Making Water Work for You!

Commonly Asked Questions about CH_2O's Sure Flow® Products

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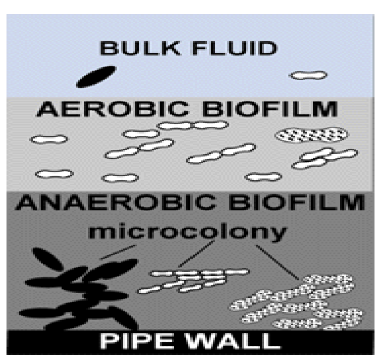
Controlling microorganisms and mineral complexes in low-flow drip irrigation systems are the keys to cultivating healthy plants and increasing yield. CH_2O's patented Sure Flow® system is a powerful oxidizer-chelant combination designed to help growers achieve maximum irrigation system performance. The patented process offers solutions for the challenging water conditions found in many irrigation systems that draw from wells, ponds, canals, storage tanks, and municipal water sources. Some of the benefits are listed as below.

- Kills algae, slime and disinfects on contact
- Encourages a "bio-clean"™ environment for plant propagation and cultivating
- Promotes water percolation to root systems
- Controls mollusks, removes sulfides and odors in water systems
- Reduces plant loss to disease
- Enhances plant marketability, quality, and increases crop yield
- Supports free-flowing drip and micro-misting irrigation systems
- EPA registered precursors for use in sprinkler, drip and other types of irrigation systems
- NSF certified precursors available
- Certified organic precursors available

The following is a list of commonly asked questions (FAQ's) relating to the CH_2O, Incorporated Sure Flow® system of treatment

Q: What is the key advantage of using Sure Flow® in removing bio-film when compared to chlorine, or other oxidants?

In a typical water system the vast majority of microorganisms live on the wetted surfaces, or walls of the system, and not in the bulk water. Organisms that are free floating are referred to as planktonic, and those attached to a surface are sessile. The general term for these thriving microbiological communities is "biofilm", and they protect themselves by creating a polysaccharide coating, which is sometimes referred to as "slime".



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Both chlorine (bleach) and peroxides react quickly and indiscriminately with organic matter, and therefore do not effectively penetrate biofilms. Accordingly, it's possible to control the planktonic organisms and achieve a chlorine residual in the bulk water while the majority of the biological problem; the sessile organisms, are safely protected under a polysaccharide film.

Conversely, the reaction mechanism of chlorine dioxide is much more selective, which gives it the ability to penetrate biofilms. Since chlorine dioxide is so effective at penetrating and removing biofilms, the molecule will be depleted while combating the true microbiological problem, biofilm, and it may take an extended dosage period before stable residuals are achieved in the bulk water. Once the biofilm is substantially depleted, the chlorine dioxide level in the bulk water will increase and then there will be a corresponding decrease in feed rate to achieve a residual level in the bulk water. A distinct advantage of the Sure Flow® system is the intentional delay in sodium chlorite conversion to chlorine dioxide. The mixed oxidants from CH_2O's patented generation process travel throughout the irrigation network and will be auto-activated by the acid present in the water in between watering cycles and overnight as the system lies stagnant. This provides thorough disinfection of low-flow irrigation networks without producing dangerous chlorine gas.

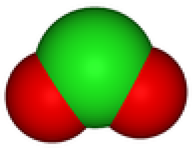
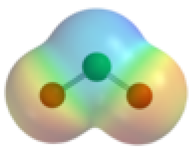
In addition to the benefits of chlorine dioxide outlined above, Sure Flow® incorporates a proprietary chelant. The chelant allows source water and fertigated micro-metal nutrients to be assimilated by the plants instead of being food for bio-film. This starves the bio-film of nutrients and insures they are available to the plant.

Q: What are the physical properties of chlorine dioxide?

Technically speaking, CH_2O does not sell "chlorine dioxide"; rather, we sell a patented oxidizer-chelant solution that is generated on-site. Generating the product on-site allows our clients to use highly concentrated precursor chemicals at an exceptionally low use-cost. Our system uses an EPA registered sodium chlorite, and an acid-chelant activator. The activators are specially formulated to react with various other materials to meet the needs of specific applications. These blends are particularly effective at inhibiting the formation of mineral complexes, which can also cause problems in irrigation systems. The precursors are injected into a reaction chamber to generate mixed oxidants, including chlorine dioxide. The chlorine dioxide solution is subsequently metered into the water system.

Chlorine dioxide is a green-yellow gas with a chlorine-like odor. Although it has a similar odor to chlorine, chlorine dioxide is very different in chemical structure and behavior. The foremost difference is that chlorine dioxide disinfects; however, it does not "chlorinate" like other chlorine compounds. As a result, no potentially carcinogenic disinfection byproducts (DBP's) are formed when using chlorine dioxide. In water solutions, chlorine dioxide remains as a dissolved gas and is approximately 10 times more soluble than chlorine. This high level of solubility allows it to permeate biofilm much more effectively than other oxidizers.

Chlorine dioxide

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Properties	
Molecular formula	ClO_2
Molar mass	67.45 g/mol
Appearance	yellowish gas or liquid
Density	3.04 g/cm^3
Melting point	-59.5 °C
Boiling point	11 °C
Solubility in water	0.8 g/100 mL (20 °C)
Solubility	soluble in alkalies, sulfuric acid
Acidity (pK_a)	2.5-3.5

Q: Why does CH_2O use a "chelant" to activate chlorine dioxide in the Sure Flow® system?

The use of chlorine dioxide by itself in low-flow irrigation networks will work to control microbial growth and biofilm. All oxidizers, including chlorine dioxide, will convert certain metals, such as iron and manganese, to their insoluble form. In turn, these metals will precipitate in the water system and feed the biofilm, which also harbors pathogens. Additionally, metal precipitation depletes irrigation water of valuable nutrients that were intended for the plants. Over time, precipitation of metals will form crystalline deposits that plug emitter orifices and restrict water and nutrient flow to the plants. As such, the use of a traditional oxidizer on its own may actually be a detriment to healthy plant growth.

A chelant is a binding agent that bonds to selected mineral ions to form a soluble complex that remains in an aqueous state. Upon evaporation of irrigation water at the emitter tip, chelated minerals form amorphous deposits. These amorphous deposits are easily washed away during the next irrigation cycle. In contrast, crystalline mineral precipitation that occurs in untreated systems will block flow throughout the irrigation network. Additionally, by keeping the minerals in solution, they are available as valuable nutrients to growing plants.

Chlorine dioxide, when applied without a chelant, only treats the water and not the plant. It is inactivated upon contact with various growing mediums, including rockwool, coco fiber and natural soils. When applied at low dosages, chlorine dioxide will not disinfect beneficial bacteria in growing media or burn plant root systems through oxidation. Beneficial bacteria have a symbiotic relationship with plants, improving water and nutrient uptake. It is important that this relationship remain intact, and not be destroyed through oxidation.

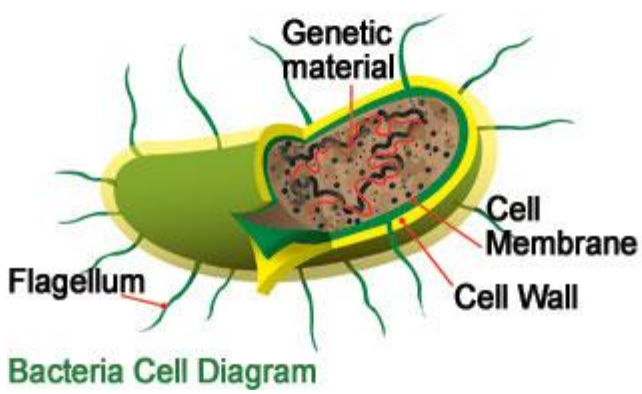
The combination of chlorine dioxide and a chelant, which is derived from phosphorous, results in a unique synergistic product that provides fungus and microbial control while preventing undesirable crystalline mineral structures. After activating CH_2O's chlorine dioxide solution, the chelant decomposes to form a plant fertilizer and powerful nutrient, which also protects the plant root system. Field trials have shown this unique combination controls many detrimental root fungus infestations. Further, the chelant will not interrupt normal fertilizer uptake. Laboratory and field trials have resulted in increased plant growth and crop yield when treated with Sure Flow®. This is due to the chelant's ability to enhance nutrient uptake.

This novel process was invented by CH_2O, Inc. and is protected by multiple U.S. and international patents.

Q: How does Sure Flow® chlorine dioxide disinfect?

Chlorine dioxide contains a chlorine atom in its molecular structure, BUT its chemical properties are <u>dramatically different than chlorine</u>. While chlorine, in its various forms, functions by substituting, or exchanging, a chlorine atom (i.e. "chlorinating") with its reactant, <u>chlorine dioxide disinfects through the transfer of electrons without transferring a chlorine atom to the reactant</u>. This important characteristic means that chlorine dioxide will not form trihalomethanes, chloramines, chloroform, or other halogenated compounds that are detrimental to plants and the environment.

The precise mechanisms by which chlorine dioxide reacts with various microbes are not entirely known, but they appear to vary by type of organism. In general, chlorine dioxide attacks the organism's cell wall and interferes with essential protein formation.



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While the scope of this document precludes citation of the many studies regarding the efficacy of chlorine dioxide on specific organisms, the molecule has proven to be more effective than chlorine at controlling a multitude of organisms over a wide range of pH conditions (chlorine rapidly loses effectiveness over pH 7). More specifically, chlorine dioxide has been shown to be effective against viruses, waterborne protozoans such as *Giardia Lambia* and *Cryptosporidium*, *E. coli*, *Legionella*, *Listeria*, and biofilms.

Chlorine dioxide has proven itself to have particular advantages over chlorine in water systems with high levels of organic loading. While chlorine reacts rapidly and indiscriminately with organics and nitrogen compounds to form chloramines and chloroform, chlorine dioxide is much more selective; thus, more chlorine dioxide is available to control pathogens. In multiple studies conducted on water with high levels of organic loading, chlorine dioxide has proven to be a more effective disinfectant than chlorine for *E. coli* under such conditions.

Q: What are the by-products of chlorine dioxide disinfection?

One of the most important differences between chlorine dioxide and chlorine is that chlorine dioxide reactions do not produce harmful halogenated disinfection by-products (DBP's) such as trihalomethanes. Additionally, chlorine dioxide does not react with ammonia, nor does it chlorinate organic molecules.

While the DBPs that result from oxidation reactions are dependent upon the conditions at the time the reaction occurs; chlorine dioxide predominately degrades to produce chloride (Cl^-) ions as the end product.

The following equations demonstrate typical chlorine dioxide decomposition. First, chlorine dioxide takes up an electron and is reduced to chlorite.

$$ClO_2 + e- \rightarrow ClO_2^-$$

The chlorite ion is then oxidized and becomes a chloride ion.

$$ClO_2^- + 4H^+ + 4e- \rightarrow Cl^- + 2H_2O$$

The chlorine atom remains bound to the oxygen until stable chloride is formed. This explains why no chlorinated substances are created.

$$ClO_2^- + H^+ \text{ (Acidity)} \rightarrow ClO_2$$

Another common oxidizer used in water systems is ozone. Unlike ozone, chlorine dioxide does not oxidize bromide ions to produce bromate, nor does it produce large amounts of aldehydes, ketones, or other DBP's that result from ozonation of organic substances.

Q: Why does Sure Flow® chlorine dioxide work in systems where chlorine isn't effective?

Chlorine dioxide chemistry is best summarized not by what it reacts with so much as by what it does not react with. Unlike chlorine, chlorine dioxide does not hydrolyze in water nor does its chemical form or biocidal effectiveness vary significantly with changes in pH.
When chlorine is added to water it dissociates to form hypochlorous acid (HOCl), which is its functional biocidal form. As pH increases, hypochlorous acid reacts and converts to hypochlorite ion (OCl^-), which has only 5% the biocidal activity of hypochlorous acid. The hypochlorous acid fraction drops dramatically above a pH of 7.0, which substantially reduces its effectiveness. Chlorine also reacts rapidly with ammonia to form chloramines, which have 1% the biocidal efficacy of hypochlorous acid and are toxic to plants. Therefore, increasing chlorine feed rate in the presence of high pH or elevated ammonia levels results in little additional benefit. Like chlorine, bromine is also pH dependant, although the dissociation curve shifts approximately 1 pH unit to the right.

In contrast, chlorine dioxide dosage rates remain fairly constant relative to pH and organic or ammonia levels.

Another distinct advantage of chlorine dioxide is its superior ability to penetrate biofilms. Chlorine is a powerful oxidizer that reacts quickly and indiscriminately with organic material. As such, it becomes inactivated before it can penetrate biofilm and disinfect the underlying bacteria. In waters with high levels of organic loading, increased total chlorine levels will be required to achieve sufficient free (available) chlorine. High levels of chlorinated compounds are toxic to plants.

Chlorine dioxide is a highly soluble gas in water solutions. Therefore, it readily penetrates biofilm to attack the underlying microbes protected by the polysaccharide coating. Also, chlorine dioxide does not readily react with organic material so the molecule is more available to act as a biocide once it has penetrated the film.

Q: How do you test for Sure Flow®, or chlorine dioxide residuals?

Chlorine dioxide residuals can be tested using several different methods. CH_2O has developed an easy-to-use drop test kit to test for total oxidant. We also have hand-held digital meters available to test for chlorine dioxide.

Regardless of the test method used, experience shows that chlorine dioxide will dissipate rapidly in water samples that are aerated, or exposed to atmosphere. Care should be taken when drawing samples and testing should be completed as soon as practicable to avoid erroneous readings.

As a means of evaluating the effectiveness of microbiological control, tests are available to determine the amount and type of bacteria, yeast, mold, or fungi present in the water.

Another very useful method that can be employed for determining if biofilms are present is an ATP (adenosine triphosphate) meter. By taking an initial base-line water sample, then dosing the system with chlorine dioxide, and evaluating the ATP level before and after the dose, it is possible to determine if additional microbes have migrated to the bulk water. An increase in ATP levels in the bulk water indicates biofilm removal. If there is no increase, or a decrease, in ATP levels it is likely that no biofilm is present.

Q: Will I still need to acid clean my irrigation system when using the Sure Flow® system?

When properly applied, Sure Flow® eliminates the need for acid cleaning irrigation networks. Not only does this result in significantly reduced labor and waste costs, it extends the life of the irrigation system. The traditional approach to cleaning uses aggressive chemicals, such as concentrated nitric acid, and hyperchlorination, both of which embrittle plastics and cause damage to pressure compensators. Plastic embrittlement in the irrigation network results in frequent system replacement. Damaged pressure compensators will cause uneven water and fertilizer application, which has a negative impact on plant growth.

Q: Why is Sure-Flow® chlorine dioxide generated on-site instead of shipped as a finished product?

Some chemicals, such as the chlorine dioxide produced by the Sure Flow® system, are generated at the point of use, rather than transported as a finished product. This practice allows for the use of highly concentrated precursor chemicals to reduce costs. Many competitive products are reacted by the manufacturer and distributed as a diluted solution. The transportation and use costs of pre-diluted chemical products increase dramatically as compared to generating on-site.

The CH_2O Sure Flow® system is specifically designed for use in irrigation systems, and provides an extremely economical and reliable method of generating chlorine dioxide on-site. By keeping the system simple and eliminating unnecessary components, CH_2O has increased reliability and safety, while producing the least expensive oxidant-chelant generation system available.

Q: How much does it cost to treat a water system with Sure Flow® chlorine dioxide?

Often we are called in to install Sure Flow® systems where chlorine injection has failed. Customers may know the quantity of sodium hypochlorite, or chlorine gas they are currently using, and they want to know how that correlates to the amount of Sure Flow® chlorine dioxide they will use. While the question seems straightforward (and it would be if there were no organic challenge, or microorganisms in the water), it is difficult, if not impossible to answer.

The following differences between Sure Flow® and chlorine add to the complexity of the calculation:

- Sure Flow® reactions are relatively independent of pH, especially between pH ranging from 2 to 10;
- Sure Flow® remains a gas in water and it does not react (hydrolyze) with water the way chlorine does;

- Sure Flow® has minimal reaction with ammonia or organic matter;
- Since Sure Flow® will kill biofilms, it will be consumed at a higher rate in badly fouled systems until the biofilm is removed;
- Sure Flow® ensures micro-metal nutrients and source-water minerals are available to the plants instead of becoming food for biofilms, and;
- Sure Flow® uses an oxidant solution to prevent pathogens from infecting plants.

For these reasons a pound-for-pound comparison cannot generally be made between chlorine and Sure Flow®. In clean water systems with little demand, 100 pounds of chlorine can typically be replaced with 20 to 30 pounds of activated Sure Flow® solution. Under real-world conditions (i.e. heavier organic challenge) it takes proportionally less Sure Flow® solution to achieve the same results.

In general Sure Flow® will be more expensive to use than chlorine or sodium hypochlorite. However, it should prove to be a more powerful oxidant, much more effective at killing biofilms, and much more environmentally friendly. Combine these features with its ability to control crystalline mineral complexes and plant disease, and the benefits typically more than justify the additional cost.

Q: What is the typical starting dose for Sure Flow®?

Once the biofilm has been killed in a fouled system, we typically work to achieve a Sure Flow® residual between 0.25 ppm and 1.0 ppm in the bulk water. This level also provides sufficient proprietary chelant to create amorphous mineral deposits that are easily washed away by the irrigation water. The actual dosage will vary depending upon the precursors used, the water quality, and irrigation application. We select the chlorite solutions and the activators based upon the specific conditions encountered at each facility.

Q: What are the safety concerns with handling Sure Flow® and chlorine dioxide?

Sure Flow® should be handled using the standard precautions that apply to all industrial chemicals. Like all oxidizers, the concentrated sodium chlorite precursor should be handled with care to avoid contact with other chemicals, skin, and organic material (dirt, cloth, etc.). Avoid storing the products in direct sunlight. Transfer equipment and storage containers should be clean and free of contamination. Spills should not be allowed to dry. The general procedure for cleaning up spills of concentrated sodium chlorite includes the following steps: dilution, chlorite reduction, and neutralization. Detailed safety and handling precautions and procedures are available through your CH_2O representative in the form of a Power Point presentation. Any product or waste disposal must be done in accordance with local, state, and federal regulations.