Legionella and Chlorine Dioxide

Chlorine dioxide (ClO_2) is effective as both a disinfectant and an oxidant in water treatment. Chlorine dioxide is a broad-spectrum microbiocide effective over a wide pH range. It is effective in controlling or eliminating the conditions (slime, biofilm, algae and protozoa) that proliferate the growth of *Legionella*.

Application Description

Legionella pneumophila, the pathogenic bacterium associated with a frequently fatal form of pneumonia known as Legionnaires' disease, has been the subject of numerous investigations since its isolation and identification in 1976. Although work is ongoing, a correlation of health risk with *Legionella* counts in cooling water has been made[1,2]. Legionella-contaminated aerosols have been found to originate from a number of sources. These include cooling towers, evaporative condensers, showerheads, whirlpool spas, hospital hot water systems, medical respiration devices, decorative fountains, and grocery store misting machines.

Treatment Alternatives

Since *Legionella* is by nature sessile, it grows in algal and bacterial biofilm, which can be present in water systems. In addition, some protozoa, such as amoeba, can engulf *Legionella*, recognizing it as a potential nutrient. Unlike most bacteria, rather than being absorbed into the amoeba, under certain conditions *Legionella* can not only survive the process but can proliferate within the amoeba, using the amoeba as a protective host. The responses of *Legionella* to different biocides depend on whether the bacteria are planktonic or located within a microniche of a bacterial biofilm.

Research clearly indicates that controlling *Legionella* in the bulk water is not adequate to prevent a cooling tower from becoming a site of infection[3]. In order to ensure that a cooling system is free of *Legionella*, a number of things have to be done, including cleaning the tower (although by itself, this is insufficient to control *Legionella*)[4,5].

All of the studies conducted to date provide valuable data that are pieces of the *Legionella* puzzle. When viewed together, these data provide a clearer picture of the necessary steps required to adequately control *Legionella*. From strictly a chemical control perspective, the biocides chosen for control of *Legionella* must be able to take all four actions listed below (and thus control strategies must include all of these) [3,6,7].

1. Inactivate Legionella and other bacteria in the bulk water.
2. Control/prevent/remove bacterial biofilm and inactivate associated biofilm bacteria.
3. Control/prevent/remove algal biofilm and inactivate associated biofilm bacteria.
4. Inactivate protozoa.

Relative Effectiveness of Treatment Alternatives

In general, the following comparison, in decreasing order of effectiveness, holds true for control and removal of bacteria by biocides present under the conditions described:

Bulk Water Bacteria: Biocide efficacy is dependent on the organism. For *Legionella* at neutral pH:
$O_3 > ClO_2 \geq HOCl \geq HOBr$

Bacterial Biofilms:
$ClO_2 >> HOCl \geq HOBr > O_3 >$ non-oxidizing

Algae:
$ClO_2 >$ certain non-oxidizing $> HOCl > O_3 > HOBr$

Amoebic Cysts and Protozoa:
$O_3 > ClO_2 >> HOCl > HOBr$

Chlorine Dioxide

Chlorine dioxide is an extremely effective disinfectant and microbiocide. Its efficacy has been well documented[8] in the laboratory, in pilot studies and in full-scale studies using potable water and wastewater.

Unlike chlorine, chlorine dioxide does not hydrolyze in water. Therefore, its germicidal activity is relatively constant over a broad pH range. Chlorine dioxide does not react with organic materials to form trihalomethanes (THMs) and is generally effective at lower dose rates in contaminated systems when compared to alternative biocides. Of the oxidizing biocides, chlorine dioxide has been shown to be very effective in all four areas identified for effective control of *Legionella;* bulk water disinfection, biofilm inactivation and removal, algae control, and protozoan inactivation. In the United Kingdom, the Health and Safety Commission published an Approved Code of Practice and Guidance (ACoP) for the control of *Legionella* bacteria in water systems in 2001[9].

Cooling Systems - The ACoP, L8 guidelines state that chlorine dioxide is effective for the control of *Legionella* when a residual of 0.5 mg/L – 1.0 mg/L is maintained in the return water. The effective concentration should be present for at least four out of every 24 hours when chlorine dioxide is applied intermittently. Under these guidelines, routine monitoring for the presence of *Legionella* is required by an accredited laboratory. If the aerobic count cfu/ml at 30°C (minimum 48 hours incubation) is 10,000 or less and the *Legionella* bacteria cfu/L is 100 or less, the system is considered under control. If the *Legionella* levels are higher than 100 cfu/L then appropriate action is required.

Hot and Cold Water Systems – The AcoP states that chlorine dioxide at levels of 0.5 mg/L can, if properly managed, be effective against planktonic and sessile *Legionella* in hot water systems.

Feed Requirements

For control of bacterial slime and algae in industrial recirculating and one-pass cooling systems, the required dosages will vary depending on the exact application and the degree of contamination present. The required chlorine dioxide residual concentrations range between 0.1 and 5.0 mg/L. Chlorine dioxide may be applied either continuously or intermittently.

The typical chlorine dioxide residual concentration range is 0.1 - 1.0 mg/L for continuous doses, and 0.1 - 5.0 mg/L for intermittent doses.

The minimum acceptable residual concentration of chlorine dioxide is 0.1 mg/L for a minimum one-minute contact time.

For more information on specific product dosing requirements, contact your Siemens Representative.

Method of Feed

Chlorine dioxide is a gas produced by activating sodium chlorite with an oxidizing agent or an acid source. Sodium chlorite is converted to chlorine dioxide through a chlorine dioxide generator and applied as a dilute solution. Chlorine dioxide solutions should be applied to the processing system at a point, and in a manner, which permits adequate mixing and uniform distribution. The feed point should be well below the water level to prevent volatilization of the chlorine dioxide.

Chlorine Dioxide Analysis

Residual chlorine dioxide concentrations must be determined by substantiated methods, which are specific for chlorine dioxide. Two suitable methods are published in *Standard Methods for the Examination of Water and Wastewater*[10].

4500-ClO_2 D	DPD-Glycine Method
4500-ClO_2 E	Amperometric Method II

References

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