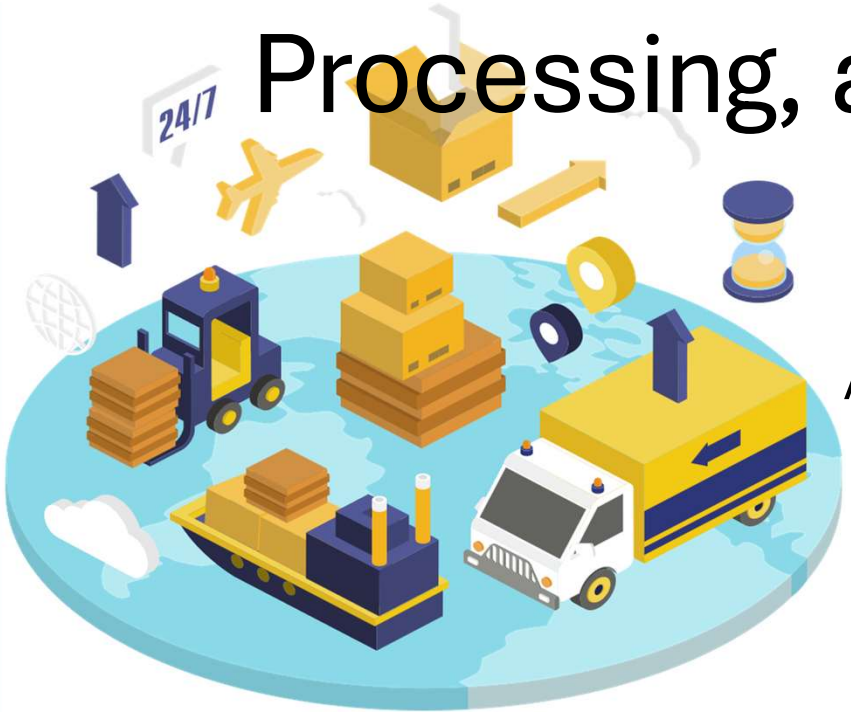
In Between Farm-to-Fork: Produce Safety During Packing, Processing, and Distribution



Laurel L. Dunn, Ph.D.
Associate Professor & Extension Specialist
Dept. of Food Science and Technology

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Overview

- Sanitizer usage in wash waters
- Food safety concerns in distribution and transport
- Well water curriculum for food producers

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TRENDING

Recall alert: Jalapeno outbreak affects 32 states, recall expands

By **Natalie Dreier, Cox Media Group National Content Desk**

August 21, 2026 at 2:59 pm EDT

HEALTH

Centers for Disease Control

Add Topic +

Confirmed cyclospora cases approach 16,000. See where people are sick

Mary Walrath-Holdridge

USA TODAY

Aug. 20, 2026, 4:10 p.m. ET

AP

WORLD U.S. POLITICS SPORTS ENTERTAINMENT BUSINESS SCIENCE MORE

US-Canada tariffs IndyCar America 250 Formula 1 Tropical Storm Moke Karmelo Anthony

HEALTH

Alfalfa sprout linked to food-poisoning outbreak in 15 states, health officials say

FDA U.S. FOOD & DRUG ADMINISTRATION

← Home / Food / Recalls, Outbreaks & Emergencies / Outbreaks of Foodborne Illness / Outbreak Investigation of E. coli O145:H28: Frozen Blueberries (July 2026)

Outbreak Investigation of E. coli O145:H28: Frozen Blueberries (July 2026)

Do not eat, sell or serve recalled GreenWise Organic Frozen Whole Blueberries and Whole Mixed Berries. FDA's investigation is ongoing.

This won’t happen to us because…

Packers and Processors

- We’ve never had an outbreak
- We wash our produce

Consumers

- I wash my produce in [water / vinegar / bleach / baking soda / etc.]
- I stopped eating produce during the last outbreak

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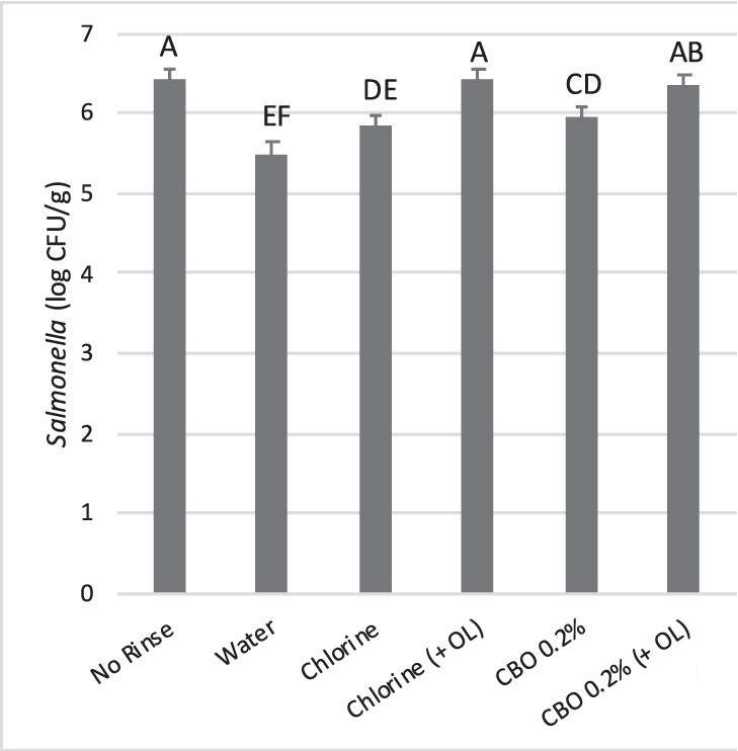
What does produce washing do?



Journal of Food Protection
Volume 82, Issue 1, 1 January 2019, Pages 159-163

Research Papers

Essential Oil Emulsions as Postharvest Sanitizers To Mitigate *Salmonella* Cross-Contamination on Peppers

L.L. Dunn [1,2], M.L. Harness [1], D.M. Smith [1], S.J. Gorman [1], Q. Zhong [1], P.M. Davidson [1], F.J. Critzer [1,3]

- Perhaps a 1 log CFU/g reduction
  1,000,000 → 100,000
- Organic load (soil) in the water will reduce some of that reduction

Washing removes dirt, not pathogens

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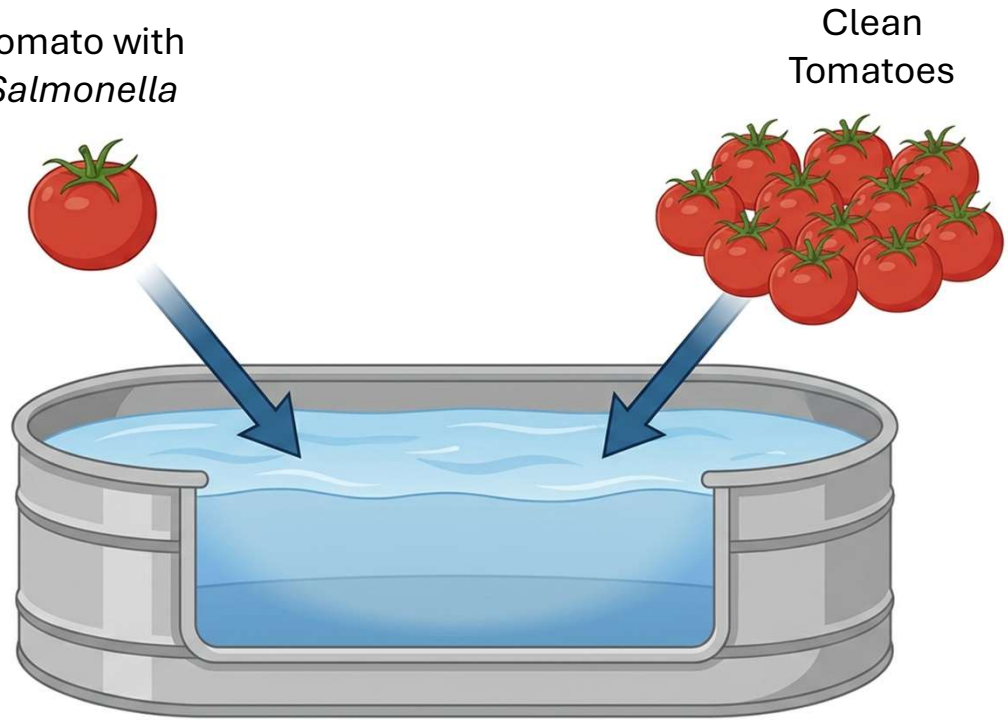
Washing gone wrong is a significant concern

How many tomatoes come out dirty?



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Washing gone wrong is a significant concern

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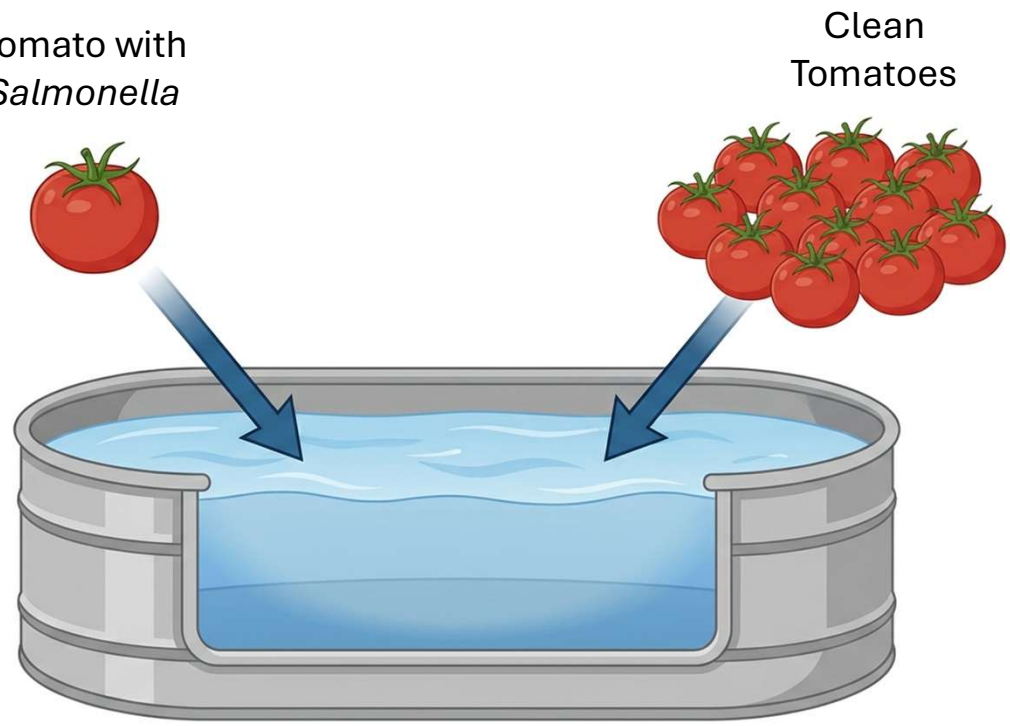

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Washing gone wrong is a significant concern

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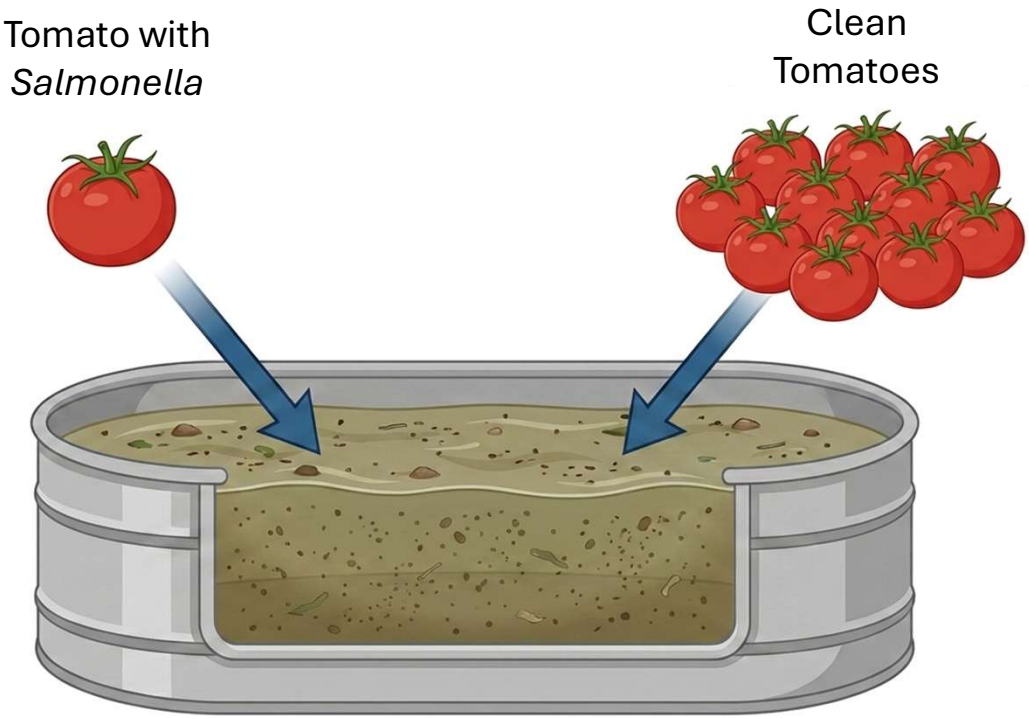

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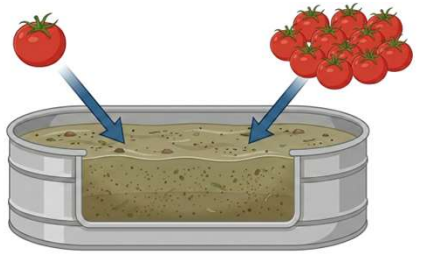
What do we need to be managing in this wash water system?



- Is there residual (measurable) sanitizer this water?
- If using sodium/calcium hypochlorite (bleach), what is the pH of that water?
- Does the firm have a schedule or set parameter established for batch changes?
  - Volume of product
  - End of day/week
  - When residual is exhausted

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Impact of pH

- Farms using peroxyacetic acid (Sanidate, Tsunami, etc.) **do not** need to focus on monitoring pH in their systems
- Chlorine is pH dependent
  - pH above 7.5 **reduced** antimicrobial activity
  - pH below 7.5 **increased** antimicrobial activity

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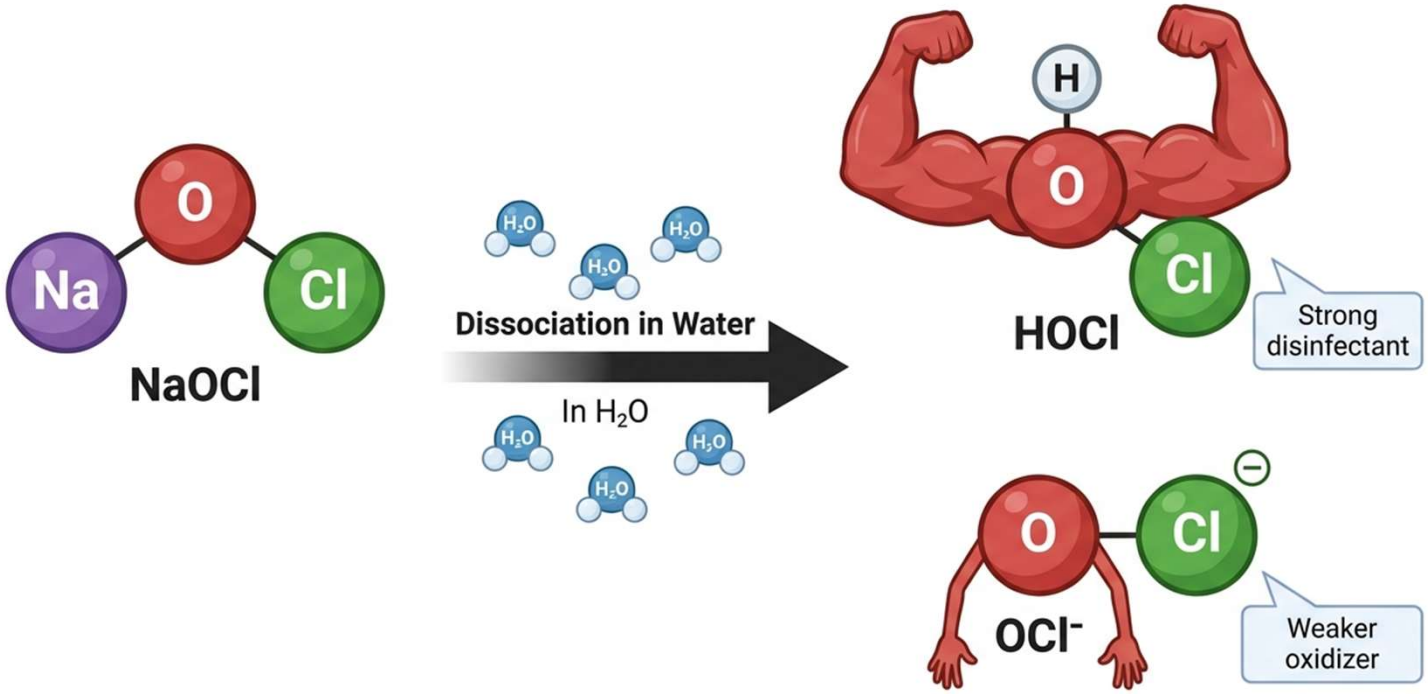
Chlorine and pH



Low pH

High pH

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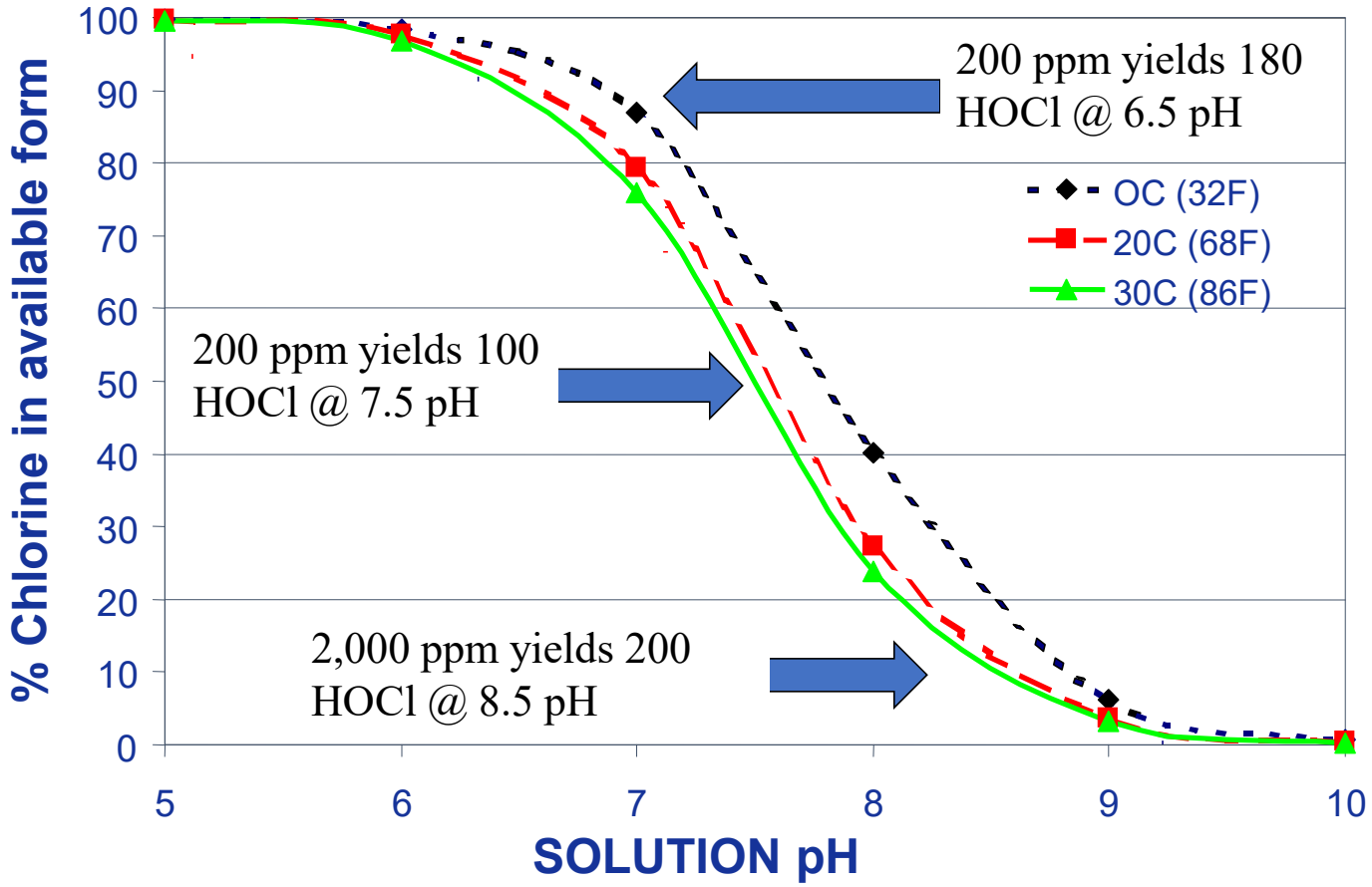
Free chlorine doesn't always mean active chlorine



Monitoring chlorine in wash water

- Measuring the **free chlorine** tells us how much unbound chlorine is in the system
- Measuring the **pH** tells us if that chlorine is in a form that is actively reducing microorganisms in the water

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Final Thoughts on Wash Water

- Adding sanitizer to produce wash waters sanitizes the water and prevents cross-contamination. It does not remove existing contamination from produce.
- It is virtually impossible to meet the Produce Safety Rule requirement of no generic *E. coli* in 100 mL of water in a recirculating system if a sanitizer is not present in that water.
- Washing produce 1) does not fix contamination events from the field and 2) can greatly increase contamination risk if a sanitizer is not used in recirculating systems

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Final Thoughts on Wash Water

Produce safety requires strict adherence to good agricultural practices during production and prevention of cross-contamination during the entirety of postharvest activities

We can’t wash our oops away

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Food Safety Involves the Entire System

Farm

Processing/Packing/Manufacturing

Retail Store

Consumer

Is Anything Missing?

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The Farm to Fork Continuum

Farm

Processing/
Packing/
Manufacturing

Distribution

Retail Store

Consumer

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Preventive Controls for Human Foods Rule
Food Safety Modernization Act

- Facilities that manufacture, process, pack or hold human food
- Identify environmental microorganisms as a hazard in their facilities must implement a preventive control to control the hazard

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Question

How does a distribution center KNOW if they have an environmental hazard that requires a preventive control?

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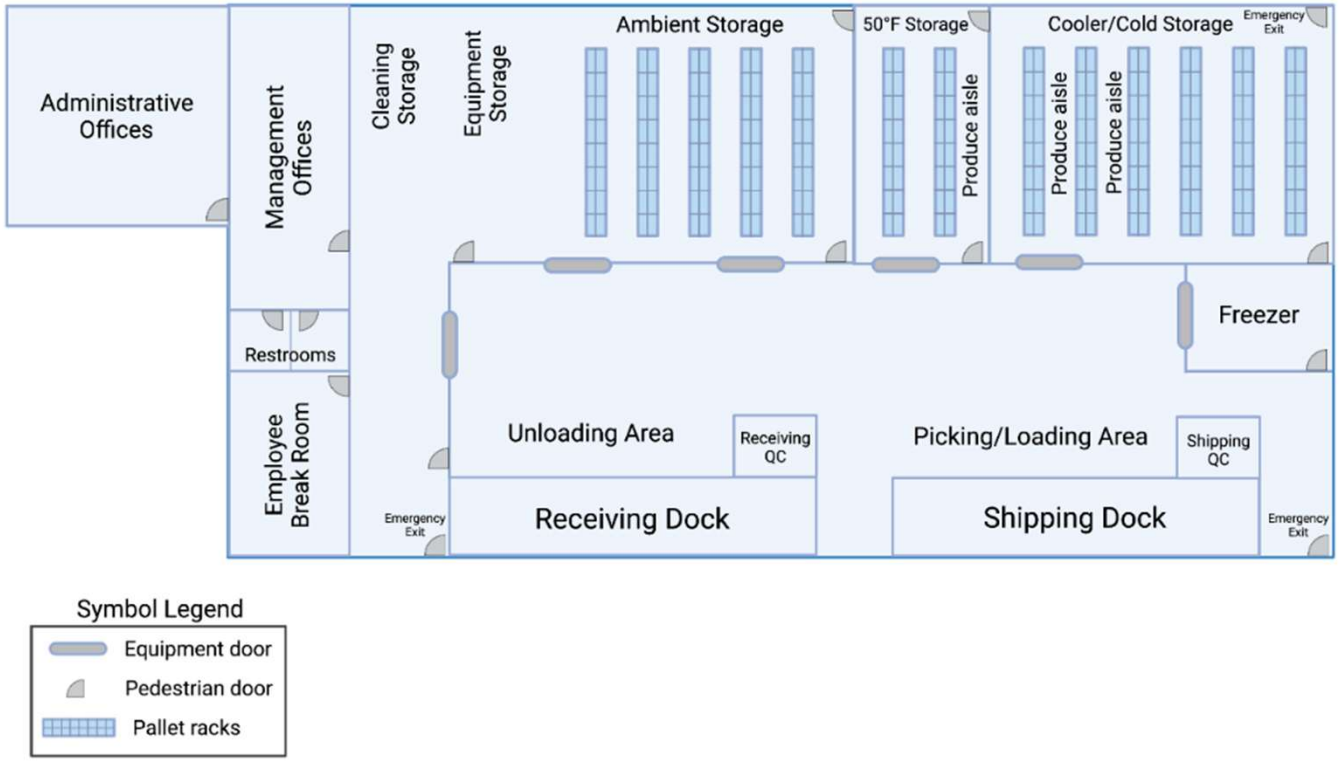
What Do Our Distribution Centers Look Like?



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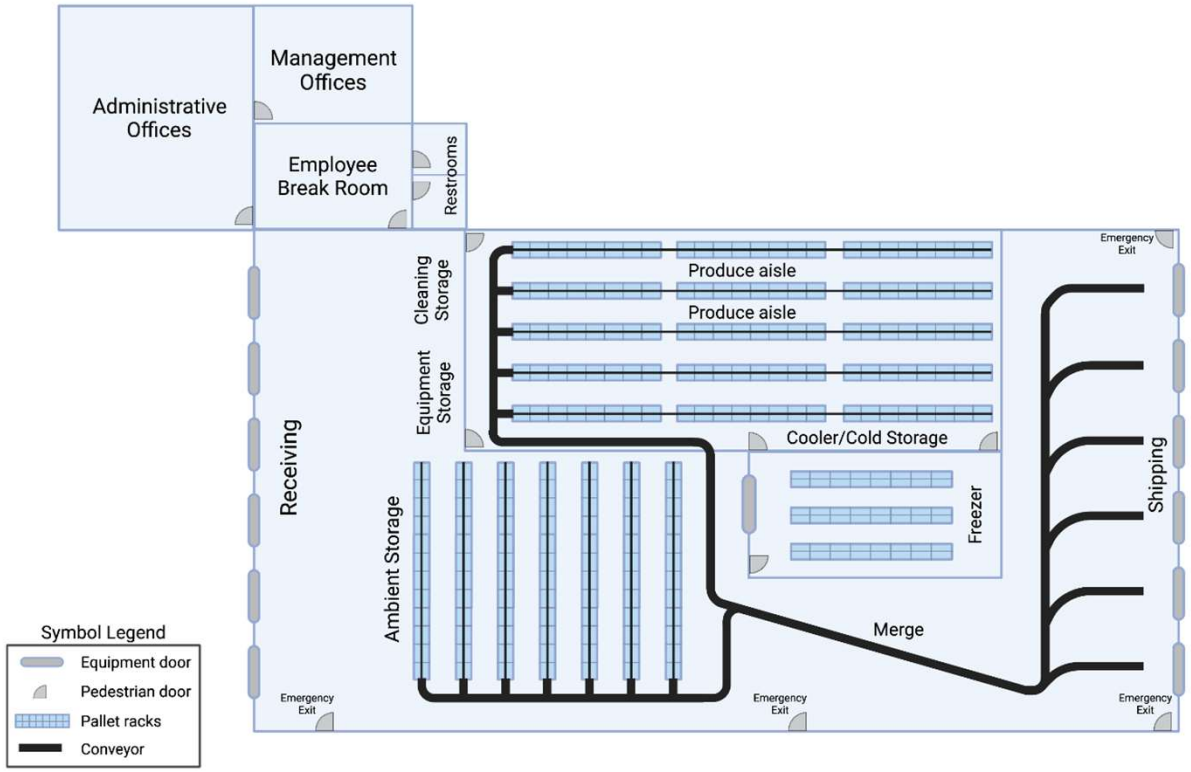
What Do Our Distribution Centers Look Like?



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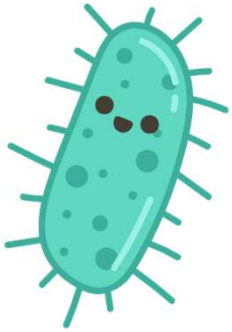
What Environmental Microbial Hazards Could be Present?



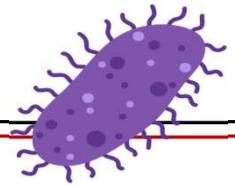
Listeria monocytogenes

Foodborne pathogen

Psychrotrophic

Enters our facilities through outdoor soils, and then thrives is the relatively clean, indoor environment

Very effective biofilm former



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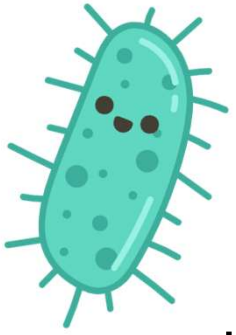
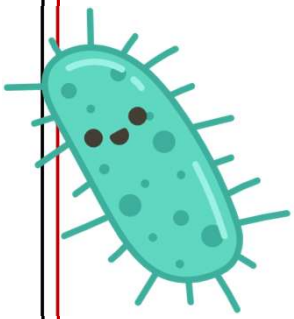
What Environmental Microbial Hazards Could be Present?

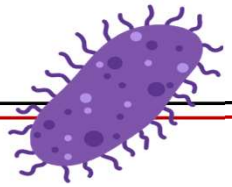


Salmonella enterica

Foodborne pathogen

Associated with fecal material, may come in on product or on pests within a facility





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Why Do We Care about Environmental Microbial Hazards in a Food Distribution Facility?

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Fresh Produce Is Not Fully Sealed

Industry Need

- Risk for contamination to fresh produce entering distribution centers (DC)
- No data on the microbial conditions within the DC environment had yet been published, especially regarding *Listeria* spp. presence
- Little data existed examining the susceptibility of fresh produce in vented packing to environmental contamination

Questions

1. Are indicators of environmental contamination present in the DC environment?
2. What features/practices may reduce or enhance a facility's risk of contamination?

A Systematic Review of *Listeria* Species and *Listeria monocytogenes* Prevalence, Persistence, and Diversity throughout the Fresh Produce Supply Chain

by Anna Townsend [1], Laura K. Strawn [2], Benjamin J. Chapman [3] and Laurel L. Dunn [1,*]

[1] Department of Food Science and Technology, University of Georgia, 100 Cedar St., Athens, GA 30602, USA
[2] Department of Food Science and Technology, Virginia Tech, 1230 Washington St. SW, Blacksburg, VA 24061, USA
[3] Department of Agricultural and Human Sciences, North Carolina State University, Campus Box 7606, Raleigh, NC 27695, USA
* Author to whom correspondence should be addressed.

Foods **2021**, *10*(6), 1427; https://doi.org/10.3390/foods10061427

Submission received: 28 May 2021 / Revised: 15 June 2021 / Accepted: 18 June 2021 / Published: 20 June 2021

Objective

Collect current cleaning and sanitizing practices through a survey and on-site observations in parallel with microbial sampling within fresh produce storage and handling areas in 30 distribution centers.

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Food Microbiology

Volume 107, October 2022, 104065

Factors that predict *Listeria* prevalence in distribution centers handling fresh produce

Anna Townsend [a], Laura K. Strawn [b], Benjamin J. Chapman [c], Mary Yavelak [c], Abhinav Mishra [a], Laurel L. Dunn [a]

Show more

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https://doi.org/10.1016/j.fm.2022.104065

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Methods

Total facilities visited: 18

Environmental sponge swabs

- 40-70 *Listeria* spp. sponge samples (n=982) collected at each facility
  - (Dey-Engley neutralizing broth, FDA BAM method)
- No food contact surfaces (Zones 2-4 only)

Environmental conditions

- Relative humidity and temperature recorded near each sample

ATP sampling

- 15-20 ATP swabs collected from each facility (aligned with sponge swabs)

Air sampling

- 10-15 air samples were collected using impaction air samplers
- Method developed with assistance from Dr. Trevor Suslow

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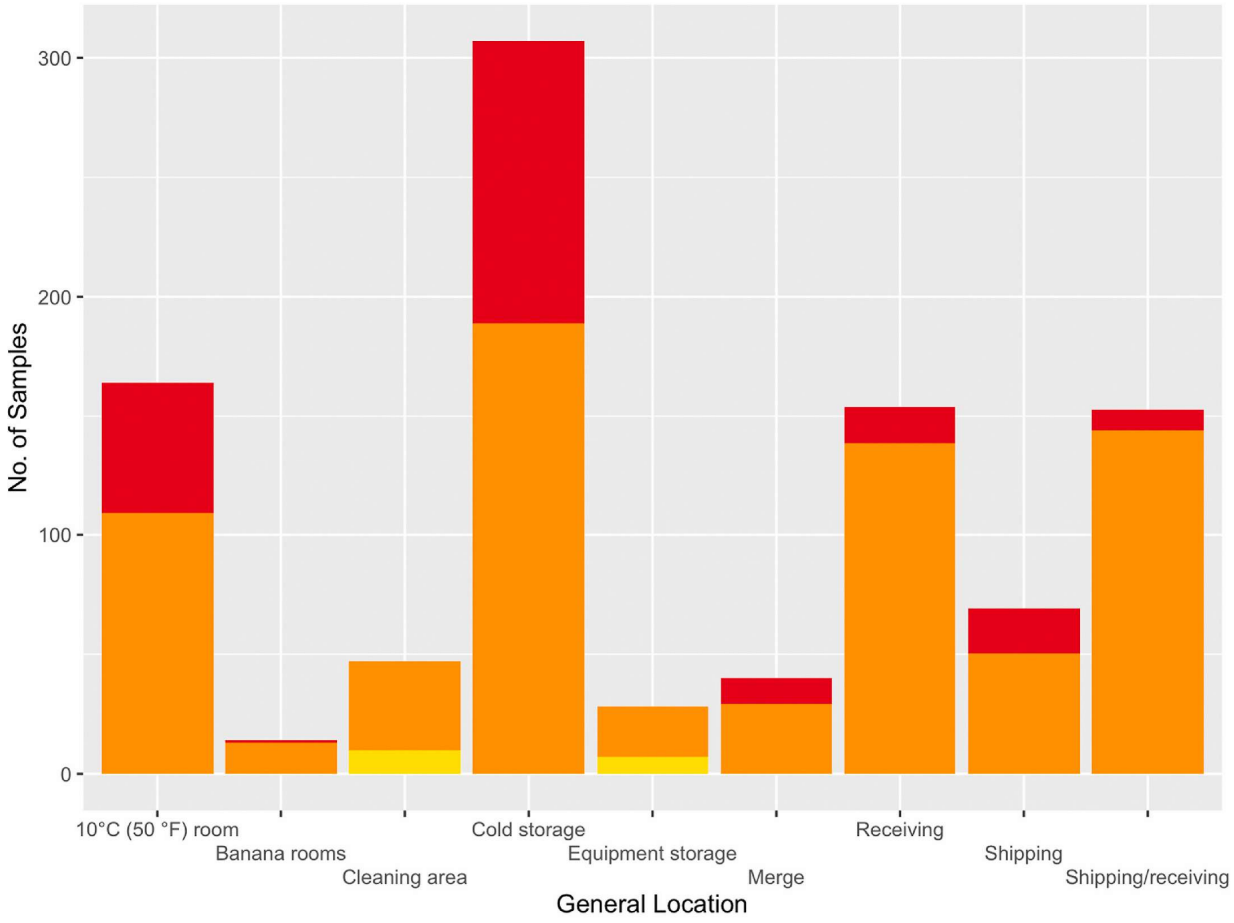
Zone Types and Areas Sampled throughout Distribution Centers Handling Fresh Produce



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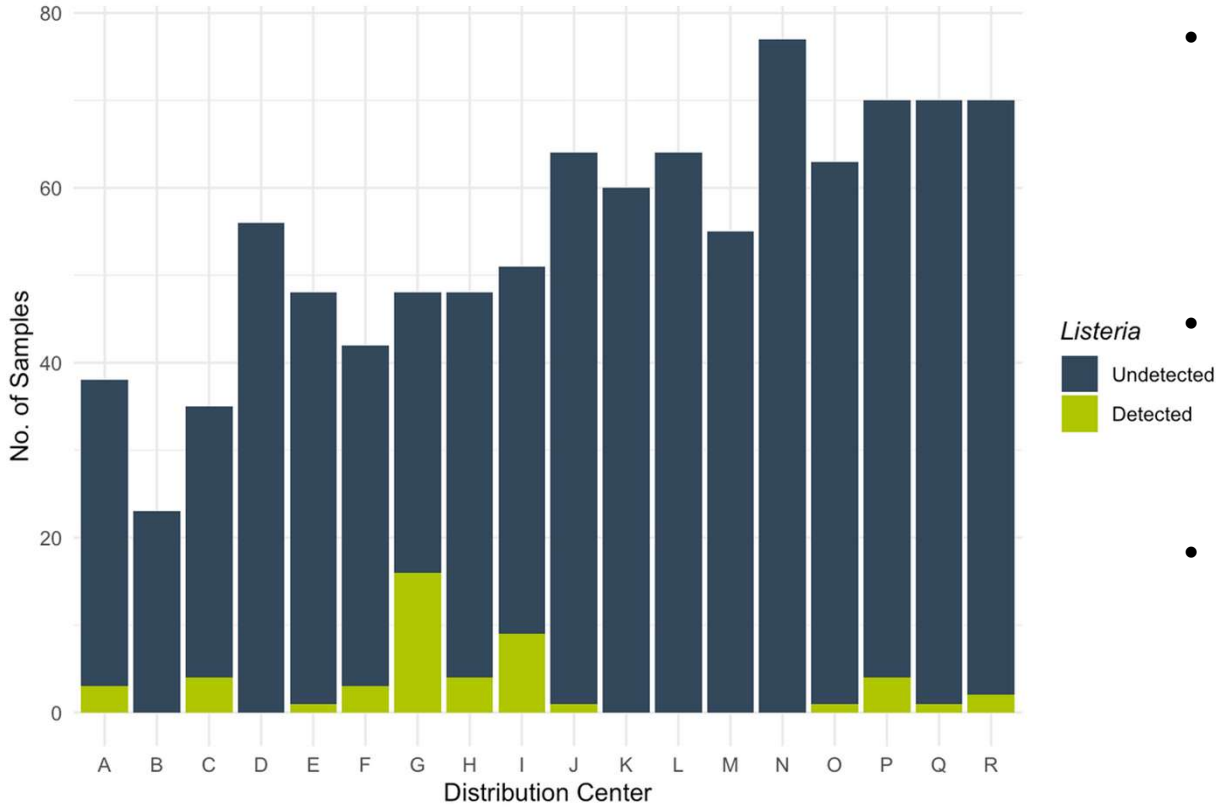
Listeria Prevalence across DCs



- Detection of *Listeria* spp.
  - 12 of 18 (66.7%) DCs
  - Total prevalence ~ 5% (49/982 surface swabs)
- Prevalence of *Listeria* spp.
  - Varied among the 18 DCs
  - 0% to ca. 33%
- Highest % detectable *Listeria* spp.
  - Center **G** - 33.33%
  - Center **I** - 17.65%

Figure 1. Stacked bar and table exhibiting total samples with undetectable and detectable *Listeria* per distribution center (DC).

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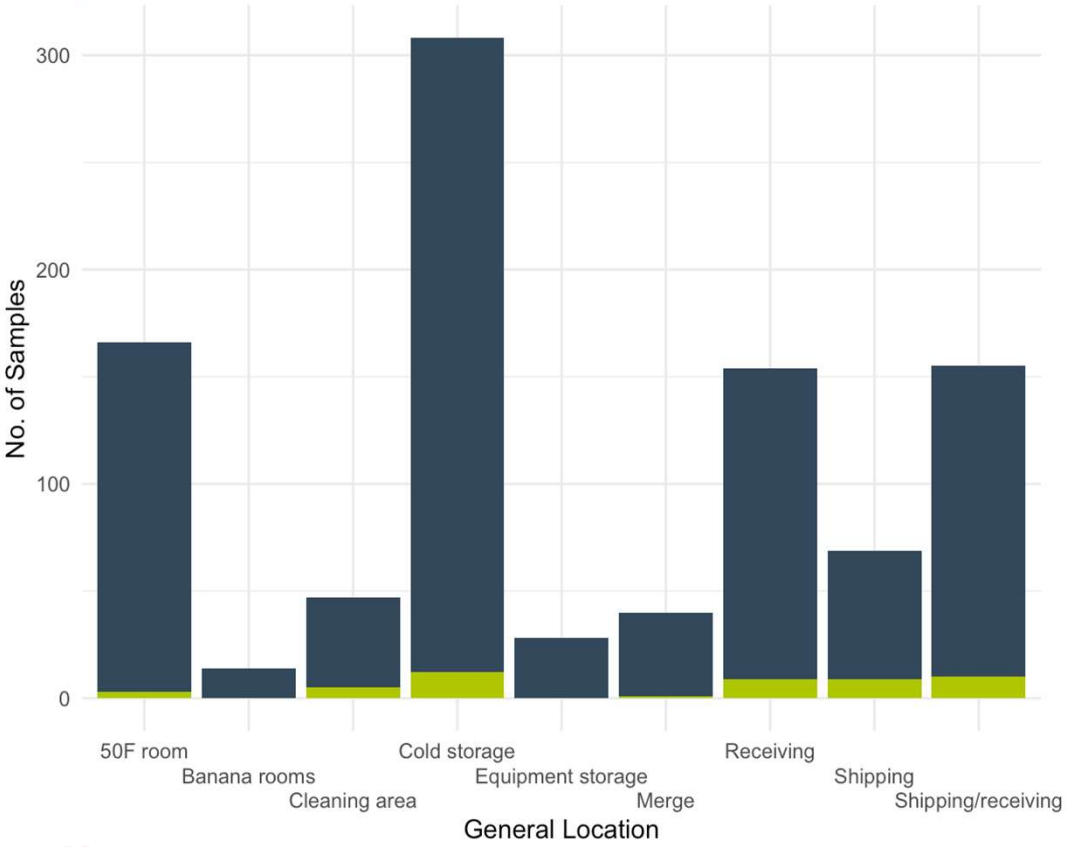

Figure 2. Stacked bar exhibiting total samples with undetectable and detectable *Listeria* per general location within DCs.

Where was *Listeria* found? (general location)

Listeria spp. detected in:

- **Shipping** 9/69 (13.04%)
- **Cleaning area** 5/47 (10.64%)
- **Shipping/Receiving** (combined docks) 10/154 (6.49%)
- **Receiving** 9/153 (5.84%)
- **Cold storage** 12/308 (3.90%)
- **Merge** 1/40 (2.50%)
- **50°F room** 3/166 (1.81%)

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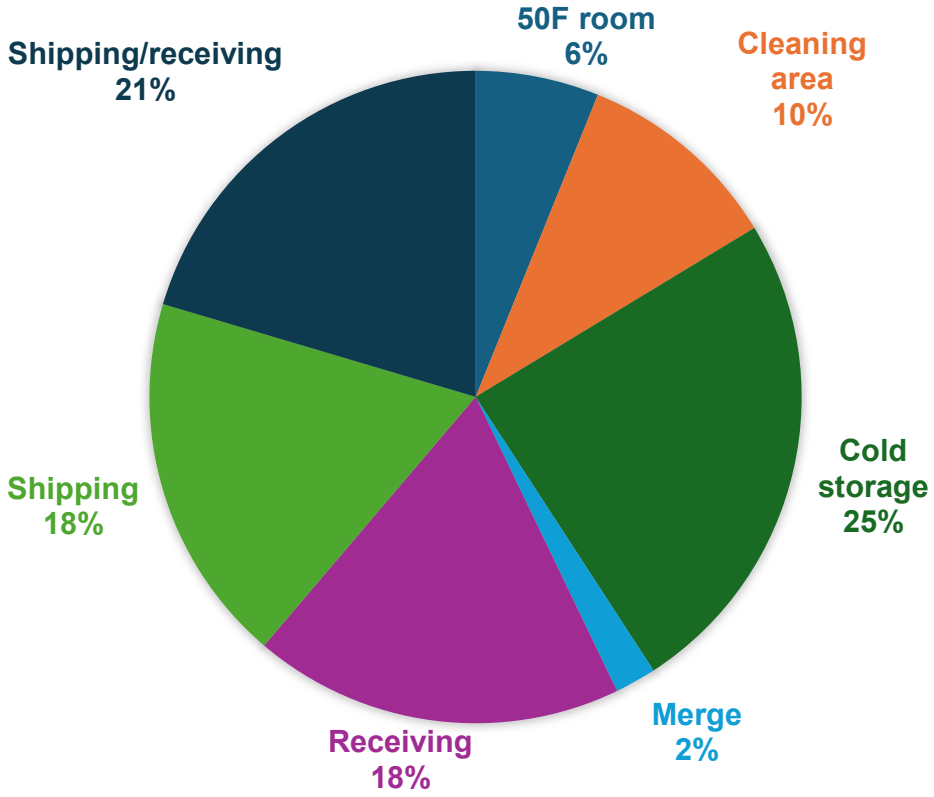
Listeria-detected sample breakdown – general location



For *Listeria*-detected samples (n = 49)**:**

- Cold storage (12/49)
- Shipping/receiving (10/49)
- Shipping (9/49)
- Receiving (9/49)
- Cleaning area (5/49)
- 50ºF room (3/49)
- Merge (1/49)

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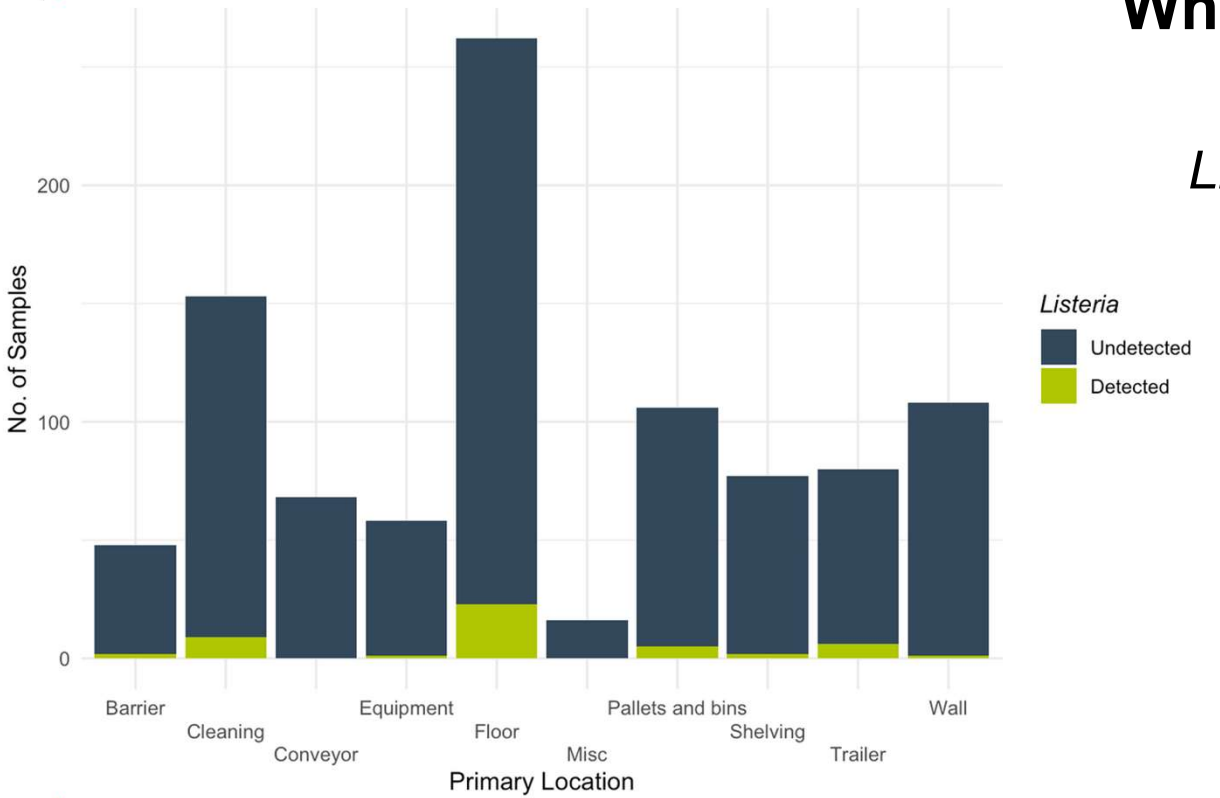

Figure 3. Stacked bar exhibiting total samples with undetectable and detectable *Listeria* per primary location within DCs.

Where was *Listeria* **found?** (primary location)

Listeria spp. detected on:

- **Floors** 23/263 (8.75%)
- **Trailers** 6/79 (7.59%)
- **Cleaning** 9/153 (5.88%)
- **Pallets and bins** 5/105 (4.76%)
- **Barriers** 2/48 (4.17%)
- **Shelving** 2/77 (2.60%)
- **Equipment** 1/58 (1.72%)
- **Wall** 1/108 (0.93%)

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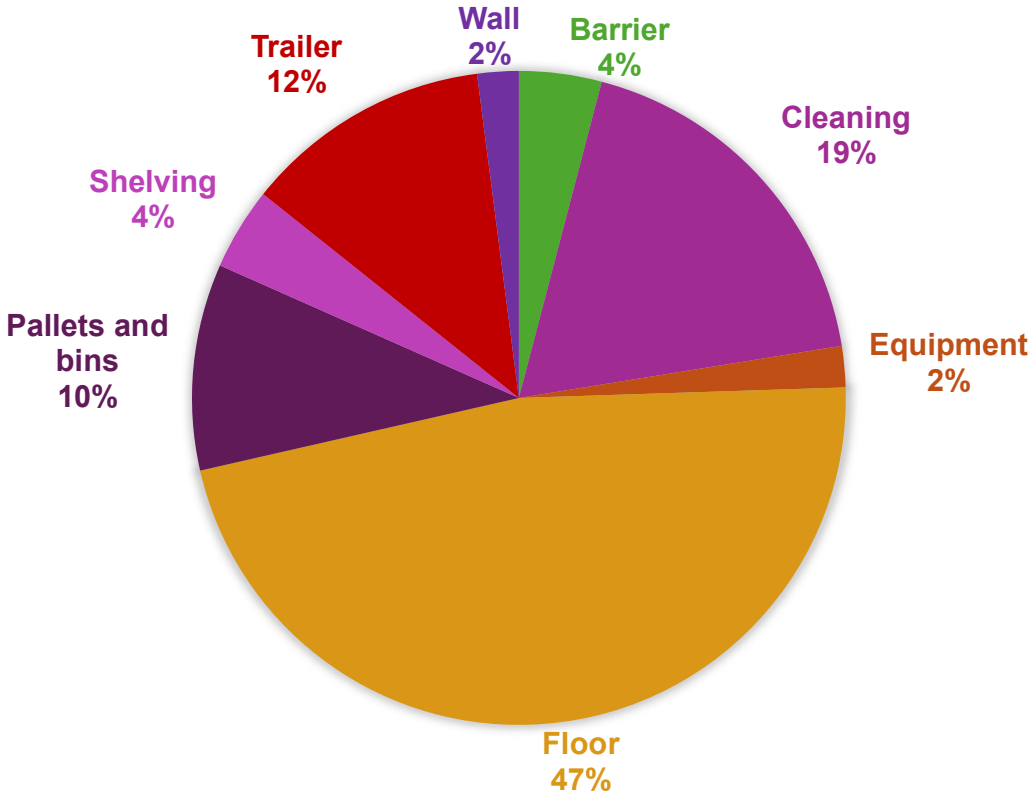
Listeria-detected sample breakdown – primary location



For *Listeria*-detected samples (n = 49):

- Floor (23/49)
- Cleaning (9/49)
- Trailer (6/49)
- Pallets and bins (5/49)
- Shelving (2/49)
- Barrier (2/49)
- Equipment (1/49)
- Wall (1/49)

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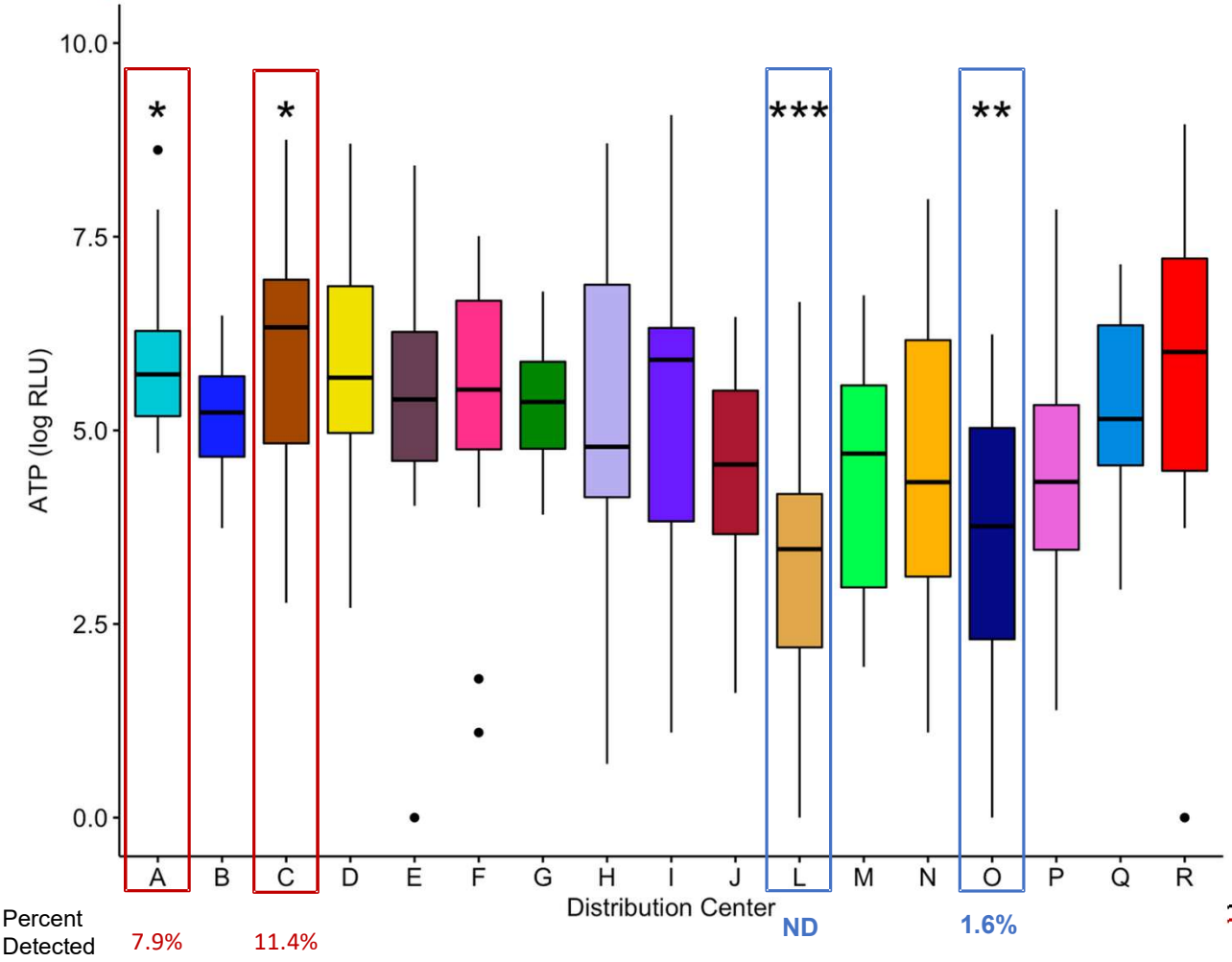
Can we predict *Listeria* presence using ATP?



Percent Detected: 7.9% (A), 11.4% (C), ND (L), 1.6% (O)

Greatest mean log(x+1) RLU values

Center **A** - 5.99 RLU
Center **C** - 5.96 RLU

Lowest mean log(x+1) RLU values

Center **L** - 3.39 RLU
Center **O** - 3.56 RLU

Adenosine Triphosphate Bioluminescence is a Poor Indicator of *Listeria spp.* Presence in Distribution Centers Handling Fresh Produce

Anna Townsend, Laura K. Strawn, Benjamin J. Chapman, Camila Rodrigues, Laurel L. Dunn
Bibliographic citation: Food Protection Trends, vol. 43, no. 1, pp. 33-39, Jan 2023
Volume 43, Issue 1: Pages 33–39
DOI: 10.4315/FPT-22-019

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Measuring Program Effectiveness : ATP testing

Instant feedback on cleaning process

1. Swab surface
2. Snap or add reagent to swab
3. Place swab in the ATP luminometer

Relative Light Units (RLU) quantify how much ATP is present

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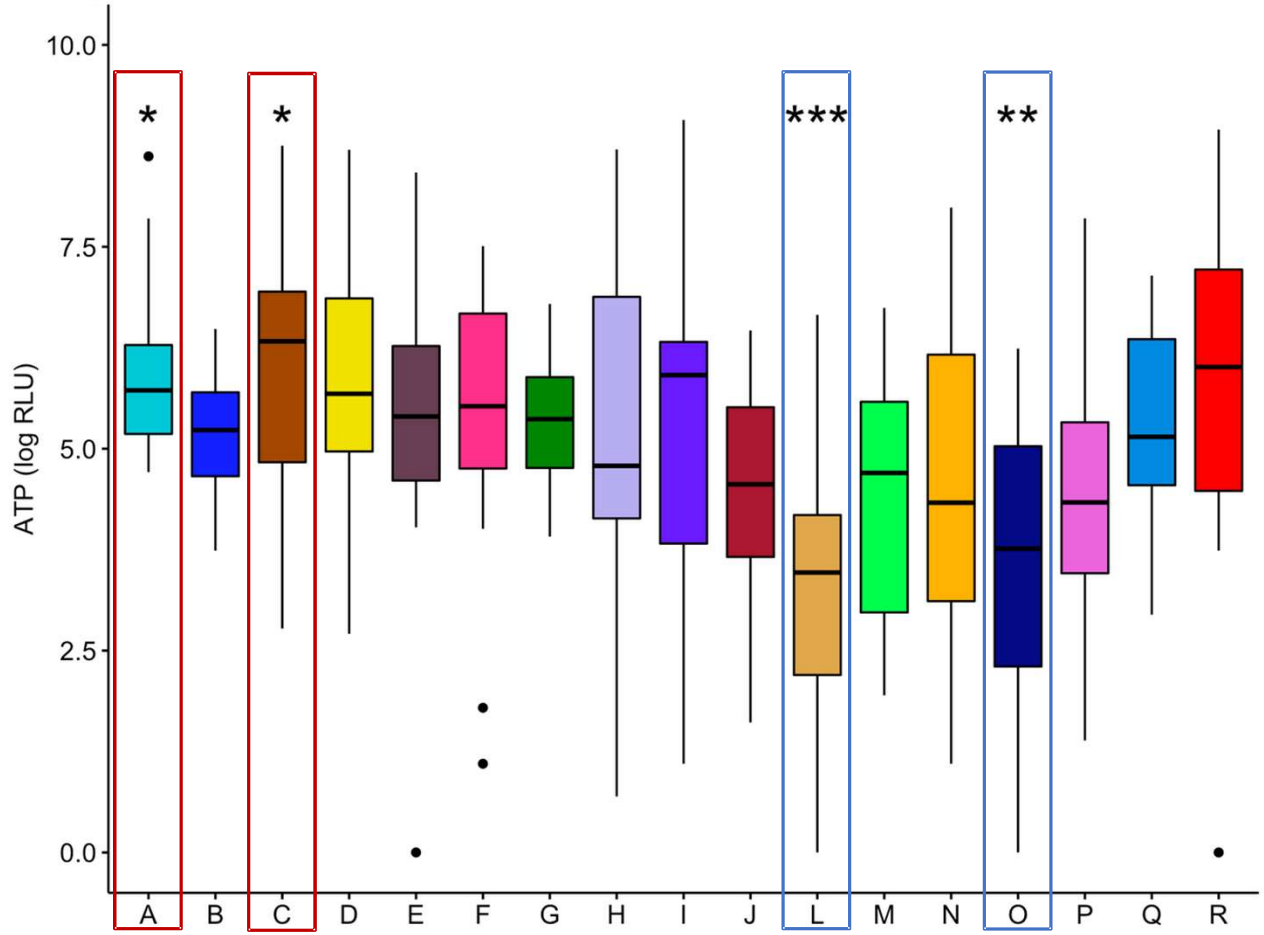
Can we predict *Listeria* presence using ATP?



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RLU = Relative Light Units (quantifies ATP)

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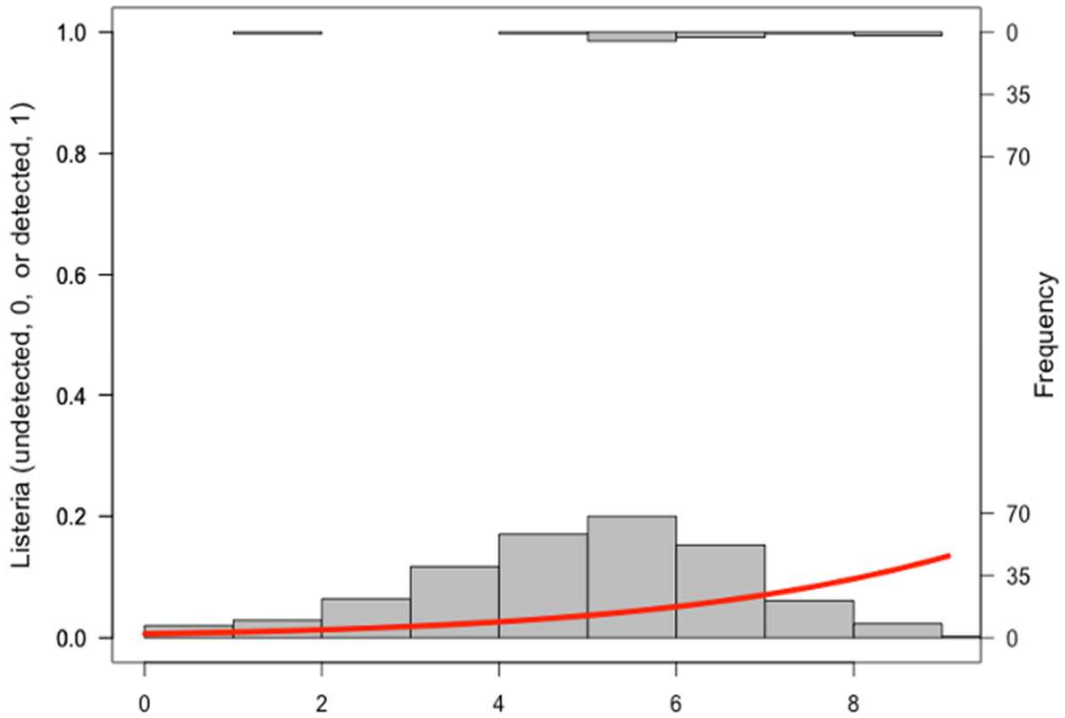
Can we predict *Listeria* presence using ATP?



Logistic regression gave an odds ratio for log transformed ATP of 0.34

- For each additional increase in 1 log RLU, the odds of *Listeria* presence increased by 0.34

ATP appears to be a poor predictor of *Listeria* spp.

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Trailers

- Collected 79 samples in trailers and on equipment used in trailers
- 6/79 (7.59%) tested positive for *Listeria* spp.
- These *Listeria*-detected samples were found on:
  - Trailer floors (n = 3)
  - Bulkhead (n = 1)
  - Plastic ribbon curtains (n = 1)
  - Shelving (n = 1)

We plan on pursuing funding to investigate microbial risks in trailers handling foods

Trailer Transport

- Are we using our own trucks?
  - What sanitation program do we have between loads?
- Are we contracting trucks? What does our contract say about:
  - Trailer sanitation between loads
  - Pets in the trailer
  - Trailer tag seal (security seal) usage
  - Refrigeration (and do we monitor this?)

Where do we go from here?

- Assess hazards within our distribution system
- Determine likelihood of risk from microbial (or other) contamination
- DCs with robust cleaning programs and environmental monitoring programs may not consider *Listeria* a significant hazard in their facilities

ELSEVIER

Journal of Food Protection
Volume 89, Issue 1, January 2026, 100673

Review

Hazard Analysis and Mitigation in Fresh Produce Distribution Centers: A HACCP Approach

Alexis M. Hamilton [1], Anna Townsend Burner [2], Laura K. Strawn [1], Laurel L. Dunn [2]

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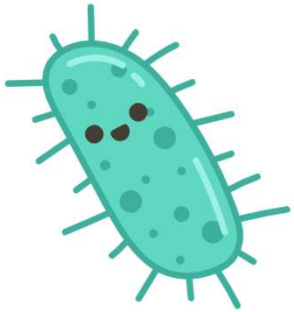
Acknowledgements



- Dr. Anna Townsend (Iowa State University)
- Dr. Laura Strawn and Dr. Ben Chapman
- International Foodservice Distributors Association (IFDA)
- Our industry partners
- Dr. Claire Murphy (WSU), Mary Yavelak (NC State)
- Dr. Jennifer Dorick
- Dr. Camila Rodrigues (Auburn)
- Dr. Trevor Suslow (UC Davis and Produce Marketing Association)
- Dr. Michelle Danyluk (University of Florida)
- Center for Produce Safety

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Well Water Management Short Course

- Stakeholders growing fresh produce or manufacturing food in a facility or home kitchen
- Inspectors of farms and food facilities
- Extension personnel

- ~ 3 hours of content
- Virtual or in-person

- Covers well management, septic systems, and food safety recordkeeping

Managing
Water
Well

Managing
Water
Well

Understanding and Maintaining Your Well

Module 1

What is a Well?

Definition: A deep hole or shaft sunk into the ground to obtain water, oil, or gas.

Image from: https://lovebackyard.com/wp-content/uploads/2017/05/a-water-well.jpg

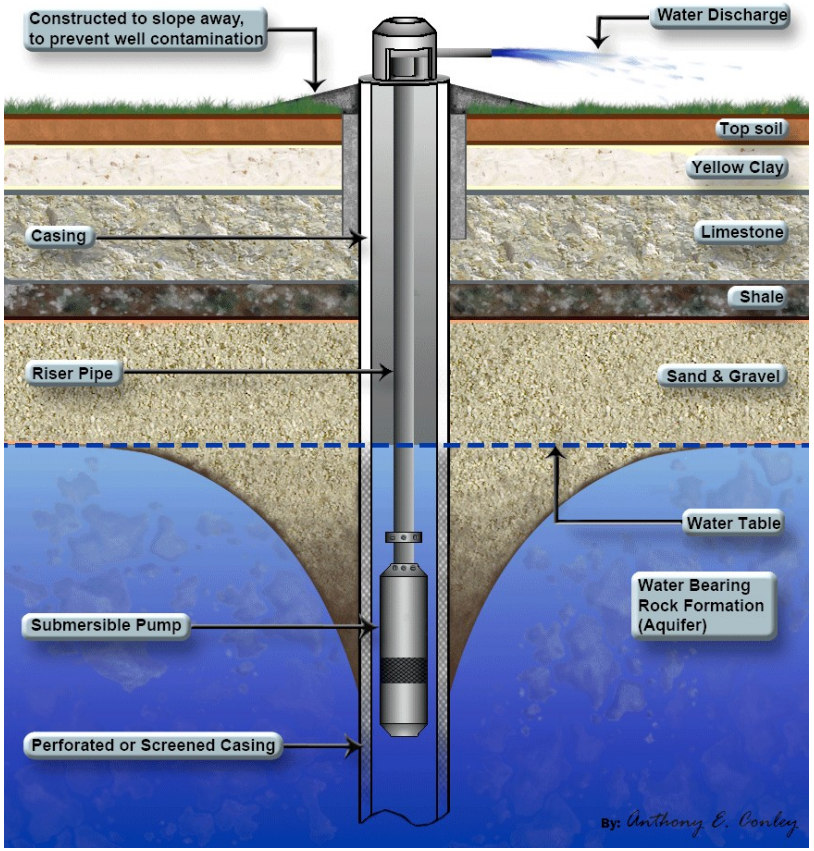


Image from: https://4.bp.blogspot.com/-8teYKYLkOsU/VKBAxUfQmWI/AAAAAAAAAWs/Gp34rzDP7kc/s1600/well-diagram.gif

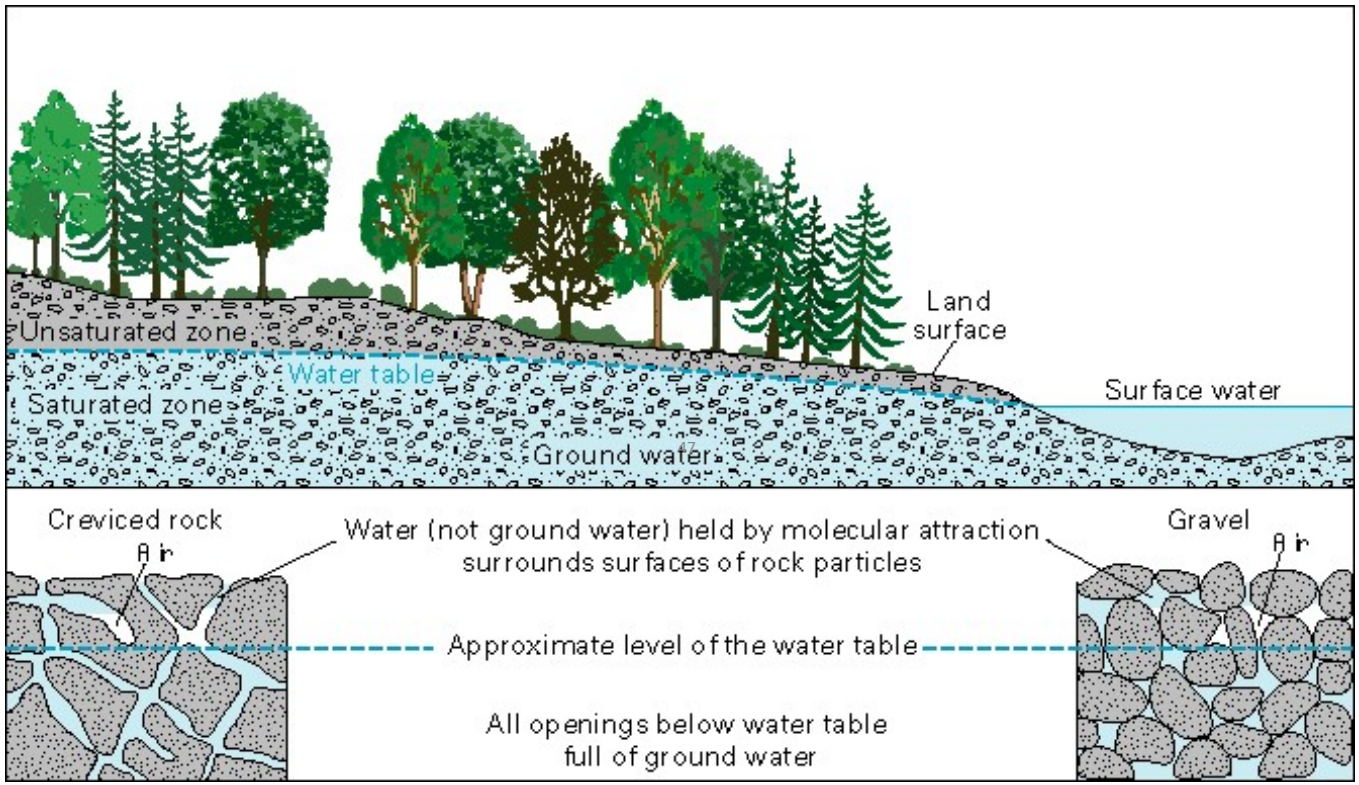
Managing Water Well

What is an Aquifer?

Managing
Water Well

- An Aquifer is…
  - Geologic media that can yield economically usable amounts of water.
  - Aquifer Confinement:
    - Unconfined
    - Confined
  - Two types of geologic aquifer formations:
    Sediment (Gravel, Sand, Silt)
    Rock (Limestone, Sandstone)

Aquifer And Water Table



https://water.usgs.gov/edu/earthgwaquifer.html

Three Common Well Types

Managing Water Well

- Which Type Do You Have?

Drilled Well

Bored or Dug Well

Artesian Well

MO1

Drilled Well

- Deep well accessing ground water
  - Could be hundreds of feet deep
- Highest water quality if the well is properly constructed and the aquifer is not contaminated

How can you

4-6 inch pipe is most obvious sign

Photo Credit: Dr. Gary Hawkins

Bored or Dug Well

- Typically, shallow well that may be impacted by nearby surface water sources
  - Could be 20-60 feet deep
- Water quality may be variable
- Water filtration or treatment systems may be necessary to ensure safety of water

How can you

Large-diameter casing (often 3 ft. or wider)

Photo Credit: Dr. Gary Hawkins

Wellhead

Managing Water Well

Electric Panel for pump and pressure switch

Air entry cover for pressure and vacuum relief

Good tight threaded connections to reduce outside entry to well

Well Casing (recommended to be at least 12 inches out of ground)

Well Seal

Pump wire

Photo Credit: Dr. Gary Hawkins

Well Casing

- No cracks or holes in casing
- Extends at least 12 inches above ground
- Should have no surface water at base

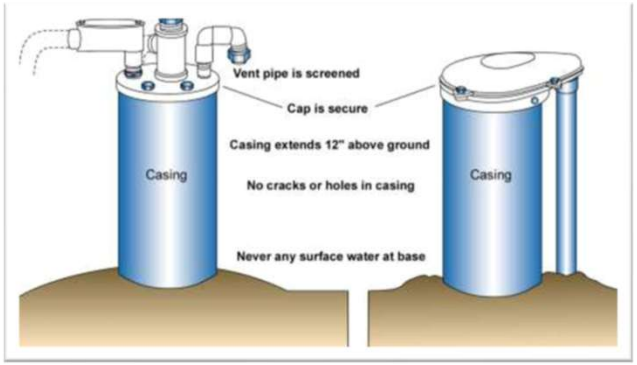
Vent Pipe (should be screened)

Casing

Managing Water Well

Well Seal or Cap

- The **well seal** or **cap** needs to be tightly secured and properly screened to help protect your well from:
  - Surface water
  - Vermin (insects, etc.)
  - Chemicals
  - Pets



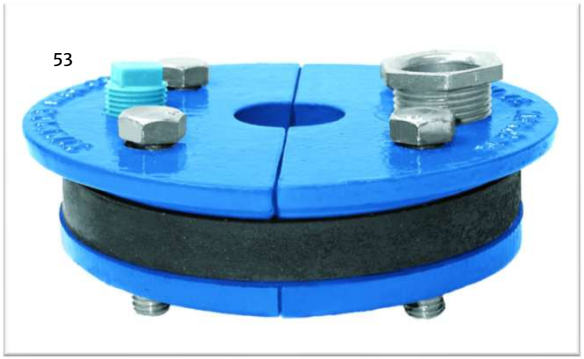


Image from: http://www.simmonsmfg.com/wp-content/uploads/2012/11/WellSeal-1Clr1.jpg
Image from: https://s3.amazonaws.com/treehouse-content/uploads/before_after/3630/large/well-cap-after.jpg
Image from: http://wellwater.oregonstate.edu/sites/wellwater.oregonstate.edu/files/well_colored_13.jpg

Managing
Water
Well

Recordkeeping

Module 3

Well Water Management Regulations

- **Public wells:**
  - Strictly regulated by federal and state laws
  - EPA's Safe Drinking Water Act
- **Private wells:**
  - Not regulated by federal EPA standards
  - Regulated at the state level
    1. Alabama's Well Water Standards
    2. Georgia's Well Water Standards (OCGA 12-5-120)
    3. Virginia's Private Well Regulations (12VAC5-630)
    4. In other states – contact your local Extension office for private well regulations

Source of Information for Private Well Water Management

Guidance may exist to help you comply with regulations:

- EPA guidance for private wells
- State-specific guidance

Georgia

- UGA Well Water Extension Program
- Agricultural and Environmental Services Laboratory
- Georgia Department of Public Health (DPH)

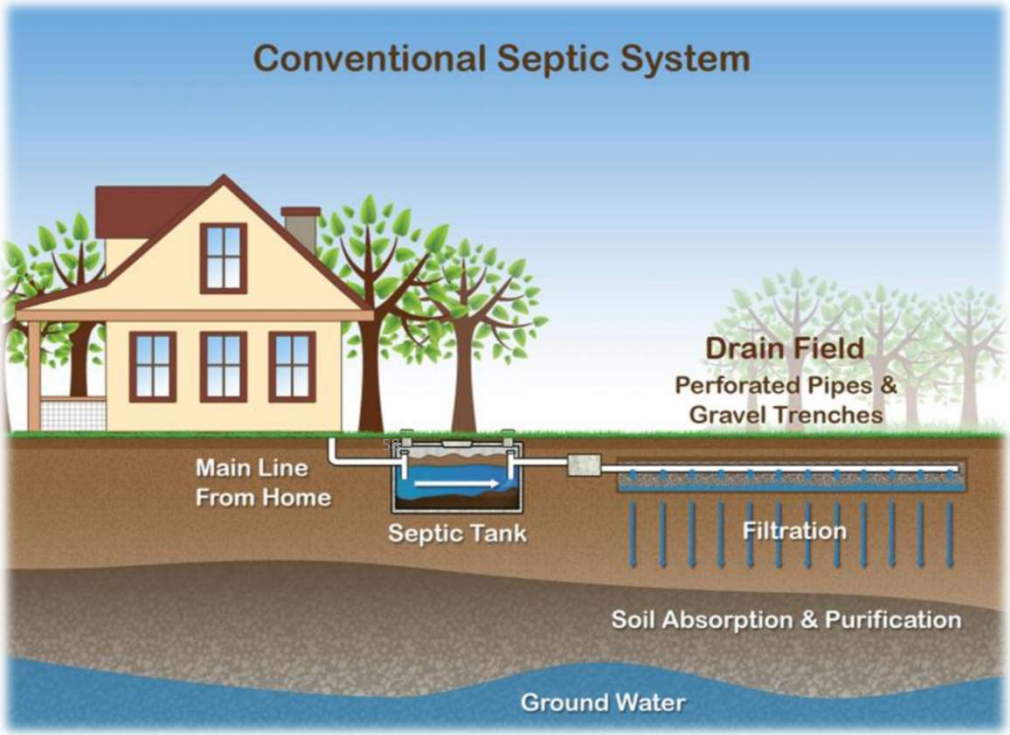
Managing
Water
Well

Septic Systems

Module 4

What is a Septic System?

Managing
Water Well

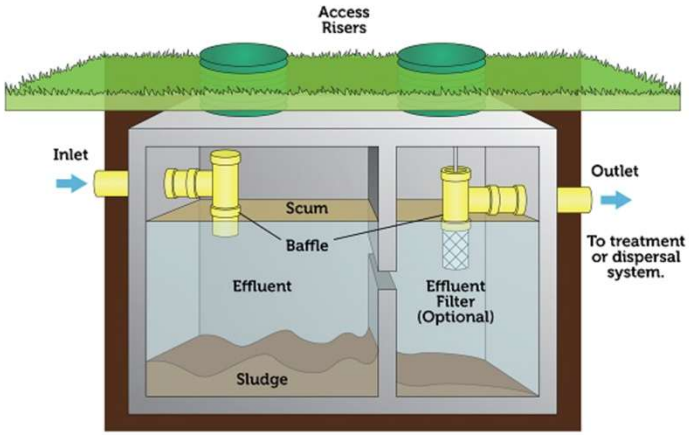


https://www.pca.state.mn.us/living-green/healthy-septic-systems

What is a Septic Tank?

- Watertight chamber made of concrete, fiberglass, PVC or plastic, through which blackwater and greywater flow for primary treatment
- Settling and anaerobic processes reduce solids and organics, but the treatment process is only partially completed
- Check your state's requirements for tank design

Managing Water Well



https://www.epa.gov/septic/types-septic-systems#septictank

How Do I Get this Offered in My State?

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  alexis.hamilton@utk.edu
- Alabama
  Dr. Camila Rodrigues
  Auburn University
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