2 lists the internal (to the water utility) and external stakeholders to consider in the development of the *L. pneumophila* monitoring program. The commitment of senior management (CEO, General Manager, etc.) to the monitoring program is critical. They should see the program as best serving their customers interests and safety. Senior management should be able to articulate why monitoring for *L. pneumophila* is aligned with the mission and vision of the organization. The potential for finding an opportunistic pathogen in the utility's water system will be a major concern for the legal department whose job it is to protect the utility from risk. However, not knowing about *L. pneumophila* risks has its own set of issues, particularly when simple methods are available and corrective actions can readily be implemented. Overall, the utility is better protected by identifying and dealing with risks than ignoring them. The operational leads (treatment and distribution) should be aligned and prepared to make corrective actions if necessary. Maintenance of a disinfectant residual throughout the entire distribution system will be important for *L. pneumophila* control, so disinfectant residuals may need to be increased; the turnover, mixing, and operations of storage facilities might need to be altered, and increased corrosion control and flushing of the distribution system might be needed to improve the stab

-ility of the disinfectant residuals. Having effective communications before and during a *L. pneumophila* monitoring program is essential to the success of the effort. The Water Research Foundation report, Customer Messaging on Opportunistic Pathogens in Plumbing Systems (#4664) can be an excellent resource as it has a number of prepared materials for various stakeholder groups and social media platforms [7]. The report includes a template for website materials to educate various customer groups on the importance of facility owners reducing building water risk and can be expanded to explain how the utility is doing its part in conjunction with facility owners by setting up a proactive routine monitoring program to detect and respond to any water quality risks. Engineering should be aware of the monitoring program because the results could require physical or design changes to improve mixing and turnover in storage facilities and/or cleaning, lining, or replacement of water mains that create excessive disinfectant decay. The laboratory is a key stakeholder in the *L. pneumophila* Monitoring Program as this group will need the resources to complete the analyses. More details on monitoring are found below. It's a good idea to include Human Resources since all employees should be aware of the objectives and results of the monitoring program. In some organizations this task might be handled by internal communications. Employees are the ambassadors of the utility to the community and should be conversant on monitoring efforts and the implications. Periodic updates to employees through normal organizational communications channels are recommended.

**Table 2.** List of Internal and External Stakeholders

Internal Stakeholders:	External Stakeholders:
Senior Management	Environmental Regulator
Legal	Public Health Agency
Operations Lead - Treatment	Political
Operations Lead - Distribution	Customer Advocates
Communications	Large Customers
Engineering	Media
Water Quality and Laboratory	
Human Resources	

Coordination with internal stakeholders should probably precede outreach to some external stakeholders, but as mentioned above, final decisions will likely not be made until there is coordination between both internal and external groups. Some informal discussion with key regulators (environmental, public health, and in some cases, economic) is suggested before formal engagement is initiated just to better understand their positions and potential concerns.

The environmental regulator may be interested in results from the *Legionella* monitoring study but also concerned that they may be

placed in a position to have to interpret and/or respond quickly to the results – something that they may not be prepared to do. Therefore, it will be important to share the objectives of the monitoring and the guidelines for responding to positive results. It will be important to get their buy-in on the response. They will also want to know how the data will be communicated, so utilities should have these plans ready. Similar to the environmental regulator, it is important to have buy-in from the public health agencies. They also may be concerned that they will be placed in a position to have to interpret the results or take appropriate actions to protect public health – so it will be important to share the guidelines for responding to positive results and get their concurrence. At the same time that the utility is performing the monitoring, it would be useful to have the public health agencies carefully monitoring for cases of Legionnaire's Disease in the community. Different utilities will have different relationships with political entities in the towns that they serve, but it may be useful to notify various political entities (e.g., mayor, city council, water authority board members, etc.) of the *L. pneumophila* monitoring program, the objectives, and goals. Some utilities may have a customer advisory board or some other customer advocate group. Notification to this group on the monitoring plans, utility responses, and communications can help build trust and support for the utility. Engaging the media early in the process is recommended. Start by inviting them to tour the treatment plant and the laboratory (especially if they've never done this before).

In addition to identifying stakeholders, consider implementing educational campaigns for the community, particularly large customers, and the media. The Water Research Foundation report (#4664 - Customer Messaging on Opportunistic Pathogens in Plumbing Systems) outlines materials that water utilities can use to proactively communicate with customers about *Legionella* in water [7].

### Develop *L. Pneumophila* monitoring protocols

There is no single right way to develop a *L. pneumophila* monitoring program. Since it is a voluntary testing program, the key here is to meet internal objectives. However, several approaches can be considered in developing a monitoring program:

1. Use the already state-approved Total Coliform Rule (TCR) sampling plan that is representative of the distribution system [8]. The utility already has an extensive database of water quality data – from which any water quality excursions can be evaluated. Extra sample bottles for *L. pneumophila* testing can be collected along with the regular TCR sampling. The extent and frequency of monitoring depends on the utility resources and the capacity of the laboratory to handle the additional testing. To help manage the number of samples, monitoring can focus on when water temperatures are >15°C since prior studies showed that *L. pneumophila* was not detected when water temperatures were cold [6].
2. The monitoring program could target storage facilities since long detention times, low turnover, and sediment accumulation

can provide opportunities for *L. pneumophila* growth. Lu et al. [4] detected *Legionella* spp. by qPCR in 66.7% of municipal drinking water storage tank sediments from 18 sites.

3. The monitoring strategy could target sites where vulnerable populations might exist including locations near hospitals, nursing homes, senior centers, etc. Sampling could also target any known points in the system where water is stagnant or disinfectant residuals are known to dissipate. Areas near or downstream of main breaks, or construction or repairs of the distribution system, may be opportunities to detect *L. pneumophila* that may be released from biofilms due to flow changes or vibrational forces.
4. Another option could be to collect samples from designated disinfectant by-product monitoring locations, as these locations could better represent high water age in the distribution system. One caveat would be to make sure that these sampling taps conform to specifications for collecting bacteriological samples. Hydraulic models could also be used to identify locations of high water age.
5. Municipal and other city or utility-owned buildings that serve the public are recommended to have water management plans [1]. Testing within the building plumbing system could be done as a means of validating the controls in their water management plan. The development of water management plans and monitoring to validate the plans would set an example to other businesses/buildings in the community to protect public health.

It is assumed that water samples would be collected, as obtaining biofilm samples are more complicated and would require specialized techniques not typically used by the utility. The frequency of sampling will depend on the availability of laboratory resources and the utility objective for the *L. pneumophila* Monitoring Program. However, the frequency of sample collection and analysis should be sufficient to evaluate trends and identify any changes in water quality over time. Monthly or quarterly sampling may be appropriate; however, sampling can be more intense during periods of warm water (>15°C). One large city utility analyzed samples every month and rotated sampling sites over the course of a year in order to gather baseline data for 100% of its TCR sampling sites. The utility is now designing its ongoing sampling strategy based on these initial results.

In addition to evaluating samples for the presence of *L. pneumophila*, the collection of additional water quality data can help to put the monitoring results into context (Table 3). The type of data collected can be identical to the routine total coliform monitoring, or additional data can be collected for this special study. In all cases, the utilities should follow their established procedures and quality control protocols for these analyses.

**Table 3.** Suggested water quality data parameters for the *L. pneumophila* Monitoring Program

Parameters to Test
<i>L. pneumophila</i>
Total coliform / <i>Escherichia coli</i>
Heterotrophic bacteria
Free/Total chlorine/Monochloramine
Temperature
pH
Total organic carbon
Nitrite, free and total ammonia *

\* For chloraminated Systems.

Once the scope of the *L. pneumophila* monitoring program has been determined, the schedule of samples can be programmed and personnel responsible for sample collection can be trained on the proper sampling methodology using appropriate sample bottles containing sodium thiosulfate. Ideally, samples should be collected from dedicated sampling stations (connected directly to the main) to avoid any influence from service lines and internal plumbing. If samples are taken at customer taps, the same procedures should be used as those for TCR monitoring (e.g., proper faucet selection, removal of aerators, flushing of the tap for 3-5 minutes before sample collection, etc.). An alternative sample collection protocol could collect samples without any flushing (e.g., first draw sample), but this procedure would primarily determine *L. pneumophila* at the tap – which may not be reflective of the levels in the water distributed by the utility.

Appropriate chain of custody forms should accompany the sample indicating the sampler's name, sample location, date, time and any other routinely collected information. *Legionella* samples should be transported at ambient temperature to the laboratory in insulated coolers as protection against extreme heat or cold. Analyses should be initiated as soon as possible or samples not processed within 24-48 hours from the time of collection should be refrigerated.

The sample collection procedure should include protocols so that to act on any results of unusual or low disinfectant results so that these results are communicated and followed-up immediately – without waiting for the *L. pneumophila* results. Chloraminated systems should have a nitrification monitoring plan so that samples with low monochloramine (or total chlorine) residuals or elevated nitrite detection can be quickly treated. Flushing of the areas of the distribution system with low disinfectant levels and can be done to restore normal residuals [9].

There are a number of commercially available *L. pneumophila* assays suitable for use in a water utility laboratory. The Legiolert assay

is a culture-based assay that detects *L. pneumophila* by a color change in the growth medium and quantification using the most probable number (MPN) of organisms in the sample (equivalent to colony forming units.) The test detects one *L. pneumophila* in 100 mL, with results ready in 7 days. Extensive studies have found that the Legiolert assay performed better than conventional methods, with a higher specificity for *L. pneumophila* in both potable and non-potable water [10-14]. The analytical technique for the Legiolert test is similar to the total coliform Colilert test, so the process is familiar to water utility laboratories [5]. The Spartan Cube is a polymerase chain reaction (qPCR) -based assay that detects the DNA of *L. pneumophila* in a sample within an hour [15]. The assay uses proprietary qPCR primer set and the results expressed as genomic units/mL. The assay has not been as widely evaluated as the Legiolert test but could be used as a rapid screening tool [1]. Other qPCR kits are available (Bioteccon) but must be used on conventional qPCR platforms – something most water utilities lack. There are also a number of commercial immunological tests for *L. pneumophila* detection (e.g., lateral flow immunoassays, solid-phase cytometry, and flow cytometry). The ScanVIT method uses a 72 hour incubation followed by microscopic counting of microcolonies using fluorescent gene-probe detection [16-17]. The point of this discussion is that there are many commercially available *Legionella* assays (and more are in development), so the utility must choose the assay that best fits their capabilities and monitoring objectives.

#### Develop *L. pneumophila* response and communication plan

Conventional water treatment practices do not produce sterile water and it is possible that low levels of *L. pneumophila* may be occasionally present, even in the best water supplies. It is important, therefore, to develop a proactive communications plan because detection of *L. pneumophila* is possible even in well-operated systems. The utility's stated goal should be to achieve zero *L. pneumophila* in the distribution system. To do this the system should emphasize maintaining an effective disinfectant residual throughout the system, proper maintenance, and infrastructure renewal. Despite these efforts, research [3,4,6] has shown that low concentrations of *L. pneumophila* can occasionally be detected even in properly operated systems. The following recommendations were used in a recent study of *L. pneumophila* in public water systems [5] and the basis for this guidance was outlined in a prior publication [18]. The protocol was developed in collaboration with regulators from the State of Washington and consistent with a quantitative microbial risk assessment of *L. pneumophila* [19] and a number of national and international guidelines (Table 4). Guidelines are not yet available for molecular methods, although the Spartan Cube reports their genomic units with a conversion to colony forming units (CFU/mL).

**<0.1 to CFU or MPN 1.0/mL.** *L. pneumophila* in distribution systems at these levels may be transitory and repeat samples are often negative [18]. Infrequent detection of *L. pneumophila* at these levels may not be of great concern if the other routine water quality data and system operations are normal.

**Table 4.** Summary of Guidelines for *Legionella* Management

Legionella Management Guideline	Reference
New York State regulations (subpart 4-2)	[20]
Allegheny County Health Department	[21]
American Industrial Hygiene Association	[22]
European Technical Guidelines	[23]
National Academy of Sciences, Engineering and Medicine	[1]

**>20% occurrence.** Determination of the frequency of occurrence depends on the number of samples collected per monitoring event. Assuming that 10 samples are collected, if more than two are positive during any particular sampling event, this would be an opportunity to notify the environmental/public health regulator and conduct a system evaluation. Assuming that 10 samples are collected, then if more than two are positive during any particular sampling event, this would be an opportunity to notify the environmental/public health regulator and conduct a system evaluation. If any deficiencies are detected, they should be corrected.

**1.0 CFU or MPN to 10/mL.** *L. pneumophila* levels in this range indicate that conditions may be favorable for growth of the organism in the system. Actions should be taken to correct any low disinfectant residuals, water stagnation, or other conditions that could lead to the proliferation of the bacteria in the system. This would be an opportunity to notify the environmental/public health regulator and conduct a system evaluation. If any deficiencies are detected, they should be corrected.

**>10 CFU or MPN /mL.** *L. pneumophila* levels in this range indicate that conditions are favorable for growth of the organism and that immediate actions should be taken to reduce the bacterial levels. Disinfectant residuals should be increased, and positive areas of the system should be flushed until the elevated disinfectant residuals are achieved. After consultation with the environmental/public health regulators, consider issuing public notification to boil tap water. As a precaution, advise the elderly and immunocompromised to avoid showers and situations where water is aerosolized. The notification can be lifted, upon concurrence with the regulators once elevated disinfectant residuals are stable and *L. pneumophila* occurrence is eliminated.

The framework includes a “system assessment if *L. pneumophila* levels exceed 1.0 cfu/mL or more than 20% positive samples. The revised Total Coliform Rule (RTCR; USEPA 2013) requires a Level 1 assessment to be conducted by the public water system owner that assesses any mechanism that could provide a pathway for microbial contamination or any sanitary defect that indicated a failure of a protective barrier to prevent microbial contamination. In the context of *Legionella* contamination, such an assessment could include failures in treatment or disinfection, main breaks, failures in storage tanks or reser-

-voirs, cross connections, backflow, etc. Similar to the RTCR, any deficiencies identified would be expected to be corrected, which could include flushing parts of the network with low disinfectant residuals, cleaning storage tanks, or boosting disinfectant levels within the distribution system.

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In a case study outlined by LeChevallier [6], a utility that had three positive *L. pneumophila* samples ranging between 1 and 5 MPN/mL implemented a flushing program to bring chlorinated water into an area where stagnation had eliminated the free chlorine residual. After applying corrective actions to the system, the utility visited each customer in the affected area (about 70 households) to explain what had happened and steps the utility was taking to correct the situation. In all, the customers appreciated the outreach, and no questions or complaints were raised. The health department was informed of the monitoring results and the utility’s response, and it approved of the actions. The episode resulted in the utility focusing their capital resources on improvements to better maintain disinfectant residuals throughout the distribution system [6].

Consider posting updates on the *L. pneumophila* monitoring program on the utility’s web page, even if all the results are negative. Posting the action levels discussed above will allow stakeholders to know when alerts will be issued. Consider including a statement on *Legionella* in the annual (or bi-annual) Consumer Confidence Report. The Water Research Foundation report (#4664) included some samples that can be used. Interested stakeholders can be directed to the utility web page for more details [7].

### Secure support for testing and reporting plan

After the details of the sampling, methods, QA/QC, and communications plans are developed it is important to review and discuss these plans with the regulators. In some states the Public Health Department has responsibility for regulating water systems, however; in many states environmental regulations and public health responsibilities reside in different agencies. It is recommended to engage both departments, either in a single meeting or separately. It is important that this meeting not be the fir-

-st time these agencies are hearing about the utility’s plan to monitor for *L. pneumophila*, as the utility should have already laid the groundwork with some type of pre-communication (either by letter, phone, or in-person meeting) about the utility’s intent and goals for monitoring *L. pneumophila*. Anticipate the need to educate these agencies by providing background information – such as prior publications of utility *L. pneumophila* monitoring programs [5,6,18].

Many public health and environmental agencies will be supportive of the utility’s desire to monitor for *L. pneumophila* but may have concerns about the implementation of the program and the specific actions that would be taken in response to detection of the organism in water supplies. Start with the shared objectives of all the stakeholders to better protect public health and better serve the public. Outline the monitoring program, the QA/QC plans, and how the results will be shared and communicated. The purpose of the meeting is to open a dialog and solicit input into the plans. Constructive ideas are welcomed, but if any objections can’t be resolved, additional planning and development may be necessary. If objections are raised, try to ask the stakeholders what would be needed to resolve these objections. It is important to have the support of the public health/environmental regulators and accommodate their relevant input.

Agree on what communications will happen during the *L. pneumophila* monitoring program. This could be periodic updates to the regulator or could be limited to an agreement to supply information when certain action levels are reached. Enlist the regulator’s support in any subsequent discussion with other stakeholders (e.g., political, community groups, media, etc.).

Employees are the ambassadors of the water utility in the community. As such, they should be aware of the objectives of the monitoring program and have background information on *Legionella* in water. In a prior case study [6], the only questions about the *Legionella* results came from employees who wanted to be able to explain the program to neighbors and friends. Therefore, periodic program updates should be made to employees through normal organizational communications channels.

Additional training and talking points should be prepared for customer service agents so that they can address routine customer inquiries. If the utility has a program for outreach to large commercial, industrial and institutional customers (CII), this customer training could include information on water management plans that these customers could implement to also manage *Legionella* issues in building water systems. Research has shown [7] that outreach by the utility can prompt CII customers to consider implementing water management plans, thus creating a strong partnership between the utility and the customer.

After securing the support of the public health/environmental regulators, subsequent discussions can be held with other important stakeholder groups. These discussions can be approached as an “inform and advise” format – where the purpose is primarily to inform the stakeholders of the program. This communication can start with just ge-

-neral information on Legionella in water and the importance of implementing water management plans. Still, it is important to be open to hear and respond to any concerns expressed by the stakeholders – after all that this overall reason for the interaction..

Consider the sequence of engagement; with political, business, and customer advocates contacted before discussions with the media. It makes a powerful statement to the media that the utility, regulators, politicians, business, and advocates are aligned on a voluntary, proactive program to better protect public health. Moreover, the program also sends a positive message to building owners to address Legionella issues in their premises.

Conduct pilot round of testing and review results

After all the preparations, it's time to implement the L. pneumophila monitoring program.

- Order all necessary supplies and check the expiration dates on any existing materials to ensure that all are ready to be used.
- Consider performing a “dry run” of sampling and analytical methods on a few sites to make sure that samplers and analysts are familiar with the protocols.
- Ensure that all the sampling sites are accessible, and the sampling faucets are appropriate for bacteriological sampling (e.g., dual handle, removable aerators, short neck, etc.). This may be particularly important for sites that are not part of a routine TCR sampling program. In all cases, it is recommended to select sampling faucets that are not too far removed from the water main, although this may be difficult in large buildings like hospitals. The reason for this recommendation is to minimize the impact of building plumbing biofilms on the sampling results.
- If dedicated sampling stations are available, it might be advisable to select these locations to minimize the impact of building plumbing biofilms on the sampling results. If a mix of sampling sites are used, it is advisable to note these distinctions (e.g., dedicated, building) in the database.
- Note any construction or distributions system activities nearby to the sampling sites as disturbances from these activities could dislodge biofilms and influence the L. pneumophila results.

Prepare the data sheets in a manner that will aid in the final analysis of the data. Collect all the data from a single sampling site in one row in the datasheet. Avoid using “less than” or “greater than” symbols in the data. Record non-detect results as “0” (zero) and “greater than” results as the highest value.

Follow the guidelines established for reporting L. pneumophila

developed in the communications plan and agreed to with the regulators. Consider giving presentations on what has been learned at local, regional, and national water industry conferences and symposia. Sharing the experiences in setting up and implementing the monitoring program will help other water utilities navigate the same path. It will demonstrate industry leadership for your utility.

### Document process for updating the L. pneumophila monitoring program

It is important in any project to perform an “after study analysis” to review the items that went well, those that did not work, and items that could have been better performed better. Areas of review can include planning, communications, sampling, analysis, documentation, and continuous improvement. Operational changes such as minimum disinfectant residuals, tank turnover, flushing, corrosion control, etc. should be included to “embed” the learning into the daily activities of the utility. Update the distribution maps/database based on new information learned in the L. pneumophila monitoring program. Any changes in the sampling locations (faucet type, plumbing materials, etc.) can be noted. Update databases on areas of low disinfectant residual or prolonged stagnation. These areas might be scheduled for periodic flushing and/or improved corrosion control. If not already noted, update the monitoring plans with information on potentially vulnerable populations, including hospitals, nursing homes, senior centers, and other critical locations.

### Summary

Despite recommendations for water utilities to “validate treatment performance by routine monitoring for L. pneumophila,” little guidance is available on how exactly to accomplish this goal. The objective of this study was to outline a process by which water utilities can plan and implement such a monitoring program. The guidance is based on the experience gained through several prior research studies and input from several state public health authorities. Unfortunately, there is no such guidance from U.S. federal agencies. The seven step process guides utilities to consider program objectives, key internal and external stakeholders, monitoring protocols and training, communications, support for testing and reporting, pilot testing and program documentation. There are a number of commercially available tests for L. pneumophila, although some have been more widely evaluated by third-party entities than others. In all cases, it is important for utilities to consider how program results will be communicated and to solicit input on the process from relevant stakeholders. In all cases, it is important for utilities to consider how that program results will be communicated and to solicit input on the process from relevant stakeholders. Finally, program documentation and sharing of the results with the public and other utilities is encouraged to help other water utilities navigate the same path and demonstrate industry leadership.

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