

VEROX®-8 Cooling Water Treatment Microbiocide-
A Comprehensive Review of a
Stabilized Chlorine Dioxide Technology

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Introduction:

The objective of this technical paper is to review, using literature searches, laboratory studies, and actual case history documentations, the performance, economic, and logistical attributes of VEROX®-8 cooling water treatment microbiocide, a stabilized, chlorine dioxide releasing program. As a broad-spectrum, pH-independent technology that functions well even in alkaline environments and systems heavily fouled with organic contaminants or biofilm deposits, chlorine dioxide is ideally suited for use in many of today's complex treatment programs. VEROX-8 is a concentrated, EPA-registered, one-drum liquid product that is fed directly to the system via a standard chemical metering pump, and does not require the use of precursor chemicals or activation equipment. As such, VEROX-8 can provide users with the benefits of chlorine dioxide without the handling, safety, or capital cost issues commonly associated with traditional "on-site" generation processes.

Microbiological and Biofilm Issues:

In cooling water treatment applications, the single biggest threat to program performance is improper microbiological control. In a recent study conducted by an independent consultant, over 90% of the piping failures observed in cooling water systems during the past several years could be directly attributed to microbiological factors ¹. Unfortunately, water treatment professionals have historically evaluated the effectiveness of microbiological control programs by visual observations of the equipment, or by periodically monitoring concentrations of planktonic bacteria in the bulk water of the cooling system using traditional plate count or dip slide methods ². Somewhat naively, bacteria counts below 1×10^5 CFU/ml alone were often deemed to indicate that good microbiological control was being maintained throughout the entire cooling water system.

With the advancements that have occurred in analytical methods during the past 15 years, microbiologists now know that sessile biofilms are the predominate form of bacterial growth that occur in all aquatic systems. From a water treatment standpoint, biofilms are undesirable deposits that can reduce heat transfer rates, block pipes, impede water flows, harbor and protect pathogenic organisms (such as *Legionella pneumophila*), foul probes, and increase frictional losses and pumping expenses ³. Although each of these individual factors can have a negative influence on a facility's overall utility and program costs, the single most detrimental impact of biofilm formation is the development of microbiologically influenced corrosion, or MIC, within the cooling system ⁴. Biofilms can greatly accelerate MIC within a system through the formation of localized differential oxygen concentration cells, and by the production and concentration of corrosive mineral and organic acids in close proximity to metal surfaces ⁴. Because of the grave consequences associated with microbiological fouling within cooling water systems, it is imperative that all water treatment professionals have at least a general understanding of the factors and mechanisms governing biofilm formation. Such knowledge is also essential if water treatment professionals are to make informed product recommendations for truly successful microbiological control programs in today's complex cooling water systems.

Over time, bacteria will adhere to almost any surface in a water handling system. Once attached, these bacteria will quickly begin to excrete protective organic substances, and develop the beginning stages of a biofilm deposit ⁵. In these deposits, living microorganisms only constitute about 5 – 25% of the overall volume of the biofilm. The remaining 75 – 95% of the volume, which is commonly referred to as the biofilm matrix, is mostly water. On a dry weight basis, biofilms consist primarily of acidic exopolysaccharide and lipopolysaccharide molecules, which themselves are comprised mostly of carbohydrates (70 – 80%) and proteins (20 – 30%) ⁶. Eventually, when enough calcium ions from the bulk water of the cooling system replace the acidic protons of the polysaccharide molecules, the deposits change consistency and develop into the gelatinous masses that we commonly associate with biofilm formations ⁶.

As a biofilm matures, the polysaccharide molecules further react with accumulated enzymes and proteins now also contained in the deposit to form biopolymers. Over time, the resulting matrix becomes more complex and filamentous, allowing the biopolymers to trap and incorporate suspended debris, precipitated mineral salts and corrosion by-products from the bulk water into the growing deposit ⁶. As such, rather than forming a smooth and continuous surface, mature biofilms are typically patchy and highly canalized deposits, which allow nutrient-bearing water to flow into and better diffuse throughout the matrix. In a cooling water system devoid of any viable microbiological control program, a biofilm can reach equilibrium within 10 to 14 days, and obtain an average thickness of 500 – 1,000 microns ⁶. Once fully formed, a biofilm matrix protects the encapsulated microorganisms by shielding them from grazing predators such as protozoa, antibodies from competing microorganisms, and, most frustrating for all of us, a wide variety of microbiocides introduced by conscientious water treatment vendors.

Once established and mature, further studies have shown that sustained biofilm growth is then primarily due to the reproduction of microorganisms already contained within the biofilm, rather than by adherence of new planktonic organisms to the deposit ⁶. For this reason, it is critical that selected cooling water treatment microbiocides are able to penetrate deep within the biofilm matrix to attack and kill entrained microorganisms if proper microbiological control is ever to be achieved in the system.

In order to enter into a biofilm deposit, a microbiocide must first successfully navigate the vast array of biopolymers and entrained debris that is protecting the host microorganisms. Because of these interferences, either a much higher concentration, or a longer period of exposure, is typically required for a given microbiocide to diffuse into a biofilm and actually attack the living microorganisms. As a result of the protection afforded by the biopolymer matrix, studies have shown that organisms living in a biofilm required 150 times the CT value of hypochlorous acid to achieve a 2-log reduction in activity when compared to similar planktonic organisms ⁶.

Although strong oxidizers such as chlorine, bromine and peroxide can destroy the biopolymers of a biofilm matrix, this activity is greatest at elevated pH levels⁶. Unfortunately, it is at lower pH levels, when the oxidizers are in their neutral forms (i.e., hypochlorous acid for chlorine) that these oxidants are able to diffuse across the cell membranes and produce the free radicals needed to destroy vital proteins and enzymes within the microorganisms. During the past decade, however, with the almost universal acceptance of alkaline-based cooling water treatment programs, most open recirculating systems are now being operated with elevated pH levels. The problem for water treatment vendors is that at even at a moderate pH level of 8.5, over 90% of the added chlorine, and 40% of the bromine, is only present in the microbiologically weaker hypochlorite and hypobromite species, respectfully, greatly reducing their effectiveness and increasing overall program costs⁷.

The greatest single obstacle to microbiocide penetration, however, occurs when the microbiocide reacts with, and is neutralized by, the surface layers of the biofilm faster than it can diffuse into the deposit. This phenomenon, commonly referred to as transport breakdown, most often occurs with the use of strong oxidizing microbiocides such as chlorine and peroxide, but recent studies have also shown that even some non-oxidizing microbiocides can be limited in this way⁵.

During the past several years, many water treatment companies have implemented microbiological control programs based upon the continuous, low-level feed of oxidizers such as chlorine and bromine to a cooling water system. Typically controlled automatically by ORP residuals in the recirculating water, these programs seek to maintain virtually sterile conditions within the recirculation water, thereby preventing the development of biofilm deposits. However, while planktonic organisms may not demonstrate an increased resistance to oxidizers, studies have shown that biofilms can develop a tolerance⁷. Characklis reported that biofilms could accumulate even in the presence of a continuous chlorine concentration of 0.8 ppm (as free chlorine), and observed that there has not been found a level of continuous halogenation at which biofilms are controlled without also significantly increasing corrosion rates within the system⁸.

Based upon our industry's new understanding of biofilm formation, it is critical that water treatment vendors now carefully consider both the penetrating ability and disinfecting power of a microbiocide before making any product recommendations in cooling water systems contaminated by, or susceptible to, biofilm deposits. In fact, in recent mathematical models conducted by the Center for Biofilm Engineering (CBE) at Montana State University-Bozeman predicted that a weak disinfectant, if it were able to penetrate the matrix of a biofilm, would outperform a stronger disinfectant that is unable to enter the deposit⁵. Unfortunately, many of the microbiocides now in general use in cooling water treatment applications have been selected and given regulatory approval by the Environmental Protection Agency (EPA) based on their ability to kill cells grown in a planktonic culture, in a narrow and relatively susceptible phenotypic state⁵.

By effectively shielding viable microorganisms from any microbiocides introduced to the system, biofilms enable bacteria to constantly re-inoculate the bulk water and then spread throughout the entire cooling water system. This is why it is virtually impossible to first achieve, and then maintain, desired levels of biological control in any system that is contaminated with biofilm deposits using many of the microbiocides currently available today.

Enhanced Tube Technology:

One emerging trend in the cooling water treatment industry that is greatly influenced by biofilm considerations is the increased use of enhanced tubes in refrigeration equipment for improved heat transfer and energy savings. With enhanced tubes, the inner surface of a conventional straight bore refrigeration tube is further milled into a rifling pattern. The rifling pattern increases the flow turbulence of water within the tube, which improves flow and heat transfer rates within the refrigeration equipment. Rifling also provides for thinner tube walls and increased surface area, factors that also help to improve heat transfer rates and improve energy savings ⁹.

However, with rougher metal surfaces, enhanced tubes are much more susceptible to scaling and fouling problems than traditional straight bore tubes. In addition, with initially thinner tube walls, corrosion control is also an important consideration in treating a system containing enhanced tubes ⁹. Therefore, if the water treatment control program is lacking in any key control aspect, heat transfer efficiencies initially gained through the purchase of an enhanced tube system (there is typically a 50 –100% cost premium when compared to traditional straight bore tubes) can be quickly lost in increased energy costs in just a few months time. For these reasons, microbiocides selected for water treatment programs operating in systems with enhanced tubes must be capable of preventing both biofilm formation and MIC, while not promoting corrosion of the critical metal heat transfer surfaces, or otherwise impacting the performance of the tubes ⁹.

Chlorine Dioxide Technology Overview:

Within the water treatment marketplace, chlorine dioxide has long been recognized as a versatile oxidizing compound. Since its first commercial use as a disinfectant at a municipal drinking water plant in Niagara Falls, NY in 1940, chlorine dioxide has been adopted and is now routinely applied in a wide variety of other industrial applications, including service as a bleaching agent in pulp and paper operations, a microbiocide in recirculating cooling water systems, a sterilizer in food processing plants, and an oxidant in waste water treatment facilities. Within these industries, chlorine dioxide is used in many different types of water handling systems to remove unwanted iron and manganese contaminants, eliminate taste, color, and odor problems, control microbiological growth, destroy troublesome toxicants, reduce turbidity levels, and lower BOD and COD concentrations ¹⁰.

Chlorine dioxide has several unique chemical attributes that clearly distinguish it from other commonly used water treatment oxidizers such as chlorine, bromine, hydrogen peroxide, and ozone. First, compared to all of these other oxidizers, chlorine dioxide has the lowest oxidation-reduction potential (see Table#1). As a weaker and more selective oxidizer, chlorine dioxide does not chemically react with or become “consumed” by many classes of background chemical compounds commonly found in water handling systems, including but not limited to all of the following:

Unreactive Background Compounds		
Ammonia	Aliphatic Amines	Polysaccharides
Acids	Carbohydrates	Saccharides
Alkanes	Ethers	Unsaturated Fatty Acids
Alkynes	Fats	Unsaturated Aromatics
Alcohols	Glycols	
Aldehydes	Ketones	

With little or no “demand” imposed by these background compounds, any chlorine dioxide added to the system remains reactive and available for use in its intended purpose. Please note that chlorine dioxide does not react with, and is not consumed by, either polysaccharides or carbohydrates, two of the major components of biofilm deposits. By not reacting with these important components of biofilm deposits, chlorine dioxide is able to maintain its desired concentration levels in the system, allowing the microbiocide to more easily diffuse through the protective matrix to encounter and attack the entrained microorganisms. As a weaker oxidizer, chlorine dioxide is an outstanding biofilm penetrant and deposit control agent, and the product is also less corrosive to system metallurgy.

Another unique feature of chlorine dioxide is its ability to accept 5 electrons in an oxidation-reduction reaction, compared with only 2 electrons for virtually all other commonly used oxidizers (see Table#1). As such, with 250 percent of the oxidation capacity of most other oxidizers, it would require 2.5 times the amount of chlorine, bromine, hydrogen peroxide, or ozone to completely oxidize the same amount of material as a specific quantity of chlorine dioxide. In addition, under ambient conditions chlorine dioxide is a true water-soluble gas that, unlike chlorine and bromine, will not hydrolyze in solution to form inactive compounds. Even over the broad 3 - 10 pH range, chlorine dioxide remains 100 percent active and available for use as an oxidizer and disinfectant. Chlorine dioxide then, as a selective oxidizer with a greater oxidation capacity, has an overall use cost comparable to that of even the least expensive oxidizers.

Table#1:

**Commonly Used Water Treatment Oxidizers
Oxidation/Reduction Potentials and Capacities:**

Material	ORP (Volts)	Oxidation Capacity
Ozone (O ₃)	2.07	2 Electrons
Hydrogen Peroxide (H ₂ O ₂)	1.76	2 Electrons
Hypochlorous Acid (HOCl)	1.49	2 Electrons
Chlorine (Cl ₂)	1.36	2 Electrons
Hypobromous Acid (HOBr)	1.33	2 Electrons
ClO₂ (Liquid Phase)	0.95	5 Electrons

Chlorine dioxide has also been proven to be a strong anti-microbial agent that can be used to control viruses, bacteria, algae, and fungi. Chlorine dioxide functions as a biocide by penetrating the outer membrane of the microorganism and disrupting the metabolic processes of the cell. This process has been proven to be more efficient than the “burning” method that is employed by stronger oxidizers such as chlorine and ozone. Use of chlorine dioxide also allows for lower effective biocide concentrations and improved program economics. Commonly encountered microorganisms readily controlled by chlorine dioxide include slime-forming bacteria such as *Pseudomonas*, and iron and sulfur reducing bacteria such as *Crenothrix* and *Desulfovibrio*, respectively. Chlorine dioxide is also very effective in controlling the common pathogens *Giardia lamblia*, *Cryptosporidium*, *E. coli*, *Staphylococcus aureus*, *Listeria*, *Salmonella*, and *Legionella pneumophila*. Chlorine dioxide is particularly effective in systems susceptible to slime-forming bacteria and biofilm deposition. Several papers have shown that weaker oxidizers such as chlorine dioxide are much better than strong oxidizers at biofilm penetration and destruction^{10,11}. For this reason, chlorine dioxide can remove and control biofilms better than strong oxidizers such as chlorine and ozone. Other studies have shown that bacterial recovery (the regrowth of bacteria after disinfection) is slower with chlorine dioxide than with any other oxidizer¹¹.

Despite the many features and benefits associated with chlorine dioxide, one major drawback has historically hindered the more widespread application of the technology. As chlorine dioxide cannot be compressed, stored, or shipped in high concentrations (5,000 ppm is considered the maximum safe concentration of the material), the product is traditionally generated “on-site” from precursor chemicals for immediate application to the indented system¹³. Even considering the recent improvements made in the performance of “on-site” generators, the use of chlorine dioxide produced by these methods is still hampered at many cooling water treatment accounts by chemical storage, handling, and related safety concerns, or by issues regarding the purchase, installation, operation, and maintenance of expensive and complicated activation equipment.

VEROX-8 Cooling Water Treatment Microbiocide-Product Overview:

VEROX-8 is a concentrated solution of stabilized chlorine dioxide designed to control microbiological growth in open and closed recirculating cooling systems and other water-dependant operations, such as papermaking equipment and oilfield operations. As an EPA-registered, single-drum microbiocide that does not require the use of complex activation equipment, or the storage of hazardous precursor chemicals, VEROX-8 can provide customers with all of the benefits of chlorine dioxide without the significant capital and operational expenditures, or plant safety concerns associated with traditional on-site generation programs.

As many people know, conventional sodium chlorite programs require that the pH of the solutions must be altered with acid prior to use. The change in pH will create chlorine dioxide, along with several byproducts, including chlorite, chlorate, and chloride ions. Whether generating the acid via electrical or ion exchange methods, or by just feeding a concentrated acid solution directly to the generator, these procedures remain the standard methods used to produce chlorine dioxide "on-site" for water treatment applications.

In the process of manufacturing VEROX-8, we do not rely on the standard production methods utilized by other vendors. Although VEROX-8 is based on a form of sodium chlorite, during its manufacturing process, a proprietary package of inert chemistries is introduced, which react with and alter the halide salts. This EPA-approved method allows for the microbiocide to be administered as a "Ready to Use" (RTU) product. As a RTU product, VEROX-8 can be administered to a recirculating cooling water system via direct slug additions with a conventional chemical metering pump. No expensive chlorine dioxide generator hardware is required, and no hazardous acidic media is needed, thus offering customers numerous economic and safety advantages to all of the chlorine dioxide technologies currently available for cooling water treatment.

As a stabilized product, VEROX-8 is fully converted to chlorine dioxide only after the product is added to the system and the active ingredients encounter the localized low pH conditions associated with microbiological growth and biofilm deposits. Using this "in-situ" activation mechanism, VEROX-8 can remain unchanged in the bulk water as an immediate precursor residual, only being converted to the desired chlorine dioxide biocide by the metabolic activity of troublesome microorganisms. This unique activation method also prevents VEROX-8 from becoming consumed by organic contaminants contained in the bulk water, and allows the product to more easily penetrate biofilm deposits before being converted to chlorine dioxide. Like all chlorine dioxide-based microbiocides, VEROX-8 will not react with background organic materials to form undesired chlorinated compounds, such as THM's and HAA's. VEROX-8 will also not react with or degrade all commonly used cooling water treatment compounds, including phosphonates, molybdate, polymers, and aromatic azoles, or materials of construction commonly found in cooling water systems, including steel, copper, or wood.

In open recirculating cooling water treatment applications, VEROX-8 is slug fed to the system via a conventional chemical metering pump (off-gassing is not an issue) to either the tower basin or a recirculating water line at a rate of 0.5 – 1.0 gallons of product per 10,000 gallons of system volume (60 – 120 ppm as product) every 2 – 5 days, or as needed to maintain control. For closed recirculating systems, VEROX-8 should be slug fed to the system via a by-pass feeder or chemical metering pump, also at a concentration of 60 – 120 ppm (as product). To prevent fouling by released deposits, VEROX-8 should only be used in closed systems that have adequate filtration. The product has also been successfully used to control microbiological growth in closed recirculating systems contaminated with glycol or organic materials. In each situation, the VEROX-8 should be fed to the system at a rate sufficient to generate and maintain a chlorine dioxide residual of 0.1 – 5.0 ppm for a period of at least 5 minutes. Customers typically use plate count analyses to verify product dosage rates.

With low product dosage rates, competitive per-pound pricing, and reduced system demand levels, the overall “use-cost” for VEROX-8 is comparable to many commonly used cooling water treatment microbiocides, including glutaraldehyde, isothiazolinone, and many other oxidizers, including stabilized bromine and bromine chloride. From a marketing perspective, as a unique and interesting product that is not currently being offered by any of the national service companies, VEROX-8 can be used by independent water treatment vendors as a door-opening microbiocide to gain access to key decision makers at those previously difficult to penetrate prospects.

Case History Documentations:

For the past 18 months, Jamestown has been actively evaluating VEROX-8 in a wide variety of open and closed recirculating cooling water systems, including applications in critical systems associated with HVAC operations in large commercial buildings and hospitals, and process cooling in industrial facilities and power generating operations. In each of these situations, many of which had a previous history of microbiological fouling and biofilm formation, the VEROX-8 microbiocide performed exceptionally well. In virtually every situation in which it was used, VEROX-8 enabled Jamestown to dramatically improve microbiological control within the treated system, secure its sales position at the customer, significantly reduce overall biocide expenditures, and improve profit margins at important contract accounts. Based upon our initial observations and successes, and fueled by “word-of-mouth” endorsements among the company’s sales representatives, VEROX-8 has quickly become one of the leading microbiocides in Jamestown’s product line. This success with VEROX-8 has allowed Jamestown to discontinue the use of several small volume microbiocides, and provided the company with additional savings in terms of reduced inventory control expenses and lower product registration costs.

For your convenience and review, four separate Case Histories, each describing the successful application of the VEROX-8 microbiocide in a critical cooling water treatment application, have been included in the Appendix section of this paper.

Conclusions:

Even now, despite having a better understanding and appreciation of the important role that proper microbiological control plays in the establishment of a truly successful cooling water treatment program, especially as it pertains to biofilm deposits, many customers and vendors still find themselves in a quandary. First, with the adaptation of alkaline-based treatment programs, many traditional oxidizing treatment programs are now operating well outside of their optimal performance ranges. In addition, many of today's commonly used proprietary microbiocides were originally evaluated by the regulatory agencies solely on planktonic bacteria populations, so their overall effectiveness on critical biofilm deposits remains untested and suspect.

Based upon over one year of actual field experiences, gained in numerous and diverse treatment programs, it is apparent that the VEROX-8 microbiocide can play an important role in many of today's most difficult cooling water treatment applications. As a broad-spectrum, pH-independent technology that functions well even in alkaline environments, and in systems heavily fouled with organic contaminants or biofilm deposits, VEROX-8 can provide users with the many known benefits of chlorine dioxide programs, without the handling, safety, or capital cost issues commonly associated with traditional "on-site" generation processes. For these reasons, VEROX-8 should be given careful consideration for inclusion as a versatile component of any company's comprehensive microbiocide product line.

Marketing and Contact Information:

VEROX-8 is manufactured by The VEROX Group, Stratham, NH and marketed to water treatment service companies exclusively by Water Solutions, LLC, Stratford, CT. VEROX-8 is currently offered in 5 gallon pails, 15 and 30 gallon containers, 55-gallon drums and 275-gallon tote containers. Repackaging and sub-registration agreements are available to qualified water treatment service companies. VEROX-8 is currently registered for use in every state except California. More detailed information regarding VEROX-8 microbiocide can be obtained by visiting the Water Solutions web page at www.watersolutions.us, or by contacting the company directly by phone at (203) 377-8747. For your convenience, electronic copies of the attached Case Histories, and a Product and Material Safety Data Sheet for the VEROX-8 microbiocide can be downloaded from the web site in a PDF format.

VEROX is a registered trademark of The VEROX Group, Stratham, NH.

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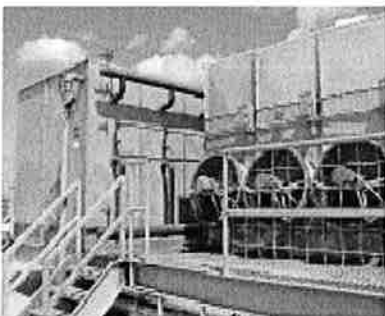
APPENDIX

VEROX[®]-8 Case History

Successful Use as a Cooling Water Treatment Microbiocide at a Large Commerical Bakery

Background:

A large New England bakery produces the rolls used to make deli sandwiches for a chain of fast food outlet stores. In the production process, the bakery uses a 300-ton open recirculating cooling water system to chill the plant's ammonia-based refrigeration equipment. With high organic loadings from air-bourne flour and other food ingredients, microbiological control has always been difficult to maintain in the system. The plant had previously used a proprietary, organic-based microbiocide, along with sodium hypochlorite, in the system. Unfortunately, product dosage rates and program costs were high, and elevated microbiological counts, biofilm formation, and foaming all presented operational problems.



Study Results:

Seeking to correct these problems in such an organically-loaded cooling system, a large regional vendor initiated a treatment program based upon VEROX[®]-8, a stabilized, chlorine dioxide releasing microbiocide recently released to the marketplace. As a water-soluble gas and selective oxidizer, the chlorine dioxide technology offered the account the following benefits:



- Will not react and degrade with nitrogen-based or most organic contaminants commonly found in cooling water systems.
- Offers broad-spectrum microbiological control, including algae, bacteria and fungi.

- Is very fast acting and easy to use.
- Provides microbiological control over a wide pH range, including alkaline waters.
- Is not aggressive to system components, including steel, copper or wood.
- Uses easy test methods to determine product residual levels.
- Very effective against biofilms, iron and sulfate reducing bacteria, and legionella pneumophila.

The study was initiated by adding a single 120 ppm (as product) slug dose of the VEROX-8 directly to the tower basin. Throughout the next 24 hours, samples were collected on a regular basis and sent to an independent laboratory for 48-hour heterotrophic plate count analysis (conducted at 35 degrees C).

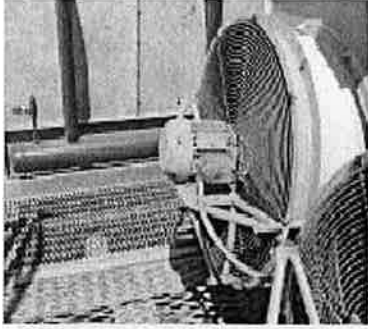
The tower system used in the study operated at approximately five cycles of concentration, with a recirculating water conductivity of 1,000 mmhos (maximum), a pH of 8.3, and a total hardness level of 80 ppm (as CaCO₃). A previous analysis had determined that the system's volume was 1,500 gallons. Results from the plate count analyses were as follows:



Time Since VEROX-8 Addition (Minutes)	Heterotrophic Plate Counts (CFU/ML)
START (prior to VEROX-8 addition)	185,000
30 minutes	130
60 minutes	120
120 minutes	110
240 minutes	120
1440 minutes	1,700

Study Conclusions:

Although plate counts in the bulk water were not especially high during the beginning of the study, biofilm deposits were present throughout the system. These deposits caused excessive foaming problems and diminished operating efficiencies on the refrigeration equipment. As a potent and fast-acting microbiocide that is not adversely affected by most organic contaminants, VEROX-8 was able to reduce heterotrophic plate counts in the cooling water system by 3 orders of magnitude in less than 15 minutes. In addition, subsequent twice per week slug additions of the product (at 40 ppm) were able to maintain biological counts below the system's recommended 1×10^4 cfu/ml control limit, eliminate foaming problems, and slowly remove existing biofilms from the system.



These outstanding results were also obtained at a significantly lower cost than the previous microbiological control program. As such, VEROX-8 enabled the water treatment service company to secure their sales portion and increase their profitability at this key contract amount.

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Verox-8®

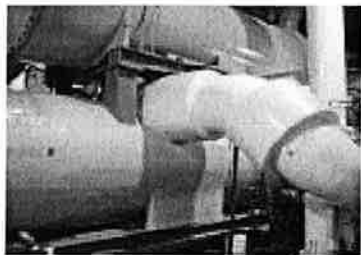
Cooling Water Treatment Microbiocide Case History at a Hospital Complex

Background:

A 465-bed acute-care hospital located in northern New Jersey operates three separate open recirculating cooling water systems, on both a seasonal and year-round basis, to provide comfort cooling throughout its urban campus. The systems, with a total capacity of 2,250 tons of refrigeration, use a moderate hardness and alkalinity municipal makeup water, and were historically operated at 7 cycles of concentration (based on conductivity). The previous water treatment vendor had used a parachlorophenol-based proprietary product and sodium hypochlorite to control microbiological growth within the systems.



Despite the routine addition of high concentrations of each of these products, microbiologically-active slime deposits were present on each of the tower's louvers, distribution decks, and sump basins. Even more troublesome deposits formed on the condensers' tubes and tube sheets, and the systems' distribution piping. Under this treatment program, the condenser tubes were always very dirty, and required routine and vigorous punching to clean. As was evident by the high iron and copper residuals in the recirculating water, elevated corrosion rates in the system were also compromising the service life of the refrigeration equipment.



During the past several years, water treatment professionals have gained an increased appreciation for the various troubles that slime deposits can

cause in cooling water systems. By excreting protective polysaccharide films, slime-forming bacteria provide the "glue" that entraps entrained suspended solids to form the tenacious deposits that we commonly see in many cooling systems. These acidic deposits aggressively attack underlying metal surfaces, leading to highly destructive pitting type corrosion problems. Slime deposits also protect the living bacteria cells from many types of microbiocides, allowing the films to constantly re-inoculate bulk water populations. Such protection makes it extremely difficult to ever gain proper microbiological control in any system heavily contaminated with biofilm deposits. Insulating and voluminous slime deposits also reduce heat transfer rates and restrict water flows, thereby reducing the efficiency of the refrigeration equipment and increasing overall system operating costs. More recently, several studies have shown that slime deposits provide the ideal growth environment for *Legionella pneumophila*, the causative agent for Legionnaires Disease, which is a major health concern in any hospital setting.

Program Application:

After being awarded an annual service contract at the hospital for the cooling water treatment program, a large regional service company initiated a microbiological control program based primarily on Verox-8, a stabilized chlorine dioxide-based product. As a selective oxidizer, chlorine dioxide is able to penetrate biofilm deposits and quickly kill the slime secreting bacterial cells. However, as a relatively non-aggressive oxidizer, chlorine dioxide will not degrade other ingredients of the water treatment program (such as phosphonates, polymers or azoles), or accelerate corrosion rates for steel or copper system components. As a concentrated, single drum, liquid microbiocide that only requires a simple chemical metering pump for product application, Verox-8 also enabled the service company to quickly established a



comprehensive microbiological control program without the capital expense and maintenance problems traditionally associated with generator-based chlorine dioxide programs.



In this program, Verox-8 was slug fed to the systems twice per week, at a dosage rate of 120 ppm (as product). During the warmest months of the summer, the program also used a weekly

slug addition of Tocide® PS-200 (THPS), also fed to the system at a dosage rate of 120 ppm (as product). Within only a few weeks time of initiating the program, all of the visible biofilm deposits were removed from the tower structures, and bulk water bacteria counts were reduced to 100 – 1,000 CFU's/ml (as measured by dip slides). With the pronounced improvement in microbiological and related deposit control, system operators were able to increase cycles of concentration in the towers to 10, a more than 40% increase that significantly reduced water and chemical consumption rates and dramatically improved overall operating costs. Iron and copper levels in the recirculating water also declined rapidly to less than 1.0 ppm and 0.1 ppm, respectively. In addition, after eight consecutive months of operation on the Verox-8 microbiological control program, the condensers were opened for their annual inspection and deemed, "the cleanest I have ever seen", by the hospital's long-time Trane service representative.

Program Summary:

In a series of critical open recirculating cooling water systems that had previously encountered persistent biofilm deposits and resulting operating problems, Verox-8 was able to provide the account with comprehensive microbiological control. The use of Verox-8 also provided the water treatment vendor with significantly lower operating costs for the systems, and the one-drum program was established quickly and easily with minimal capital, manpower or maintenance expense.



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Tocide is a registered trademark of Rhodia Corporation.*

Verox-8® Cooling Water Treatment Microbiocide Case History at a Large Commercial Building

Background Information:



A very large and prestigious, dual purpose commercial and institutional property in New York City uses a 1,100-ton refrigeration plant to provide comfort cooling to office space and 436 heat pumps located in student dormitory rooms. The 17,000-gallon open condenser water system operates at 10 cycles of

concentration (based on conductivity), with a 3,300 gpm recirculation rate, and a temperature differential of 5 – 30 degrees F. When initially placed on-line over 10 years ago, the mechanical contractor left the system untreated for a period of 12 – 18 months. Then, for a period of 4 – 5 years, the previous water treatment vendor used a simple inorganic phosphate program in the system to control corrosion and deposition. Unfortunately, these treatment programs caused many long-term operating problems in the system, including:

- Severe microbiological fouling and aggressive underdeposit corrosion.
- Excessive consumption of oxidizing microbiocides such as liquid chlorine and bromine, and BCDMH. Consumption rates for non-oxidizing products, such as glutaraldehyde and isothiazolinone, were also high.
- Persistent foaming problems caused operating difficulties with the electronic controls used to regulate water levels in the system.



- Phosphate, iron and microbiological-based deposits caused severe pitting of the condenser tube sheets, and numerous failures of the schedule 80 black iron distribution piping and copper branch piping.
- Constant blockages in the heat pumps resulted in the loss of climate control in critical tenant and student spaces.
- Elevated concentrations of aggressive oxidizing microbiocides degraded the azole-based copper corrosion inhibitor and accelerated the corrosion of mild steel system components.

Besides the obvious operational problems, these difficulties also significantly increased maintenance costs and power consumption for the system.

Program Application:

Once it became available to the marketplace, a regional water treatment vendor evaluated the use of VEROX®-8, a stabilized, chlorine dioxide-based microbiocide that is packaged in an easy-to-use liquid form. As a selective oxidizer, chlorine dioxide is not degraded by waterborne organic contaminants and provides broad-spectrum microbiological control over the wide 6 – 10 pH range. In addition, chlorine dioxide will not interfere with other ingredients of the water treatment program or accelerate corrosion rates of copper and mild steel system components.

To facilitate the cleaning process, the feed of all other microbiocides was discontinued, and Verox-8 was slug fed to the system on a daily basis at a rate of 200 ppm (as prod-



uct). After a period of two weeks, bulk water bacteria levels declined to 100 – 1,000 CFU's/ml (as measured by dip slides). Daily dosage rates were then reduced to 80 ppm, and bacteria levels remained steady at 1,000 CFU's/ml, or less. After one month, Verox-8 was then fed to the system on alternative days, and as the only microbiocide in the program, provided the facility with the following benefits:

Mild steel and copper corrosion rates (as measured with coupons) declined to less than 1.0 mpy and 0.1 mpy, respectfully, with no visible indications of pitting problems.

- Algae deposits were completely eliminated from the system, and foaming problems were no longer an issue.
- Biofilm deposits were slowly removed and eliminated from the system.
- Blockages within the heat pumps have been dramatically reduced.
- Condenser units opened very clean, improving the operating efficiency of the entire system.
- The supplemental feed of steel and copper corrosion inhibitors was discontinued, greatly improving program costs.

Program Summary:

In this difficult treatment application, Verox-8 was successfully used as a "stand-alone", easy-to-use, broad-spectrum, and cost-effective cooling water microbiocide.



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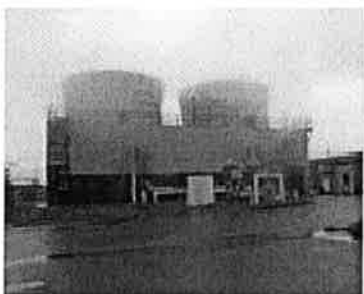
VEROX®-8

Cooling Water Treatment Microbiocide

Case History at a Coal Fired Cogeneration Power Plant

Background Information:

A 50-mw fossil fuel cogeneration plant located in western New York State operates a 30,000 gpm, forced draft open recirculating cooling water system to provide chilled water to the plant's condenser and auxiliary equipment. The critical



240,000 gallon system operates with a 20 - 30 degree F delta T, typically seeing supply temperatures of 70 - 90 degrees F., and return temperatures of 90 - 120 degrees F. The tower system operates at approximately 15 cycles of concentration (based on conductivity), with a recirculating water conductivity of 3,500 mmhos, a total hardness level in the 1,600 - 2,000 ppm range (as CaCO₃), and a pH level controlled between 8.0 and 8.4 via the feed of acid to neutralize alkalinity.

Historically, the system operated with a high suspended solids concentration, as air-borne contaminants from the adjacent coal storage piles were constantly scrubbed from the air and added to the water, a scenario that created



ideal conditions for increased microbiological activity within the cooling system.

Previously, the plant had used a powdered oxidizing microbiocide, a combined chlorine/bromine compound, with only limited success. In addition, program costs were high and there were frequent

mechanical problems with the device used to feed the product to the system.

Program Application:

After taking over all water treatment responsibilities at the plant, a large regional water treatment company quickly initiated a microbiological control program in the towers that addressed concerns surrounding the mechanical feed equipment while also providing a more economical alternative to the costly dry product. Based upon the high sediment and organic loading at the plant, the vendor initiated a microbiological control program based upon Verox®-8, a stabilized chlorine dioxide-releasing product. As a selective oxidizer that operates over the broad 6 - 10 pH range, Verox-8 provided the plant with the following benefits:

- Use of a convenient, single drum, liquid microbiocide that only required a simple chemical metering pump and timer for product application.



- Elimination of the troublesome dry chemical feeder and associated mechanical problems.
 - Application of a fast-acting oxidizing microbiocide that will not readily degrade in the presence of organic contaminants in the recirculating water.
 - Use of a broad-spectrum, single product microbiological control program that is effective against algae, bacteria, and fungi. The product is also able to penetrate and remove existing biofilms from metal surfaces.
 - Application of a product that won't react and degrade other water treatment components such as phosphonates, polymer, and azoles, or promote the corrosion or breakdown of system components, including steel, copper, or wood.
-

The microbiocide program initiated by the vendor used a 40 ppm dosage of Verox-8 (as product), fed to the system on a slug basis, twice per week, directly to the tower basin. Microbiological testing performed on the system water showed that planktonic bacteria counts (as measured by dip slides) were constantly maintained below 1.0×10^4 cfu's/ml. In addition, previously developed slime deposits were slowly and completely removed from the system.

Program Conclusions:

- Verox-8 proved to be a potent and fast acting microbiocide that was easily administered to the system.
- Use of the troublesome dry chemical feed system was eliminated.
- Bulk water bacteria counts can be maintained below industry standard control ranges by only using twice per week slug additions of Verox-8.
- Slime growths can be completely controlled to below detection limits.
- Excellent results can be obtained at much lower treatment costs than with many traditional oxidizing programs.



Program Summary:

Use of the Verox-8 stabilized chlorine dioxide microbiocide enabled this cogeneration power facility to implement a one-drum microbiological control program that significantly lowered program cost, eliminated feed equipment mechanical problems, and provided comprehensive control of bacteria, fungi and algae in the plant's critical open recirculating cooling water system.



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