CHEMIXENE® LIQUID

Food Processing Applications

Distributor Handbook

1. Not corrosive.
2. EPA approved
3. Low toxicity.
4. Tasteless.
5. Odorless.
6. Approved for human & livestock consumption.
7. Kills Avian influenza & Newcastle virus etc.
8. Kills Salmonella & E. coli etc. See list below.
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I. INTRODUCTION

This handbook has been designed to present a thorough and up-to-date assessment of our sanitizer CHEMIXENE® and its remarkable chlorine dioxide chemistry. This material will assist you with understanding product chemistry, on-site setup and troubleshooting of operations. Included in this document are sections concerning a brief history of the compound, a thorough description of the product, its chemistry, activity and details of its various applications. The materials provided here are designed to inform and educate both the technical sales representatives and the end users. A thorough study of this document should supply the reader with a fundamental understanding of CHEMIXENE®’s unique characteristics which are ideal for today’s “zero tolerance” marketplace.

Seldom has a product been so thoroughly evaluated. Because CHEMIXENE® has been the pioneer in chlorine dioxide technology; it was the first chlorine dioxide product to go through EPA re-registration. Likewise, when the manufacturer of CHEMIXENE®, OCS LLC Inc. (OCS LLC’S), petitioned the FDA for the safe use of chlorine dioxide-based products on food contact surfaces (USDA, D-2 sanitizer), the acceptance of the petition was based solely on data produced by OCS LLC CHEMIXENE®’s profile of excellence is no illusion. Numerous independent processing facilities, government research laboratories, private laboratories and universities have selected CHEMIXENE® as “the best of the best.” Read on, because the facts are in front of you. Welcome aboard!

II. A BRIEF HISTORY LESSON

Chlorine dioxide was discovered as a gas by Sir Humphrey Davey in 1811, three years after he had discovered chlorine. It’s an ironic tale of two compounds, that of chlorine and chlorine dioxide, very similar to the tortoise and the hare. As we all well know, chlorine became the sanitizing product of the 1900’s. It was inexpensive, readily available and the most effective antimicrobial compound of the time.

With chlorine in the spotlight, there seemed to be no compelling reason for the development of another disinfectant. In the 1940’s, its powerful bleaching abilities were recognized. It was then approved and used to bleach wheat flour and to remove objectionable tastes and odors from municipal waters. A short time later, its use to bleach wood pulp was realized and its primary industrial use was born. In the 1950’s and 1960’s some research articles began to appear discussing the antimicrobial activity of chlorine dioxide.

The 1970’s signaled the birth of chlorine dioxide as a viable product and compound. In 1976, the newly formed EPA discovered that trihalomethanes (chloroforms) were being produced in our drinking water as a by-product of chlorination. These “THMs” were known to be carcinogenic.

A health effects study the following year detected increased cancers in areas where high THM levels were found in the drinking water. The first nail in chlorine’s coffin had been driven.

The EPA’s Division of Drinking Water began a long-term program to discover replacements for chlorine in drinking water. Of the three leading candidates, chlorine dioxide was judged to be the best overall compound based on high antimicrobial activity, its ability
to remain in solution, and most importantly, that it does not chlorinate. **Therefore, chlorine dioxide does not produce chlorinated organics such as THMs.** Suddenly, there was a flurry of activity around chlorine dioxide. The antimicrobial activity of chlorine dioxide went from “about as good as chlorine”, to “a little better than chlorine”, to now “as much as 7 times better than chlorine”.

The actual production of chlorine dioxide into the 1960's had been almost exclusively via gas generators. These were large, hazardous and clearly industrial type devices, not to be taken lightly by the operators. They were acceptable for large applications such as pulp bleaching, municipal drinking water treatments and other industrial uses, but not very convenient for most of its potential antimicrobial uses. During the 1970's, aqueous phase generators were developed. In these systems, the dry chlorine dioxide gas was not produced in air, but in water-based solutions of precursor compounds, normally sodium chlorite and a mineral acid. Later, hypochlorite solutions were added to this mixture to further drive the reaction of chlorite more completely to chlorine dioxide. This “chemical efficiency” seemed perfectly logical since it was known that sodium chlorite has only bacteriostatic activity at best and that chlorine dioxide was a powerful antimicrobial. In addition, it was believed that any “left over” chlorite would only dilute out the positive effects of the chlorine dioxide.

During the 1970's and 80's, OCS LLC'S began developing its product line, several antimicrobial and deodorizing liquid products. Manufacturing procedures were being developed and optimized, and the newly discovered disinfecting abilities of CHEMIXENE® and Chemixine (a registered trade name of CHEMIXENE®) were being documented. The term “Stabilized Chlorine Dioxide” became attached to these solutions because gaseous chlorine dioxide was generated in the process, then stabilized, i.e. dissolved and chemically reacted with a liquid stream of proprietary composition.

**CHEMIXENE® is formulated from scratch,** using unique proprietary processes. Concentration, pH and buffer capacity are unlike simple solutions of chlorite and are important factors contributing to CHEMIXENE®’s enhanced activity upon activation.

During the mid-1980's, it was realized that the antimicrobial activity of activated CHEMIXENE®, even without complete chemical conversion of chlorite to chlorine dioxide, was exceedingly high. In some cases, the antimicrobial activity was even higher than pure chlorine dioxide solutions of equal concentration. This ultra-high activity was first documented in commissioned studies conducted in support of EPA re-registrations and in work undertaken in support of a FDA Indirect Food Additive Petition. Later, numerous other studies confirmed this earlier work. Currently, the base CHEMIXENE® product label holds 18 pages of specific EPA registered applications and the approval for chlorine dioxide as a USDA D-2 sanitizer was based solely on data generated from CHEMIXENE®.

Chlorine dioxide chemistry has now come into its own. Whether generated or activated, chlorine dioxide’s superiority over chlorine is an undisputed fact. For microbial, slime and odor control in high volume process systems, chlorine dioxide generators will often be the best solution, but for significant bacterial reductions and high-level sanitizing/disinfecting, nothing can compare with CHEMIXENE®.

**III. PRODUCT DESCRIPTION AND CHARACTERISTICS**

What Exactly is CHEMIXENE®?
CHEMIXENE® is a highly refined, two percent chlorite containing liquid product. It is NOT a simple solution of tech grade sodium chlorite, as many people will try to tell you. The process by which CHEMIXENE® is manufactured is not the same as that of tech grade sodium chlorite. It is not produced from a dilution of concentrate or dry sodium chlorite, but formulated from scratch, using unique processes. The proprietary stabilization process involves the actual generation of gaseous chlorine dioxide, using the Solvay Process, then dissolving and reacting the gas in a stabilizing solution followed by other refinements and processing. Concentration, pH and buffer capacity are unlike simple solutions of chlorite and are important factors contributing to CHEMIXENE®’s enhanced activity upon activation.

What is “Activation”?  

The process of stabilizing chlorine dioxide involves, as mentioned above, dissolving the gas into a buffered aqueous solution and essentially converting it into its “salt” form. In this state it is safe to transport and store. In order to get the full power of its chlorine dioxide chemistry, we must retrieve the gas back from its stable salt. This is easily accomplished by simply lowering the pH of CHEMIXENE® to a specific predetermined level. This is activation. The food grade acid activator should always be added to a measured amount of concentrate before diluting. Using citric acid, the ratio is 1 gram of citric acid powder to 10 ml. of CHEMIXENE®, or approximately 1 oz. of activator for every 10 fl. ounces of CHEMIXENE®. When using concentrated food grade phosphoric acid as an activator, a range of 1 to 15/1 to 20 ratios should be used (i.e., 1-part acid to 15 parts CHEMIXENE®). Be aware that phosphoric acid activation will occur almost immediately, whereas citric acid activation requires approximately 5 minutes. After a pronounced yellow color appears, the activated concentrate should be diluted with the appropriate volume of water for its final use concentration. Do not keep activated concentrate undiluted for more than five (5) minutes, since the limits of solubility will be exceeded, and small amounts of gas can escape from the solution.

How Does CHEMIXENE® Compare Against Other Products?  

CHEMIXENE® is the best antimicrobial product currently available in the United States.

This rather strong statement can be proven conclusively. Here are the facts:

In a nation-wide search to locate the best disinfectant for their specific needs, The Boeing Company, Douglas Aircraft and United Airlines Medical Division all conducted separate evaluations of available products to sanitize their onboard water systems and holding tanks and to treat their onboard potable drinking water. All three companies selected OCS LLC’s stabilized chlorine dioxide. Their principle areas of concern were antimicrobial activity, low corrosion and off flavors and odors in their water systems. As a result, CHEMIXENE® is in the maintenance manuals of both Boeing and Douglas Aircraft as the recommended compound for water system disinfection. In a comprehensive study of disinfectants published in the Journal of Industrial Microbiology, volume 4 (1989) 145-154, Dr. Ralph Tanner at the University of Oklahoma found CHEMIXENE® to be the overall most effective antimicrobial product tested. Copies of this study are available upon request. The products evaluated covered the complete spectrum of sanitizers, including other chlorine dioxide-based products.
The results indicate that CHEMIXENE® was dramatically more potent in its antimicrobial activity than standard sanitizers.

In a similar comparison conducted at the USDA National Veterinary Services Laboratories located on Plum Island, NY, CHEMIXENE® was evaluated, along with numerous other products, to identify the most effective compound against a battery of highly dangerous viral diseases of animals. In this evaluation, CHEMIXENE® produced 100% kills of all test organisms, and as a result of this testing, was selected as the disinfectant of choice for use in their facilities.

What Are CHEMIXENE®'s Characteristics?

Inactivated CHEMIXENE® has the following characteristics:
- Colorless liquid, with a very light odor
- Buffered mixture of oxychlorides “salts”
- pH range of 8.2 to 8.5
- Very low acute toxicity, which is an EPA Category III
- Non-flammable, non-explosive, stable solution
- Primary activity of a bacteriostatic and deodorant

Activated CHEMIXENE® has the following characteristics:
- Ultra-high antimicrobial activity against a broad spectrum of microorganisms, both vegetative cells and spores
- Active over a broad range of pH, from 1 to 10
- Very low corrosive potential at use concentrations
- Resists neutralization due to organic load
- Does not produce toxic chlorinated by-products and does not chlorinate under normal use conditions
- Very active against biofilms
- 10 times more soluble in water than chlorine

What Are CHEMIXENE®'s Key Selling Points?
- Ultra-high activity
- Does not produce chloro-organic by-products, as chlorine sanitizers do
- Very low corrosion potential
- Very flexible with a multitude of registered uses - a single solution to multiple problems
- Uniquely active against biofilms - dramatically performs when others won’t
- Ideally suited to current market conditions
- The public is keenly aware of the danger of bacterially contaminated food and is demanding higher standards in its manufacture.
- Industry is now aware of the chlorination problems with chlorine sanitizers.
- CHEMIXENE® is what’s HOT - it’s “the good stuff” people are asking for.

IV. PRODUCT CHEMISTRY

1. Basics of Chlorine Dioxide Chemistry

Chlorine dioxide chemistry is centered around the conversion of sodium chlorite into chlorine dioxide. This conversion occurs when solutions of sodium chlorite are acidified with various
acids. This sounds simple but chlorine dioxide chemistry is actually very complex. An in-depth discussion of chlorine dioxide chemistry is likely to confuse both salespeople and customers alike; therefore, we will simplify this issue as much as possible.

When in a discussion about chlorine dioxide chemistry, you are likely to hear mention of the following compounds:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Chlorate</td>
<td>NaClO</td>
<td>This is an oxychloride compound that is used in the Solvay process to generate gaseous chlorine dioxide. Its ion can also be a minor component of the by-product of the reaction of chlorine dioxide.</td>
</tr>
<tr>
<td>(Chlorate ion)</td>
<td>3 ClO₃⁻</td>
<td>This oxychloride compound is the primary precursor to chlorine dioxide in use today.</td>
</tr>
<tr>
<td>Sodium Chlorite</td>
<td>NaClO₂</td>
<td>Chlorite is the ion that is also the primary by-product of the reaction of chlorine dioxide with other compounds.</td>
</tr>
<tr>
<td>(Chlorite ion)</td>
<td>2 ClO₂⁻</td>
<td></td>
</tr>
</tbody>
</table>
Chlorous Acid  
\[ \text{HClO}_2 \]
This is a weak acid that is intermediate in the reaction path between sodium chlorite and chlorine dioxide. It is thought to have high antimicrobial activity, especially when combined with chlorine dioxide itself. It is produced and maintained only under certain conditions of pH and concentration.

Chlorine Dioxide  
\[ \text{ClO}_2 \]
Generally regarded as the “active ingredient” in chlorine dioxide chemistry. It is a powerful oxidizer and exists as a gaseous free radical in nature.

Various Intermediates  
It has been postulated that as many as 22 intermediates may exist under various conditions. The Red Complex, \[ \text{Cl}_2\text{O}_4 \], is just one example.

The chemical conditions under which chlorine dioxide generators operate is not conducive to the formation of chlorous acid, or many of the possible intermediates. They rely solely on the chlorine dioxide molecule as their active ingredient. Generated chlorine dioxide normally uses tech grade sodium chlorite, an acid and sometimes hypochlorite (bleach) to drive the reaction as completely as possible towards the production of chlorine dioxide. The “activation” of CHEMIXENE® is designed to limit the complete conversion of chlorite to chlorine dioxide, allowing for the formation and retention of other high potential antimicrobial compounds such as chlorous acid and other intermediates. Unlike tech grade sodium chlorite, CHEMIXENE® has a well-defined concentration of components, buffer capacity and pH which are responsible for optimum antimicrobial activity. Exactly how these activated solutions may react to produce these enhanced microbial kills is not currently well defined, but there is conclusive proof that chlorine dioxide is not the sole active ingredient.

At the University of Florida, a direct comparison was made to answer exactly this question: “Is chlorine dioxide the sole active ingredient in CHEMIXENE®?” Two solutions were prepared, one from generated chlorine dioxide and one from activated CHEMIXENE®. The amount of chlorine dioxide was equalized in both solutions at 12.5 ppm, and then both solutions were used in an antimicrobial test against Listeria monocytogenes. Aside from the equal amounts of chlorine dioxide, the CHEMIXENE® solution contained almost 73 ppm of unconverted oxychlorides species. If chlorine dioxide is the only active ingredient and the unconverted material has no antimicrobial activity, then this should have no effect and the results should be similar in both solutions. The differences were enormous. The generated chlorine dioxide produced less than a one-tenth log reduction, while activated CHEMIXENE® produced almost an eight-log reduction. The number of bacteria that survived after the generated ClO₂ exposure was 64 million, while activated CHEMIXENE® eliminated all but 5 bacteria as shown in the following table:
Comparison of Solutions Containing Equal Concentrations of ClO₂ Against Listeria monocytogenes Scott A

<table>
<thead>
<tr>
<th>Generated ClO₂</th>
<th>Activated CHEMIXENE®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine Dioxide</td>
<td>12.5 ppm</td>
</tr>
<tr>
<td>Other Species</td>
<td>4.7 ppm</td>
</tr>
<tr>
<td>Bacteria</td>
<td>7.3 x 10⁷</td>
</tr>
<tr>
<td>After Exposure</td>
<td>6.4 x 10⁷</td>
</tr>
<tr>
<td>SR Log</td>
<td>-0.07</td>
</tr>
<tr>
<td>Other Species</td>
<td>72.9</td>
</tr>
<tr>
<td>Bacteria</td>
<td>ppm</td>
</tr>
<tr>
<td>After Exposure</td>
<td>≤ 5</td>
</tr>
<tr>
<td>SR Log</td>
<td>-7.86</td>
</tr>
</tbody>
</table>

These results clearly show that “other species” must play a significant role in CHEMIXENE®’s antimicrobial activity.

2. Chemical Structure and Mode of Activity of Chlorine Dioxide Chemistry

As mentioned earlier, the chlorite ion and chlorine dioxide are chemically linked. It is no accident that the two molecules are quite similar. While the mode of activity of chlorine dioxide intermediates or chlorous acid is not well understood, that of chlorine dioxide is. Chlorine dioxide exists as a free radical in nature. Its molecular structure, and that of its precursor compound, chlorite, is pictured below:

![Figure 1 Chlorous acid](image)

The chlorite molecule is not converted directly to chlorine dioxide but goes through at least one intermediate compound, chlorous acid, which is then converted to chlorine dioxide. Under various conditions of concentration and pH, the rate of conversion and path of chemical reactions can vary dramatically. This is where the complex nature of chlorine dioxide chemistry is found.

Exactly which molecule does what within these complex solutions is purely an academic discussion since the total activity of these solutions is the ultimate test. Regardless, these oxychloride species are oxidizers and, as such, are in search of easily obtainable electrons. Once the chlorine dioxide locates and abstracts an electron, it is reduced back towards the chlorite ion, as shown in the following diagram:
The antimicrobial activity of these solutions is believed to stem from the source of the electron abstracted by the chlorine dioxide component. There are at least four specific amino acids that readily react with chlorine dioxide. These are two aromatic amino acids, tryptophan and tyrosine, and two sulfur bearing amino acids, cysteine and methionine. The “ring” structures of tryptophane and tyrosine have a rich source of electrons which can be readily captured by strong oxidizers such as chlorine dioxide. The sulfur bearing amino acids have electronegative character and also readily give up electrons. The structures of these amino acids can be found in the following diagram:
The oxidative attack on the above amino acids is significant when you realize their function as the building blocks of proteins. Chains of amino acids form polypeptides which link together to form proteins. Proteins perform many functions in nature. Muscle is protein, for example, and so are enzymes.

Enzymes are catalysts for the biochemical reactions necessary for life in all living cells. Enzymes are also responsible for respiration, metabolism, cellular repair, and active transport across the cell membrane, protein synthesis and so on. Without enzymes, the cell will die in a matter of seconds. The abstraction of electrons from the reactive amino acids will cause structural disruption of the protein chain, or in the case of the sulfur containing amino acids, a disruption of the disulfide bonds holding several protein chains.

In either case, the enzyme will be dysfunctional, and the associated biochemical reaction will cease. Above is a representation of the polypeptide chains and chlorine dioxide’s oxidative attack. Note in figure 2 how the disulfide bonds, responsible for the structural integrity of the polypeptide molecule, are broken, allowing for the two chains to separate. Because enzymes must be in an exact 3-dimensional shape, this separation “denatures” the enzyme and renders it inactive. This is the direct cause of microbial cell death.

3. A Comparison between Chlorine and Chlorine Dioxide Chemistry

The principle reaction of chlorine or hypochlorite solutions (bleach) involves both oxidation and chlorination through a process of electrophilic substitution. The active ingredient of bleach is hypochlorous acid, which only exists in near neutral to acidic pH. Bleach is a highly alkaline solution having little or no antimicrobial activity. One of the most negative aspects of the use of chlorine is that it produces chlorinated organic by-products such as chloroform, a trihalomethane (THM). These have been found to be carcinogenic (cancer causing).

Chlorine dioxide chemistry is non-chlorinating but reacts through a pure oxidation process under normal circumstances. Because it is not an ion or an acid, it is largely unaffected by alkalinity or acidity, which makes it effective over a broad pH range unlike chlorine. Chlorine dioxide, a non-chlorinator, does not react to form useless chlorinating side reactions as chlorine does. This allows chlorine dioxide to resist neutralization in heavy organic loads. The following comparative table may be helpful in noting the differences:
# Chlorine v. Chlorine Dioxide

<table>
<thead>
<tr>
<th></th>
<th>Hypochlorite’s</th>
<th>Chlorine Dioxide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Ingredient</strong></td>
<td>Hypochlorous Acid</td>
<td>Chlorine Dioxide</td>
</tr>
<tr>
<td><strong>Primary Chemical</strong></td>
<td>Chlorination and oxidation.</td>
<td>Oxidation only, no chlorination.</td>
</tr>
<tr>
<td></td>
<td>Produces chlorinated by-products, THM’s and Chloramines.</td>
<td><strong>Does not form THM’s</strong> or other Chlorinated by-products.</td>
</tr>
<tr>
<td><strong>Corrosion</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Taste &amp; Odor</strong></td>
<td>Produces &quot;chemical&quot; taste</td>
<td>None at use concentrations</td>
</tr>
<tr>
<td><strong>Effective PH</strong></td>
<td>Narrow (6.8 – 7.6)</td>
<td>1 – 10</td>
</tr>
<tr>
<td><strong>Reaction in Water</strong></td>
<td>Hydrolyzes in water</td>
<td>Does not hydrolyze in water</td>
</tr>
<tr>
<td></td>
<td>Readily neutralized by</td>
<td></td>
</tr>
<tr>
<td></td>
<td>organic Load</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neutralization by organic Load</td>
<td></td>
</tr>
</tbody>
</table>
Reaction to Biofilms | Largely ineffective | Highly reactive

V. PRINCIPAL INDUSTRIES FOR THE USE OF CHEMIXENE®

1. Dairy, Brewery, Soft Drink and Bottling Plants
   A. Sanitation of All Food Contact Surfaces
   B. CIP Sanitizing of Processing Lines
   C. Water Additive for Pasteurizers, Bottle Warmers and Coolers
   D. Lube Additive for All Conveyors and Chains
   E. Water Systems Disinfectant for Biofilm Removal
   F. Sanitation of Filler Head Assemblies
   G. Sanitation of Tank Trucks and Rail Tankers
   H. Bacterial, Mold and Odor Control Throughout the Facility

2. Vegetable Processing
   A. Flume Water Treatment for Slime and Odor Control
   B. Sanitizing Rinse for Whole, Uncut Fruits and Vegetables
   C. Sanitation of All Food Contact Surfaces
   D. Sanitizing Rinse for Cut and Peeled Fruits and Vegetables for Shelf-Life Extension

3. Fish Processing
   A. Sanitation of All Food Contact Surfaces
   B. Slime, Bacteria, Mold and Odor Control throughout the Facility
   C. Antimicrobial Rinse of Fish for Shelf Life Extension

4. Poultry Processing
   A. Sanitation of All Food Contact Surfaces
   B. Slime, Bacteria, Mold and Odor Control throughout the Facility
   C. Antimicrobial Rinse of Poultry Carcasses for Salmonella and Other Bacterial Control
   D. Disinfection of Animal Confinement/Grow out Facilities
   E. Disinfection of Water Distribution Systems
   F. Water Disinfection within Grow out Facilities
   G. Fogging for Disease Control within Grow out Facilities

5. Processed Foods/Frozen Foods
   A. Sanitation of All Food Contact Surfaces
   B. Slime, Bacteria, Mold and Odor Control throughout the Facility
   C. Sanitation/Disinfection of Cold Rooms and Freezers
   D. CIP/COP Sanitizing of Food Processing Kettles, Vats and Transfer Lines
   E. Deodorization of Rendering Areas
   F. Disinfection of Condensate Pans and Drip Lines
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CHEMIXENE®
FOOD PROCESSING INDUSTRY APPLICATIONS
FOOD CONTACT SURFACES

In 1985, OCS LLC’S first submitted an indirect food additive petition for chlorine dioxide to the FDA. In August of 1987, the petition was granted allowing, for the first time, chlorine dioxide to be used as a D-2 sanitizer in all food plants. The accepted OCS LLC’S petition is published in 21 CFR 178.1010. Other companies may try to claim credit for this ground-breaking work; but make no mistake, OCS LLC’S, the industry leader in chlorine dioxide technology, set the standard.

General Uses
As a D-2 sanitizer, CHEMIXENE® may be used throughout the food plant on all food contact surfaces, including: transfer lines, fillers, vats, conveyors, tanks, blenders, Formax’s and all other processing equipment. CHEMIXENE® is best applied with cold water at 100-200 ppm in a flood sanitizing application on previously cleaned surfaces. Application is most easily achieved via a central sanitizing system or station. Please note that the required minimum concentration of CHEMIXENE®, 100 ppm, is half that of chlorine’s 200 ppm, reflecting the enhanced potency of the product. CHEMIXENE® is far less aggressive to stainless steel and soft metals than chlorine. This makes its use as a terminal sanitizing rinse in CIP a real advantage in reducing corrosion in lines, while maintaining the highest level of antimicrobial activity.

Important Note: 100 ppm Activated CHEMIXENE® solutions should not be held in a closed or flooded situation for long periods of time, i.e. hours or days, due to the potential for corrosion problems on soft metals. For long term application, such as overnight and weekends, CHEMIXENE® may be used effectively at 20 ppm non-activated for bacterial control with no concerns over the potential for corrosion.

Cold Rooms, Freeze Tunnels and Spirals

There are certain applications that are especially well suited for CHEMIXENE®. One such application is sanitizing in cold areas, such as: cold rooms, freeze tunnels and spirals. In these areas, cryophilic bacteria can slowly build up over time until "suddenly" there is a very significant problem. CHEMIXENE® is highly effective in these areas because of its increased kill capacity and its ability to be applied as a fog. Because chlorine dioxide is ten times more soluble in water than chlorine, this application can "pull" the active ingredient into cracks and crevices that might otherwise be missed. If the sanitizing compound does not come into contact with organisms, it cannot destroy them. Contaminated spirals can especially benefit from CHEMIXENE®’s ability to be fogged. CHEMIXENE® may be sprayed or fogged into the spiral housing, at a concentration of 100 to 200 ppm, immediately after a thorough cleaning of the structure. When fogging, set the OCS LLC’S fogger upright on the floor and vacate the area until the fog has dissipated. Repeat as needed.
CIP Sanitizing
The most obvious application is the principal terminal sanitizing rinse in the CIP systems of the brewery/dairy/bottling plant. This is where the ultra-high power of chlorine dioxide chemistry is best realized. The broad spectrum, fast killing antimicrobial activity cannot be duplicated. Just as important, no toxic residues remain to inhibit fermentations. CHEMIXENE® does its job quickly and completely, breaking down readily into more inert materials. The unique chemistry of CHEMIXENE® does not chlorinate, therefore, producing no chloro-organic, toxic by-products. CHEMIXENE® has been determined to be viricidal as well as bactericidal, helping to avoid “dead vats”. CHEMIXENE® is approved as a terminal sanitizing rinse at 100 ppm in the USDA book of approved compounds. Although breweries are not USDA inspected, they often use the USDA book as a benchmark of acceptance. Activated CHEMIXENE® solutions can be provided by the AANE™ (Automated Activation Non-Electric system) or can be prepared and held in storage vessels until required. CHEMIXENE® is then injected into the CIP system at the common sanitizer injector point as with any typical sanitizer.

Chain and Conveyor Lube Sanitizer Injection
This application is one of the most popular and exciting CHEMIXENE® uses that has been developed in the last 5 years. It brings together almost all the unique advantages of CHEMIXENE® in one single application!

By simply injecting CHEMIXENE® into the lube stream at as little as 20 ppm (inactivated), several significant benefits result. First you realize substantial bacterial control of the conveyor lines. Numerous accounts have reported 2-3 log reductions of counts on the conveyors. Second, by attacking the biofilms attached to the conveyors and the underlying rails, various soils are loosened, and the natural cleaning action of the lube is enhanced. Dirt and grit slide off with the use of a pressure hose. The chains and conveyors run more smoothly with less wear on chains and motors. The addition of CHEMIXENE® increases the lubricity of the lube, unlike quads and aldehydes, resulting in a savings that can be realized in lube usage itself.

The final benefit is one that the line people will really appreciate. Even low concentrations of CHEMIXENE® in the lube will help deodorize the area immediately surrounding the can or bottle line. This area will be noticeably fresher and nearly odor free - an extra benefit of CHEMIXENE®. CHEMIXENE® may be added to the dilution make up water prior to dilution, or to the diluted lube via a water driven proportioning pump or equivalent.
Reduction of Bacteria on Conveyor Lines
Using CHEMIXENE® as a Lube Additive

Filler Head \ Assemblies

One of the most difficult areas, in which to maintain a continually sanitary condition, is found in the filler head assemblies. This is a critical point in the process because of its high potential for contamination of food product. In the midst of this whirling equipment, changing pressures, product spills, slime build up, strong drafts and air currents, the liquid product has its most likely chance of exposure to contamination, particularly microbial contamination. The filler head assemblies are considered food contact surfaces, and often do contact food directly. To maintain the sanitary condition of these filler head parts is a continual challenge.

Because this area is under almost constant threat of contamination, the standard cleaning and sanitizing of the heads during the normal sanitation process, while extremely important, may not be adequate to insure a sanitary condition throughout the processing day. Certainly, a thorough cleaning, with close attention to product build up, debris accumulation and biofilms in and around the filler heads, followed by an application of CHEMIXENE®, will produce the optimum conditions at the start of the
production day. However, the real challenge is to maintain a fresh clean environment within the filler head assembly during production.

Low dose applications of CHEMIXENE®, misted onto the filler assembly during short scheduled breaks in the production day, have proven to be of considerable benefit. Automatically applying CHEMIXENE® via misting heads, at levels as low as 5 ppm, significantly improves the sanitary condition of the immediate area. CHEMIXENE®'s ability to attack biofilms, inhibit bacterial growth and deodorize the surrounding environment greatly contributes to a reduction in potential contamination. In organoleptic studies at a major brewery, no adverse taste was imparted to the beer when dosed directly with similar concentrations. In fact, CHEMIXENE® has EPA base label applications for treatment of stored potable water at 5 ppm for direct consumption.

For sanitation of filler head assemblies and surrounding housings, clean the area as normal with a good detergent and rinse thoroughly. Apply CHEMIXENE® at an activated strength of 100 ppm using a cold flood or cold spray application, whichever is most appropriate. Allow to air dry before bringing equipment back on line.

To apply CHEMIXENE® onto the filler head assembly during short breaks in the production day, it is recommended that the application be a fine mist of 5 ppm activated. Spray heads can be affixed onto the existing structure or framework surrounding the filler head assembly. A pressurized system, utilizing an AANE unit or other appropriate device, may be used to process and deliver the solution to the misting nozzles. An activating switch from the filler head should be used to prevent application while the equipment is in operation. A simple timer is used to control the misting burst to approximately 5 - 10 seconds. No rinse is required as CHEMIXENE® has a USDA D-2 rating, not requiring a potable water rinse.
PROCESS WATER TREATMENT

Chill water systems

Because CHEMIXENE® has a uniquely powerful effect against biofouling in closed water systems, such as chill water, its use in these systems can be a major application. CHEMIXENE® maintained at a concentration between 3-5 ppm, will keep the system clean and free flowing. CHEMIXENE® has several chemical characteristics especially suited for this and similar applications. CHEMIXENE® is highly soluble in water and it is active over a much broader range of pH. CHEMIXENE® resists neutralization by organics and iron to a much greater degree than other compounds and is much less corrosive than hypochlorite’s and other halides. CHEMIXENE® out-performs all other compounds in this application, and FDA has no objection to its use in this application. In especially dirty systems, pre-cleaning and complete system disinfection may be necessary prior to CHEMIXENE® application. In addition, a small sand filter installed in line will greatly improve the performance of all such systems.

Very much akin to chill water systems are the problems encountered with ice builders or ice making equipment, common in most food plants. Again, the most common problem seems to be biofouling or slime accumulation. Depending on the request of the plant, CHEMIXENE® may be applied as a periodic single spray application for acute problems or metered into the input water to prevent slime occurrence.

Pasteurizers, Bottle/Can Warmers, Coolers

These waters are usually semi-closed loop systems, which means they are essentially open to the atmosphere and readily undergo contamination. Through the process of spills and broken bottles/containers, they possess a significant organic load, and a high potential for biological load. Slime and odor causing microorganisms not only survive but flourish in these waters. There are considerable economic, esthetic and health reasons for keeping these waters in a sanitary condition.

Retort waters, i.e., recirculation waters used to heat and/or cool sealed containers, require treatment compounds to have a USDA G-5 listing. CHEMIXENE® as a listed G-5 compound may be used for the full range of retort water treatment applications. Except for the “hot” section of the pasteurizer, the systems that hold these waters are susceptible to biofilm build up. This effect will produce a condition called heat transfer resistance in the heat exchanger elements of these systems, resulting in wasted energy and increased costs. Biofilms also cause clogging and restriction of lines, orifices and pumps, again resulting in inefficiencies and additional costs for down time and repairs. In an Institute of Food Technology (IFT) summary report on the last two years of biofilm research, the active ingredient of CHEMIXENE®, chlorine dioxide, was listed as one of the most effective compounds for the destruction of biofilms. Our experience conforms completely with their findings. CHEMIXENE® is highly effective in removing biofilms from these
systems. In many of these systems, such as can coolers, the ambient bio-load may be so great that a thorough cleaning/disinfecting procedure of the sump and cooling canals may be required prior to the routine injection of CHEMIXENE® into the waters. If this is not done, it is likely that the sloughing bio-load will temporarily, but dramatically increase the bacterial counts of the cooling waters. This phenomenon will not occur with chlorine due to its almost complete lack of reactivity with biofilms.

Another costly factor with these waters is their ultimate discharge to the drain. The longer these waters can be retained in a sanitary condition, the more savings are realized in water costs, water discharge and energy required to heat up the replacement water. Finally, the best reason for using CHEMIXENE® in these waters is that the condition of the bottles and cans is significantly improved. This dramatic improvement enables the processor to reduce the percent of rejected containers, thereby realizing a significant production increase. Typically, halogen based (chlorine, bromine) compounds display a high degree of corrosiveness over time, and in some cases, relatively short times. According to corrosion studies, the chlorine dioxide chemistry of CHEMIXENE® is no more corrosive than plain water and is completely compatible with phosphate based anti-corrosion water treatment products commonly used in these systems.

CHEMIXENE® can solve or prevent all these problems. Depending on the configuration of the system, CHEMIXENE® can be batch loaded to the water system at a final concentration of 5 ppm on a periodic basis or can be metered in on a timed basis during the process day. Phosphoric acid activation is preferred. This application has extended pasteurizer waters 4-6 times their previous discharge cycle and has been highly economical in overall costs associated with these systems. CHEMIXENE® has all the necessary government approvals (EPA) (FDA) for these applications.

**Water Filtration and Distribution System Disinfection**

These water systems have been considered closed systems and therefore immune to contamination, particularly since residual chlorine or other water disinfectants are routinely applied to these systems. Weekly micro sampling of water often reveals quite the opposite. Most of us would consider the nutrient level in plain water not enough to support microbial growth. Again, this is not the case. Published work indicates that biofilms can and do establish themselves in such water systems. Also, trace elements and the pipe itself can support microbial growth, usually in the form of a biofilm. Once a biofilm is established within a distribution line, it can serve to “seed” the rest of the system. From time to time, back pressures can occur within most distribution systems which can literally draw product into these water lines. This influx of nutrients can cause a population explosion of biomass, extending the area of contamination far beyond its original location. Because planktonic (free floating) cells are much easier to destroy than those rooted in a protective biofilm, a disinfection procedure often produces excellent results initially, but within 7 - 10 days the counts return. Ordinary disinfectants are unable to destroy the sessile cells of the biofilm. This is where CHEMIXENE®’s unique chlorine dioxide chemistry is the difference between a solution and a temporary fix. CHEMIXENE® is able to penetrate, disrupt and destroy the biofilm where chlorine is
Disinfection of the water distributor network within a large plant can be an involved process with the most difficult factor being the identification and isolation of specific “runs” or circuits of waterline. Each line should be walked and potential sources of continual contamination (dead legs, corroded valves, old sample ports, leaks) should be identified and corrected. This should be done in a systematic fashion, beginning at the central most location and working outward. A fairly accurate estimation of the volume of the line should be calculated and a like volume of activated CHEMIXENE® solution at 100 - 200 ppm, depending on the severity of contamination, should be prepared. Existing water from the isolated line should be discharged and replaced with the disinfecting solution, making sure that all areas of the circuit have contact with the solution. After a minimum of one hour holding time (not to exceed 2 hours) the line should be drained and flushed with clean potable water. CHEMIXENE® may be used as a primary water disinfectant in municipal water at levels of 0.5 ppm and in stored potable water up to 5.0 ppm. If feasible, CHEMIXENE® treated water should be used to refill these lines, otherwise normally treated water may be used. Once the first circuit is disinfected and samples taken, the same procedure should be employed sequentially with the remainder of the waterlines.

**NON-FOOD CONTACT AREAS**

**General Uses**
CHEMIXENE® also has a USDA P-1 approval for bacteria and mold control on environmental surfaces. The most frequently isolated cultures of *Listeria* come from floors, drains and lower walls. From this location, the organisms can be splashed up onto the equipment and other locations. Scientific studies, conducted with the help of FDA who supplied the *Listeria* cultures, demonstrated conclusively that CHEMIXENE® was highly effective against all gram-positive bacteria.

Another area where *Listeria* is most often cultured is in the condensation pans and drip lines coming from the overhead cooling units and condensate in general. Because this area is usually difficult to reach, these pans may only be cleaned once per month or less. CHEMIXENE® will attack the bacterial slime that builds up and clogs the pan drain and condensate lines, dramatically reducing bacterial load. An extension wand on the central sanitizing station drop can be used to easily flush these pans between cleanings.

Clearly, the floor is by far the dirtiest surface within a plant and is the source of a great amount of contamination. Certain processing plants have established sanitation methods developed specifically for floors. Often a strong caustic is applied to the floors, scrubbed in, and then rinsed. Studies have shown that puddles on the floor after this procedure remain well above pH 11. Neither chlorine nor quat are effective at this high pH. Persistent counts on the floors may be due to this pH effect. CHEMIXENE® is more resistant to this pH neutralizing affect but will also suffer a decreased activity. When using any sanitizer on a floor, always check the residual alkalinity of the surface.

While mold growth may not be nearly as threatening as certain bacteria, they are
unsightly and can cost the cleaning crew valuable time. In dairy, cheese and soft drink plants, mold contamination can become a very costly problem indeed. Again, CHEMIXENE® is just as effective as the quat that has traditionally been used, but with its ability to be fogged, its ease of use is enhanced.

**Mold and Odor Control of Environmental Spaces**

There are many places within the brewery/dairy/bottling plant which foster malodorous and musty smells, due in large part to mold and bacteria. This is frequently the case in the storage cellars, Government Cellars and waste disposal areas where temperatures and humidities are near ideal for growth of these organisms. CHEMIXENE® destroys microorganisms by chemically oxidizing their molecular components. Malodors are neutralized in exactly the same manner. They are destroyed, not masked, by oxidation. Bacterial, mold and odor control is easily restored by an initial application of activated CHEMIXENE®, from 200 to 500 ppm depending on the severity of the problem, sprayed onto the walls, floors and waste cans. Follow this initial application with a periodical maintenance dosage of 100 ppm inactivated, and a fresh odor-free environment will be maintained. Please remember that when spraying activated solutions of CHEMIXENE® into the environment, a NIOSH approved chlorine dioxide face mask should be used.

**DIRECT FOOD APPLICATIONS**

**Produce**

The applications on produce are strictly governed by FDA regulations. The current FDA position is, “FDA is not objecting to the use of a rinse containing up to 5 ppm chlorine dioxide for rinsing uncut and unpeeled fruits and vegetables with the exclusion of cut and peeled potatoes, provided this treatment is followed by a potable water rinse.”

A direct food contact petition has been submitted to the FDA by the National Food Processor Association that would significantly modify the current limitations. It may allow for the use of chlorine dioxide-based products on cut and peeled fruits and vegetables, as well as uncut and unpeeled, and it could do away with the need for a potable water rinse after treatment. The current methods of treatment and expected results are compiled in the following Informational Summary, reviewing some twenty years of experience.
   
   A. The study was conducted on lettuce and celery using inactivated CHEMIXENE® solution strengths from 10 to 50 ppm.
   
   B. Lots 1 through 6 were treated as follows:
      1. Rinse tank water (Normally dirty water)
      2. Clean water with 10 ppm
      3. Clean water with 20 ppm
      4. Clean water with 30 ppm
      5. Clean water with 50 ppm
      6. Clean water with no treatment
   
   C. After the single treatment, lots were split and stored either unrefrigerated or cooler at 36 degrees F. The condition of the vegetables was noted after a six-day storage period.
   
   D. Results demonstrated that a rinse of 20 ppm inactivated was superior to all other treatments on both lettuce and celery resulting in significant shelf life extension. Based on this study, the Michigan Co-op instituted on CHEMIXENE® rinse program on their vegetables that is in effect to this day. This constitutes a use history of this successful application of over twenty years.
   
   E. Because of regulatory constraints, we have revised the recommendation to an “activated” 5 ppm treatment that has shown equivalent superior results.

2. Summary of results from field trials/case histories in support of Olin FDA Petition 3G0020, generated by the American Frozen Food Institute.
   
   A. The cover letter from Dr. Sussman does a good job in summarizing the results of the two-year evaluation of chlorine dioxide’s use within the potato processing plants. From the location of the plants, it is clear that the company involved in this study is Lamb-Weston.
   
   B. The reduction in bacteria within the processing system was very dramatic, as was the improvement in the product appearance. In addition, there was a 30% savings in water use because they were able to recycle the process water which had been impossible before.

   
   A. The report is composed primarily of a technical description of the pathogens of concern for bananas and mangos. The final (Page IV) describes Dr. Barredo’s recommendation for control of the pathogenic
species of concern. His recommendations are for inactivated Chemixine® (an additional brand name of CHEMIXENE®) at 600 to 1000 ppm. These recommendations are for field applications, whereby the solutions are sprayed directly onto the unwashed fruits. Activated solutions would require much less concentration than these recommendations. A range of 100 ppm to 500 ppm activated has been shown effective against the referenced fungal organisms. These recommendations would apply only to fruits that are enclosed by an outer covering such as bananas and would not be appropriate for more delicate fruits and vegetables.

4. A report developed by G.R. McNeely and Produce Supply Co. of Spokane, WA. in 1985, entitled "Use of Chemixene® in Rinse Water of Prepared Salad".

   A. The study was conducted on a prepared salad vegetable mixture and on raw and processed potatoes.

   B. Test concentrations of Chemixene (an additional brand name of CHEMIXENE®) were at 10, 14, and 19 ppm (activated). The evaluation occurred over an eight-week period.

      i. All Chemixene treatment concentrations demonstrated shelf life extension up to 21 days. Control samples displayed significant deterioration within ten (10) days. This field trial confirmed the ability of Chemixene/CHEMIXENE® solutions to extend marketability of fresh packed prepared salads to a truly remarkable degree.

   C. Potato data is summarized by saying "After that time period (five days), it becomes apparent that the presence of Chemixene makes a detectable difference in visual quality and finally, in the quality of the finished product."

   D. While this evaluation was conducted at a 10-ppm activated concentration, it is clear that 5 ppm (activated) solutions will make a significant improvement in shelf life extension.

5. Produce studies conducted at Smitties Supermarkets and Red Owl Supermarkets. These are in-house studies.

   A. Both studies were conducted using a 10-ppm inactivated CHEMIXENE® concentration. The Smitties test was a one dose study while the Red Owl study applied the product daily in the spray water. In both cases bacterial swabs were taken from the vegetables themselves.
B. In both cases a reduction in bacterial numbers were noted, demonstrating a range of reduction from 43% to 68%, and a shelf life extension of 1 to 2 days.

C. While the results were good, much better results would have been realized if the solutions had been activated, as they were in the Produce Supply study above.


A. This is an old publication but one that is very often cited in current FDA petitions. The study investigates the advantages of chlorine dioxide in the processing waters of vegetable canning operations.

B. Results indicate that ClO₂ is ..."highly effective in controlling bacteria and slime formation in pea and corn canners. Also, "Total bacteria counts on product were significantly lower when chlorine dioxide was used." Finally, "Substantial savings in water may be realized through reuse of water treated with chlorine dioxide to control bacteria."


A. Residue analyses were performed on whole carrots, shredded carrots, lettuce and bean sprouts treated with Chemixene at 5 to 20 ppm total available chlorine dioxide in processing wash water. Similar studies were performed on shredded carrots and bean sprouts treated with chlorine at 50 and 100 ppm in process wash water.

B. The analytical method used was DPD titration for the determination and quantification of chlorine dioxide, free chlorine, monochloramine, dichloramine and total available chlorine.

C. Residues associated with the use of Chemixene were detectable only on lettuce treated at 20 ppm total available chlorine dioxide. Residues of 1.0 mg/kg of produce for both chlorine dioxide and total available chlorine were detected. No other determinable levels of any residues detectable by the DPD method were found.

D. Significant residues associated with the use of chlorine at 100 ppm in the process wash water for bean sprouts were found. Residues of 0.1 mg/kg monochloramine, 12.7 mg/kg dichloramine, and a total available chlorine residual of 13.4 mg/kg were found. Carrots treated with chlorine produced a colored extract which interfered with the test procedure and, thus, residues of chlorine species on the carrots could not be determined. Residues of sodium on carrots treated with chlorine were more than twenty times that of carrots treated with Chemixene. Carrots treated with chlorine showed 1054 mg/kg of
sodium as compared to 49 mg/kg of sodium for the carrots treated with Chemixene.

E. The treatment of produce with Chemixene in the process wash waters resulted in very low levels of detectable residues at high treatment levels. These residues are not associated with breakdown products of chlorine dioxide or reaction of chlorine dioxide with organic constituents of the vegetables. The high residue levels associated with the use of chlorine indicate significant reaction with constituents of the produce to form chlorinated organics. Adverse organoleptic effects and potential health considerations are often associated with chlorinated organics in food.

In Summary, the benefits of CHEMIXENE® and its active ingredient, chlorine dioxide, cannot be disputed. The only things that have hindered chlorine dioxide’s universal use is the lack of FDA approvals for cut and peeled (processed) fruits and vegetables and the dissemination of product information throughout the industry. The FDA has approved chlorine dioxide’s application on uncut vegetables.

The following procedure for treatment of salads and prepared produce can give considerable benefit to the quality and shelf life of these products and will conform to FDA requirements.

STEP #1 Inspect and remove gross rot and debris from the incoming produce. This minimizes the possibility of the spread of bacteria and mold onto the processed produce. This step will also minimize water and CHEMIXENE® usage in STEP #3.

STEP #2 OPTIONAL: Wash the unpeeled and uncut produce in clean water to remove excess dirt and foreign materials. This step should be as gentle as possible to prevent the impaction of spoilage bacteria into the produce.

STEP #3 Rinse the uncut and unpeeled produce in a clean solution of 5 ppm activated CHEMIXENE®. This is the main change from the "standard" chlorine process. CHEMIXENE® does not react with organics and "dirt" as rapidly as chlorine. Moving this step into the wash water thoroughly cleans the produce, and the carried-out remnant of the additive solution protects the cut and injured areas during the processing step.

STEP #4 Potable water rinse. Following treatment with CHEMIXENE®, a potable water rinse of the produce is required. Potable water for rinse purposes may contain true levels of chlorine dioxide, or its by-products, at levels up to 0.5 ppm total oxidizing species. Chlorine dioxide, however, may not be added to potable water inside food processing facilities for produce rinse applications. CHEMIXENE® may be added to incoming potable water prior to produce processing facility entry. Consult your OCS
STEP #5 Prepare produce: cut, peel, shred, etc....
The remnant of the additive solution carried out of the sanitizer wash helps keep the knives and equipment from spreading spoilage organisms to the cut and injured surfaces.

STEP #6 Spin or air dry and package.
Although there are some minor changes from the normal chlorine type system, the use of CHEMIXENE® in this procedure produces results that exceed any other method of processing fruits and vegetables. Aside from the shelf life extension that can be realized using chlorine dioxide chemistry, recent studies conducted in England have shown that chlorine treatments seriously degrade the nutrient content of the produce, while chlorine dioxide chemistry has no such effect.

Poultry Applications
Aside from the standard food processing applications already detailed elsewhere, CHEMIXENE® meets the criteria as a Secondary Direct Food Additive. Direct contact applications are governed by two different FDA regulations: 21CFR 173.300(b)(1) Chlorine Dioxide and 21CFR 173.325(b) Acidified Sodium Chlorite.

Applications - Poultry Industry

1. Terminal Sanitizer - Food contact surfaces in processing areas
   - Evisceration
   - Further Processing

2. Process Water Treatment/Direct Contact
   - Direct Contact Applications - Carcass Wash, Process Rinses, Chill Tanks, Post Chiller Carcass Wash

3. Grow out/Hatcheries
   - Watering Systems Disinfection
   - Drinking Water Treatment
   - Confinement Facilities Disinfection
   - Confinement Fogging for Disease Prevention/Control

4. Odor Control
   - Processing and Rendering Areas

5. Specialty
Uses

- Spot Sanitizing/Disinfection of Environmental Spaces

Before and after bacteria counts taken along a lubed conveyor/filler system in a large soft drink manufacturing plant.
Table 1 – Chemixene Comparison Test – Chemixene concentration required for > 10^5 reduction in Viable cell counts in 60 seconds. (milligrams/liters)

Comparison of Disinfecting Agents

Disinfectant Concentration required for a 5 log reduction

P. aeruginosa  S. aureus  S. cerevisiae  E. coli

CHEMIXENE  Quat  Sodium Chlorite
Peroxy Compl  Chlorine  Acid Anionic Comp

(See chart on page 33)
VII. Disinfectant Comparison Summary

Abstract

The antimicrobial activities of eleven disinfectants against Staphylococcus aureus, Pseudomonas aeruginosa and Saccharomyces cerevisiae were determined using a method based on the A.O.A.C. germicidal and detergent sanitizer assay. Based on the activity against the test organisms after 30 and 60 second exposures to each disinfectant, the chlorine dioxide based CHEMIXENE® product demonstrated the highest biocidal activity in the assay.

Late in 1987, OCS LLC, Inc. began a dialogue with Dr. Ralph Tanner at the University of Oklahoma concerning the need to document the relative effectiveness of OCS LLC’S’s chlorine dioxide product with those currently in the marketplace. OCS LLC’S had previously commissioned numerous bactericidal studies, which demonstrated an exceedingly high biocidal activity. It was evident, however, that a direct comparison of biocidal activity among available disinfectants was difficult at best, due to the use of various testing methods, protocols and test conditions of products. It was decided that a disinfectant comparison study, based on the standard A.O.A.C. germicidal and detergent sanitizer assay, would be conducted and would include commercially available products representing major disinfectant chemical groups. In this way, one could readily and directly compare the relative potency of disinfectant products to determine which was the most effective under identical criteria. Because OCS LLC’S’s chlorine dioxide products are found in a wide array of applications, it was decided to select disinfectants from both the food processing and hospital/medical environments for evaluation. Two different sodium hypochlorites were evaluated. Simple bleach was identified as “chlorine compound I” while a high concentration commercial hypochlorite solution was labeled “chlorine compound II”. Since OCS LLC’S had long contended that significant differences exist among chlorine dioxide-based products, another chlorine dioxide-based product was evaluated and identified as “chlorine compound III” while OCS LLC’S’s chlorine dioxide product was “chlorine compound IV”. The iodophor was a formula of iodine and phosphoric acid commonly used for dairy equipment sanitation. Hydrogen Peroxide was evaluated due to its use in food processing, largely overseas and its sometime use in the medical area. The glutaraldehyde-phenol and the acid glutaraldehyde are both medical environment disinfectants whose trade names are Sporocidin and Wavicide respectively. The quat or quaternary ammonium compound and the acidified quat are both private formulations specifically for the food processing applications. The phenol product is the standard hard surface disinfectant used in microbiology labs throughout the country. Because it is well known that different types of disinfectants often produce different kill rates on various microorganisms, three different organisms were used in evaluating the disinfectants. The three organisms, each representing a major class of microbe, were P. aeruginosa, a Gram-negative bacterium, S. aureus, a Gram-positive bacterium and S. cerevisiae, a fungal yeast.

The criteria of the test itself was to determine the lowest concentration of the various disinfectants which would produce a 99.999% reduction of organism after only a sixty second contact time with the chemical. In this way, the strength or potency of the disinfectants can be seen by comparing the concentrations, expressed as parts per million (ppm) necessary to produce the required kill within the specified contact period. Those products which meet the kill criteria at lower concentrations are judged to be more potent disinfectants than those that must use higher concentration to achieve the same result.
By looking at the products that are effective using the lowest concentrations, it is quite clear that “chlorine compound IV” is significantly superior to all other tested products. Compound IV is OCS LLC’S’s chlorine dioxide product, marketed under the trade names CHEMIXENE®, CHEMIXENE® and SANOGENE®. This published report graphically demonstrates that the OCS LLC’S product line of the disinfectants represents state of the art in disinfection products today and should play a significant role in disinfection programs, in both the food processing and medical environments.

VIII. COMPARISON WITH OTHER DISINFECTING AGENTS

<table>
<thead>
<tr>
<th>Chemixene</th>
<th>Active Ingredient Concentration (ppm)</th>
<th>P. aeruginosa</th>
<th>S. aureus</th>
<th>S. cerevisiae</th>
<th>E. coli 0157:H7</th>
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<tbody>
<tr>
<td>CHEMIXENE®</td>
<td>Chlorine Dioxide 20,000</td>
<td>5</td>
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<td>Alcide-LD</td>
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<td>Chlorine</td>
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<td>C-13</td>
<td>Sodium Hypochlorite 85,000</td>
<td>820</td>
<td>820</td>
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<td>Iodophor</td>
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<td>Wavicide-01</td>
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<td>0</td>
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<td>620</td>
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<td>Sporocidn</td>
<td>Glutaraldehyde activated 20,000</td>
<td>1,600</td>
<td>2,200</td>
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<td>H2O2</td>
<td>Hydrogen Peroxide 300,000</td>
<td>36,000</td>
<td>68,000</td>
<td>270,000</td>
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<tr>
<td>Quat</td>
<td>Quaternary Ammonium Compounds</td>
<td>580</td>
<td>140</td>
<td>74</td>
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<td>Acidified Quat</td>
<td>As Quat + Phosphoric Acid</td>
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<td>Amphyl</td>
<td>Phenolic Compounds</td>
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<td>Perox Compound I</td>
<td>Peracetic Acid &amp; Hydrogen Peroxide</td>
<td>30</td>
<td>60</td>
<td>300</td>
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<td>Perox Compound II</td>
<td>Peracetic Acid &amp; Hydrogen Peroxide &amp; Acetic Acid</td>
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<td>Dodecylbenzenesulfonic Acid &amp; Phosphoric Acid</td>
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<td>Acid Anionic Compound II</td>
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<td>150</td>
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<td>60</td>
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</table>

(See graph on page 31)
COMPARISON OF THE ACTIVITIES OF CHLORINE DIOXIDE OR PERACETIC ACID AGAINST LACTIC ACID BACTERIA

Comparative testing of chlorine dioxide and peracetic acid were conducted as previously described (Tanner, R.S. 1989. Comparative testing and evaluation of hard-surface disinfectants. J. Indust. Microbiol. 4: 145-154.) With the following exceptions:

a. Cultures of a strain of Pediococcus and a mixed culture of Lactobacillus sp. were obtained from a brewing company.

b. 10 mM potassium phosphate was included in the medium to stimulate the growth and viability of the lactic acid bacteria (which are dependent of substrate level phosphorylation for metabolism and growth).

c. Test cultures were incubated for 48 hours at 30° C; enumeration plates were incubated for 72 hours.

d. Sodium thiosulfate (5,000 ppm) was used to neutralize each of the oxidizing Chemixenes tested.

e. The tests containing peracetic acid (100, 200, and 500 ppm) also contained hydrogen peroxide (620, 1,200, and 3,100 ppm, respectively).

### Viable Cells/ml (60 second exposure)

<table>
<thead>
<tr>
<th>Condition</th>
<th>ppm</th>
<th>Pediococcus</th>
<th>Lactobacillus</th>
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</thead>
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<tr>
<td>Control</td>
<td></td>
<td>2.5 x 10^6</td>
<td>1.6 x 10^6</td>
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<tr>
<td>Chlorine dioxide</td>
<td>20</td>
<td>&lt; 2 x 10^0</td>
<td>&lt; 2 x 10^0</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>&lt; 2 x 10^0</td>
<td>&lt; 2 x 10^0</td>
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<tr>
<td></td>
<td>10</td>
<td>&lt; 2 x 10^0</td>
<td>&lt; 2 x 10^0</td>
</tr>
<tr>
<td>Peracetic acid</td>
<td>100</td>
<td>&gt; 10^5</td>
<td>&gt; 10^5</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>8.5 x 10^2</td>
<td>&gt; 10^5</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>&lt; 2 x 10^0</td>
<td>7.3 x 10^5</td>
</tr>
</tbody>
</table>

The results indicate that 20 ppm chlorine dioxide could reduce viable counts of lactic acid bacteria at least 99.999% in a 60 second speed-of-kill assay. The results suggest that about 1,000 ppm of peracetic acid would be required to achieve a similar reduction in viability, using this test. These results are for comparative purposes only.

Dr. Ralph S. Tanner
September 14, 1991
IX. Summary of Food Processing Government Registrations

Product Application: Food Processing Disinfectant
(Sanitizer) Trade Name: CHEMIXENE®
Chemical Family: Mixture of Oxychlorine
Compounds Active Ingredient: 2.0% Chlorine Dioxide
E.P.A. Registration No.: 9804-1

CHEMIXENE® is an E.P.A. registered disinfectant/sanitizer with applications in food processing plants.

E.P.A. registration as a terminal sanitizing rinse for food contact surfaces in food processing plants such as poultry, fish, meat, and in restaurants, dairies, bottling plants and breweries. (100 ppm)

E.P.A. registration for disinfection of environmental surfaces on floors, walls and ceilings in food processing plants such as poultry, fish, meat, and in restaurants, dairies, bottling plants and breweries. (500 ppm)

E.P.A. registration as a sanitizing rinse of uncut and unpeeled fruits and vegetables at 5 ppm followed by a potable water rinse.

E.P.A. registration as a bacteriostat in ice making plants and machinery. (20 ppm)

F.D.A. approval as a terminal sanitizing rinse, not requiring a water rinse, on all food contact surfaces. (100-200 ppm) 21 CFR 178.1010

F.D.A. Letter of no objection for the use of stabilized chlorine dioxide at 20 ppm for treating ice used for icing fish in the round.

F.D.A. approval as an antimicrobial agent on raw agricultural commodities at 500-1200 ppm acidified sodium chlorite followed by thermal processing or a potable water rinse. 21 CFR 173.325

F.D.A. approval as a sanitizing wash for cut and peeled fruits and vegetables at 3 ppm free chlorine dioxide followed by thermal processing or a potable water rinse. 21 CFR 173.300

F.D.A. approval as an antimicrobial agent on raw agricultural commodity in preparing, packing or holding. Applied as a dip or spray at 500-1200 ppm acidified sodium chlorite followed by a thermal process or a potable water rinse. 21 CFR 173.325
SUMMARY OF FOOD PROCESSING
GOVERNMENT REGISTRATIONS
PAGE 2

F.D.A. approval as an antimicrobial agent in water used in poultry processing at 3 ppm chlorine dioxide. 21 CFR 173.300

F.D.A. approval as an antimicrobial agent in poultry processing water as a component of:
- Carcass spray or dip at 500-1200 ppm acidified sodium chlorite. 21 CFR 173.325
- Prechiller/chiller tank at 50-150 ppm acidified sodium chlorite. 21 CFR 173.325

F.D.A. approval as an antimicrobial agent in water or ice (40 – 50 ppm acidified sodium chlorite) used to wash, rinse, thaw, transport, or store seafood. 21 CFR 173.325

F.D.A. approval as an antimicrobial agent in the processing of red meat as a component of a carcass spray at 500-1200 ppm acidified sodium chlorite. 21 CFR 173.325

F.D.A. approval as an antimicrobial agent on processed, comminuted or formed meat food products (unless precluded by standards of identity…). Applied as a dip or spray at 500-1200 ppm acidified sodium chlorite prior to packaging. 21 CFR 173.325

U.S.D.A., D-2 approval as a terminal sanitizing rinse, not requiring a potable water rinse, on all food contact surfaces found in food processing plants. (Use According to Label Instructions.)

U.S.D.A., P-1 approval for bacterial and mold control in federally inspected meat and poultry processing plants for environmental surfaces. (Use According to Label Instructions.)

U.S.D.A., 3-D approval for washing fruits and vegetables that are used as ingredients of meat, poultry and rabbit products followed by a potable water rinse. (Use According to Label Instructions.)

U.S.D.A., G-5 approval for cooling and retort water treatment. (Use According to Label Instructions.)
X. AANE™

Automated Activation Non Electric

For the majority of CHEMIXENE® applications, activation is required. What is "activation" and why is it required? Chlorine dioxide is a gas in nature, as is chlorine. The process of stabilizing ClO₂ involves dissolving the gas in water and converting it into its "salt" form. In this state it is safe to transport and store. In order to obtain the full power of chlorine dioxide, we must retrieve the gas back from its stable salt. This is easily accomplished by simply lowering the pH of CHEMIXENE®. This is activation. This does not mean that the resultant sanitizing solution has an extremely low pH, since only the alkaline CHEMIXENE® concentrate is primarily affected.

While the concept is simple, we realize extra steps involved in a product's use are not convenient. Therefore, OCS LLC has designed a modular Automated Activation Non-Electric system (AANE) that is tough and reliable and completely removes any inconvenience from the use of CHEMIXENE®.

AANE can be configured for the following areas:

- A sanitizing step after CIP or COP operations. AANE can be readily fitted into the CIP solution supply lines at the proper time and concentration.

- Central sanitation systems can be automated to deliver from 25 to 150 ppm active CHEMIXENE® solution from the centrally located AANE.

- Large quantities of active 25 to 150 ppm sanitizing solutions can be made for flood sanitizing of equipment, product vessels, and potable water holding tanks.

- Potable water treatment and certain process waters can be treated at 3-5 ppm at fixed flow rates of 100 to 200 gpm.

- Water flow of .1 to 40 gallons per minute can be proportionally treated from 1 to 100 ppm of active CHEMIXENE®.
provide solutions for many application needs, such as:

- **Clean In Place (CIP)** sanitizing
- **Clean Out of Place (COP)** sanitizing
- Potable water treatment
- Potable water vessel disinfection
- Central sanitizer systems
- Waste water treatment for bacteria and some contaminants
- Deodorization of process and waste disposal areas
- Sanitizing of food service equipment
- Preparation of solutions for fogging and spraying
- Vegetable and fruit flume water treatment
- Anti-bacterial rinse water for fruits and vegetables

As seen from the above list, there are very few applications that CHEMIXENE® cannot be configured for. For specific details, please contact one of our technical service representatives.

**XI. ECO-BENEFITS OF CHEMIXENE®**

**A CHLORINE DIOXIDE BASED ANTIMICROBIAL**

Halogen-based disinfectants such as chlorine and iodine have been the backbone of the sanitation/disinfectant industry for many decades. They have good, broad spectrum activity against microbial organisms, are cost effective and easy to use. Until the advent of the 1970's, corrosion was the biggest concern when using chlorine-based compounds. Additionally, when hypochlorite solutions are mixed with acids, chlorine gas evolves presenting a significant acute hazard that is preventable with proper training and handling. Unfortunately, the data concerning a more significant and chronic problem with halogens and chlorine has been growing over the past 15 years. Chlorine's strong tendency to chlorinate through electrophilic substitution of organic materials has been shown to be the root cause of the accumulation of numerous toxic substances within our water, soil and atmosphere. These include such notable compounds as chloroform, chlorophenols and dioxin, all acutely toxic or carcinogenic. Chloroform is formed from the reaction of chlorine and human acid, a naturally occurring substance commonly found in surface waters. This chlorination occurs at municipal water treatment facilities where chlorine is added to disinfect the water and protect the population from pathogens. The compound dioxin is inadvertently produced from the reaction of chlorine with lignin, a component of wood during wood pulp bleaching, as are the chlorophenols. The
ability of these compounds to bioaccumulate within the environment has caused both concern and alarm, so much so that the federal government has mandated that the use of chlorine must be reduced and/or eliminated whenever possible.

If the use of chlorine is to be drastically reduced, what compound is available that will still have chlorine's activity and yet, not produce chlorinated or other toxic by-products? The answer appears in two separate sources. In the American Water Works Association Journal, June 1986, the entire issue was devoted to a water disinfectant compound that was not just equal to chlorine's disinfection ability but actually several times better. In addition, its reaction is through a process of oxidation, not chlorination, therefore, producing no chlorinated by-products such as chloroform. The use of this compound has expanded by leaps and bounds during the past 5 years. The compound discussed was chlorine dioxide. In October of 1993, the Alliance for Environmental Technology, a group of environmentally concerned multinational scientists, prepared a document entitled "A Review and Assessment of the Ecological Risks Associated with the Use of Chlorine Dioxide for the Bleaching of Pulp." The in-depth report concluded that the substitution of chlorine dioxide for chlorine (in pulp bleaching) will result in:

1. Reduction in the quantities of organochlorines produced
2. Reduction in the degree of chlorine substitution in the organochlorines produced
3. Reduction in the degree of persistence of the organochlorines produced
4. Reduction in the potential for bioaccumulation and food chain transfer
5. Reduction in potential toxicity
6. Reduction in adverse ecological effects

They further state, "Based on the data available, the Panel concludes that mills bleaching with high chlorine dioxide substitution (100%) employing secondary treatment and receiving water dilutions typical of most mills in North America, present an insignificant risk to the environment from organochlorine compounds."

Clearly, the replacement of chlorine with chlorine dioxide has resulted in numerous benefits to the environment in these above cases. Similar benefits can be realized by the use of chlorine dioxide in typical food plant sanitation programs as well.

It is highly likely that large volumes of organic materials are being chlorinated and subsequently routinely discharged to the drain during nightly sanitation shifts in our processing plants. Even so, in a food plant the emphasis must be directed towards a sanitizer's ability to sanitize. A company cannot jeopardize the safety and quality of a food product just to be environmentally friendly.

OCS LLC'S filed an indirect food additive petition with the FDA for the safe use of a stabilized chlorine dioxide product, CHEMIXENE®, as a sanitizing rinse for food-processing equipment. This petition was accepted by FDA on Aug 12th, 1987 and was published in the Federal Register, Vol. 52, No. 155 August 12th, 1987. This allows for the use of chlorine dioxide on all food contact surfaces in all USDA inspected food plants. All data reviewed by the FDA in this petition was generated from studies on CHEMIXENE®. In order to receive this acceptance, both EPA and FDA have strict requirements that must be met, which involve product chemistry, product toxicity and product efficacy. The petition filed on CHEMIXENE® indicates a low acute toxicity (category III) and
exceptional antimicrobial activity, demonstrating a minimum of twice the potency of the standard chlorine compound. This enhanced activity is substantiated and more adequately defined in an article published in the Journal of Industrial Microbiology, 4 (1989) 145-154, entitled, "Comparative testing and evaluation of hard-surface disinfectants." The study found dramatic differences in the antimicrobial activity of 10 different disinfectants against 3 different organisms. CHEMIXENE® (chlorine compound IV) was most efficacious against the tested organisms by a very significant margin. CHEMIXENE® displayed, as a minimum, a tenfold advantage over commercially available sodium hypochlorite. Surprisingly, CHEMIXENE® produced almost the same advantage against another chlorine dioxide-based product (chlorine compound III), who's manufacturing process differs distinctly from that of CHEMIXENE®.

It is somewhat remarkable, after learning about these advantageous characteristics of chlorine dioxide, that the compound had not completely replaced chlorine years ago. The reason for chlorine dioxide's delayed arrival on the scene has to do with some of its other chemical characteristics. Like chlorine, chlorine dioxide exists as a gas. In both cases, this gas is pungent and acutely toxic. Unlike chlorine, it cannot be compressed into gas cylinders since high concentrations above 10 - 12 % of ClO₂ can explode. In addition, the active chlorine dioxide molecule tends to breakdown to more stable salt forms such as sodium chlorite, sodium chlorate and chlorine. This short shelf-life of weeks, or at most months, effectively prevents the manufacture, storage and transportation of a chlorine dioxide product with any significant concentration. Most large volume chlorine dioxide applications, such as pulp bleaching and municipal water treatment, solve these problems by employing industrial chlorine dioxide generators. Most of these have a reaction of high concentrations of sodium chlorite with mineral acids and sometimes sodium hypochlorite and meter the resulting chlorine dioxide into a moving water stream.

An attempt has been made to down scale these generators and fit them into small scale operations such as food plants. The experience of many of these plants reveals that these generators, in practical use, require a trained operator almost full time to keep them properly calibrated and operational. Since the technology of these generators is not generally understood, mechanical failures of the system tend to take these devices off-line for days and weeks at a time until a factory technician can arrive to repair the device. Many complain that the generators are "gassy" and more than one has caused an evacuation of the plant.

The CHEMIXENE® approach is much simpler. Because CHEMIXENE® is not a simple solution of sodium chlorite, but a mixture of oxchloride species, including sodium chlorite, all which is required to release the potential chlorine dioxide is a lowering of the pH of CHEMIXENE®. After activation, simply pour the solution into a given volume of potable water and apply as you would any sanitizer. For higher volume uses, such as CIP or Central Sanitizing Systems, an Automated Activation and Non-Electric System, or AANE unit fits the requirements quite nicely. AANE is an aqueous system using lower concentrations of precursor materials, allowing for maximum efficiency and safety. The fact that chlorine dioxide is ten times more soluble in water than chlorine, coupled with a design that utilizes low concentration processing, ensures that the chlorine dioxide is at all times dissolved in an aqueous phase.

As with any successful endeavor, the goal of the CHEMIXENE® program has been
to enhance the benefits and eliminate the liabilities associated with chlorine dioxide. From a preponderance of published data, chlorine dioxide does not form trihalomethane. Its principal chemical reaction is one of oxidation, not chlorination. CHEMIXENE®’s antimicrobial activity is also well documented and impressive. CHEMIXENE®’s product label bears a precautionary signal word of “caution”, indicating an acute toxicity rating of category III. There is no lower acute toxicity rating in the industry. Chlorine dioxide is approved for the disinfection of drinking water and is allowed on fruits and vegetables as a sanitizing rinse. CHEMIXENE®’s concentration and aqueous activation systems reduce use hazards to well within industry standards. Unquestionably, the use of CHEMIXENE® is a highly viable option as a multi-use sanitizer within the full range of food plants found in North America.

XII. WHAT YOU SHOULD KNOW ABOUT CHLORINE DIOXIDE AND CHEMIXENE®

As mentioned previously, the active ingredients of CHEMIXENE® involve chlorine dioxide chemistry. Chlorine dioxide is a yellow green gas with a very distinct pungent chlorine like smell. During the manufacture of CHEMIXENE®, the gas is converted into a stable salt, for safe and stable storage, transport and handling. The stable solution is a clear liquid, having a very minute odor of chlorine. The storage of CHEMIXENE® should be in a cool place, out of direct sunlight. Any spill of the CHEMIXENE® concentrate should be flushed with plenty of water to the drain. Inactivated CHEMIXENE® concentrate, as it exists in its original container, will not produce chemical burns, or generate chemical fumes.

Nonetheless, any contact of CHEMIXENE® concentrate on skin, eyes or clothes should be rinsed thoroughly with potable water as it can be an irritant with prolonged exposure. Any spill, particularly large spills, should not be allowed to dry onto or to absorb into materials such as rags, sawdust, cardboard or wooden pallets. If this occurs, and the solution dries onto these materials they become much more flammable. Spills may be chemically neutralized using sodium thiosulfate.

Active solutions of CHEMIXENE®, produced by lowering the pH of the concentrate will have a yellow color and a chlorine-like odor. This indicates that chlorine dioxide is being generated and is present in the solution. Chlorine dioxide is a gas that is dissolved in water, similar in principal to carbon dioxide being dissolved in soft drinks. Chlorine dioxide is 10 times more soluble in water that chlorine, which effectively keeps it in a solution. Activated solutions which are not diluted within a short period of time will begin to produce a slight green “smoke” from the top of the solution. This indicates that the chlorine dioxide gas concentration within the liquid has gone beyond its solubility and is escaping into the atmosphere. This is not comparable to a chlorine gas release when an acid is added! The simple addition of water to the solution will increase the solubility and prevent additional smoke from forming. The dilution chart found in the back of this handbook demonstrates the proper dilution rates. A D-2 sanitizing solution rate would be just less than 2/3 oz. per gallon of water. For most volume uses, our Automated Activation and Non-Electric System (AANE) handles all activating and diluting of the sanitizer. For small “spot” sanitation when very small, quantities can be made up on a weekly basis and held in 5, 30- or 55-gallon drums on drum stands to be allocated as needed.
Because ClO₂ is a gas dissolved in water, cool water flood sanitizing procedures are recommended, just as you would use with chlorine or quat. Hot water, above 105 F, and medium or high-pressure applicators are not recommended.

CHEMIXENE® is a powerful sanitizer, not a cleaner, and should not be added to alkaline foam products. The most appropriate sanitizing procedure for all products is to flood sanitize after the surfaces have been cleaned and rinsed free of any soap residual. As a D-2 sanitizer, CHEMIXENE® does not require a potable water rinse after application.
XIII. TOXICITY DATA SUMMARY

Acute Toxicity Studies

1. Rabbit Skin Irritation
   A. 0.5 milliliters of undiluted CHEMIXENE® concentrate was applied to the intact skin of the test animal.
   B. Test site was occluded for four hours and then examined at 1 ½ hrs, 24 hrs, 48 hrs. and 72 hrs. for irritation and defects.
   C. Test score 0.3
   D. Descriptive rating – practically not an irritant
   E. Rabbit Acute Dermal Toxicity

2. Rabbit Acute Dermal Toxicity
   A. Test sited was treated with 2020 mg/kg undiluted CHEMIXENE® concentrate on a total of ten test animals.
   B. Test sited were occluded for 24 hours and animals were monitored for toxic effects.
   C. No animal deaths occurred during the evaluation.
   D. Descriptive rating – LD – 50 of undiluted CHEMIXENE® is greater than 2020 mg/kg

3. Rabbit Eye Irritation
   A. 0.1 milliliter of undiluted CHEMIXENE® concentrate was placed into the left eye of the test animals.
   B. After 30 seconds, the treated eyes of one half (1/2) the test group were rinsed with deionized water for one minute.
   C. Test scores of 4.3 for the washed eyes and 5.3 for the unwashed eyes.
   D. Descriptive rating – washed eye was “minimally irritating” and unwashed eye was “mildly irritating”.


4. Rat Acute Oral Toxicity

A. 35 male and female albino rats were given three and four dose levels of undiluted CHEMIXENE® concentrate, respectively, over the test period and observed for a 14-day period.

B. At the end of the test period, or discovery of a deceased animal, a gross necropsy examination was performed.

C. LD-50 rating males 4560 mg/kg, females 4150 mg/kg, overall 4360 mg/kg

D. Descriptive rating – Category III toxicity suitable precautionary statement “Caution”

5. Rat Acute Inhalation Toxicity – 500 ppm Activated

A. Ten male and ten female albino rats were exposed to a concentration of 500 ppm, activated with citric acid crystals, in the amounts of 4.39 mg/l in males and 5.61 mg/l for females in an aerosol over a 4-hour exposure period.

B. Animals were monitored for mortality during the exposure period and for 14 days after.

XIV. Descriptive rating – the acute LC-50 for the 1000 ppm CHEMIXENE® solution was greater than 5.75 mg/l.

PROPER ACTIVATION AND DILUTION OF CHEMIXENE®

Each gallon of CHEMIXENE® yields:

<table>
<thead>
<tr>
<th>Gallons of CHEMIXENE® Concentrate</th>
<th>Gallons of Activated Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,000</td>
<td>400</td>
</tr>
<tr>
<td>2,000</td>
<td>200</td>
</tr>
<tr>
<td>1,000</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>40</td>
</tr>
</tbody>
</table>

Each gallon of CHEMIXENE® requires 13.6 ounces (395 grams) of citric acid crystals or 3.5 oz (105 ml) of 75% phosphoric acid for proper activation. Proper activation is achieved when the pH of the CHEMIXENE® concentrate is depressed to approximately 2.2 – 2.5. Once proper activation is achieved, the active concentrate must be diluted with the appropriate volume of water to insure total solubility of the active chlorine dioxide component.

The following procedure will apply for all activations except when utilizing the Automatic Activation Non-Electric (AANE) unit:

Measure out the desired volume of CHEMIXENE® concentrate into a clean vessel in a well-ventilated area. Add the required amount of activator, stir and allow to react for five minutes. Avoid breathing any fumes that may be produced. After five minutes, dilute with clean water to your desired final concentration. Once this solution is activated and diluted properly, the solution will remain active for up to one week when stored covered,
out of direct sunlight. Note: Activator must be added to **CHEMIXENE®** before dilution.

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Ounces per Gallon</th>
<th>Milliliters per liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ppm</td>
<td>0.032 fl. Oz./Gallon</td>
<td>0.25 ml/liter</td>
</tr>
<tr>
<td>10 ppm</td>
<td>0.064 fl. Oz./Gallon</td>
<td>0.50 ml/liter</td>
</tr>
<tr>
<td>20 ppm</td>
<td>0.128 fl. Oz./Gallon</td>
<td>1.00 ml/liter</td>
</tr>
<tr>
<td>40 ppm</td>
<td>0.256 fl. Oz./Gallon</td>
<td>2.00 ml/liter</td>
</tr>
<tr>
<td>50 ppm</td>
<td>0.32 fl. Oz./Gallon</td>
<td>2.50 ml/liter</td>
</tr>
<tr>
<td>100 ppm</td>
<td>0.64 fl. Oz./Gallon</td>
<td>5.00 ml/liter</td>
</tr>
<tr>
<td>200 ppm</td>
<td>1.28 fl. Oz./Gallon</td>
<td>10.00</td>
</tr>
<tr>
<td>500 ppm</td>
<td>3.25 fl. Oz./Gallon</td>
<td>25.00 ml/liter</td>
</tr>
</tbody>
</table>

**Activator ratios**

Citric Acid Crystals: Each fluid oz. of **CHEMIXENE®** requires 3 grams or 0.10 ounce of citric acid for proper activation. Alternately, use 10 grams of citric acid activator for each 100 ml of **CHEMIXENE®**.

A good rule of thumb is to use a ratio of 1 ounce of activator to 10 fluid oz. of **CHEMIXENE®** (or 1 gram of citric acid to each 10 ml of **CHEMIXENE®**).
MATERIAL SAFETY DATA SHEET

SECTION 1: CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME
CHEMIXENE®

CHEMICAL FAMILY
Mixture of Oxchlorine Compounds

MANUFACTURER
OCS LLC, Inc.

EPA REGISTRATION NUMBER:
9804-1

EFFECTIVE DATE:
June 2004

SUPERSEDES:
April 2002

SECTION 2: COMPOSITION/INFORMATION ON INGREDIENTS

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>C.A.S. No.</th>
<th>% by Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Chlorite</td>
<td>7758-19-2</td>
<td>3.35%</td>
</tr>
</tbody>
</table>

SECTION 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
Clear liquid with very faint chlorinous odor
May cause skin reaction. May cause eye irritation.

POTENTIAL HEALTH EFFECTS

INHALATION: Prolonged inhalation of fog or mist may be irritating to nose and throat.

SKIN: Based on rabbit studies, product is listed as “practically not an irritant”. Prolonged exposure may produce localized irritation, contact dermatitis, mild erythema and edema.

EYE: Based on rabbit studies, product has been given an EPA Category III rating as a mild irritant. Exposure can produce slight irritation of conjunctiva, cornea and eyelid.

INGESTION: Ingestion may produce gastric discomfort, nausea, vomiting and diarrhea. Intake of large quantities may produce methemoglobinemia.

SYSTEMS OF OVER EXPOSURE
Skin and eye irritation. Exposures to chlorine dioxide from activation can produce coughing.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE
Skin disorders, such as dermal allergies and dermatitis. Exposure to chlorine dioxide produced by activation can aggravate pulmonary disorders, such as emphysema.

CHRONIC EXPOSURE EFFECTS
May cause localized irritation to areas exposed to product.

SECTION 4: FIRST AID MEASURES

The following procedures are recommended as emergency first aid only. They are not intended to replace or supplant the treatment advice of a physician or other authorized health care specialist.
Inhalation: Move person to fresh air. If person is not breathing, call 911 or an ambulance, and then give artificial respiration, preferably mouth-to-mouth if possible. Call a poison control center or doctor for further treatment advice.

Skin Contact: Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for further treatment advice.

Eye Contact: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for further treatment advice.

If Swallowed: Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center of doctor. Do not give anything by mouth to an unconscious person.

NOTES TO PHYSICIAN

Chlorine dioxide vapors are emitted when this product contacts acids or chlorine. If these vapors are inhaled, monitor patient closely for delayed development of pulmonary edema which may occur up to 48-72 hours post inhalation.

SECTION 5: FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Autoignition temperature</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Flammable Limits – LEL</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Flammable Limits – UEL</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>

EXTINGUISHING MEDIA

Water unless contraindicated by other materials involved in the fire.

FIRE-FIGHTING EQUIPMENT

Standard protective gear with self-contained breathing apparatus.

SPECIAL FIRE-FIGHTING PROCEDURES

Do not allow product to evaporate to dryness. If chlorine dioxide gas is produced, vent to atmosphere. Open or vent any large containers.

UNUSUAL FIRE OR EXPLOSIVE HAZARDS

The sodium chloride in dried CHEMIXENE® is a strong oxidizer, which supports combustion. Chlorine dioxide, which may evolve from CHEMIXENE® solutions, is explosive in the gaseous phase at concentrations greater than 10% by volume. Do not allow chlorine dioxide gas to accumulate within a confined space.

Note: See STABILITY AND REACTIVITY (SECTION 10) for hazardous combustion and thermal decomposition information.

SECTION 6: ACCIDENTAL RELEASE MEASURES

ENVIRONMENTAL NOTIFICATION

All spills and leaks involving more than 10 gallons should be reported to the nearest regional EPA office or designated state emergency response office with 24 hours. Spills from ocean vessels or which may contaminate U.S. coastal waterways should be reported to the nearest Coast Guard office within 24 hours.

SPILL OR LEAK PROCEDURE

Small spills, involving less than 10 gallons, may be flushed to a designated and permitted sewer system with the amount of water that is about 10 times the amount of the spill.

Large spills, involving more than 10 gallons, should be contained and neutralized using any one
of the three neutralizers: i) sodium sulfite, ii) sodium bisulfite, or iii) sodium thiosulfate. The neutralization reaction can be extremely exothermic, and therefore, care should be taken to add the neutralizer in small increments. Sodium sulfite is the most preferred (least exothermic) neutralizer that can be used in the ratio of 1 lb. per gallon of spilled material. Sodium thiosulfate can be used in the ratio of 2 lbs. of anhydrous salt or 3 lbs. of pentahydrate salt per estimated gallon of the spilled material. The neutralized solution can then be flushed to a designated and permitted sewer system with double the amount of water. The product that is not neutralized may be disposed of as chemical waste in the manner indicated below. The vicinity of the spill should be thoroughly flushed with water after clean-up. At no time should the spilled material be allowed to dry to a crystalline salt. Do not discharge this product to storm drains or to any surface or groundwater source unless specifically allowed under a valid NPDES permit.

If the neutralizer is not available, volumes larger than 10 gallons should be carefully transferred into a container and taken to an authorized chemical disposal site (Class I or landfill) in accordance with all federal, state, and local regulations. Consult with selected facility regarding the need for prior neutralization of waste.

SECTION 7: HANDLING AND STORAGE

HANDLING

Use product only as directed by the label. Avoid contact with skin and eyes; avoid breathing any vapors or fumes resulting from product activation. Wash thoroughly after handling. Thoroughly rinse all protective gear and handling equipment, such as transfer pumps and lines, with water prior to reuse or storage. Keep away from children, animals, and unauthorized personnel.

PRODUCT STORAGE

Store in a cool, dry, well-ventilated location away from acids, chlorine and chlorine compounds, hypochlorites (bleach), organic solvents, sulfur and sulfite compounds, phosphorus, combustible/flammable materials, and direct sunlight. Keep containers tightly closed when not in use and open carefully to prevent spillage. Storage on wooden floors and pallets is not recommended. Do not contaminate water, food or feed by storage or disposal.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS

VENTILATION

Open air or good room ventilation is normally adequate for safe use of this product. Avoid breathing any vapors or fumes resulting from acid activation.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Eye/Face Protection

Good manufacturing practice recommends use of chemical safety goggles for all applications involving chemical handling.

Skin Protection

Good manufacturing practice recommends that, at a minimum, rubber, neoprene, or other chemically impervious gloves be worn for all applications involving chemical handling.

Respiratory Protection

In accordance with OSHA regulations (29 CFR 1910.134 and 29 CFR 1910.1000), fogging or spraying applications may require worker respiratory protection, such as: (1) NIOSH/MSHA approved air-purifying respirators, or (2) NIOSH/MSHA approved canister/cartridge facial respirators rated for chlorine/acid vapors or specified for chlorine dioxide.

General

Product should be stored and applied in close proximity to a safety shower, chemical eyewash station or other fresh water source.
SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odor, Color, Grade</td>
<td>Clear liquid with very faint chlorinous odor</td>
</tr>
<tr>
<td>General Physical Form</td>
<td>Liquid</td>
</tr>
<tr>
<td>Volatile Organic Compounds</td>
<td>&lt;0.1% by weight</td>
</tr>
<tr>
<td>Flash Point</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Evaporation Rate</td>
<td>Comparable to water</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Complete</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>213°F (100.5°C)</td>
</tr>
<tr>
<td>Vapor Density</td>
<td>0.02 kg/m³</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>23.7 mm Hg (25°C)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.03 g/ml (20°C)</td>
</tr>
<tr>
<td>pH</td>
<td>8.0 – 8.5</td>
</tr>
<tr>
<td>Melting point</td>
<td>Not determined.</td>
</tr>
</tbody>
</table>

SECTION 10: STABILITY AND REACTIVITY

CHEMICAL STABILITY

Stable

Materials and Conditions to Avoid:

Avoid storing product under conditions in which it could evaporate to crystalline salt. Avoid accidental contact of concentrate with acids, chlorine compounds, hypochlorites (bleach), sulfur and sulfite compounds, phosphorous, organic solvents and combustible/flammable material.

Hazardous Reaction and Decomposition Products:

Exposure to acids or chlorine compounds can produce uncontrolled generation of chlorine dioxide gas.

Hazardous Polymerization:

Hazardous polymerization will not occur

SECTION 11: TOXICOLOGICAL INFORMATION

ANIMAL TOXICOLOGY

- Inhalation LC₅₀: >5.61 mg/l
- Dermal LD₅₀: >2,020 mg/kg (rabbit)
- Oral LD₅₀: 4,360 mg/kg (rat)

CARCINOGENICITY

Active ingredients are not listed by ROTECS, OSHA, IARC, NTP or EPA. No evidence to date implicating product as a carcinogen or tumor promoter.

MUTAGENICITY

Though product active ingredient is a chemical oxidant, no evidence to date for mutagenicity from whole animal or in vitro studies.

REPRODUCTIVE/DEVELOPMENTAL TOXICITY

No known effects to date.

SECTION 12: ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION
This product is toxic to fish and aquatic organisms. Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the sewage treatment plant authority. For guidance, contact your State Water Board or Regional office of the EPA.

SECTION 13: DISPOSAL CONSIDERATIONS

CONTAINER DISPOSAL
Triple rinse. Then offer for recycling or reconditioning; or puncture and dispose of in a sanitary landfill; or by incineration; or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

PESTICIDE DISPOSAL
Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

DISPOSAL PROCEDURE
Small quantities, less than 10 gallons, may be flushed to an authorized and permitted sewer with copious amounts of water. Larger volumes should be taken to an authorized chemical disposal site (Class I or landfill) in accordance with all federal, state and local regulations. Consult with selected facility regarding the need for prior neutralization of waste.

SECTION 14: TRANSPORT INFORMATION

Not DOT Regulated

SECTION 15: REGULATORY INFORMATION

US FEDERAL REGULATIONS

TSCA
All product ingredients are on inventory.

SARA TITLE 312/313
Neither the product nor its constituent ingredients are listed under SARA reporting requirements. Chlorine dioxide produced from activation is listed under SARA 313.

RCRA
Not considered a hazardous waste either categorically or by chemical listing.

FIFRA
CHEMIXENE® is an EPA registered sanitizer (EPA No. 9804-1)

FEDERAL OSHA REGULATIONS
Neither product nor constituent ingredients is classified as an acute or chronic health hazard by OSHA. Chlorine dioxide produced by activation is regulated with an air exposure limit of 0.1 ppm TLV and 0.3 ppm STEL.

STATE LAWS

CALIFORNIA: Not regulated under the provisions of Proposition 65 (Safe Drinking Water and Toxic Enforcement Act of 1986)

NEW JERSEY: Sodium Chlorite is listed under New Jersey’s Chemical Inventory Notification Requirement (NJAC 7:1Z). Estimated release notification, however, is not required.

NOTE: Regulatory requirements are subject to change and may vary from one location to another. It is the user’s responsibility to ensure compliance with all applicable federal, state and
local regulations pertaining to the purchase, transport, storage, use and disposal of this product.

CHEMICAL INVENTORIES

This material contains one or more substances listed on the TSCA Inventory. Commercial use of this material is regulated by the EPA.

This MSDS has been prepared to meet the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200

SECTION 16: OTHER INFORMATION

NFPA Hazard Classification

Health: 1  Flammability: 0  Reactivity: 1  Special Hazards: None

National Fire Protection Association (NFPA) hazard ratings are designed for use by emergency response personnel to address the hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies. Hazard rating primarily based on the inherent physical and toxic properties of the material but also include the toxic properties of combustion or decomposition products that are known to be generated in significant quantities.

NOTICE: Manufacturer believes the information contained herein is accurate; however, we make no guarantees with respect to such accuracy and assume no liability in connection with the use of the information contained herein by any party. Any party using this product should review all such laws, rules or regulations prior to use.

Product may bleach clothing and fabric materials, such as draperies and carpets.

NO WARRANTY IS MADE, EXPRESS OR IMPLIED FOR A PARTICULAR PURPOSE OR OTHERWISE