Legionella: Ubiquitous Organism, Comprehensive Cure

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This paper details the thought processes and successful solution Geisinger Health System, a large, rural healthcare facility, implemented to eliminate legionella bacteria from its domestic water supply.   The main campus of the health system is home to a large medical center with a level one regional trauma center, and comprises 460 acres with 2,000,000 square feet of buildings. The medical center provides quaternary care, and has a joint venture rehabilitation facility. The campus also serves as the corporate office for the health system.

The campus-wide domestic water system has a 550,000-gallon reservoir supplied by a well, a spring, and the local municipal system drawn from the Susquehanna River. The site holds a non-transient non-community water permit from the Commonwealth of Pennsylvania.

Geisinger's Facilities Operations group is responsible for this site as well as approximately 60 others spread across 31 of Pennsylvania's 67 counties, including a second hospital and a chemical dependency center. Facilities Operations primary responsibilities include all maintenance and repair, preventive maintenance, infrastructure renewal, utilities management, central plant operations, grounds care, fleet operations, waste management, security services, and construction and renovation projects. The Management group is comprised of an associate vice president, four Facilities Operations managers, and a manager of security. Facilities Operations employs 160 people to provide those services throughout the healthcare system.

Statistics show that 50% of healthcare facilities harbor the dangerous legionella organism in their domestic water systems. The organism is particularly dangerous in healthcare institutions because the organism attacks people with compromised immunological and respiratory systems. A susceptible host contracts the disease by inhaling aerosolized water droplets containing the organism. Legionnaires disease is a type of pneumonia that is fatal if not diagnosed and treated early. The strategy we devised to locate and rid our system of the bacteria used a multidisciplinary approach. Our effective solution became the first successful system implemented at a hospital in the United States. The results conclusively prove that the organism is controlled, and the safety of the patients and staff enhanced.

In 1997, our environmental water sampling on the campus yielded positive legionella cultures. We immediately took steps to prevent further occurrences and threats to our patients including forming a task force consisting of infectious disease physicians, an infection control nurse, and industrial hygiene and facilities management personnel. The task force made a list of all possible sources to check for the organism including air intakes, air handlers, cooling towers, medical air pumps, water storage devices, humidifiers, and the domestic water system. After examining and culturing those areas, the task force found the problem centered around the domestic water supply because aerators on sinks and showerheads showed positive swab cultures. The group made the decision to remove all aerators and proceed with a thermal disinfection procedure, known as a heat and flush. This procedure poses a significant risk to the patients because domestic hot water temperatures are elevated to 180 degrees Fahrenheit for eight to 12 hours to allow the purging of all fixtures for 15 to 20 minutes. To reduce the scald hazard, we placed signs that explained the process and delineated the scald hazard on all the sinks. We used the signs to record the location and flush data, which created a record and insured all sites were disinfected. After that procedure, we re-cultured the water to find out if we had successfully disinfected the system. When subsequently we found environmental positives, we repeated the heat and flush procedure.

At this point in time, the task force realized those procedures were temporary solutions, and that we needed a program to eliminate and prevent the organism's colonization. The facilities department advocated for routine, random surveillance (culturing) to monitor the problem and determine action levels. At that time, however, that contradicted the Centers for Disease Control (CDC) recommendations. The CDC recommended against routine sampling, largely because there was no recommendation for remediation. We decided that science had to rule to resolve the problem, and that environmental sampling was crucial to measure the severity of the problem and the progress made in solving the dilemma. The results indicated the problem to be pervasive, but the levels of the cultures were not alarmingly high. We began sampling the water system on a monthly basis. Positive cultures led to a building-wide heat and flushes with re-sampling to affirm the effectiveness. We realized the time cycle between positive results, heat and flush, and repeat positive results were diminishing. It seems the heat and flush procedure merely killed the flora and those organisms near the surface of the biofilm. Legionella bacteria below survived the treatment insulated by the existing biofilm in the piping network. Once the procedure was finished, the organism re-emerged, seemingly fertilized by the sacrificial insulating layer of biofilm. It was clear to us that additional comprehensive measures would be necessary to eradicate this persistent menace.

While we searched the literature for an optimal solution, we implemented the following interim measures to mitigate the risks to our patients:

- Because we are a licensed potable water supplier, our first step was to increase our chlorination levels to one part per million (ppm).
- Clinicians revised the protocols for the diagnosis and treatment of pneumonia and placed a greater emphasis on sensitivity to a diagnosis of legionella. Physicians immediately

placed symptomatic patients on an antibiotic effective against legionella and ordered a urinary antigen test to confirm the diagnosis.

- Facilities elevated the hot water temperatures to 125 degrees Fahrenheit at the point of use. Legionella thrive at temperatures of 90 to 122 degrees, coincident with the temperature hospitals normally operate domestic hot water systems. Although that change is beyond recommended operating parameters, we experienced no incidences of scalding, and we assessed the risks were much less than the exposure to patients during the periodic heat and flush protocols.

With the aforementioned straightforward practice changes accomplished, we started researching how to disinfect and maintain our systems to be legionella free. Based on numerous case studies, we installed a silver copper ionization (CSI) system in the domestic hot water loop of our joint venture rehabilitation hospital. The rehabilitation hospital was the site of several environmental isolates.

Our evaluation of the copper silver ionization system yielded several concerns if we were to apply it across our entire campus. The campus contains multiple buildings and an application of CSI would require the installation of at least 12 systems to treat all the patient care areas. That option required a high capital cost, significant maintenance requirements, and it only addressed the hot water system, albeit the most likely for contamination. It also didn't seem prudent for us to add heavy metals to domestic water. Copper/silver is not an Environmental Protection Agency (EPA) approved drinking water disinfectant. In using CSI, one must assume that no one drinks domestic hot water, an assumption we were not willing to make.

The last concern we had was about the domestic cold water system. On a campus that has developed during the past 90 years, we thought there was adequate opportunity in older buildings for cold water to warm to incubation temperatures because of the proximity to steam lines, poor insulation, or a variety of other reasons. We decided that electing not to treat the cold water was not a prudent option.

The disinfectant most intriguing us was chlorine dioxide (ClO2). ClO2 is an EPA approved disinfectant for potable water. It has eight times the efficacy of chlorine against legionella, but has low corrosive tendencies toward metals. Interestingly, reports show that ClO2 actually penetrates and removes biofilm, the breeding ground of legionella, in piping systems. A real bonus of ClO2 is that it forms no trihalomethanes as byproducts during the disinfection process.

We applied to the Pennsylvania Department of Environmental Protection (PADEP) for a permit modification because we are a potable water supplier. That action would not be necessary at most hospitals since they normally use a municipal water source. The PADEP limited our ClO2 concentrations to one ppm in the distribution system and .8 ppm at the point of use. They also required monthly reports of those measurements as well as chlorite testing.

We injected the ClO2 into our 550,000-gallon reservoir that serves the entire campus and provided control by placing oxygen reduction potential (ORP) probes in the reservoir and at the outlet of a pumping station to measure the levels. Next, we installed three ClO2 generators, each with a capacity of 1.1 pounds per day.

To measure the effectiveness of the program, we expanded our testing regime to about 50 distal points around the campus. We started treatment in June 2000, and despite the injection of ClO2 we found positive cultures. Our thought was that the biofilm was consuming the ClO2 during the biofilm destruction process and was not yet reaching the distal sites. That scenario continued for months despite trace ClO2 residuals at the distal sites. After three months, we saw a decrease in the number of positive sites and colony counts. That steady decline continued for nine months, at which point we had three persistently positive sites, albeit with low colonization.

We inspected the piping system with boroscopes in those locations, and in all instances we discovered dead legs within the walls, the result of some prior renovation. After we removed the dead legs, all sites produced negative cultures. We have now been totally negative on our cultures for about six months. We believe we finally eliminated the biofilm because we started to see our ClO2 concentrations at the distal sites approach the levels in the reservoir.

Coincident with our improvements to the domestic water system, we examined all other opportunities to thwart the potential of legionella. The largest undertaking we encountered was our cooling towers. Most of the towers at our sites were 10 to 12 degree approach cross flow towers. Despite good chemical control, side stream filtering, and the use of alternating biocides, we still found occasional positive cultures.

Since the majority of the towers were more than 15 years old, we decided to change them out to five-degree approach counter flow towers with no sump. That tower design has a minimum water velocity of eight feet per second (fps), which doesn't allow sediment to drop from solution as it does in the basins of conventional towers. The sediment, like biofilm, is the smorgasbord table for legionella. Additionally, the lower approach temperatures means that the tower is operating five-to-seven degrees cooler, which generally removes the overlap between its operating range and the ideal incubation temperatures for legionella. The real beauty of that change is that it has a short operating return on energy savings. Counter flow towers generally reduce the fan horsepower by 50 percent compared to a cross flow tower. Additionally, reducing the condenser water temperature reduces the kilowatts per ton of refrigeration (kw/ton) by three percent per degree Fahrenheit for a reduction in power of 15 percent to 20 percent. The energy savings provided a three-year payback in all instances, as well as providing additional peak chiller capacity. Since investing in this type of tower we have not had any positive legionella cultures in our cooling towers.

Another modification we made to our systems involved our medical air supply. Although we never had a positive culture from the cooling water of our liquid ring compressors, we were concerned with the potential. The fact that the water could sit in a standby pump for a period of time in a hot equipment room was disconcerting to us, particularly since our most susceptible patients used it. We have since changed to an entirely dry system at our hospitals. At our smaller sites we are using scroll compressors, and at the large campus we use variable frequency drive oil free screw compressors.

Like the cooling towers, that change also had ancillary benefits. By removing the water and having only electricity required, we increased the reliability of our systems. We can now have a water outage without losing medical air. We also consolidated our systems, reducing our compressor count from 11 to two on the main campus, and dryers from eight to two, with resultant savings in maintenance. The change also resulted in significant energy savings. Since the kilowatt per standard cubic foot of air produced (kw/scfm) is lower in these machines, we reduced our running horsepower by 50 percent. Additionally, we purchased the compressors with heat of compression dryers that utilize the waste heat from the compressor to dry the desiccant. Unique to the design of the dryers is the fact that the purged air is recycled back through the dryer, resulting in no bleed loss, typically 15 percent of the air produced. Those innovations also resulted in a system upgrade that yielded less than a three-year payback.

We also made operating changes to minimize our risks. Although we have only two domestic hot water storage tanks, we flush each one weekly to prevent sediment buildup and a harbor point for legionella. On patient units that are partially or temporarily closed, environmental services personnel run the water while cleaning the rooms to assure it does not become stagnant and that ClO2 is getting to the site. We are more conscious of ponding water on our roofs, particularly proximate to fresh air intakes. During renovations we are vigilant in checking for dead legs in our piping system and removing them, as well as some planned projects to re-pipe entire buildings no longer used for patient care.

The result of the multifaceted changes we made is that we have not had a single case of nosocomial legionella. The technologies we employed were reasonably inexpensive, or yielded significant operating returns to cover the investment. The key point is that there is no magic bullet for the elimination of legionella. What we found is that a facility that applies a collaborative, engineering approach can effectively manage the issue of legionella.

Table 2. Disinfection Methods for Legionella in Potable Water Systems

Parameters	Copper/Silver (Cu/Ag) Ionization	Continuous Chlorination	Heat and Flush	Chlorine Dioxide
Concentration applied	Cu = 0.2 – 0.8 ppm Ag = 0.02 – 0.08 ppm	2-4 free residual chlorine	160°F for 30 min	ClO_2 = 0.5 – 1 ppm
On-site efficacy documented in peer-reviewed literature	Yes	Yes	Yes	Yes
Residual protection throughout the distribution system	Yes	Yes	No	Yes
Time to recolonization after system shutdown	6-12 weeks	1-2 weeks	Varies[1]	No info available
Temperature	Residuals unaffected by high temperature	Residuals decrease as temp increases	NA[2]	Residuals decrease as temp increases
pH	Elevated pH (>8.5) may affect efficacy	Elevated pH (>8.0) affects efficacy	No effect	No effect
Disinfection by-product	None known	Trihalomethane (THMs)	None	Chlorates Chlorites
Taste and odors	None	Yes	No	Minimal at high concentrations
Pipe corrosion	None observed	Highly corrosive	Old pipe may be affected	Corrosive
Maintenance issues	Scale control Routine electrode cleaning Routine ion monitoring with AA or ICP[3]	Chlorine storage Concentration control and monitoring Corrosion control with silicate	Scalding possible Labor intensive	Concentration control and monitoring using DPD method

	Pre-ClO_2 (4/98-5/00)	Phase II (2/01-4/02)
Mean ClO_2 (mg/L)	0	0.50 (n=82)
Positivity	9% (2/22)	0%* (0/80)
Mean Concentration (CFU/ml)	30 (n=2)	0

	February – August '01	September '01 – April '02
Hot Distal Water Positivity	27%	3%