SPECIAL FEATURE

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Cooling Tower Solutions

Testing of a new ozonation system for cooling towers

Recently, cooling towers have become recognized as a major source of *Legionella* infection. This fact has stimulated a growing number of lawsuits and it is expected that this trend will continue.[1,2,3] In Europe, Australia, the Pacific Rim and the United States, awareness of the *Legionella* problem has grown to the point where disinfection is the primary requirement for cooling water treatment, exceeding corrosion and scale control in importance and potential economic impact.

Legionella can live inside of various species of protozoa where they are shielded from biocides. Under conditions of normal usage, Legionella and the protozoa that harbor them are not much effected by commonly used biocides.[4] However, ozone has been shown fast and effective at killing *Legionella* and other bacteria, yeasts, molds, viruses, protozoa and algae.[5,6,7] In addition, ozone breaks down quickly, leaving no residual that would prevent discharge of treated water. Many investigators consider ozone to be the most effective biocide for water treatment.

On the other hand, experience with ozone has resulted in some general concerns leading to a sense of confusion regarding its potential. These concerns include dosage, corrosion, dependability and cost.

Dosage

Numerous methods have been presented to calculate the amount of ozone needed to treat a given volume of water. Unfortunately, they differ substantially and seldom work in practice. Some are based on the physical chemistry of ozone, others on real-world measurements and practical experience. However, all assume consistent water conditions as a foundation for developing a standard dosing formula. This is the problem. No two cooling towers are exposed to the same environmental conditions, and the water they contain differs in chemistry, type and amount of suspended solids, temperature and a host of other physical and chemical parameters. In addition, these parameters will change from day to day and season to season. Consequently, each cooling tower is a unique chemical system and no single formula can characterize the ozone needs of all towers.

Dissolving Ozone. Ozone does not easily dissolve in water (saturation ≅ 3 mg/L at room temperature), presenting the challenge of dissolving enough ozone to effectively disinfect and treat the water. Sparging, either into the sump itself or a contacting tower, often is used to obtain ozone solution. Due to ozone's low solubility, a contacting tower of considerable height (often 20 feet or more) is needed to develop an adequate dissolved ozone residual. Sparging directly into a shallow sump does not allow much contact between gas and water and is ineffective at obtaining high ozone residuals. Most ozone generators used for cooling towers produce ozone by corona discharge. It often is overlooked that the hydrostatic head produced by water above a sparging diffuser pressurizes the system, resulting in collapse of the corona and significant reduction of ozone output. As a result, actual ozone output in the field often is significantly less than rated in factory bench tests.

The other important method is aspiration of ozone through a venturi injector into water flowing through a pipe. This can be effective, but requires a small diameter pipe (≅ 3/4 inches) with limited water volume and specific percent pressure differentials. If proper conditions are not met, the gas and water separate into slugs or horizontal layers that minimize contact between gas and water. Even when conditions are ideal, the gas and water will remain mixed only for a limited distance (maximum 30 feet), and then only if the pipe is straight.

Too much ozone. Considering ozone's low solubility and the absence of dependable methods to calculate ozone demand, it has been common to produce the maximum amount of ozone possible to ensure that enough will dissolve to cover all possible extremes. It is not uncommon for pounds of ozone to be supplied to cooling towers. Continuous release of excess ozone into the atmosphere may be a health hazard to those who are chronically exposed. Most humans are exquisitely sensitive to the odor of ozone and easily can smell it at concentrations far lower than would be required to produce any health impact. Still, any detectable ozone odor may cause people concern.

Corrosion

Many of the metals used in HVAC systems are oxidized easily and will react unfavorably when in contact with strong oxidants. Aluminum, zinc, copper and iron are examples of metals that will react with dissolved ozone. Additionally, excess ozone can outgas in pipes, tubes or other enclosed spaces, damaging corrodible metal parts even more aggressively than ozone in the dissolved state. Discussions of ozone corrosiveness often overlook the fact that high concentrations of other oxidants including chlorine also can result in similar levels of corrosion damage. Corrosion, then, is more the result of too much oxidant rather than the specific type and generally is not a problem in systems where ozone levels are consistent with demand.

Table 1: Plate Counts from the Test Tower

Date	Plate Count Tower(cfu/ml)	Plate Count Pond (control)
09/12/00	TFTC*	TNTC** #
10/09/00	TFTC	
10/19/00	TFTC	
11/13/00	TFTC	
11/27/00	TFTC	
11/29/00	TFTC	

* Too Few To Count ** Too Numerous To Count # at a dilution of 1:1,000

Cost and Dependability

The cost of ozone generators escalates with increasing generating capacity. Systems required to produce and regulate large amounts of ozone require multiple generator tubes, high voltage and current levels, complex controls and accompanying circuitry and delicate balancing of power supplies to each generator. All these complexities have made ozone generators expensive and increase the potential for failure. As a result, they have a reputation for being delicate and undependable as well as a costly investment. The most dependable generators are simple, inexpensive and run unstrained but generate rather small amounts of ozone.

Solutions to the Ozone Problems

A prototype* recently donated to the Environmental Science Department of Pierce College for testing and evaluation is a simple sidestream system using a single tube corona discharge ozone generator that was set to produce 10 grams of ozone per hour during field tests. The system includes a novel approach towards mixing ozone and water, and the use of this mixture for tower treatment. An explanation of the system and the results of the first round of testing are presented here.

Ozone Mixing and Contacting

The system mixes ozone and water in a mixer/disinfector composed of 2-inch PVC pipe. Vertical and horizontal sections are connected by 90 degree elbows to form a rectangular-helical configuration that packs large lengths of pipe into a small space. Water passing through the elbows is sheared, producing turbulence after every turn. This turbulence and the intimate contact of water and fine ozone bubbles it produces is maintained throughout the length of the contactor/disinfector. Using an appropriate pump and flow rate, pipe of any diameter and length can be used to treat larger systems. The prototype system has a flow of 43 gpm with a turnover of the system volume through the contactor/disinfector every 12 minutes.

Disinfection of Tower Water

The contactor/disinfector treats water in the confined spaces of its piping. Here, bacteria and other microbiota, particles and dissolved chemicals are in contact with an emulsion of microscopic bubbles of ozone gas as well as the dissolved phase. Because ozone is much more concentrated and active in the gaseous state, the additive effect of both gaseous and dissolved phases allows small amounts of ozone to have the effect of much higher concentrations. After the water is disinfected in the contactor/disinfector, it then is reintroduced to the tower at the top of the fill where it cascades over the fill elements on its return to the sump. In this process, the fill is exposed

Table 2: Plate Counts from Dosing Experiment
(water temp = 70° F)

Hour	Plate Count (cfu/ml)
0	730
2	TFTC*
4	TFTC
6	TFTC
8	TFTC
24	TFTC

* Too Few To Count

to ozonated water for disinfection. In addition, when the fan is on, outgasing ozone is mixed with the aerosol plume. This would be expected to disinfect the drift plume to some degree.[7] Since it is the aerosol plume that spreads *Legionella*, this aspect will be the focus of additional future testing.

Spot Treatment

Careful examination of a cooling tower will reveal protected surfaces, corners and other recesses that are not contacted by circulating water. These areas, often marked by algae, support microbial populations that are not exposed the biocide being used. To treat this problem, the system taps a flow of ozonated water directly from the contactor/disinfector outlet. This is diverted through tubing to a moveable nozzle that can be positioned to direct a small flow of ozonated water to a trouble area for spot treatment.

Corrosion Control

As mentioned previously, ozonated water from the contactor/disinfector is piped to the top of the fill where it is allowed to spill over the fill elements to return to the sump. In this process, ozone and other dissolved gases are removed by the natural tendency of a cooling tower to airstrip water cascading over the fill. Ozone is stripped from the water by the time it reaches the sump. Therefore, no ozone residual is developed there. Since the water is disinfected in the contactor/disinfector, there is no need to develop an ozone residual in the sump itself. Removal of the ozone before the water reaches the sump minimizes corrosion problems because only the ozone-depleted sump-water passes to the chiller. The small amount of ozone used for spot treatment of sump and fill surfaces is consumed by the organics being treated and should not result in development of a corrosive residual in the sump water.

Cost and Dependability

No cost estimates were supplied for the prototype, and insufficient time has elapsed to evaluate the dependability of the ozone generator. The simplicity of the system, however, suggests it can be produced economically in regard to existing commercially available systems.

Field Tests

As part of ongoing research at Los Angeles Pierce College in Woodland Hills, Calif., the prototype was installed for testing on a 100-ton BAC cooling tower on campus. At this time, chemical feed lines were disconnected and the tower drained and refilled with city water from the makeup line. The test system has been operating since July 2000, with an ozone output of 10 gm/hr. Bacterial levels were monitored by heterotrophic plate counts following standard methods.[8] It is well documented[5,6,7] that ozone effectively kills a wide spectrum of microbes including *Legionella* and associated protozoa. Therefore, a heterotrophic plate count is a good indicator of ozone's overall biocidal effect.

Plate counts on sump water from the test tower were made at regular intervals throughout the study. (See Table 1.) All counts were TFTC** and most actually were zero. A plate count below 500 cfu/ml is considered acceptable for drinking water and cooling towers with plate counts nearing 1 million cfu/ml have been defended as acceptable. The counts in this test were surprisingly
low, therefore pond water was used as a control to confirm the methods. Testing of the spot treatment system is planned for the upcoming spring when temperatures are high enough to allow typical bacterial activity.

Ozone Levels and Dosing

Dissolved ozone was measured with a Hach Indigo ozone test kit. Ozone levels in the output of the contactor/disinfector ranged from 0.28 mg/L to 0.60 mg/L, depending on water temperature. This is well into the concentration range for effective disinfection. At the same time, no ozone was detectable in sump water, confirming that air stripping in the fill cascade effectively removes ozone. An experiment was designed to determine how long the ozone system must run each day to accomplish disinfection.

The ozone system was turned off so an elevated level of bacteria could develop in the sump water. During this interval the average water temperature was 70° F. After four days, the plate count reached 730 cfu/ml and this was considered adequate for the test. This experiment was conducted at a school, so it did not seem wise to allow the counts to go higher.

For the test, the ozone system was turned on at 8:00 am, and plate count samples were collected at the start and at two-hour intervals for the first eight hours and at 24 hours. Even with the relatively low starting plate count, it was expected that the ozone would reduce the bacterial levels in a progressive manner, allowing development of a decay-curve from the data. This curve then would be used to determine dosing in terms of how much time the ozone system should operate each day to obtain acceptable disinfection. Surprisingly, the plate count was zero (TFTC) at the first two-hour count and stayed TFTC from that point onward. (See Table 2.) The volume of water in the test system is 500 gallons. These results, then, indicate that two hours operation per day was adequate to disinfect 500 gallons of water. Ozone generation has been limited to two hours per day since (105 days), and plate counts have remained TFTC (Table 1), confirming the value of this dosing approach. In the warmer months this may need to be adjusted to provide for higher bacterial activity at higher temperatures. The dose can be increased easily by adjusting the ozone output to maximum, increasing the hours of operation, and/or using additional generators in parallel as required for really large systems.

Corrosion Rates

An important aspect of the system is the claim that the removal of ozone will minimize the potential for corrosion. To address this, the test tower was fitted with corrosion coupons. As illustrated in Table 3, copper, galvanized and soft iron corrosion coupons, exposed to the sump water for five months, showed levels of corrosion similar to or lower than those resulting from other corrosion control methods.

Summary

The results of these tests indicate that the prototype system accomplishes excellent disinfection of tower water during the late summer and fall, while producing less corrosion than most chemically treated towers. Dosing is reduced to a time of operation that can be fine tuned on site to obtain the best results. Finally the system is simple enough to be made dependable and inexpensive. Additional studies of the spot treatment system and plume disinfection are planned for the upcoming spring.

* *Patent pending, Ozone Applications in Los Angeles.*

** *Note: According to standard methods,[8] a plate count less than 30 cfu/ml on an undiluted sample is not statistically valid and must be recorded as "Too Few Too Count," or TFTC. Likewise, if more than 300 colonies appear on the sample with the highest dilution, it is not statistically valid either and must be recorded as "Too Numerous To Count," or TNTC.*

Table 3: Corrosion Coupon Results for the Test Tower

Metal	Corrosion (mpy*)
Copper	0.3565
Galvanized	1.9876
Mild Steel	2.9057

* mils per year

REFERENCES

1. Meyer, W.C. "Controlling Legionella in Cooling Towers." *IAQ Applications* (ASHRAE), Spring, 2000, p. 9–12.
2. Meyer, W.C. "Avoid Legionellosis Lawsuits Over Cooling Towers." *Chem. Engineering*, Sept. 2000, p. 113–117.
3. Meyer, W.C. "Legionella: Minimizing Risks." *Water Engineering and Management*. Aug. 2000, p. 24–25.
4. Kusnetsov, J.M. et al. "Efficacy of Three Prevention Strategies Against Legionella in Cooling Tower Water Systems." *Jour. Appl. Microbiol.*, 1997, June, vol. 82, no.6, p.763–8.
5. Dominque, F.L. et al. "Effects of Three Oxidizing Biocides on Legionella Pneumophilia Sereogroup 1." *Appl. Environmental Microbiology*, 1988, March, vol. 54, no. 3, p. 741–7.
6. Korich, D.G. et al. "Effects of Ozone, Chlorine Dioxide, Chlorine and Monochloramine on *Cryptosporidium* parvum Oocyst Viability." *Appl. Environmental Microbiology*, 1990, May vol. 56, no. 5, p. 1423–8.
7. Restand L. et al. "Efficacy of Ozonated Water Against Various Food-Related Microorganisms." *Appl. Environmental Microbiology*, 1995, Sept. vol. 61, no. 9, p. 3471–5.
8. Gerherdt, P. ed., *Manual of Methods for General Bacteriology*. American Society for Microbiology. 1981, p. 185–88.

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