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WHITE PAPER

IMPROVED COOLING WITH ClO_2

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Chlorine dioxide offers increased efficiency and effective water treatment for cooling systems.

Appropriate treatment of a cooling system's water is essential for many reasons. Clean pipes mean higher heat exchange efficiency, lower energy consumption, lower maintenance cost and longer equipment life. Additionally, the importance of adequate treatment goes beyond efficiency and cost savings; there are also environmental concerns and health-related risks associated with inappropriate treatment methods.

For example, consider an open recirculating system, where water is continuously recirculated and exposed to air. Water moving through the heat source (condenser, chiller, evaporator, etc.) increases in temperature and is cooled by evaporation in the tower. Air continuously passes through the cooling tower introducing oxygen, silt and environmental debris into the system. The warm, humid environment in the tower is ideal for biological growths such as algae, fungi and bacteria, whose colonies produce the biological slimes that can foul heat exchangers. Slimes and deposits can plug tubes and decrease heat transfer efficiency. Excessive fungal growth can penetrate the tower fill, digesting the wood and, ultimately, collapsing the tower. Microbiological growth under deposits or slimes might speed corrosion rates to the point of perforating the surface.

A cooling tower environment is ideal for the growth of pathogens. Organisms such as Legionella can easily maintain a significant colony level and spread through the drift from the tower, causing diseases that could be potentially fatal to operating personnel. Effective control of these factors is imperative.

TRADITIONAL WATER TREATMENT OPTIONS

Traditional treatment methods use biocides that are added to the tower and chilled water systems. These biocides are intended to prevent three potential problems:

- Biological growth, which can impede heat transfer and, consequently, energy losses.
- Destruction of structural material.
- Environmental and human hazards.

The use of oxidizing and nonoxidizing biocides to kill or prevent the growth and reproduction of microorganisms is common. However, nonoxidizing treatment methods present several disadvantages:

- Nonoxidizing chemicals need to be added in a large quantity to be effective, which increases the cost of operating the cooling system.
- The chemicals are usually toxic to humans and animals and must be properly stored and handled.
- The toxicity of nonoxidizing biocides presents an environmental hazard; disposal of water treated with these chemicals is regulated and requires special (and often costly) handling.

Oxidizing biocides are less susceptible to these drawbacks and, in most cases, are more effective. Typical oxidizing biocides include chlorine, bromine and chlorine dioxide. However, chlorine and bromine have their own limitations because they react rapidly with chemicals and microorganisms present in the water. The microbiological effect might be limited to a short period of time, and high quantities of the biocides might be required to achieve adequate microbiological control.

Consumption of chlorine and bromine by chemical reactions other than microbiological control is only one limitation. pH usually plays an important role in the chemistry of a cooling system and becomes an important factor to consider because the effect of chlorine and bromine is directly dependent on the pH range of the water that is being treated. As a result, adding these chemicals doesn't always have a desired effect. Figure 1 shows the percentage of active content in the water for chlorine, bromine and chlorine dioxide on a 4 pH to 10 pH range.

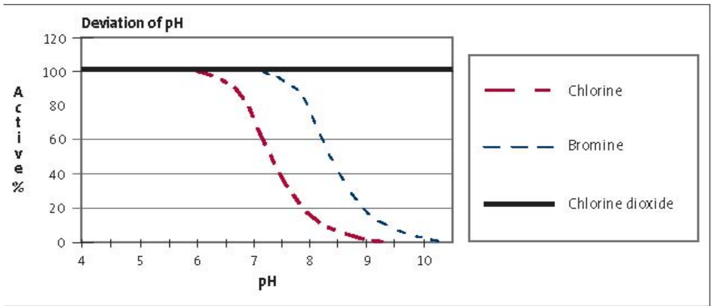

***Figure 1**. Chlorine, bromine and chlorine dioxide each exhibit a different level of active content in water at a pH range from 4 to 10.*

Additionally, chlorine and bromine are relatively unstable, and can react with other chemicals present in the water such as nitrogen, ammonia or inhibitors and form undesired byproducts. Chlorine can also form trihalomethanes (THM) and haloacetic acids (HAA5), which are suspected carcinogens.

Of the three most common oxidizing biocides, chlorine dioxide (ClO_2) presents the most effective water treatment option.

WHY TREAT WITH CHLORINE DIOXIDE?

ClO_2 is a yellowish-orange gas that has an ozone-like odor and is highly soluble in water. The chemical and biochemical effects are based on the conversion to chlorite during the disinfection process and reduction to chloride through purely chemical degradation processes.

ClO_2 cannot be stored and therefore must be generated at the location where it is to be used. Because of its high redox potential (ability to acquire electrons) compared to other biocides, chlorine dioxide has a much more powerful disinfecting action against all kinds of germs and contaminants such as viruses, bacteria, fungi and algae.

The oxidation potential with ClO_2 is higher than with chlorine, so far fewer chemicals are required for water treatment. The longer dwell time is also particularly advantageous due to the selective disinfection. Even germs and bacteria that are resistant to chlorine can be killed almost completely by chlorine dioxide. However, special measures need to be taken to combat these germs since they can adapt to conditions that are fatal to many organisms and are, for the most part, resistant to biocides.

The major difference between chlorine dioxide and chlorine or hypochlorite is the gradual effect it has on degrading biofilm at low doses. A concentration of 1 ppm will kill virtually all Legionella in the biofilm within 18 hours. A marked reduction in the biofilm can be achieved within the same amount of time for a concentration of 1.5 ppm. Furthermore, the disinfecting action of chlorine dioxide is virtually independent of the pH value, meaning that it can also be used without any consequences in alkaline environments.

IMPLEMENTING A ClO_2 TREATMENT PROGRAM

As previously mentioned, chlorine dioxide must be generated onsite. A typical ClO_2 system includes a ClO_2 generator, metering pumps and ClO_2 measurement and control systems. Batch operations will also require a batch tank.

ClO_2 GENERATOR

Typical ClO_2 generation systems use two or three precursors to generate ClO_2. A mix between hydrochloric acid and sodium chlorite at the proper concentrations and under a controlled environment can generate between 500 and 3300 mg/L of ClO_2. Figure 2 shows different types of ClO_2 generators.

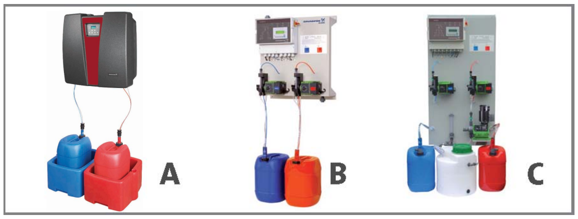

***Figure 2**. Common types of ClO_2 generators include (from left)*
(A) diluted continuous or batch, (B) high volume diluted continuous or batch and (C) concentrated continuous or batch.

The diluted continuous or batch system (A) uses diluted chemicals (9% HCl and 7.5% $NaClO_2$) and operates in a continuous or batch mode. The continuous mode typically uses a flow meter or measurement and control system driving the injection of ClO_2 proportionally into the water directly from the generator. The batch mode method is commonly used and operated for operations that have several points of injection in one location. The generator function in this case is limited to filling the batch tank with a specific amount of ClO_2 at a predetermined concentration. Typically, a level sensor installed on the batch tank will drive the operation of the generator.

The high volume diluted continuous or batch system (B) also uses diluted chemicals (9% HCl and 7.5% $NaClO_2$) either on continuous or batch modes.

The concentrated continuous or batch system (C) uses concentrated chemicals (33% HCl and 24.5 $NaClO_2$) and can also operate in either a continuous or batch mode. It is typically used in industrial applications where the supply of diluted chemical is limited or where the logistics to deliver the chemical are challenging.

BATCH TANK AND PUMPS

Once generated, ClO_2 needs to be used within a short period of time to prevent chemical degradation. The batch tank should be sized to the application so that the ClO_2 can be refreshed at least once every day or two, depending on concentration, temperature and other related factors.

After the batch tank is filled, metering pumps are used to inject the ClO_2 into the water. Digital dosing pumps are recommended since this type of pump will ensure accurate and almost continuous and smooth injection of the ClO_2 into the system. These pumps receive a signal from the flow meter or measurement and control system and inject ClO_2 almost continuously into the water. See Figure 3.

***Figure 3**. Digital dosing pumps ensure accurate and almost continuous and smooth injection of the ClO_2 into the system.*

MEASUREMENT AND CONTROL

As soon as the ClO_2 enters the water, it will start reacting with organic material and attaching to any biofilm or bacteria formation. Since the organic content and flow might vary, the level of ClO_2 in the water at a specific sampling point must be determined. The sample runs through the measurement and control system measuring cell where a digital sensor is used to determine the ClO_2 level.

The measurement and control systems send an output signal to either the pumps or the generator to close the loop and increase or decrease the injection of ClO_2 based on the water's ClO_2 content and flow variations. Temperature values are also displayed and tracked at the measurement and control system.

***Figure 4**. Measurement and control systems are used to determine the residual level of ClO_2 in the water at a specific sampling point – typically at the end of the loop after the ClO_2 has reacted throughout the cooling system.*

ClO_2 ADVANTAGES

- ClO_2 attacks and destroys free pathogens and it prevents and removes bio-film formations.
- ClO_2 is a far more effective disinfectant than identical concentrations of chlorine and is independent of pH in the 4 pH to 10 pH range. (See figure 5.)
- ClO_2 does not form disinfection byproducts such as THMs and HAA5s and does not affect the smell or taste of the water.
- ClO_2 has considerably less environmental impact compared to other treatment options.
- ClO_2 has a greater sustained-release effect for longer-lasting disinfection.

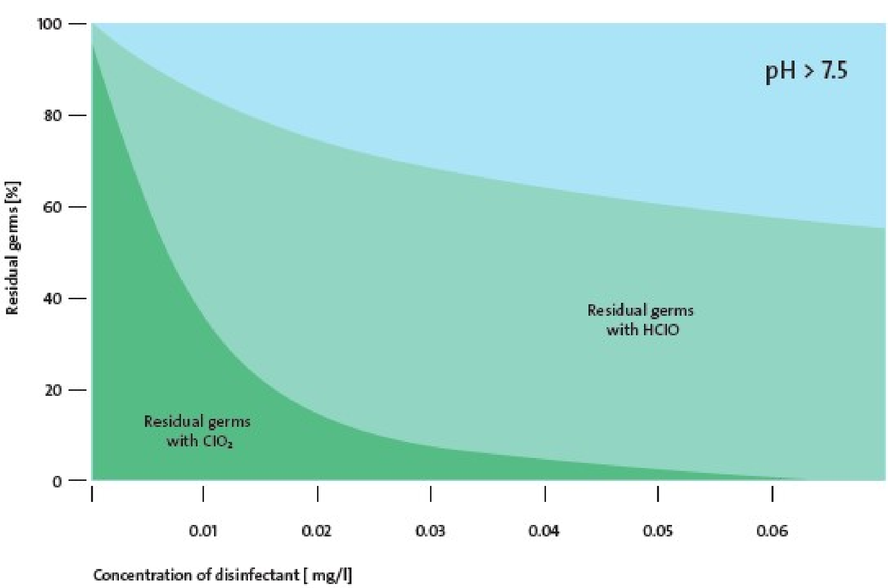

***Figure 5**. A comparison of the disinfecting action of chlorine dioxide and chlorine at a pH level of >7.5 shows the advantages of chlorine dioxide in the system.*

EFFECTIVE APPLICATION

A ClO_2 system is an effective water treatment alternative under the following circumstances:

- Cooling systems with high levels of pH where other oxidizing biocides are not effective.
- Systems where biofilm removal can account for a significant increase in efficiency and decrease in energy costs.
- Systems with high biofilm recovery rates where high levels of chemicals need to be injected to control biofilm growth and removal.
- Systems where local regulations prevent the disposal of byproducts into the environment.
- Systems with rigorous safety regulations and possible Legionella or bacteria contamination.
- Systems where traditional water treatment methods are inefficient.

CONCLUSION

In many cooling systems, a ClO_2 system provides effective water treatment. The associated operation and maintenance costs of ClO_2 generating equipment are minimal and can be calculated into the design of the system. And once installed, the advantages can be seen almost immediately. For example, on a 1000-ton chiller operating 12 hours per day, 365 days per year with a biofilm thickness of 1/1000", the elimination of biofilm can represent savings of more than $30,000 annually.

Several cooling systems around the world are looking at ClO_2 as a more effective and viable alternative for water treatment. As the use of ClO_2 versus traditional methods for cooling system water treatment increases, the benefits will become even more apparent.

CHARACTERISTICS OF TYPICAL DISINFECTION SOLUTIONS

Disinfection principle	Removes biofilm	Effective against bacteria in biofilm	Effective against free bacteria	Affects water taste and smell	Sensitive to water-pH	Life cycle cost	User scalding risk	Long-term effect
Thermal treatment	No	Low	Mid	No	No	High	Yes	No
UV radiation	No	No	High	No	No	Mid	No	No
Filtration	No	No	No	No	No	Mid	No	No
Chlorination (hypochlorite sol.)	No	Mid	High	Yes	Yes	Low	No	Mid
Ozone	No	No	High	No	No	Low	No	No
Chlorine dioxide	Yes	High	High	No	No	Low	No	High

***Figure 6**. This chart illustrates how the typical solutions for disinfection perform on several different parameters.*