Legionella Outbreak Prevention for Cooling Towers

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Introduction

Recent reports of *Legionella* outbreaks in the U.S. have raised awareness of the need to control microbiological growth in cooling towers. Judicious use of microbe inhibitors, on-site microbiological testing and established operational control practices are required to maintain effective prevention.

Water scarcity, environmental limitations on toxic chemicals, and health and safety concerns are driving the need for improved methods to control microbiological proliferation and prevent Legionella outbreaks in cooling tower systems.

This report reviews the history and etiology of Legionella control practices. The report then presents a natural chemistry process that provides outstanding microbiological control, along with integrated testing methods, to reliably prevent *Legionella* outbreaks. The process includes significant water savings and maintains exceptional scale and corrosion control. Case studies with ATP testing were used to verify the efficacy of the inhibiting chemistry in preventing microorganism survival.

Legionella Survival Factors

According to Bartram$_{(2)}$, Legionella bacteria and cysts are endemic and found in almost all bodies of water, soil, and municipal water supplies. Cooling towers are natural accumulators of Legionella derived from air scrubbing and makeup water. Bartram states water conditions that tend to promote growth of Legionella include:

- *Stagnation*
- *Warm water temperatures between 20° and 50°C (68° and 122°F)*
- *pH between 6.0 and 8.5*
- *Sediment that tends to promote growth of commensal biofilm*
- *Presence and growth of amoebae, the only microbiological host that harbors the organism*
- *Sludge, scale, sediment, and biofilm that can harbor Legionella cysts and/or the host amoebae.*

Traditional hard water treatment seldom allows tower operation above 6 COC, and limits pH to 7.0 to 8.9 range. Hard water treatment is vulnerable to scale deposition which can harbor biological growth. Hard water treatment is also vulnerable to biofilm formation, since managing the complexities of biocide application, monitoring and cost trade-offs is required.

Managing *Legionella* Survival and Prevention of Outbreaks

Cooling system operating practices and maintenance are critical factors in managing pathogen risk, as noted by The World Health Organization.

> *"Visual inspection and periodic maintenance of the system are the best ways to control growth of Legionella and related organisms. Good maintenance is necessary both to control Legionella growth and for effective operation. The system should be properly monitored and maintained to prevent buildup of scale and sediment and bio-fouling, all of which support Legionella growth and reduce operating efficiency."(2)*
>
> *System design and operation can have a large impact on micro-organism counts. Piping dead-legs and periods of shut-down and start-up, raise specific concerns. "A system should be designed in such a way that water circulates through all parts of the system that should be wetted whenever it is operational. Dead-legs on existing systems should be removed or shortened (so that their length is no longer than the diameter of the pipe), or should be modified to permit the circulation of chemically treated water." (2)*

Biofilm and algae may harbor *L. pneumophila*, but the bacteria do not proliferate extracellularly, rather they procreate exclusively within an amoebae host.

According to Kuiper (2004),

> *"Extracellular growth of legionellae in association with other microorganisms may happen in nature, particularly in biofilms. Recent studies suggest that the only manner in which L. pneumophila generates progeny in biofilm systems is through intracellular growth in amoebae."(4)*.

According to Tom Marie, M.D. *"Various amoebae species and human beings are the only two known hosts of L. pneumophila."(5)*

Cooling tower maintenance, including spray-downs and basin cleaning to remove accumulations and biofilm, will minimize safe havens for *L. pneumophila and* host amoebae.

Proactive treatment and maintenance can prevent Legionella infestation, and avert taking the cooling system offline for decontamination. Decontamination requires staff to wear "encounter suits", as they are exposed potentially fatal pathogens and high levels of chlorine used to eliminate the infestation.

Pre-treatment Softening of Cooling Tower Makeup Water

This treatment replaces calcium carbonate scaling water with highly-soluble sodium carbonate chemistry. The softened makeup is concentrated by tower evaporation, typically to 50 to 100 COC range to produce TDS residuals from 20,000 to 100,000 mg/L, and pH in the 9.6 to 10.2 range. The treatment employs natural silicates in the highly-cycled soft water to mitigate corrosion. The soft makeup chemistry has been used since 2005. Eight US corrosion and scale control patents for application of silica and azoles in soft water above pH 9.0 are held by WCTI (7).

Soft water treatment chemistry can operate at 1% to 2% wastage of total makeup with efficient pre-treatment design. The retained and concentrated water volume then naturally generates the elevated pH and TDS for micro-biostatic chemistry.

Several biostatic chemistry benefits result from the concentration of softened tower makeup:

1. The increased concentration of natural total dissolved solids (TDS) in the make-up water shifts the osmotic pressure across microorganism cell membranes. Thus, single-celled life encounters a function-limiting environment with an osmotic driving force causing water to migrate from inside the cells, disrupting their normal life cycle; a natural biostatic condition.

2. Because the resulting pH is in the 9.6 to 10.2 range,

   "Proteins, DNA and RNA find themselves outside their iso-electric point and begin to denature and hydrolyze. Over half of the 20 most common amino acids are reactive at pH levels below 9.4. If the pH is raised to 9.7, 17 of the 20 amino acids will react and their proteins will hydrolyze. Statistically, it is highly improbable that any organism/cyst/virus will have a peptide chain without at least some of the bonds being at sites which will hydrolyze at pH 9.6 or above. This natural "biostatic" action occurs without addition of traditional toxic biocides." (1)

Operating the cooling system with a variable combination of high pH and TDS chemistry naturally inhibits microbiological growth. The chemistry inhibits biofilm and the amoebae host of the parasitic *L. pneumophila*. If *Legionella* trophozoites are produced and expelled from their protected environment into water concentrated to elevated-pH values above 9.6, the pH is lethal to these vulnerable organisms. The free-living *Legionella* cells become gradually less vulnerable as pH values decline below 9.6.

Heterotrophic Bacteria and Legionella Testing Practices:

Microbiological counts at or below the 10^4 CFU/ml range are typically accepted as adequate control. Testing for *Legionella* bacteria with serogroup typing is also frequently recommended. However, there are noted concerns with reliance on *Legionella* testing.

According to World Health Organization,

"There appears to be little correlation between Legionella culture test results and human health risk. Legionella testing cannot be considered a control measure, because of:

- *uncertainties about the reliability of culture*
- *time delays*
- *differences between culture requirements for different Legionella species*
- *dynamics of the population"* (2)

According to OSHA:

"Legionella tests are not recommended as a guide for control measures, because their inherent unreliability means that the results cannot be used as a reproducible, sensitive and timely measure of

system control. Legionella testing should only be used to verify and validate a Water Safety Plan (WSP) —test results should not be seen as a surrogate for a comprehensive control strategy."(6)

Cooling towers are high-profile systems since they are a habitat for Legionella and other dangerous organisms. Reliable test and monitoring methods are needed for on-site control and response.

Test Reliability Issues for High TDS/pH Chemistry (High COC Tower Operation)

Laboratory plate count procedures require a diluted sample to be placed on nutrient culture media, which then detects both active and dormant (cyst) organisms. The lab dilution methods thus reduce the biostatic effects of the tower water chemistry, which allow dormant organisms to grow. The plate count methods also do not take into account samples with 10X-50X higher concentration of dormant organisms resulting from cooling towers operated at 50-100 COC. The higher dormant organisms are naturally concentrated from air and water sources, as compared to test methods designed for traditional hard water makeup towers operated at 2-6 COC. These two factors lead to false-high microbiological counts.

Field testing with agar dip-sticks is also problematic due to sampling technique variables. Key variables include sample exposure time, uniform drainage, and standard incubation temperature. Inconsistencies lead to frequent reporting errors, and only aerobic organisms are detected.

The inherent inaccuracy of plate count, dip-stick and Legionella testing of high pH/TDS chemistry necessitated the search for a more reliable test method. Recent testing and analysis shows Adenosine Triphosphate (ATP) technology provides a proactive and reliable test method for high COC chemistry.

ATP Testing Methods:

ATP methods have several advantages over traditional plating methods. They require less than a minute to perform and detect every microorganism in the water, whether alive, dormant (cysts), or recently dead. ATP testing is a USDA approved methodology for food plant sanitation, relied on for over 20 years. ATP will detect increases in microorganisms immediately, allowing proactive intervention. In contrast, decisions are delayed 24-48 hours for dip-stick cultures, and longer for remote lab testing.

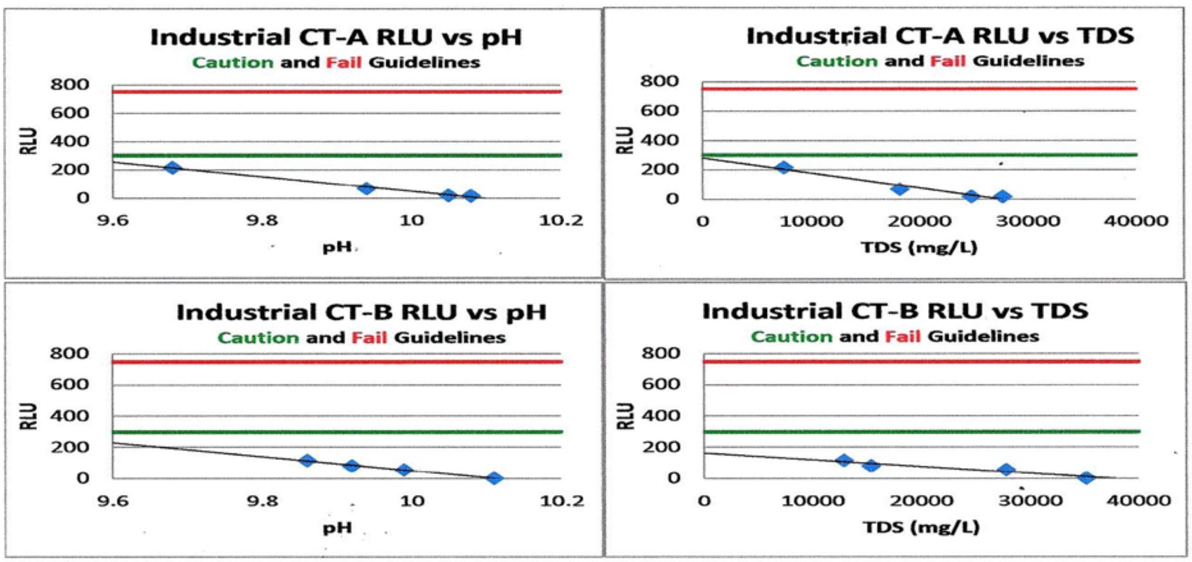
The ATP test uses an enzyme solution that is activated by ATP in the sample, causing luminescence to be quantified by a photometer and reported as "Relative Light Units" or RLU. An article by *Davenport, Ph.D.*(3) provides interpretation and guidelines for Total ATP / RLU in cooling water systems (see table below).

	Open Recirculating (e.g. cooling towers)
Pass	< 300 RLU
Caution	300 – 750 RLU
Fail	> 750 RLU

Davenport, Ph.D.(3).

ATP Case Analysis:

ATP testing was performed in two industrial cooling towers that were using the high-cycle, high-pH, high-TDS treatment program. No biocides were used to treat these systems. The ATP results demonstrated strong correlation with dip-slide CFU counts at the inhibitive levels of the chemistry. The dip-slide results on seven samples were at 100 CFU or less, and one sample was 1000 CFU, all considered excellent microorganism control. The following graphs show strong correlation between ATP / RLU values and the concentrations of the inhibitive pH and TDS chemistry. The ATP results were exceptionally low, approaching zero RLU, at the higher pH / TDS chemistry concentrations, and were well below the 300 RLU Caution guideline for cooling towers.



Case Conclusions:

- ATP results show that microbial life is naturally inhibited by increasing pH/TDS levels.
- Exceptionally low ATP values confirm insignificant microorganism presence.
- Biochemistry confirms Legionella trophozoites will perish rapidly in contact with high pH/TDS water(1).

Summary:

A reliable control mechanism was needed to inhibit survival of microorganisms in circulating cooling water systems, and to prevent Legionella outbreaks. A simple process elevates pH and TDS levels through normal evaporative concentration of soft makeup to cooling towers that provides a concurrent mechanism for microbiological control. High pH/TDS chemistry is naturally inhibitive of the biochemical functions of prevalent microorganisms (including amoebae, active bacteria and dormant cysts), and lethal to Legionella trophozoites that requires a protected environment. ATP testing provides immediate confirmation of the efficacy of the inhibitive chemistry. The broad spectrum of effectiveness with this chemistry, supported by ATP testing, provides a reliable process for preventing Legionella outbreaks.

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