PAPER NO: **TP09-05**

CATEGORY: **LEGIONNAIRES DISEASE**

COOLING TECHNOLOGY INSTITUTE

CHEMICAL FREE BACTERIA & LEGIONELLA CONTROL: A CASE STUDY USING HYDRODYNAMIC CAVITATION

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Presented at the 2009 Cooling Technology Institute Annual Conference
San Antonio, TX - February 8-12, 2009

Abstract

This paper describes an alternative, patented, non-chemical cooling water treatment system that has proven to be effective in controlling / eradicating bacteria and Legionella. The VRTX system is a side-stream treatment system and includes a mechanical VRTX unit and a separation/filtration unit. The VRTX unit works primarily on the principals of Controlled Hydrodynamic Cavitation (CHC). The CHC actions destroy microbial cell walls and converts dissolved calcium and bicarbonate ions into calcium carbonate ($CaCO_3$) colloids, when cooling water is pumped through the VRTX unit. The separation unit is used to remove the precipitated calcium carbonate and other suspended solids from the recirculating cooling water to keep the cooling water system clean.

The VRTX system eradicates bacteria by a combination of synergistic actions including: pressure, vacuum, kinetic impact at the water collision point, hydrodynamic cavitation, sonic waves and oxidizing chemicals produced from cavitation. In this paper, laboratory and field tests results are presented to demonstrate the effectiveness of VRTX system in controlling bacteria and Legionella in cooling water systems.

Introduction

Identifying, monitoring and controlling Legionella and Legionnaires' disease have become a worldwide health issue and concern. Legionellosis is a collectable term describing infection produced by the pathogen Legionella, a bacterium found water and the environment – naturally occurring surface water as well as potable and non-potable water supplies.

The mode of Legionnaire infection is the inhalation of bacteria Legionella laden, small water droplets (aerosol) or aspiration of contaminated water. The disease has two distinctive forms: Legionnaires' disease, a severe form of infection that includes pneumonia and Pontiac fever, a milder illness.

Cooling water systems can frequently be colonized with Legionella bacteria. Several cooling water systems can readily produce airborne water droplets (aerosol). In industry the primary sources of airborne water droplets are cooling towers, evaporative condensers, and air wash systems.

In this paper an alternate technology to chemicals is described for cooling water treatment. The system is a patented, mechanical device using the principles of kinetic energy, chemical equilibrium and hydrodynamic cavitation to treat fluids. Extensive laboratory testing and field tests have shown that this non-chemical treatment method can effectively control scale, corrosion and bacteria activities, including Legionella, in cooling water systems. The emphasis of this paper is on bacteria and Legionella control / eradication.

Disinfection Alternatives

Overall, there are several common ways to control and eradicate Legionella. Biocides, both oxidizing and non-oxidizing, have proven to be effective in portable, non-portable and industrial cooling water applications. However, the use of biocides causes environmental concerns and is subject to ever-increasing legislation some may be banned and alternatives will be costly.

The use of copper and silver ionization has proven to be effective in laboratory testing and field-testing. This method is very effective in portable water systems. In non-portable water systems, especially in cooling towers and evaporator condensers, cycles of concentration can be above 3, causing the alkalinity and hardness levels to increase, notably calcium levels. Increased hardness in the recycled water will cause scaling to occur on the electrodes and the effectiveness can be reduced. Additionally, bacteria resistance can build over a period of time.

Ultraviolet is also effective in portable water systems but, again, it is less effective in non-portable water systems and in cooling water systems such as cooling towers and evaporator condensers, where calcium carbonate and/or other solids will deposit on the lamps. In wastewater treatment applications and cooling water treatment applications, scaling frequently occurs and cleaning of the UV lamps is sometimes required on a daily basis. In addition, UV may not kill Legionella presence in biofilms and, if biofilms are present, UV must be used in conjunction with other treatment methods.

Ozone is effective in portable water but is not as effective in non-portable water and cooling water systems. The strong oxidation potential of ozone is what makes it most attractive for use as a biocide in water systems. However, it becomes less effective when there is chemical oxygen demand (COD) present. The organic matters in water will consume the available ozone. The strong oxidation potential of ozone makes it corrosive to some materials such as rubber fittings, gaskets, and certain kinds of metals and alloys. In addition, numerous filed tests have indicated that ozone has no capability to control scale formation in cooling water systems.

Brief Description of CHC Technology

VRTX system is a side-stream treatment system (see Figure 1). It includes two parts: a VRTX unit and a separation/filtration unit in addition to controls and a corrosion coupon rack (see Figure 2). The separation/filtration unit is used to remove the precipitated calcium carbonate and other suspended solids from the recirculating cooling water.

The patented VRTX chamber consists of a pressure equalizing chamber and a cavitation chamber (Figure 3). Inside the cavitation chamber, two pairs of nozzles are positioned opposite each other at specific distances, lengths and angles. Sump water is first pump into the pressure equalizing chamber at a pump pressure of ~70 PSI. From the equalizing chamber, water is channeled into the cavitation chamber, where water is forced to rotate at high velocities. The rotation of water streams creates a high vacuum, typically greater than -27.5’ Hg. This high vacuum condition causes micro-sized bubbles to form in the water streams. These bubbles are filled with a mixture of vapor and dissolved gases, most commonly carbon dioxide and oxygen. The water streams in two nozzles rotate in opposite directions. Meanwhile, the water streams travel forward at accelerating speeds. Upon exiting from the nozzle, the opposite water streams collide at the mid-point of cavitation chamber. At this point, pressure increases spontaneously, causing the sudden implosion of micro-sized bubbles. At the moment of collapse, hydrodynamic cavitation generates intensive shocking waves and produces extremely high temperatures. Under these conditions, chemical reactions can occur and bacteria are ruptured by both mechanical and physical forces.

Bacteria Control

VRTX technology kills bacteria by a combination of different actions: pressure, vacuum, kinetic impact and shear force at collision point, hydrodynamic cavitation, sonic waves and oxidizing chemicals produced from cavitation. The exact mechanism is still under investigation. Nonetheless the following summarizes two actions that contribute to VRTX's ability to control and eradicate bacteria.

- Dramatic changes in pressure and vacuum: Figure 4 illustrates the changes of hydrostatic pressure in water passing through the VRTX unit.

- Typically the membrane wall of most bacteria is fragile. Under such dramatic and rapid pressure changes, over an extremely short period of time (several micro seconds), the membrane wall is weakened or damaged. The direct impact of shear and collision forces created by the collision of water streams also contributes to rapture the membrane. Once the membrane is broken, the liquid components inside the cell will leak out, leading to the death of bacteria. In addition, extracellular polymeric substance (EPS) associated with biofilm and which surround and protect free-floating bacteria is readily stripped away and destroyed.

- Microjet – When micro-sized bubbles collapse near a suspended solid or bacteria, it implodes asymmetrically. A jet of liquid is formed on the side of bubble opposite the bacteria and penetrates through the bubble at ~ 250 mil/hr. A microjet (Figure 5) is strong enough to puncture metal plates, causing premature pump failures. It can easily punch through the cell wall of bacteria.

- Intermediate species – Cavitation results in extremely high temperatures and high pressures in localized areas. As a result, water molecules are split up and form free radicals:

$$H_2O \rightarrow H + OH^{\bullet}$$

The dissociation of water is thought to be produced by electrical discharges resulting from hydrodynamic cavitation or by thermal dissociation due to adiabatic compression of the collapsing bubbles. Hydroxyl radicals can combine to form hydrogen peroxide:

$$OH^{\bullet} + OH^{\bullet} \longrightarrow H_2O_2$$

Hydrogen peroxide is also formed by the reaction between hydrogen atoms and dissolved oxygen in water:

$$H + O_2 \longrightarrow HO_2^{*}$$

$$HO_2^{\bullet} + HO_2^{\bullet} \longrightarrow H_2O_2 + O_2$$

These species are unstable and exist for short periods of time. However, they are continuously generated which contribute to bacteria kill.

In summary, it is believed that the synergistic combination of actions, dramatic changes in pressure, vacuum, impact, sheer and hydrodynamic cavitation contribute to the eradication of microorganisms.

Laboratory Evaluations

The effectiveness of VRTX in eradicating bacteria has been demonstrated over several years by field tests and independent third party evaluations. Figure 6 is a summary of work performed in the VRTX facility showing the effectiveness of CHC on E. Coli. The data was compiled over a five year period. Testing performed with Heterotrophic bacteria indicates that this technology is close to 100% effective depending on the number of times the bacteria sees the unit. Data taken at the Special Pathogens Laboratory shows that in less than 30 minutes of treatment, complete kill of Legionella is possible. More recent testing in the UK has confirmed these results (Figure 9). This data shows a 4-5 log kill after only 4 to 5 passes through the CHC unit. This data is to support certification of the VRTX device for Legionella control in the UK.

Field Evaluations

Data from third part evaluations of chemical vs. VRTX treatment are presented in Figures 10-12. As seen, CHC treatment performs as well if not better than chemical treatment. In the case of the Legionella data, CHC significantly outperforms the current chemical treatment. In all cases studies, CHC can control bacteria and Legionella to recommended levels.

A phase 1evaluation of the VRTX process was conducted from May to August 2007 at a cooling tower at a designated hospital. Background of the cooling system is given in Table 1. During this period baseline data on chemical treatment was obtained followed by partial chemical and VRTX treatment (Table 2). As shown, the combination of chemical and VRTX was able to keep bacterial and Legionella levels below those obtained through chemical treatment. A summary of the results to date are given in Table 3. As stated, this was the first phase of the evaluation. Continuation of the study using only VRTX has been on-going since June of 2008 with the final results expected by December 2008.

Summary

VRTX technology is a non-chemical alternative for controlling scale, corrosion and bacteria. VRTX is targeted for industrial applications (process streams and wastewater streams) and cooling water systems, cooling towers, condensers and air washers. In these applications scaling and corrosion are not limiting factors, as they are successfully treated by VRTX. VRTX’s ability to control/eradicate bacteria is not compromised by moderate to high levels of TDS, TSS, alkalinity and hardness typically found in industrial cooling water systems.

The fundamental principles of VRTX allow it to be used in cooling water systems. It has been successfully tested under laboratory conditions on both lab-grown and naturally grown Legionella. Equally important have been several field studies and case histories. The technology is promising and encouraging, and additional validation will come from additional field-testing, verification and documentation of said testing, in the near future. The latter is ongoing and the results will have to be over a one-to-two year period. For now, the technology has proven to be sound and quite able to control and eradicate bacteria and Legionella.

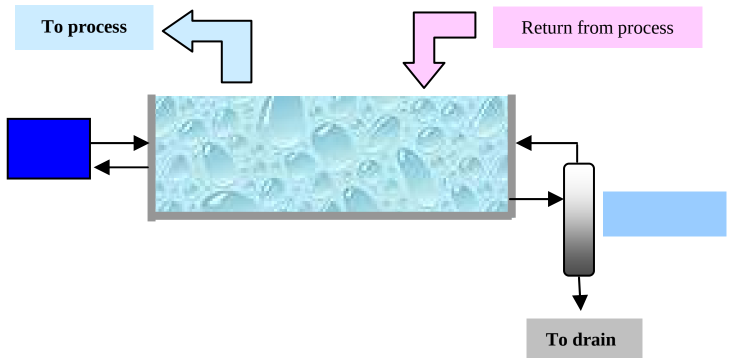

Figure1: Schematic of VRTX system layout

Figure 2. A Standard VRTX Unit with a Separator System and Controls

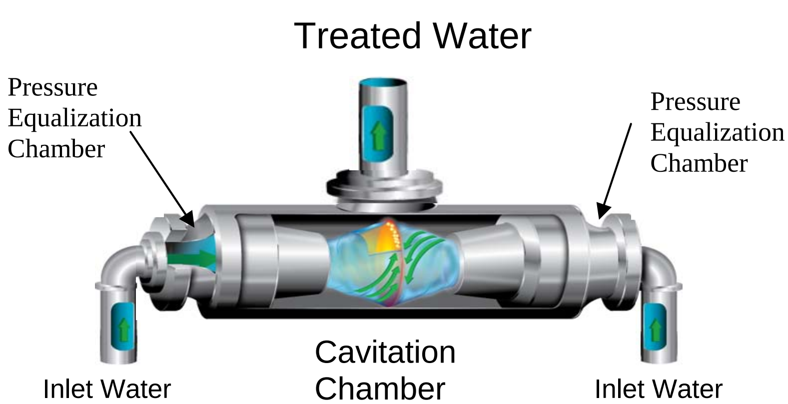

Figure 3. Diagram of the Hydrodynamic Cavitation Equipment

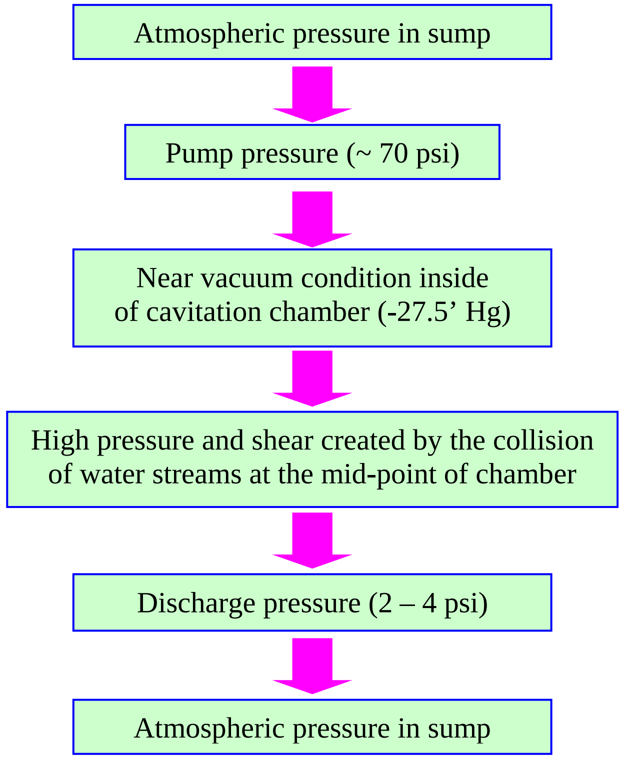

Figure 4. Changes in Pressure of Water Passing VRTX Unit

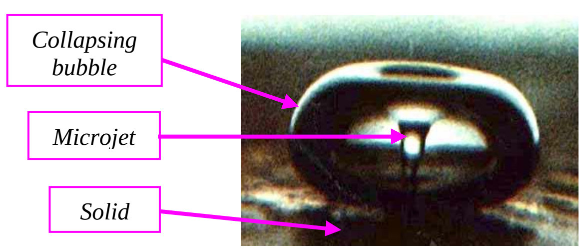

Figure 5. Microjet Created by Cavitation

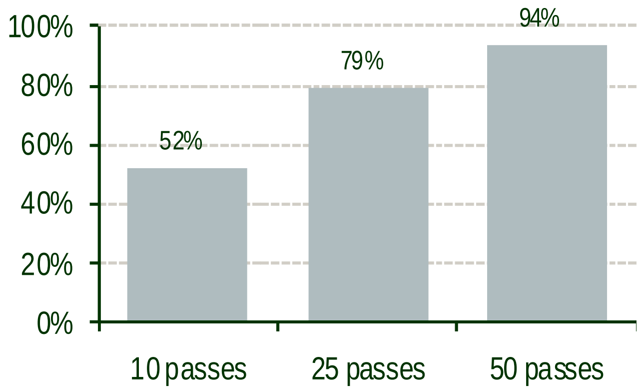

Figure 6. Summary of Five Years of E. Coli Laboratory Testing

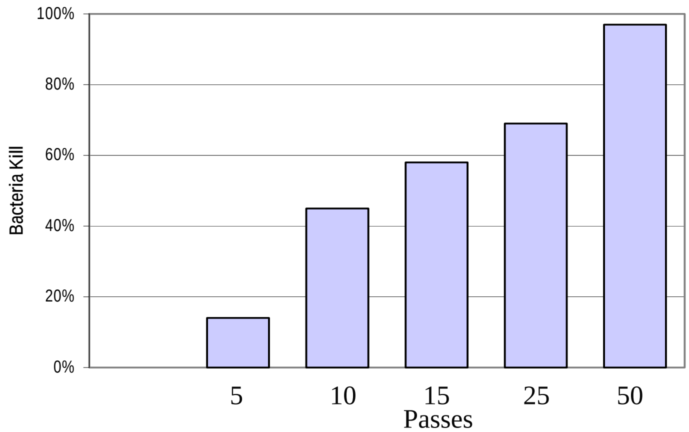

Figure 7. Laboratory Testing on Heterotrophic Bacteria

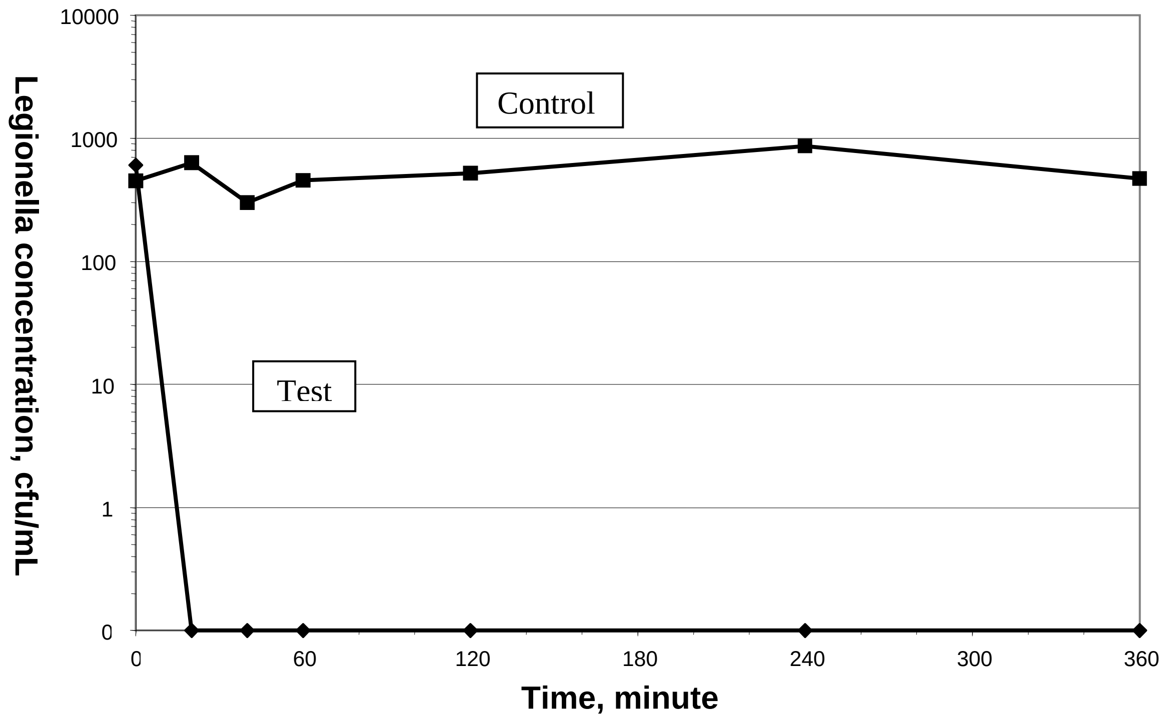

Figure 8. Test Results at Special Pathogens Laboratory, VA Medical Center, Pittsburgh, PA (Naturally Grown Legionella Pneumophila serogroup I)

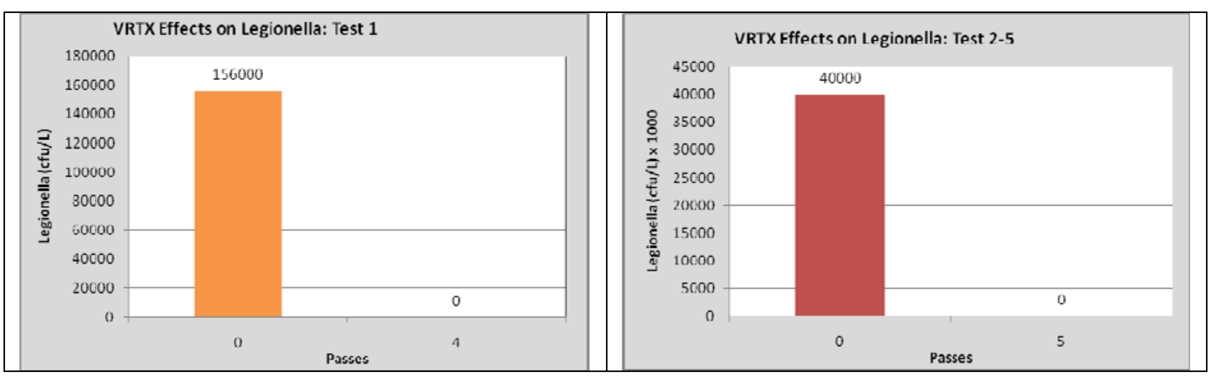

Figure 9. Legionella Laboratory Testing in the UK (9-08)

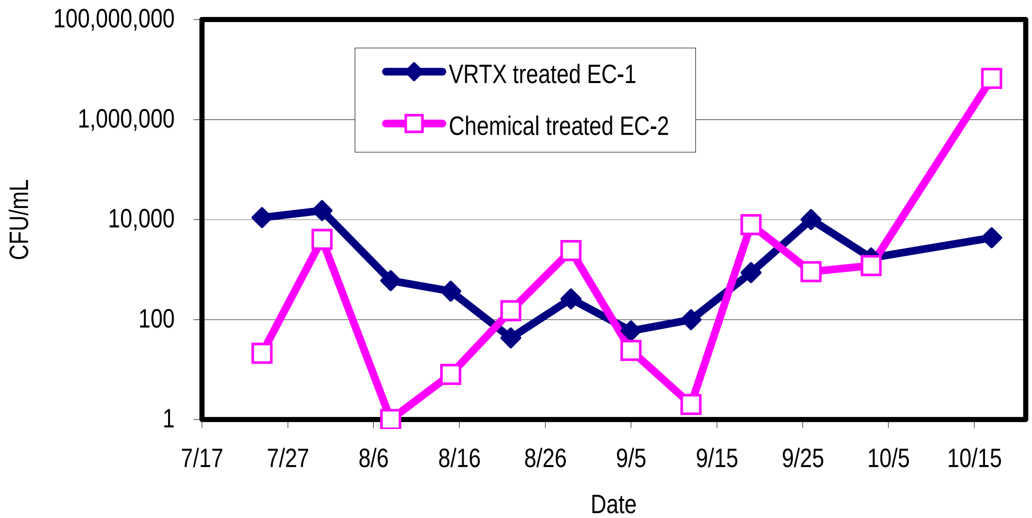

Figure 10. Total Bacteria in Evaporative Condensers
(Food Manufacture)

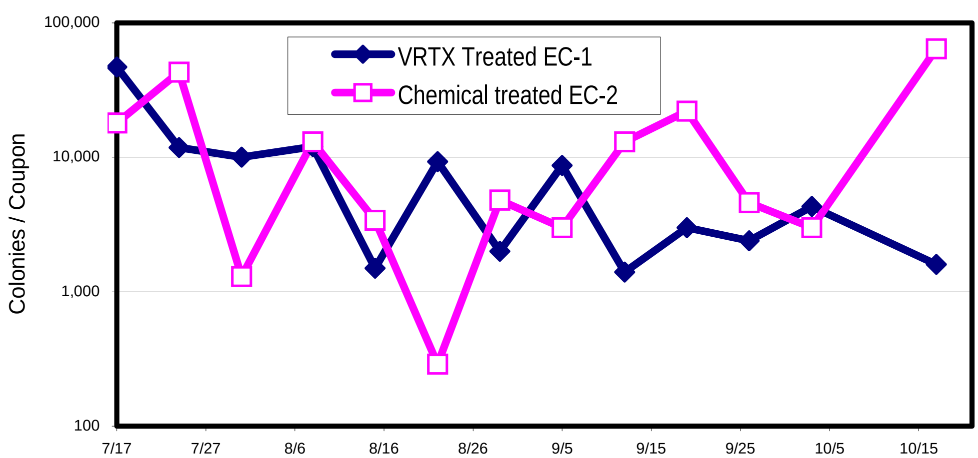

Figure 11. Sessile Bacteria in Evaporative Condensers
(Food Manufacture)

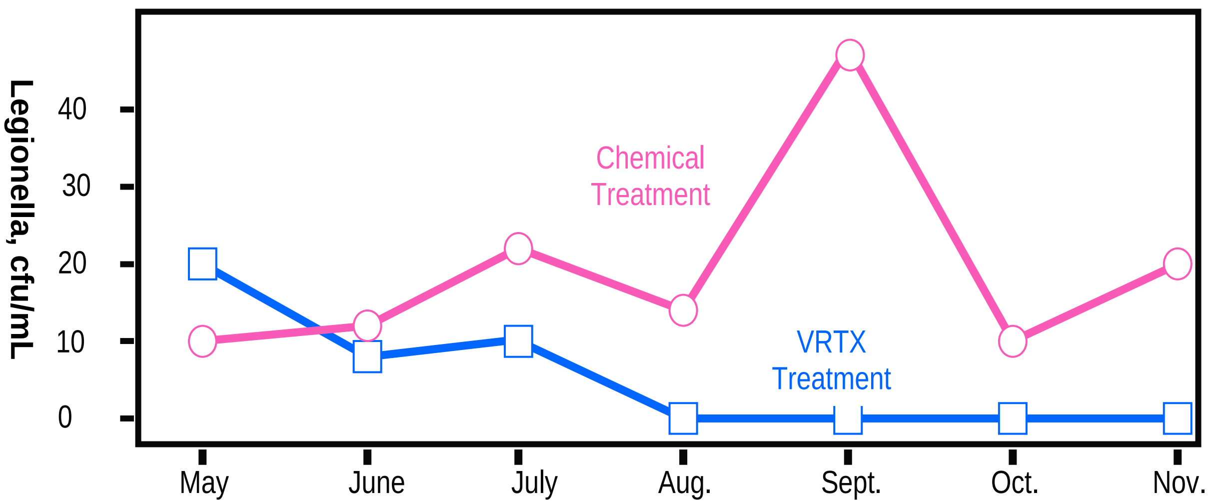

Figure 12. Legionella Control at a Food Manufacturer

Table 1. VRTX Setup at a Hospital Cooling Tower

- Cooling Towers: 9292 kW
- Flow 6600 gal/min
- Total volume: 5300 gal
- Seasonal Use (6 months)
- Water quality (400 um/cm conductivity)
- Unit evaluated VRTX 125
- Automatic filtration 32000 gal/hr
- Installation on 10 inch flange in recirculation header

Table 2. Hospital Cooling Tower Treatment Results from June to October 2007

Sample			Legionella	aerobes	aerobes	legionella
			basins	37 degrees C	22 degrees C	return cooling
date			cfu/l	cfu/ml	cfu/ml	cfu/l
frequency			2x week	2x week	2x week	2x week
method						
guideline				50000	100000	
MAIN WATER		SETTING				
23-5-2007	TOWER 1	CHEMICALS	<50	126600	148000	
23-5-2007	TOWER 2	CHEMICALS				
21-6-2007	TOWER 1	CHEMICALS	<50	20333	75333	
21-6-2007	TOWER 2	CHEMICALS	<50	62667	48667	
5-7-2007	TOWER 1	CHEMICALS	<50	754651	902591	
5-7-2007	TOWER 2	CHEMICALS	<50	50173	73333	
12-7-2007	TOWER 1	CHEMICALS	no sample	94500	3500	
12-7-2007	TOWER 2	CHEMICALS	no sample	11000	6111	
7-8-2007	RETURN	CHEMICALS	no sample	no sample	no sample	700
21-8-2007	RETURN	CHEMICALS	no sample	no sample	no sample	1300
10-9-2007	TOWER 1	VRTX + 1/2 CHEM	<50	610	120	<50
10-9-2007	TOWER 2	VRTX + 1/2 CHEM	<50	2585	1210	
13-9-2007	TOWER 1	VRTX + 1/2 CHEM	<50	84500	29000	<50
13-9-2007	TOWER 2	VRTX + 1/2 CHEM	50000	74500	59500	
18-9-2007	TOWER 1	VRTX + 1/2 CHEM	50	8000	51000	<50
18-9-2007	TOWER 2	VRTX + 1/2 CHEM	<50	21000	44500	
21-9-2007	TOWER 1	VRTX + 1/2 CHEM	<50	2450	1000	<50
21-9-2007	TOWER 2	VRTX + 1/2 CHEM	<50	2200	900	
25-9-2007	TOWER 1	VRTX + 1/2 CHEM	<50	46000	2550	<50
25-9-2007	TOWER 2	VRTX + 1/2 CHEM	<50	13100	10000	
28-9-2007	TOWER 1	VRTX + 1/2 CHEM	<50			
28-9-2007	TOWER 2	VRTX + 1/2 CHEM	<50			
5-10-2007	end VRTX test					

Table 3. Summary of VRTX Evaluation at the Hospital

- Primary objective achieved: no Legionella detected in recirculating cooling water
- Bacteria counts are lower using VRTX/ ½ chemicals vs. chemicals
- Better heat transfer using VRTX (observation)
- Water savings created using higher cycles of concentration