Environmental of Pathogens: Sources and Survival

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Sources of Pathogens on the Farm

- **Water** – Most variable factor
- **Animal Manure** – proper composting
- **Farm Animals** – Location from field and runoff control
- **Wild animals** – birds, deer
- **Harvesting, Handling, Processing** – Human factor, equipment wash water
Occurrence of Pathogens in Irrigation Waters used for Produce Production

- **Central America** (2002, 2005) - ~50% of samples positive for *Giardia* and/or *Cryptosporidium*
- **Nigeria** (2001) – 2 to 14% positive for *Salmonella*
- **Brazil** (2006) – 23.5% positive for *Salmonella*
- **Arizona** (2005-2006) 20% positive for norovirus, 21% positive for *Salmonella*
Microbial Water Quality Standards for Irrigation Water

- Geldreich and Bordner (1971) suggested 1,000 fecal coliforms/100mL
- WHO reclaimed wastewater. 1000 E. coli/100 mL
- Recently Suggested Guidelines by producers in the United States
  - 126 E. coli /100 ml – geometric average
  - No more than 235 E. coli / 100 ml in a single sample
  - No greater or equal of 576 E. coli / 100 ml geometric average of 5 samples
Produce Safety Rule: Agricultural Water

- Must be: Safe and of adequate sanitary quality for intended use
- Geometric Mean (GM): <126 CFU (colony forming units) generic *E. coli*/100 ml
- Statistical Threshold Value (STV): <410 CFU generic *E. coli*/100 ml
Agricultural Water – Proposed Microbial Standards

Is the water sourced from a public water system/supply and do you have required documentation? [112.45 (a)(1) or 112.45 (a)(2)]

OR

Is the water treated following the requirements in section 112.43 of the proposed produce safety rule? [112.45 (a)(3)]

NO

Is the water intended to or likely to contact the harvestable portion of produce (other than sprouts) or food contact surfaces during growing? [112.44(c)]

Yes: No Testing Required [112.45(a)]

Yes: Microbial standard for such use: The geometric mean is not to exceed 126 colony forming units (CFU) of generic E. coli per 100 mL and the estimate of the statistical threshold value (STV) of samples must not exceed 410 CFU of generic E. coli in 100 mL of water. (The STV approximates the 90th percentile of the water quality distribution and is intended to be a value that should not be exceeded by more than 10 percent of the samples taken.) [112.44(c)]

Yes: The water may still be used for this purpose if you:

- Meet the microbial standard using a calculated die-off or removal rate:
  - Apply an appropriate time interval (in days) between last irrigation and harvest using a microbial die-off rate of 0.5 log per day, and/or;
  - Apply a time interval (in days) between harvest and end of storage using an appropriate microbial die-off rate, provided there is adequate supporting scientific data, and/or;
Where did value of 126 CFU/100ml of generic *E. coli* come from?
EPA Recreational Water Quality Standard

• USEPA Ambient Water Quality Criteria (1986)
• Recreational Water Quality Criteria (2012)
• Based on population survey data
• Recreational swimmers/beach goers

• 126 CFU (Colony Forming Units)/100 ml = 8 cases of gastrointestinal illness per 1000 swimmers
New Terms!!

**Agricultural Water** = Direct Contact with Harvestable Produce

**Geometric Mean (GM)** = Central Tendency

**Statistical Threshold Value (STV)** = Variability

**Microbial Water Quality Profile** = initial survey findings are used to calculate the GM and STV

**Die-off** = Amount of reduction in bacteria < 4 days

**Annual Verification Survey** = an annual survey of a minimum of five samples per year is required to update the calculations of GM and STV
Normal Distribution of Water Quality Test Results

CFU generic *E. coli*/100 ml

Geometric Mean

Statistical Threshold Value
Covered Produce **AND** Direct Application

**SURFACE OR GROUND WATER**

1. **Microbial Water Quality Profile**
   - **Yes**
     - **Maintain Normal Operations**
     - **Monitor Water Quality**
   - **No**
     - **Apply Mitigation Strategy or Discontinue Use**
     - **Monitor Water Quality**
Apply Mitigation Strategy

**Time Interval Between Irrigation and Harvest**
- 0.5 log reduction per day (≤4 day)
- OR alternative data

**Time Interval Between Irrigation and End of Storage**
- Must have supporting data
- Recordkeeping

**Microbial Water Quality Profile → 1 day die-off**
- 240 CFU/100 ml → 76 CFU/100 ml
- 610 CFU/100 ml → 194 CFU/100 ml

**Goal:** Provide same level of public health protection as using irrigation water that met the standard

**Treat Water**

**Discontinue Use**
- Inspect
- Make changes
- Retest
Microbial Water Quality Standards for Irrigation Water

- Current proposed standard on hold!
- FDA expected to come out with a revised standard in four years after an extensive review
Problems with Irrigation Waters

- 70% of irrigation in the world occurs in developing countries
- Most of the irrigation waters in the developing world are impacted by human waste
- Currently no standards for irrigation waters to be used for produce production from non-reclaimed wastewater source
- All produce in the Western U.S. and Mexico is irrigated
Sources of Irrigation Water

- Ponds
- Rainwater Collection
- Small Streams
Sources of Water

Irrigation Channel

Groundwater
Rainwater Rooftop Collection

- Salmonella
- Campylobacter
- Cryptosporidium
- Giardia
Large Scale Man-made Irrigation Systems

- Water travels hundreds of miles through these systems – very complex systems
- The ecology of pathogens in these systems has not been given serious study
Sources of Pathogens in Irrigation Channels

- Storm water Runoff
- Irrigation return flows
- Pets
- Urban Centers
- Livestock
- Birds
Bathers in Irrigation Source Water
Sources of feces in irrigation canals

Dogs

Birds

Stormwater runoff
Major Factors Controlling the Survival of Pathogens in Irrigation Channels

- Ultraviolet Light
- Temperature
- Sediments

Cross Section of Irrigation Channel
Summary of microbial indicators for irrigation water samples

<table>
<thead>
<tr>
<th>County and sampling period</th>
<th>Statistical parameter</th>
<th>Total coliforms MPN/100 mL</th>
<th>E. coli MPN/100 mL</th>
<th>Enterococcus MPN/100 mL</th>
<th>Clostridium perfringens CFU/100 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Southern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 2001 through March 2003</td>
<td>Arithmetic average</td>
<td>9665</td>
<td>43</td>
<td>458</td>
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<tr>
<td></td>
<td>Geometric average</td>
<td>2056</td>
<td>6</td>
<td>82</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2310</td>
<td>6</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>57</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<tr>
<td></td>
<td>Maximum</td>
<td>&gt;241,920</td>
<td>&gt;1,300</td>
<td>&gt;2,419</td>
<td>42</td>
</tr>
<tr>
<td><strong>Central</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 2002 through February 2003</td>
<td>Arithmetic average</td>
<td>50506</td>
<td>9418</td>
<td>2532</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>Geometric average</td>
<td>4258</td>
<td>18</td>
<td>198</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2620</td>
<td>15</td>
<td>159</td>
<td>2</td>
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<tr>
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<td>Minimum</td>
<td>46</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<tr>
<td></td>
<td>Maximum</td>
<td>&gt;2,419,200</td>
<td>&gt;2,419,200</td>
<td>&gt;241,920</td>
<td>&gt;300</td>
</tr>
</tbody>
</table>
Site SRP 13B (rank 21) showing the levels of indicator organisms throughout the study period.

Log MPN/100 mL

Date

Site SRP 8B (rank 20) showing the levels of indicator organisms throughout the study period.

Log MPN/100 mL

Date

C. perfringens expressed as CFU/100 mL

Concentration of fecal bacteria varies greatly over a year.
Source of Fecal Contamination in Irrigation Canals

- Through the use of genetic markers the animal source of the fecal bacteria can be determined.

- Canals in southern Arizona:
  - 70% birds
  - 20% humans
  - 10% ruminants (deer, cattle, horses)
The University of Arizona

Lettuce Field

Water Sampling

Soil Sampling

Lettuce Sampling

FDA
Impact of Irrigation Water Quality on Crop Contamination

- Highest to lowest contamination after irrigation
  - Cantaloupe (growth of *E. coli* observed)
  - Lettuce
  - Bell Pepper
Surface Soil Inactivation Rates

- Inactivation rate (1/day)

- PRD1
- E. coli 25922

- Greenhouse
### Time (days) to Achieve 99.9% Reduction

<table>
<thead>
<tr>
<th>Organisms</th>
<th>$T_{99.9}$</th>
<th>Cantaloupe</th>
<th>Lettuce</th>
<th>Bell Pepper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>Humid</td>
<td>Dry</td>
</tr>
<tr>
<td><strong>E. coli O157:H7</strong></td>
<td></td>
<td>3</td>
<td>&gt;14</td>
<td>1</td>
</tr>
<tr>
<td><strong>E. coli ATCC 25922</strong></td>
<td></td>
<td>10</td>
<td>&gt;14</td>
<td>3</td>
</tr>
<tr>
<td><strong>Salmonella sonnei</strong></td>
<td></td>
<td>10</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td><strong>Salmonella enterica</strong></td>
<td></td>
<td>5</td>
<td>&gt;14</td>
<td>1</td>
</tr>
<tr>
<td><strong>Hepatitis A Virus</strong></td>
<td></td>
<td>&gt;14</td>
<td>&gt;14</td>
<td>&gt;14</td>
</tr>
</tbody>
</table>
Observations
Microbial Water Quality and Irrigation Water

- Storm events impact water quality in irrigation canals
- Lower water quality in lateral canals
- “Hot Spots” of lower water quality in canal systems
- Lower water quality if canals pass through urban areas
- Increase in *E. coli* in return flows
What’s needed to Assess Risks

- Simple Sanitary Survey
  - Water source
  - Potential for runoff from adjacent farmland or farm animals. Location of septic tank.
  - Distances between potential sources and barriers

- Apps
  - Use of local weather data to assess times of increased risk to water quality
  - Check list of factors to assess risks
We analyzed over 1,200 samples collected over 15 years to assess what factors could indicate elevated levels of *E. coli* were present in irrigation waters.

When should I sample? What effects presence of *E. coli*?
Ag Water app

- Assist growers with GM and STV calculations to determine if their water meets the standards for unrestricted application to produce before harvest

- Assist growers with making food safety management decisions if their water does not meet the standards in the rule, and

- Evaluate current sampling conditions for irrigation water quality to determine the probability of microbial contamination
Main Factors Influencing Occurrence of Coliform and *E. coli* Bacteria in Irrigation Water

- Air Temperature
- Solar Irradiation
- Rainfall
- Dissolved solids – electric conductivity
Main Influential Factors on Water Quality

- Precipitation
- Temperature
- EC/Salinity
- Sediment

*Bacterial Loading*: 
*E. coli* and Salmonella in surface water conveyance systems
WELCOME!
Welcome to the Ag Water application. This tool allows you to assess your water quality, determine your water quality profile and determine your microbial risk.

About Us and Contact Information

Please sign in below or click the link to create a new account.

Email Address

Password

Sign In

Disclaimer: Advice offered within Ag Water app is based on FSMA and LGMA agricultural water recommendations. The creators of Ag Water app will hold no responsibility for decisions made based on its use.

Create Account Forgot Password

Welcome Dametreea Carr
Main Menu

App Overview

Microbial Water Quality Profile

Current Water Sampling Conditions

Settings

About Us and Contact Information

College of Agriculture and Life Sciences
**App Features**

- Add lab results from tested water samples
- Automatic calculation of Geometric average (GM)
- Comparison with standard
- Yes/No result
- Calculation of die-off required
- Western Center for Food Safety Excel Spreadsheet
- University of Arizona
  - Online Calculator
  - App

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**Does your water quality profile meet the FSMA Produce Safety Rule Values?**

<table>
<thead>
<tr>
<th>Difference between WQP values and Rule values (log CFU E. coli/100 ml)</th>
<th>Meets Produce Safety Rule values?</th>
<th>Is microbial die-off required?</th>
<th>Apply number of days between last irrigation and harvest to comply with Rule requirements (die off rate is 0.5 log CFU E. coli/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>-0.12</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>STV</td>
<td>0.21</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

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**LGMA Standard**

Compare Results to LGMA Standard for Foliar Irrigation OR Non-Foliar Irrigation.
Assess Water Sampling Condition

Add Water Source

Water Source Name

Next

Current Water Sources

<table>
<thead>
<tr>
<th>Location</th>
<th>Determine Risk</th>
<th>Delete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>Determine Risk</td>
<td>Delete</td>
</tr>
<tr>
<td>Site 2</td>
<td>Determine Risk</td>
<td>Delete</td>
</tr>
<tr>
<td>Site 3</td>
<td>Determine Risk</td>
<td>Delete</td>
</tr>
<tr>
<td>Canal 7</td>
<td>Determine Risk</td>
<td>Delete</td>
</tr>
</tbody>
</table>

Delete All

Help
CURRENT WATER QUALITY CONDITIONS

This feature evaluates current environmental conditions to determine the potential for microbial contamination in a water source. The probability of contamination is determined using environmental data, current weather conditions, and a user survey that includes water quality parameters specific to the water source in question.
Questions