

Bio-hydrox™

for the control of biofilm,
biofouling, scaling &
corrosion in storage, cooling
and premise water systems

ENVIROCLEEN

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CONTENTS

- 1 Introduction.....3
- 2 The problem4
- 3 The solution.....4
- 4 The technology5
- 5 Bio-hydrox vs Ozone6
- 6 Value proposition for the treatment of cooling systems.....7
- 7 Value proposition to reduce environmental impact.....8
- 7.1 Water savings8
- 7.2 Energy savings.....8
- 7.3 Financial savings8
- 8 Green chemistry.....9
- 8.1 The principles of green chemistry9
- 9 Real Time Monitoring11
- 10 Scientific Validation12
- 11 Other applications13
- 12 National Sanitary Foundation, NSF Intl.....14
- 13 U.S. Food and Drug Administration, FDA14
- 14 U.S. Environmental Protection Agency, EPA14
- 15 Logistics14

1 INTRODUCTION

Enviroclean LLC is delighted to introduce Bio-hydrox advanced oxidation reagent and share what our mineral oxychloride liquid formulation can offer. Bio-hydrox has excellent features that will be a great fit for your current operations and future designs.

The mineral oxychloride technology is the first advanced oxidation process (AOP) to earn US Environmental Protection Agency approval for potable and non-potable water disinfection. In 2018, EPA granted FIFRA registration for treating cooling water systems, among other label claims, and in July of 2021 it expanded the original label to over two dozen new claims, and awarded approval for the same applications that commercial chlorine based chemicals have been granted as water treatment products and broad sanitizers.

The mineral oxychloride reagent is the only AOP that is commercialized as a consumable liquid product because its stability and long shelf life allows it to maintain maximum performance throughout the supply-chain process in the water treatment chemical industry.

Bio-hydrox is water based and easily scalable. It does not need highly trained labor. The treatment can be fully automated.

Bio-hydrox does not require external energy source and it can be implemented with negligible capital cost, and the operational expenses are significantly lower than all other AOPs. Savings can be realized even when comparing to other traditional chemical treatments.

Bio-hydrox works well in cold, warm, dry and humid weather conditions, and in an ample pH range environment. It provides long residual protection.

Since its EPA approval in 2018, Bio-hydrox has been used for Legionella remediation in over 30 states, and it is used on a continuous basis as part of Legionella risk management for building water systems in hospitals and nursing homes in NY, NJ, PA, IN, WI, MO, UT, and AZ.

In storage tank applications we have successfully been using Bio-hydrox in TX municipal water wells and in off-the-grid communities spring water storage tanks in rural Canada. Several municipalities in CA use it for final disinfection and to maintain water quality in their distribution.

You will realize excellent results when using this product. Thank you for taking the time to review the information herein.

Yours faithfully,

Emma Flanagan
President
Enviroclean, LLC.

2 THE PROBLEM

Water distribution structures in cooling systems, industrial processes and premise networks face common issues associated with scale formation, corrosion, deposition and persistent biofilm.

Microbiological control has always been the primary driver of using disinfectants, biocides and algaecides. Without the availability of effective treatments that prevented the formation of biofilms, which allow bacteria to find shelter and protect themselves from elements that may harm them and makes them extremely resistant to biocides, it has been very challenging to maintain water systems free of pathogens and some feasible solutions are cost prohibiting. More often than not, it has not been possible. On top of the list, is the search for solutions that support complete eradication of Legionella bacteria from water systems. Until now, controlling the bacteria had been only about efforts to reduce the chances of an onset and not about a permanent solution that eliminates the possibility of its existence.

Another problem with biofilms is their thermal resistance. They have very high insulating properties and one of the areas that is often overlooked is how well the biocide program is working on how it affects the heat transfer, energy efficiency and production capacity.

Biofilm is a manifestation of system fouling, the accumulation of unwanted materials on the surfaces in contact with a flow of water. It can seriously deteriorate the capacity of the surface to transfer heat. It is an extremely complex phenomenon with the presence of biological contributors and mineral, non-biological encrustations, formed from the combined effects of several processes involving inorganic and organic molecules or ions depending on the chemical composition of the water. When compared to mineral fouling, biofouling presents significantly more thermal resistance than the most common sources of scaling.

The reason biofouling is considered of paramount importance is that it can create multiple operation challenges. Among these is corrosion, pitting corrosion, harboring of pathogenic organisms, and the significant thermal resistance it presents. Although fundamentally different processes, scale, corrosion and biofilm all potentially share a common thread with microbiology

3 THE SOLUTION

Bio-hydrox™ is a non-toxic water treatment product that prevents biofilm and is available as an eco-friendly alternate to chlorinated chemicals and non-chlorinated biocides. It is a novel advanced oxidation process, very effective at eliminating waterborne pathogens and control system fouling. A stand-alone technology that resolves the cluster of challenges in all water systems and that other water treatment processes have not been able to conquer in a practical way.

4 THE TECHNOLOGY

ADVANCED OXIDATION FORMULA OF OXYGEN CHELATED MINERALS STABILIZED IN A WATER BASED SOLUTION.

Water treatment oxidants attract electrons and initiate oxidation. When oxidation reaction takes place the chemistry of the substance or microorganism that loses the electron is disrupted and cannot longer exist in its previous form. **In a general sense, Advanced Oxidation Processes (AOPs), are chemical treatment procedures that catalyze oxidants and intensify the results.** The catalysts are a source of energy that helps the reagent act faster, stronger, and amplify the chain reaction. Bio-hydrox™ catalysts are mineral salts regarded as trace nutrients. Oxidant reagents are the source of oxygen. Most commons are ozone, water, Hydrogen Peroxide and halogenated oxidants like Sodium Hypochlorite.

Compared to all oxygen-based reagents Bio-hydrox™ ranks the highest at applying active energy to initiate oxidation, otherwise known as electrochemical potential.

REAGENT NAME	FORMULA	ELECTROCHEMICAL POTENTIAL (Volts)
Fluorine	F^2	3.06
Mineral Oxychloride Solution	$M_xO_yCl_z$	2.8 - 2.9
Hydroxyl Radical	OH^\cdot	2.8
Sulfate Radical	$SO_4^{\cdot-}$	2.6
Oxygen Ion	O^-	2.42
Ozone	O_3	2.07
Persulfate Anion	$SO_2O_8^{2-}$	2.06
Peracetic Aci	$C_2H_4O_3$	1.81
Hydrogen Peroxide	H_2O_2	1.78
Potassium Permanganate	$KMnO_4$	1.7
Chlorine Dioxide	ClO_2	1.57
Hypochlorous Acid	$HOCl$	1.49
Chlorine Gas	Cl_2	1.36
Hypobromous Acid	$HBrO$	1.33
Oxygen (Molecule)	O_2	1.23
Bromine	Br_2	1.09
Hypo-iodous Acid	HIO	0.99
Hypochlorite Ion	OCl^-	0.94
Sodium Hypochlorite	$NaOCl$	0.94
Iodine	I_2	0.54
Hydroperoxide Anion	HO_2^-	-0.88
Perhydroxil Radical	HO_2^\cdot	-1.7
Superoxide Radical Anion	$O_2^{\cdot-}$	-2.4

Advanced oxidation processes (AOPs) were first proposed in the 1980s for drinking water treatment and later were widely studied for treatment of different wastewaters. In a general definition, physicochemical procedures which promote in situ generation of hydroxyl radicals in enough quantity to effect a significant change at the sub-molecular level of contaminants, pollutants, and recalcitrant and refractory matter, and achieve broad water purification are described as “advanced oxidation processes”. They also extend to some oxidative reactions with sulfate, permanganate, titanium, and other radicals.

5 BIO-HYDROX VS OZONE

Bio-hydrox is also called “liquid ozone” because when it is introduced into a water system it generates reactive oxygen molecules which is a similar outcome to injecting ozone gas in the water. There are a few key differences though. Ozone is a tri-atomic molecule and when it breaks apart it liberates oxygen ions. It is a linear process and requires external energy source. The oxidation potential of ozone is 2.07 V and the energized oxygen ion has an oxidation potential of 2.42 V. On the other hand, Bio-hydrox is a more complex molecule and when it breaks apart, it liberates not one, but six species of reactive oxygen in the form of ions, cations, and radicals, in a self-regenerating process. The combination of these energized oxygen compounds has an oxidation potential above 2.8 V, the highest in the industry of water treatment oxidants. Ozone can generate effective hydroxyl radicals in high pH water but requires continued energy input. The following table summarizes the major differences:

	OZONE	BIO-HYDROX MINERAL OXYCHLORIDE
Capital investment and operational expenses	Very high. Needs to be generated onsite with on demand energy consumption.	Minimal. Only needs liquid dosing system. Does not require external energy source.
Implementation & maintenance	Needs skilled personnel. High maintenance. Hazardous handling. 5% maximum solubility and less soluble and less effective in warm weather.	Easy to operate. Can be fully automated with ORP controller. No hazards. 100% soluble at all temperatures. Effectivity increases in hot weather.
Biocidal effectivity	Excellent. High effectivity and very rapid reaction rate.	Higher effectivity and faster reaction rate.
Oxidative effectivity	High. However, it can create Bromate and HAA5 disinfection byproducts. $E_v = 2.1$ to 2.4 Volts.	Excellent. Provides advanced oxidation. No disinfection byproducts. Can breakdown existing DBPs. $E_v = 2.8$ V to 2.9 Volts.
Biofilm	Does not generate enough residual activity to be effective.	Destroys biofilms effectively, even mature colonies. It is anticorrosive and anti-scalant and prevent the formation of substrates where biofilm can adhere.
System protection	Needs continuous injection to maintain proper level of protection. It requires an excess energy production to increase the oxidation potential above 450 mV. E. Coli and Legionella can survive.	Excellent residual protection. Target ORP level of 700 mV is easily maintained with only a single application most times. . This level of oxidative energy is not tolerated by any known bacteria.

More: <https://www.linkedin.com/pulse/liquid-ozone-vs-water-treatment-applications-emma-flanagan/>

6 VALUE PROPOSITION FOR THE TREATMENT OF COOLING SYSTEMS

BASIC SYSTEM FEATURES	BIO-HYDROX™ TREATMENT EFFECTIVENESS
<i>pH adjustment</i>	Bio-hydrox™ is very effective at an ample pH range and will not alter water pH
<i>Biofilm formation</i>	Bio-hydrox™ oxidizes organic matter and block its adsorption to exposed surfaces
<i>Elimination of mature biofilm</i>	Bio-hydrox™ breaks down extracellular substances and penetrate deep layers
<i>Scaling</i>	With no biofilm in the system there is nothing to attach to, and no buildup.
<i>Corrosion</i>	With no biofilm in the system bio-corrosion is not possible and inorganic corrosion will be reduced.
<i>Heat transfer efficiency</i>	With no biofilm in the system it will significantly improve
<i>Water usage</i>	Will decrease. Cleaner water means more cycles and less make up water
<i>Energy savings</i>	Reduced consumption in a cleaner system

- **Direct cost savings with less energy consumption.** Negligible capital investment and no added energy demand.
- **Direct cost savings with less chemical consumption:** Most water treatment chemicals will be eliminated.
- **Larger amount of cycles of concentration:** Less frequent need to discharge the blowdown water due to better performance of a cleaner system.
- **Water/sewer savings:** Less make-up water will be needed.
- **Additional savings in water use** if non-potable water can be used.
- **Additional savings in operation and maintenance cost** with reduced need of technical personal and labor cleaning.
- **Simple and non-invasive installation.** A chemical storage container and an automatic controller panel with a dosing pump.
- **Water chemistry always in compliance.** Our treatment uses non-toxic product that does not generate any disinfection by-products or alters the pH of the water. The application bears no limitations that may prevent complete oxidation of all contaminants.
- **Applicable and effective** for all cooling tower systems.

7 VALUE PROPOSITION TO REDUCE ENVIRONMENTAL IMPACT

7.1 WATER SAVINGS

The main concern of the operators and chemical treatment specialists has been to keep the wetted surfaces clear of scale, biological growth and corrosion, and only occasionally on system efficiency. Because it has been the general belief that water is inexpensive, and when coupled with a lack of understanding of water treatment by system operators, the subject of water efficiency is never raised. Consequently, all decisions regarding water have been left to the chemical treatment specialist who has no stake in the potential savings or operating costs.

Bio-hydrox™ advanced chemical treatment achieves a deeper level of purity and water reuse will be a new consideration in multiple applications. In closed system loops the water can withstand more cycles. On the other hand, the technology supports the opportunity to afford the additional savings of using degraded water to run cooling systems. In other words, the chemical can deliver efficient treatment and meet all regulations while controlling the issues without the need of the extra expense to run the system with potable water.

An independent field study evaluating alternative advanced oxidation technologies that can reduce water demand in cooling systems was conducted between 2014 and 2017 by the US government General Services Administration, division of public building services, and published on Jan 2019. Results in this study were seen almost immediately. The solution began to remove biofilm and reduce the temperatures in the condensers thereby increasing the energy load of the plant. In surfaces with significant biofouling the evidence of successful biofilm control was sufficient with a simple visual inspection. Researchers assessing the technology found that the advanced oxidation system met regulatory water standards and performed better than the conventional chemical treatment, significantly decreased fouling and reduced water use by an estimated 26 percent.

7.2 ENERGY SAVINGS

A Bio-hydrox™ protocol will control energy losses by avoiding the decrease in thermal efficiency and increase in the pressure drop otherwise caused by fouling

7.3 FINANCIAL SAVINGS

Less capital expenditures by eliminating the need of oversized plants to make up for loss in operation efficiency.

Less energy losses due to the decrease in thermal efficiency and increase in the pressure drop.

Less production losses during planned and unplanned plant shutdowns for fouling cleaning.

Less maintenance cost including cleaning of heat transfer equipment and use of antifoulants.

8 GREEN CHEMISTRY

While most advanced oxidation processes share the success criteria for water savings, reduction in chemical costs, optimal water chemistry and cost effectiveness, Bio-hydrox™ offers the only solution that meets all 12 green chemistry program principles as determined by the United States Environmental Protection Agency.

Green chemistry is the design of chemical products and processes that reduce or eliminate the generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal.



In the realm of water treatment, it is important to understand that green chemistry does not create hazards. Bio-hydrox™ is safe to use and within the recommended dosages it will not have any ill effect on humans or animals. It offers *innovative, scientific solutions, to real world environmental problems, while preventing pollution at the molecular level.*

8.1 THE PRINCIPLES OF GREEN CHEMISTRY

Bio-hydrox™ meets the 12 principles of United States EPA Green Chemistry Program.

1. **Prevent waste** Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.

Bio-hydrox™ residuals are oxygen, water, carbon dioxide and micronutrients.

2. **Maximize atom economy** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.

Bio-hydrox™ is a catalyzed product using minerals at concentrations resembling biologic water which maximizes oxygen radical re-generation and management.

3. **Design less hazardous chemical syntheses** Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.

The residual minerals of Bio-hydrox™ are utilized as micro-nutrients in both plant and animal biological systems.

4. **Design safer chemicals and products** Design chemical products that are fully effective yet have little or no toxicity.

Toxicity is a matter of relative concentration. The chemistry of Bio-hydrox™ have been proven in various studies to reach the greatest effectiveness with the lowest concentration compared to other chemical products in like applications.

5. **Use safer solvents and reaction conditions** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.

Bio-hydrox™ solvent is water. The safest and most abundant in nature

6. **Increase energy efficiency** Run chemical reactions at room temperature and pressure whenever possible.

Bio-hydrox™ advanced oxidation process requires the least amount of activation energy compared to the rest of the AOPs, and it is self-generated by its own mineral catalyst reactions. It has optimal performance at ambient conditions.

7. **Use renewable feedstocks** Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.

Bio-hydrox™ components are water, oxygen and minerals, which are recycled thru nature.

8. **Avoid chemical derivatives** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

Utilizing principles of chelation and biological water, Bio-hydrox™ is designed to mimic nature in the generation, management and catalyst of oxygen radicals. The derivatives of catalyst are reactive oxygen species. There is no waste at the end of the chain reaction.

9. **Use catalysts, not stoichiometric reagents** Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.

When oxidation happens, atomic oxygen is released Bio-hydrox™ captures released oxygen atoms and transforms the oxidation energy which is transferred downstream and recreates the process again and again.

10. **Design chemicals and products to degrade after use** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.

When Bio-hydrox™ chemical is exhausted and there is no more oxidative energy to continue, the residuals are inert trace nutrients that are consumed by nature.

11. **Analyze in real time to prevent pollution** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

Bio-hydrox™ does not generate any by products. Real time monitoring is supported by ORP levels and provide an excellent tool to assist the applications and use the least amount of chemical needed to accomplish the specific goals.

12. **Minimize the potential for accidents** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Bio-hydrox™ is a non-toxic liquid substance, not explosive and not flammable. Oxygen radicals are very short live and in case of a catastrophic spill their energy will be depleted quickly, and the environment will begin recovery right away.

9 REAL TIME MONITORING

BACTERIAL ACTIVITY IN THE WATER CAN BE MONITORED WITH A SIMPLE DEVICE IN A CONSISTENT AND RELIABLE WAY.

The technology of Bio-hydrox™ found the perfect match with a monitoring tool known as ORP, or Oxidation-Reduction Potential. ORP is a term used frequently in the water treatment industry and is a measure of the cleanliness of the water and its ability to remove contaminants. ORP is a convenient quality control method to assess the ability of Bio-hydrox™ to perform a task. The ORP meter will indicate, in a quick and precise way, when Bio-hydrox™ has created an oxidative environment capable of causing a level of damage not compatible with the possibility of Legionella bacteria survival.

The higher the ORP level the more residual activity is available to protect the water and the quicker the bacteria are removed.

An ORP of 600 mV is considered disinfected water. The World Health Organization stated in the 1971 Guidelines for Drinking Water Quality that the oxidation reduction potential was the most accurate indicator of water quality and established 650 mV the recommended ORP level for potable water.

ORP Level (in mV)	Application
0 – 150	No practical use
150 – 300	Aquaculture
250 – 450	Tap water
400 – 600	Cooling towers
650	Water is considered potable
600 – 750	Premise water systems
750 – 850	Swimming pools and hot tubs
800 and above	Absence of pathogens, water sterilization

ORP level can also be viewed as the level of bacterial activity of the water because it has been demonstrated by several scientific studies that there is a direct link between ORP levels and coliform bacteria count in water.

The chart below, on the left, lists a summary results from various lab simulation and commercial hydrocooler survey studies (UC Davis, Trevor S. Suslow). The chart on the right is also a good example. It lists a summary of results from various lab simulation and survey studies on halogenated oxidants.

ORP level	CFU/100 mL
200	300
300	36
400	3
600	0

Pathogen/Indicator	Survival in seconds (s) or hours (h) at ORP (mV)		
	< 485	550 < × < 620	> 665
<i>E. coli</i> O157:H7	> 300 s	< 60 s	< 10 s
<i>Salmonella</i> spp.	> 300 s	> 300 s	< 20 s
<i>Listeria monocytogenes</i>	> 300 s	> 300 s	< 30 s
thermotolerant coliform	> 48 h	> 48 h	< 30 s

10 Scientific Validation

A time kill assay 3rd party study conducted by Special Pathogens Lab, a CDC-ELITE facility in Pittsburg, PA, USA, demonstrated Bio-hydrox™ chemical formulation eliminated *Legionella* bacteria on contact. 100% kill, 6 log reduction, achieved immediately, at an ORP of 679 mV.

Time Points (sec)	ORP (mV)	mg/L Added Oxidant	Viability (CFU/mL)		% Reduction	Log Reduction
			Test	Control		
Immediate	512	0.24	2.20x10 ⁶	2.45x10 ⁶	0	0
30			2.24x10 ⁶	1.85x10 ⁶		
120			2.43x10 ⁶	2.05x10 ⁶		
Immediate	679	2.8	0	2.45x10 ⁶	100	6.32
30				1.85x10 ⁶		
120				2.05x10 ⁶		

Conclusion

This evaluation demonstrated:

1. the oxidant, Bio-hydrox, in a distilled water solution at an ORP range of approximately 650-700 mV killed 100% of *Legionella* present at a concentration of $\sim 2 \times 10^6$ CFU/mL
2. killing of *Legionella* was not observed at the lower ORP range of 500-550 mV
3. that an ORP reading, if measured properly, can be a method to monitor the oxidation-reduction reactivity of Bio-hydrox in a solution at a level that will kill *Legionella*.

11 OTHER APPLICATIONS

THE FOLLOWING CLAIMS ARE SUPPORTED BY REGULATORY INSTITUTIONS AND CASE STUDIES.

- Bio-hydrox™ is an excellent gas scrubber and will purify air as well.
- Controls lead by controlling biofilm and bio-corrosion.
- It mineralizes organics and neutralizes pharmaceuticals and emerging contaminants.
- At an ORP above 700 mV Bio-hydrox™ has a level of reactivity that can actively oxidize everything it touches.
- In hospital settings it can be used to wash hands and wounds.
- Removes pathogens and pollutants on the surface of fruits and vegetables, meat, frozen food, seafood.
- Excellent in manufacture of anti-microbial ice.
- Surface cleaning, food preparation. Removes sources of food borne illness.
- Cleaning of silverware, dishes, cups, pots, pans and cooking tools in cold water.
- Remove bio-contaminants in laundry.
- Reduces major issues like spoilage, cross contamination and pesticides.
- Membrane protection
- Water well sanitation
- Aquaculture
- Recreational waters
- Marine parks
- Irrigation, post-harvest wash
- In situ cleaning
- Process lines sanitation
- Bio-hydrox™ has a conservative stability of 6 months and takes less storage space than chlorinated biocides.



12 NATIONAL SANITARY FOUNDATION, NSF INTL

Bio-hydrox™ is certified NSF/ANSI Standard 60 as an approved drinking water treatment chemical.

NSF International is an organization devoted to public health safety and protection of the environment. One of the most important aspects of testing and certifying drinking water treatment chemicals to NSF/ANSI 60, the standard for health effects, is the Maximum Use Level, MUL, to which the chemical is certified. The standard addresses the health effects implications and guarantees the safety of the treatment chemicals when used as intended and within the maximum use level.

Bio-hydrox was approved for the treatment of drinking water at a maximum concentration level of 84 mg/L. This value is well below the regular dose in potable water applications. In the Legionella study shown above, Bio-hydrox™ achieved immediate elimination of a 6-log bacteria population at an added amount of 2.8 mg/L, thirty times less than the MUL. It is very safe to use in any water treatment application.



13 U.S. FOOD AND DRUG ADMINISTRATION, FDA

All the ingredients in the chemicals used with Bio-hydrox™ are found to be safe for use in food contact and human consumption and comply with various regulations within the Food and Drug Administration, FDA. All the constituents used in their manufacturing are sourced in US. All the components are food grade and considered GRAS (Generally Recognized as Safe).



14 U.S. ENVIRONMENTAL PROTECTION AGENCY, EPA

Some states require registration with their own agencies in addition to a federal registration. The chemicals we use with Bio-hydrox™ are in compliance with federal regulations and approved in accordance with FIFRA section 3(c)(5).

15 LOGISTICS

Bio-hydrox™ sold in USA is 100% sourced and made in the USA.

As of the Summer of 2021, there are nine manufacturing plants worldwide: Domestic locations are found in CA, TX and FL.

Bio-hydrox™ is available in cases of 1 gallon jugs, 30 and 55 Gal drums, 275 gal totes and tankers.