Introduction to Postharvest Water Disinfection Management

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Postharvest Water Applications

- Pre-Cooling Operations:
  - HydroVac™
  - Ice Injection
  - Hydro-Cooling
- Wash and Dip Tanks
- Flume Wash Systems
- Spray Wash Systems
- Ice-making
- Cooling Canals
In Many Cases of Produce Related Food-borne Illness, Postharvest Water Quality at Centralized Packing Has Likely Played a Role in the Extent of the Outbreak

The Predominant role of Disinfection is to prevent introduction and to minimize re-distribution of plant and human microbial pathogens in water. Reduction of surface microbial load is secondary.

What is the Goal of Water Treatment?

Washing Will Not Remove 100% of Firmly Attached Pathogens

Triple washed cilantro leaves

Primary Wash 93% Removal

Tertiary Wash 99.9% Removal
Presence of aggregates remaining attached to the plant surface after vigorous washing

S. enterica [GFP] on cilantro leaf 6 days after inoculation

Credit: Maria Brandl, USDA/ARS

Appropriate Mechanical Action Contributes to Removal of Microbes from Surfaces to Allow Disinfectants to Do Their Work

Examples
- Brush bed
- "Jacuzzi" bath
- Ultrasonic bath
- CO₂ cavitation

Water Infiltration to Produce May Be Significant During Postharvest Handling

- Apples
- Melons
- Peppers
- Spinach
- Mango
- Citrus

Temp
Pressure
Time
Depth
Water deficit
Vacuum

Adequate water sanitation will minimize problems.
Factors in Tomato Fruit Infiltration

- More than 2 min immersion
- More than one layer of fruit submerged
- Typical weight gain < 0.2%
- Stage 1 and 2 fruit more prone than 5 and 6
- Stem scar drying promotes air barrier formation
- Fruit with stem/calyx attached behave as fresh
- Surfactants in water may increase infiltration > 1%
- Waxed fruit may absorb more water in re-pack

Proper Packing and Processing

Water Sanitation is no Mystery

- Maintain consistent sanitizer levels in dump tanks and spray washers
- Regularly check automated sanitizer equipment during daily packing
- Double check automated equipment with manual methods
Types of Water Disinfection Methods

- Non Chemical
- Ultra Violet
- Ultra-Filtration
- Chemical
  - Oxidizer
  - Oxidizer and Acid
  - Non-Oxidizer

Highly Purified Facility Water
Reverse Osmosis and UV-C

UV and Ozone are Especially Good for Disinfection in Ice Production
The Problem
What is the right treatment level?
• Multiple chemical choices
• Multiple product types
• Diverse microbe types
• Different load throughput
• Varying wash/cooling conditions
• Different equipment designs
• Different retention times

Examples of Chemical Disinfection Options
• Chlorination
  – Hypochlorous Acid (HOCl) + ROS
  – Chlorine Gas
  – Sodium Hypochlorite
  – Calcium Hypochlorite
• Chlorine Dioxide
• Chlorobromination
• Peroxyacetic Acid
• Peroxide
• Ozone
• Copper ions + low HOCl (+ Silver ions)

Measuring Chlorination Dose

OCI has about 1/80th the killing potential of HOCl
Free Cl is a mix of forms
Chlorine is Strongly Impacted by pH

<table>
<thead>
<tr>
<th>pH</th>
<th>HOCl</th>
<th>OCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>95%</td>
<td>5%</td>
</tr>
<tr>
<td>7.0</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>7.5</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>8.0</td>
<td>20%</td>
<td>80%</td>
</tr>
</tbody>
</table>

Sodium Hypochlorite Stability Is Reduced with Heat and Light

Do not control by volume-dosing


pH Impact is Much Greater Than Temperature

Figure 1: Available Chlorine (%) at Different pHs and Water Temperatures

From Ritenour et al. MRRC Report; 1999-9
**Chlorination Advantages**

- Sodium Hypochlorite (liquid)
- Most widely used method
- Relatively inexpensive
- Readily available and flexible
- Easy to adopt for small-scale
- Broad spectrum of activity (yeasts, molds, bacteria, most viruses, algae)

**NaOCl Disadvantages**

- Potential for toxic chlorine gas formation
- Poor penetration
- Corrosive
- Irritation
- Unstable (out of pH range <6.0, high temp), short half-life
- Formation of potentially toxic by-products (THM’s, chloramines)
- Potential for sodium injury

**Sodium Injury from Liquid Chlorine**

[Image of apples showing sodium injury]
**Calcium hypochlorite**
- Controlled erosion delivery
- No sodium build-up

**Hyperchlorination of Surface Water May Increase Formation of Undesirable Disinfection By-Products**

Trihalomethanes
- chloroform, bromodichloromethane
  *Known or suspected cancer inducers*

Ozone < Chlorine Dioxide < Chlorine
S. Richardson, EPA

**Chlorine Dioxide \( \text{ClO}_2 \)**
- Oxidizer 2.5x “more effective” than chlorine
- Low Sodium, Low Chlorite
- Does not form by-products THMs /DBP’s
- Does not form chloramines
- Effective at wide pH ranges
Chlorine Dioxide Chlorine Dioxide
Generators

Preliminary Assessment on Efficacy of Chlorine Dioxide in Dump and Flume Water Quality Management
Michelle Danyluk, UF
Karan Khurana, Pulse Instruments, Inc.
Cooperating Tomato Packers
Trevor Suslow, UCD

POTENTIAL MICRO-LOAD FROM INCOMING TOMATO FRUIT

<table>
<thead>
<tr>
<th>Sample Location Code</th>
<th>PCA</th>
<th>ECC-TG</th>
<th>ECC-E. coli (presumptive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roma-type incoming</td>
<td>6.25</td>
<td>5.11</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td>Mature Green Incoming</td>
<td>7.16</td>
<td>6.16</td>
<td>4.15</td>
</tr>
</tbody>
</table>
Ozone (O₃)

- Highly effective oxidizer
- No residual concerns
- Minimal DBP’s
- Kills pathogens Cl doesn’t
Ozone (O₃) Disadvantages

- Unstable (short half life)
- Difficult to monitor concentrations
- Difficult to adjust needs based on demand
- May require use of secondary disinfectant
- Must be generated on site
- Worker Safety Issues, Toxicity
- Corrosive

Peroxyacetic Compounds

\[ \text{H}_2\text{O}_2 + \text{CH}_2\text{COOH} \rightarrow \text{H}_3\text{COOH} \]

Hydrogen Peroxide + Acetic Acid = Peroxyacetic Acid
Peroxyacetic Acid (POAA) Advantages

- Less impacted by organic matter and soil
- Low foaming
- Oxidizer and Metabolic Poison
- Broad spectrum of antimicrobial activity (particularly good on yeast and mold spores)
- No residue & breaks down to water, oxygen and acetic acid
- Generally non-corrosive

Effect of Disinfectant Concentration and Time on Reduction of Salmonella Mixture
### Peroxyacetic Acid Disadvantages

- Corrosive to soft metals and skin
- Strong, pungent odor of concentrate and dilution (worker discomfort & safety)
- Varied activity against fungi
- Build up of acetic acid in water
- Need to monitor water turn-over closely
- Prolonged exposure to product may cause tissue damage

### Copper Ionization Treatment

- Low voltage electrodes release ions in water stream
- Cu ~ 300 ppb; sometimes Ag ~ 40 ppb
- Research supports efficacy
  - Cooling towers
  - Ponds and pools
  - Well water holding tanks
- Very stable in 'clean' water systems
- Very slow acting
- Performance requires low (0.4-0.8 ppm) chlorination
- Uses in postharvest wash and cooling operations

### Measurement

- Spot Checking
  - Chemical Test Kit
  - Chemical Test Strips
  - Colorimeter
  - Direct Measurement Meter
- Portable ORP and pH Meter
- Fixed Continuous Meter
  - ORP and pH Meter
  - Direct Ion Sensor
**Test Strips**
- Fast Spot Checking
- Simple "Dip & Read" 1 Step
- Colorimetric Analysis
- Visual Reading
- Low Cost

**Analysis Methods - Colorimeter**

**Portable Hand Meters**
- Spot Checking
- Simple "Dip & Read" 1 Step
- Relatively Fast
- Higher Accuracy
- Calibrated Measurements
- Digital Reading
- Relatively Low Cost
**Chlorine Sensors**

**Measurement Range**
- 0-2.00 ppm
- 0-20.00 ppm standard,
- 0-200.0 ppm optional

**Monitor, Control, Document**

**Demand-based Disinfection**
- Oxidation Reduction Potential (mV)
- Predicts Disinfection Potential
- Measures Disinfection Potential **NOT** ppm
- Single Value Assessment of Disinfection

**Oxidation-Reduction Potential (ORP)**

*for Water Disinfection Monitoring, Control, and Documentation*

TREVOR S. HUGGARD, Extension Research Specialist, Department of Vegetable Crops, University of California, Davis

Large volumes of water are commonly used during the processing and preservation of minimally processed fruits and vegetables. Economic considerations and regulatory discharge regulations make water recirculation a common practice in the industry. For products that require a cycle of water recirculation to increase the potential risk of foodborne illness by recontaminating a spent source, current standards such as the U.S. Food and Drug Administration’s guidelines state that water must be disinfected prior to re-use.

Distribution of water is a critical component in the personal consumer environment.

**Comparative Oxidative Disinfection Potential: Penicillium expansum**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>Free Cl</th>
<th>ORP (mV)</th>
<th>% Spore Kill 15 secs</th>
<th>% Spore Kill 5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ppm Cl</td>
<td>8.2</td>
<td>100</td>
<td>688</td>
<td>0.9</td>
<td>55</td>
</tr>
<tr>
<td>100 ppm Cl</td>
<td>7.1</td>
<td>100</td>
<td>900</td>
<td>90</td>
<td>99.9</td>
</tr>
<tr>
<td>200 ppm Cl</td>
<td>9.8</td>
<td>201</td>
<td>742</td>
<td>20</td>
<td>99.9</td>
</tr>
<tr>
<td>200 ppm Cl</td>
<td>6.9</td>
<td>200</td>
<td>919</td>
<td>99</td>
<td>99.99</td>
</tr>
<tr>
<td>MWS</td>
<td>7.5</td>
<td>2.2</td>
<td>372</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Comparison of Peroxyacetic Acid Concentration and ORP

- Municipal Water
- Tsunami 100
- PeraSan
- Biocide HS

pH 5.2-8.1
Temp = 2.5°C

T. Suslow UCD; unpublished data

Soil may carry pathogens and interferes with disinfection

Tomato Flume Water Clarity (FAU = NTU)
**Investment in Filtration and Sedimentation**

*Makes All Recirculating Systems Perform Better*

**Flume Flocculant**

**Self-purging filtration**

**Table:**

<table>
<thead>
<tr>
<th></th>
<th>Flume Line Shed A</th>
<th>Flume Line Shed B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Turbidity (FAU)</td>
<td>3060</td>
<td>333</td>
</tr>
<tr>
<td>Conductivity</td>
<td>1558 mS</td>
<td>721 mS</td>
</tr>
<tr>
<td>pH</td>
<td>7.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Free Cl</td>
<td>55</td>
<td>12</td>
</tr>
<tr>
<td>ORP</td>
<td>420</td>
<td>825</td>
</tr>
<tr>
<td>Total fecal coliform</td>
<td>log 5.4 CFU/100ml</td>
<td>&lt; 0.9 log CFU/100ml</td>
</tr>
</tbody>
</table>

**Graph:**

*HOCL Needed to Maintain ORP 750 mV*

- *Turbidity (FAU)*
- *Free Cl*

**Soil g/l**

Chualar Loamy Sand

- **Free Cl**
- **pH**
- **Conductivity**
- **Quality Turbidity (FAU)**

*Investment in Filtration and Sedimentation*
Take Home Messages

- The potential risks of waterborne contamination demand special attention for Quality and Safety
- Select disinfectant on microbial reduction objectives
  - Weigh the pros and cons of each sanitizer to find the one that's right for your operations