Contamination Control and Decontamination of Low Moisture Food Processing Facilities Using Chlorine Dioxide Gas

Kevin Lorcheim
Sr. Manager
Low water activity (a$_w$) foods are those with a water activity less than 0.7. Common low water activity foods are:

<table>
<thead>
<tr>
<th>Food</th>
<th>Water activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut Butter</td>
<td>0.7</td>
</tr>
<tr>
<td>Dried Fruit, honey</td>
<td>0.6</td>
</tr>
<tr>
<td>Pasta Noodles (~12 moisture) spices (~10% moisture)</td>
<td>0.5</td>
</tr>
<tr>
<td>Whole Egg Powder (~5% moisture)</td>
<td>0.4</td>
</tr>
<tr>
<td>Cookies, Crackers, Bread crusts</td>
<td>0.3</td>
</tr>
<tr>
<td>Instant Coffee</td>
<td>0.2</td>
</tr>
<tr>
<td>Whole Milk Powder, Dried Vegetables, Corn Flakes, Dehydrated soups</td>
<td>0.03</td>
</tr>
</tbody>
</table>
7 Steps of Effective Dry Sanitation

1. Pre-sanitation preparation
2. Securing and disassembling
3. Dry cleaning
4. Detail cleaning
5. Self-inspection
6. Final Inspection
7. Final sanitizing and assembling
7 Steps of Effective Dry Sanitation

1. Pre-sanitation preparation
2. Securing and disassembling
3. Dry cleaning
4. Detail cleaning
5. Self-inspection
6. Final Inspection
7. **Final sanitizing** and assembling

Chlorine dioxide gas fits in during Step 7 as a final decontamination step
Chlorine dioxide gas is an EPA registered sterilant, capable of eliminating all viruses, bacteria, molds, and spores.

**Chemical Properties:**
- Yellow-Green Gas
- Water Soluble
- Boiling Point 51°F
Types of Antimicrobial Pesticides

Sterilizers (Sporicides): Used to destroy or eliminate all forms of microbial life including fungi, viruses, and all forms of bacteria and their spores. Spores are considered to be the most difficult form of microorganism to destroy. Therefore, EPA considers the term Sporicide to be synonymous with "Sterilizer."

Disinfectants: Used on hard inanimate surfaces and objects to destroy or irreversibly inactivate infectious fungi and bacteria but NOT necessarily their spores. Disinfectant products are divided into two major types: hospital and general use.

Sanitizers: Used to reduce, but not necessarily eliminate, microorganisms from the inanimate environment to levels considered safe as determined by public health codes or regulations.

Antiseptics and Germicides: Used to prevent infection and decay by inhibiting the growth of microorganisms. Because these products are used in or on living humans or animals, they are considered drugs and are thus approved and regulated by the Food and Drug Administration (FDA).

http://www.epa.gov/oppad001/ad_info.htm
There are four keys to achieving an effective decontamination

The decontamination method must:

- Be able to kill the organism in question
- Achieve good and complete distribution
- Achieve thorough and total penetration
- Achieve sufficient contact time at the correct concentration
Traditional sanitation methods can have difficulty guaranteeing that all organisms have been contacted / contacted with the proper dosage.

The decontamination method must:

- Be able to kill the organism in question
- Achieve good and complete distribution
- Achieve thorough and total penetration
- Achieve sufficient contact time at the correct concentration
Niches
Niches
Niches
Scratches²,³ - Crevices - Punctures¹

Traditional Sanitation

With the difficulty that traditional sanitation can have in reaching ALL of the organisms including the niches and harbor locations, you’re left playing microbial whack-a-mole with persistent contaminations that keep popping back up.
**Distribution**

*A chemical can’t kill what it can’t reach.*

<table>
<thead>
<tr>
<th></th>
<th>Chlorine Dioxide Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>51°F</td>
</tr>
<tr>
<td>Natural State at Room</td>
<td><strong>Gas</strong></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
</tr>
</tbody>
</table>

Gasses fill the space they are contained within evenly and completely.

Chlorine Dioxide Gas is able to evenly fill the area it is decontaminating, no matter how large, tall or filled with equipment.
Distribution

86'
Distribution
Penetration into Crevices
Organisms sizes vs ClO₂ molecule

- Norovirus 27-38 nm
- Adenovirus 90 nm
- E. coli 2 µm
- Fog / Mist Droplet 5 µm

Magnified scratch in stainless steel harboring bacteria
## Process Verification

<table>
<thead>
<tr>
<th>QA Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration Monitor</td>
<td>Verifies the concentration of CD gas during a decontamination and overall cycle dosage</td>
</tr>
<tr>
<td>Biological Indicators</td>
<td>Verifies that the decontamination cycle achieved 6-log sporicidal reduction</td>
</tr>
<tr>
<td>Swab Testing</td>
<td>Verifies that the organism itself is no longer present</td>
</tr>
</tbody>
</table>
Concentration Monitoring

The concentration of chlorine dioxide gas can be monitored and logged during a decontamination.

2 main methods:

Chemical Sensor

uv-vis spectrophotometer
Chemical Sensor:

**Advantages:**
- Relatively Inexpensive

**Disadvantages:**
- Difficult to monitor multiple points within environment
- Less accurate due to saturation issues

Uv-vis spectrophotometer:

**Advantages:**
- Highly accurate
- Able to monitor multiple points within environment

**Disadvantages:**
- More expensive
Decontamination Dosage

Biological indicators consist of a semi-permeable outer packaging and an interior carrier impregnated with bacterial spores. For sterilization, BI’s contain over 1 million bacterial spores, providing the ability to prove a 6-log (99.9999%) sporicidal reduction.

Biological Indicators for chlorine dioxide gas use either *bacillus atrophaeus* or *geobacillus stearothermophilus* spores.
After the decontamination process is complete, BI’s are collected and aseptically dropped into growth media tubes and incubated. If even one spore was not killed, they will grow and the bacteria will multiply causing turbidity (cloudiness) or a color change within the media tube.

CD gas has a 36-48 hr incubation time depending on BI manufacturer.

Positive for growth
(Decon unsuccessful)

Negative for growth
(Decon successful)
Penetration into Open and Closed Cabinets

BI Placed in OPEN Cabinet

BI Placed in CLOSED Cabinet

BOTH BIs Killed
Penetration Under Forklift Tire

BI Killed
Penetration Behind Objects

BIs Killed
Penetration into Grain, Powdered Milk, Protein Powder, Sugar, Flour, Baby Formula

ALL BIs Killed
Certain chlorine dioxide gas products are registered as sterilants, which means they are capable of eliminating all viruses, bacteria, molds (fungi) and spores.
Spores are the most resistant microbial organisms. Spore reduction is aided by increased humidity (~65% RH) which causes spores to swell and crack, allowing the chemical to enter and inactivate the spore.

<table>
<thead>
<tr>
<th>Decreasing Resistance</th>
<th>Type of Microorganism</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bacterial Endospores</td>
</tr>
<tr>
<td></td>
<td>Mycobacteria</td>
</tr>
<tr>
<td></td>
<td>Non-enveloped, non-lipid viruses</td>
</tr>
<tr>
<td></td>
<td>Fungi</td>
</tr>
<tr>
<td></td>
<td>Gram-negative vegetative bacteria</td>
</tr>
<tr>
<td></td>
<td>Gram-positive bacteria</td>
</tr>
<tr>
<td></td>
<td>Enveloped, lipid viruses</td>
</tr>
</tbody>
</table>

Spore Reduction

- Disinfectant
- Sterilant
Some organisms which form spores include:

<table>
<thead>
<tr>
<th>Organism</th>
<th>Associated Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus cereus</td>
<td>Rice, Grains, Cereals</td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td>Home-canned foods, honey, baked potatoes</td>
</tr>
<tr>
<td>Clostridium perfringens</td>
<td>Meats, Stews, Gravies</td>
</tr>
<tr>
<td>Molds</td>
<td>Cheese, Meats, Grain, Flour, Nuts, Apples</td>
</tr>
</tbody>
</table>
Antimicrobial Efficacy

<table>
<thead>
<tr>
<th>Target Organism</th>
<th>Dosage Required using CD Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spores</td>
<td>~600 ppm-hrs for 6-log kill</td>
</tr>
<tr>
<td>Listeria</td>
<td>~300 ppm-hrs for a 5-log kill</td>
</tr>
<tr>
<td>Salmonella</td>
<td>~100 ppm-hrs for 6-log kill</td>
</tr>
</tbody>
</table>

Dosage measured in ppm-hours

600 ppm-hours can be attained by holding a:

300 ppm concentration for 2 hours \((300 \times 2 = 600)\)

or

100 ppm concentration for 6 hours \((100 \times 6 = 600)\)

or

Any equivalent combination of concentration and time*

Chlorine dioxide has been validated to be effective at lower relative humidity, but requires a higher dosage.

<table>
<thead>
<tr>
<th>RH</th>
<th>Dosage Required for 6-log Spore Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>65%</td>
<td>~600 ppm-hrs</td>
</tr>
<tr>
<td>55%</td>
<td>~1000 ppm-hrs</td>
</tr>
<tr>
<td>45%</td>
<td>~1550 ppm-hrs</td>
</tr>
</tbody>
</table>

Raising the humidity levels within a dry environment goes against traditional thinking as it can promote microbial growth.

However, this is followed up with a gaseous sterilant which is capable of reaching and eliminating any microbes within the space.

As the gas is eliminated (typically through the air handling unit) the environment is brought back to its normal dry environment.
A study was performed to demonstrate the effect of chlorine dioxide gas on *Salmonella typhimurium* (ATCC# 14028) at 25% RH

<table>
<thead>
<tr>
<th>Sample</th>
<th>Treatment</th>
<th>CFU Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test 1</strong> (5 glass slides)</td>
<td>720 ppm-hr</td>
<td>&lt;10</td>
</tr>
<tr>
<td><strong>Test 2</strong> (5 glass slides)</td>
<td>720 ppm-hr</td>
<td>&lt;10</td>
</tr>
<tr>
<td><strong>Test 3</strong> (5 glass slides)</td>
<td>720 ppm-hr</td>
<td>&lt;10</td>
</tr>
<tr>
<td><strong>Positive Control</strong> (5 glass slides)</td>
<td>N/A</td>
<td>3.2 x 10^7</td>
</tr>
</tbody>
</table>

Study performed at EMSL Analytical, Inc
Cinnaminson, NJ 9/12/2017
### Cycle Flexibility

<table>
<thead>
<tr>
<th></th>
<th>Chlorine Dioxide Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Not a factor above 52 F</td>
</tr>
<tr>
<td>Starting Relative Humidity</td>
<td>Not a factor</td>
</tr>
<tr>
<td>Equipment Within Space</td>
<td>Not a factor, gas gets everywhere</td>
</tr>
<tr>
<td>Room Shape / Size</td>
<td>Not a factor, gas gets everywhere</td>
</tr>
</tbody>
</table>
Chlorine Dioxide Gas is able to achieve these principles due to its chemical properties.

The decontamination method must:

- Be able to kill the organism in question (Sterilant)
- Achieve good and complete distribution (True Gas)
- Achieve thorough and total penetration (True Gas & Small Molecule)
- Achieve sufficient contact time
- at the correct concentration (Accurate Concentration Monitoring)
Safety
How to Decontaminate Safely

The key component to decontaminating a space safely is to contain it within the area you are treating. This can be done through the following steps:

- Sealing all penetrations leading in / out of the space (such as pipes)
- Sealing off the HVAC system handling the space (where applicable)
- Sealing off the doors and entry points to the space
Chlorine Dioxide is Non-carcinogenic

**Current Uses:**

- Over 700 municipalities use chlorine dioxide to disinfect their public drinking water.
- Used in poultry processing rinse water
- Used in fruit and vegetable rinse water
- Listed as an allowed substance on its National Organic Program’s National List of Allowed and Prohibited Substances

*Chlorine Dioxide is not classified as a carcinogen by any health agency*
The smell of CD is distinguishable from, but similar to the smell of chlorine. This is beneficial as chlorine’s odor is widely known and recognized, so there is no learning curve for personnel in recognizing when there is CD present. While one’s nose is not meant to be used as a primary means of odor detection due to the variance in sensitivity to smell that personnel have, it provides an extra layer of personal protection.
Chlorine dioxide gas is not an ozone-depleting chemical, and can be emitted to the atmosphere in most places*. This offers a quick method of aerating a space after a decontamination is complete.

- Chlorine dioxide gas rapidly dissipates and dilutes in the atmosphere to reduce the danger level
- Sunlight breaks down the gas as well to further reduce any danger

*Emissions are regulated at the state level. Most states do not limit the emission of chlorine dioxide gas.
Whey Powder Processing Facility

578,000 ft³
~75 ft Tall Main Floor
+ Production Floor
+ Bin Room
+ Packaging Room

1st Decon – Contamination Response
2nd Decon – Yearly Preventive Decon
3rd Decon – Yearly Preventive Decon
4th Decon – Contamination Response
5th Decon – Yearly Preventive Decon
Whey Powder Processing Facility
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Chlorine Dioxide Gas

Chlorine dioxide gas is able to achieve a complete 6-log sporicidal decontamination of all surfaces within a space, including hard-to-reach areas such as crevices.

This allows it to successfully treat large areas all at once without missing any organisms and without leaving a residue.
Questions?

Thank you

Kevin Lorcheim
ClorDiSys Solutions, Inc
kevinlorcheim@clordisys.com
908-236-4100