This is the second part of the Agricultural Water Module.

This section will focus on agricultural water uses during and after harvest of the produce crop.

Postharvest water encompasses water that meets the definition of agricultural water and is used during and after harvest which can include agricultural water used in the field during harvest as well as during packing or holding activities.

Learning Objectives

- Understand the required quality of water for harvest and postharvest activities
- Identify ways water may become contaminated
- Describe cross-contamination and infiltration
- Understand the purpose of using antimicrobial products, including sanitizers
- Describe practices to maintain and monitor the quality of water used in postharvest activities
- Identify records needed to properly document and monitor water quality
- Describe corrective actions to use if postharvest water is outside microbial criteria

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If a contamination event happens in the field (in spite of best efforts, the farm environment will never be zero risk), it could spread through postharvest water including washing and cooling water.

Human pathogens are easily spread through water, so managing water through appropriate sanitation practices reduces risks.

Postharvest water quality management, including treatment (chemical or physical), can be used to reduce cross-contamination risks.

Managing postharvest water quality can reduce food safety risks, but also can reduce risks from plant pathogens that could lead to postharvest rot and quality deterioration.

Water is used in many ways during produce harvest, washing, cooling, and packing. Postharvest water management is important because there are many opportunities for spreading contamination if water is not managed properly.
For postharvest water management, there are two main things that growers will need to understand and manage, 1) the water quality at the start of use and, 2) water management strategies such as water treatments used to reduce cross-contamination risks by the water.

Sanitizers are generally considered to be part of a broader group of substances called antimicrobial pesticides. These antimicrobial pesticides can be used for antimicrobial treatments. The antimicrobial product label will describe approved uses, such as for water or for food contact surfaces, as well as approved concentrations or dosages. EPA regulates and registers antimicrobial and chemical pesticides.

One misconception is that sanitizer added to water is meant to ‘wash’ the produce—instead sanitizers are used to prevent the spread of contamination via water.

Treatments of water that contact the produce, including the use of sanitizers, must be registered by EPA for that use. Registration information should be on the label, but in some cases the label information is included in paperwork that comes with the product. Growers may need to find additional information from the manufacturer that specifically lists allowable contact with fresh produce or food contact surfaces.

Always follow the product label, because the label is the law.

There are many different types of sanitizers available, including organic options.

§ 112.41 specifies that all agricultural water must be safe and of adequate sanitary quality for its intended use.

§ 112.44(a) includes specific microbial criteria for agricultural water used for certain high risk purposes.

§ 112.43 discusses water treatment requirements, if used.

§ 112.48 provides requirements for agricultural water used during harvest, packing, and holding activities.
Cross-contamination can occur when produce touches a surface, tool, container, equipment, worker’s hands, or water that is contaminated.

The focus of this module is to prevent cross-contamination from water used during harvest and postharvest practices.

Development of a cleaning and sanitizing schedule to prevent the buildup of microorganisms on food contact surfaces, tools, equipment, and harvest containers is very important and will be discussed in more detail in the next section of the curriculum, Module 6: Postharvest Handling and Sanitation.

Be sure to remind participants that it is important to cover worker health and hygiene requirements during worker training (especially handwashing) so workers know how to recognize and reduce risks throughout harvest and postharvest handling.

Water that is used for harvest and postharvest activities must meet the standard of no detectable generic E. coli based on a 100 mL water sample. Untreated surface water must not be used for postharvest uses (§ 112.44(a)). This is a different microbial criterion than applied to production water (water used during growing activities), as discussed in Part I of this module.

Water quality must be tested using EPA Method 1603 (modified mTEC) or an equivalent method in accuracy, precision, and sensitivity as described in §§ 112.151(a) and (b).
§§ 112.44(a)(1) to (4) explicitly covers certain postharvest uses:

- Used as sprout irrigation water. Please direct any sprout producers to the Sprout Safety Alliance since educational materials have been developed specifically for this commodity.

- Any water that directly contacts covered produce during or after harvest activities (e.g., washing, hydro-cooling)

- Any water that directly contacts food contact surfaces

- Used to make ice that directly contacts covered produce and/or food contact surfaces

- Used for washing hands during and after harvest activities

- If generic E. coli is detected in the 100 mL water sample or if the agricultural water is determined to not be safe or of adequate sanitary quality for its intended use, the grower must immediately discontinue its use (§ 112.45(a)).

Before resuming use of the water source and/or water distribution system for postharvest uses, § 112.45(a) requires that growers either:

1) Re-inspect the entire affected agricultural water system to the extent it is under their control, identify any conditions that are reasonably likely to introduce known or reasonably foreseeable hazards into or onto covered produce or food contact surfaces, make necessary changes, and take adequate measures to determine if the changes were effective and, as applicable, adequately ensure that their agricultural water meets the microbial quality criterion in § 112.44(a); or

2) Treat the water in accordance with the requirements of § 112.43.

§ 112.43(a)(1) requires that when agricultural water is treated in accordance with § 112.45(a)(2) any method used to treat agricultural water must be effective to make the water safe and of adequate sanitary quality for its intended use and/or meet the relevant microbial quality criteria in § 112.44, as applicable.
§ 112.46(c) requires that untreated ground water sources, such as well water, must be tested during an initial year and annually thereafter.

- Initial year: At least 4 times during the growing season or over a period of a year, and based on these results, determine appropriate use.
- Subsequent years: At least 1 time during the growing season or over the period of a year.

- Agricultural water samples must be representative of the intended use.
- If test values in subsequent years exceed the water quality standard (no detectable generic E. coli in 100 mL water), water sampling must be resumed to at least four times per growing season or year.

- Postharvest uses were listed in this module, slide Water Quality Criterion for Harvest and Postharvest Activities.

- §§ 112.46(a)(1) and (a)(2) state that if water is sourced from a public water supply (such as municipal drinking water), growers subject to the rule do not need to test the water source as long as they have Public Water System results or a current water supply certificate of compliance that the water meets requirements of the Safe Drinking Water Act, or that it is free of detectable generic E. coli in 100 mL of water.

- If public water supply water is held in containments open to the environment prior to using it as agricultural water, it would be considered equivalent to untreated surface water and it would not be suitable for use as postharvest water (§ 112.44(a)).
Single Pass Water

- Must not have detectable generic E. coli in 100 mL sample
- Produce Safety Rule does not require water treatment
- Antimicrobial products, such as sanitizers, can be added as a commonly recommended Good Agricultural Practice
  - May reduce the buildup of microorganisms (biofilms) in equipment and on food contact surfaces

Recirculated and Batch Water

- Must have no detectable generic E. coli in 100 mL sample at the beginning of use and maintain safe and adequate sanitary quality throughout use
- Treatment is not required but can be used to maintain water quality and reduce cross-contamination risks
- Any antimicrobial product used in the water must be labeled for use with fruits and vegetables
- A schedule must be established for changing batch water or a process in place for minimizing the build-up of organic material in the water

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- Single pass water must have no detectable generic E. coli in a 100 mL water sample (§ 112.44(a)(2)).
- Although the FSMA Produce Safety Rule does not require treatment of single pass water, addition of sanitizer should be considered.
  - When used in water that contacts equipment and food contact surfaces, sanitizers may reduce buildup of microbes and biofilms on equipment surfaces, brushes, and rollers.

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- All recirculated and batch water must begin with a microbial water quality that has no detectable generic E. coli in 100 mL water sample (§ 112.44(a)) and is safe and of adequate sanitary quality for its intended use (§ 112.41).
- A sanitizer is one way to prevent build-up of microorganisms in the water AND to prevent cross-contamination to fresh produce that contacts the water.
- Any sanitizer used in harvest and postharvest activities must be labeled for use in water that contacts fresh produce.
- Use of a sanitizer, or other physical or chemical treatment, is not required in the FSMA Produce Safety Rule, but,
  - § 112.41 requires water be safe and of adequate sanitary quality for the intended use; and
  - § 112.48(a) requires water be managed as necessary to maintain its safety.
Recirculated and batch water can be easily contaminated by incoming loads of produce which could introduce a “known or reasonably foreseeable hazard” such as pathogens, so a plan for maintaining and monitoring quality of recirculated and batch water is critical.

§§ 112.48(a) and (b) require that growers who are covered by the regulation establish water change schedules for re-circulated water to maintain its safety and adequate sanitary quality, and visually monitor for buildup of organic material.

Growers should also be aware of state and local waste water discharge issues and ordinances if you will be discharging large volumes of waste water.

There are many variables that impact post-harvest water quality and management practices.

At the start of use, water must have no detectable generic E. coli in 100 mL water sample (§ 112.44(a)).

pH, temperature, and turbidity can also impact how water is managed to reduce risks and maintain sanitary water quality. Each of these are discussed in detail in the next three slides. A key point for each is presented on this slide.

- The addition of sanitizers can change the pH of the water. Some sanitizers, such as chlorine, are most effective at specific pH ranges, so growers may need to monitor and alter the water pH to maintain the effectiveness of the sanitizer. More details are provided in the next slide.

- Water temperature can influence the occurrence of infiltration, which may introduce pathogens to the interior of the produce. The FSMA Produce Safety Rule requirements for water temperature (§ 112.48(c)), intended to minimize potential for infiltration, are described in detail in the Temperature slide of this module.

- Turbidity can be used as an indicator of when water should be changed and is discussed more in the Turbidity slide of this module.
Water pH can affect the efficacy of sanitizers, especially chlorine.

§ 112.43(b) requires monitoring of treatments for agricultural water at a frequency adequate to ensure that the treated water is consistently safe and of adequate sanitary quality for its intended use.

pH test strips are the most common way to get a general understanding of pH levels. They can be purchased for a low cost but they are not as sensitive or accurate as other methods, such as an electronic pH meter or titration kit. Some farms choose to use multiple monitoring methods throughout the day. Be sure to check the expiration date of any type of monitoring strips or titration kit.

Adding a sanitizer can change the pH of the water, so monitor and adjust as needed. When modifying the pH be sure to use an approved food grade product such as citric acid or acetic acid.

§ 112.48(c) requires that you must maintain and monitor the temperature of water that is appropriate for the commodity and operation (considering the time and depth of submersion) and is adequate to minimize the potential for infiltration of microorganisms of public health significance into covered produce.

Differences between water temperature and temperature of harvested produce may cause infiltration to occur (explained on the next slide).
Many commodities may have significant field heat and water may be used to cool the produce before storage and transportation. Be sure that the system you are using to cool produce is effective and does not increase produce safety risks.

Temperature is also important because it can affect how well a sanitizer works. Be sure to read all labels for any temperature requirements before using a sanitizer.

Chlorine tends to evaporate into a gas when the water temperature is too high so be cautious about worker health and safety if chlorine is used with warmer water temperatures.

Properly calibrated thermometers can be used to monitor both water and produce pulp temperatures.

Use non-glass/non-mercury thermometers; handheld infra-red thermometers are a non-contact option.

There can be a higher risk of infiltration if the produce is submerged rather than sprayed with water or floated. The longer the produce is in contact with the water, the higher the risk.

Tomatoes, cantaloupes, mangoes, and apples are commodities commonly considered to be susceptible to infiltration; however, other commodities may be susceptible too.

Fruit with bruises, wounds, or large stem scars can have a greater risk of infiltration.

If the produce is warmer than the postharvest water, especially in bulk water situations such as dump tanks, cooling of the produce with water may create a vacuum inside and cause water to be taken up into the produce.

Contact with contaminated water could be problematic, as the produce may be not only contaminated on the outside, but may also become contaminated on the inside by infiltration water.

Photo note: Blue dye shows movement of water into warm cantaloupe after submersion in cold wash water with dye.
Turbidity is the level of water cloudiness. Water may become turbid after one load or multiple loads of produce. Removing soil, leaves, and other debris prior to running produce through a bulk or batch water cooling or washing system can reduce turbidity in the tank.

§ 112.48(b) requires that those subject to the rule visually monitor the quality of water that is used during harvest, packing, and holding activities for covered produce (for example, water used for washing covered produce in dump tanks, flumes, or wash tanks, and water used for cooling covered produce in hydrocoolers) for buildup of organic material (such as soil and plant debris).

Turbidity can be measured and monitored using a variety of methods such as electronic turbidity meters or turbidity tubes equipped with a Secchi Disk.

Reducing turbidity is key because suspended soil and organic matter can interfere with water quality tests such as pH and chlorine strips. Organic matter can also bind or ‘consume’ sanitizers, making them less effective.

Some antimicrobial products, including sanitizers, are less impacted by turbidity, so growers may want to choose a product that functions better in these conditions if turbidity is difficult to manage in a particular washing system.

Additional Resource:

Top FAQs about Produce Wash Water Management for Small-Scale and Direct Market Farms (Including the Secchi Disk method).
Changing water on a regular schedule can help reduce the chances of cross-contamination from water to fresh produce.

The specific schedule for changing water will depend on how much produce you are washing/cooling, what type of produce, type of equipment (e.g., large scale vs. small scale, presence of filtration device), weather during harvest (e.g., muddy conditions during harvest), and type of sanitizer.

§ 112.48(a) requires that postharvest water must be managed, as necessary, including by establishing and following water-change schedules for re-circulated water, to maintain its safety and adequate sanitary quality and minimize the potential for contamination of covered produce and food contact surfaces with known or reasonably foreseeable hazards (for example, hazards that may be introduced into the water from soil adhering to the covered produce).

Used water from washing and cooling produce must be properly disposed of so that it does not serve as a source of contamination to food contact surfaces and other areas used for covered activities (including production and packing areas) (§§ 112.132 and 112.133).

§ 112.130(c) requires appropriate disposal of waste associated with handwashing facilities and taking appropriate measures to prevent waste water from handwashing facilities from contaminating covered produce, food contact surfaces, areas used for a covered activity, agricultural water sources, and agricultural water distribution systems with known or reasonably foreseeable hazards.
• Waste water should be discharged away from production and packing areas, preferably down a drain or into a catch basin.

• Always check local and EPA regulations before discharging water into sewer systems or the environment, especially if the water contains a sanitizer or other chemical additive.

• Aquatic organisms can be sensitive to chlorine and other sanitizers; therefore, make sure that any waste water discharged to natural areas will not adversely affect surrounding vegetation or wildlife.

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• There are many different types of sanitizers available to use in postharvest water systems.

• A commonly used sanitizer is chlorine because it is inexpensive, however, it can be corrosive to certain materials such as stainless steel.

• Ozone, peroxyacetic acid, and hydrogen peroxide are other options for postharvest systems.

• There are many organic options available. Be sure growers check with their organic certifier before they use a sanitizer to make sure it is acceptable. Synthetic substances allowed for use in organic crop production can be found in 7 C.F.R. § 205.601 (2015).

Additional Resources:


• University of California Davis: Postharvest Technology Yellow Pages.

Notes:
Not all sanitizers are approved for use in water that contacts fresh fruits and vegetables.

Be sure to read the labels and check any local, state and federal requirements and registration lists of approved products. U.S. EPA maintains a list of antimicrobial product registration.

Growers should understand how to calculate the amount of sanitizer needed for the volume of water based on the target concentration of the sanitizer to make sure it is effective at controlling their target microorganisms, and write the steps and target sanitizer concentration into Standard Operating Procedures for their staff to follow.

Growers should review § 112.43 because it contains several sections that discuss requirements for safety and sanitary quality of water, including use of water treatments, delivery, and monitoring. All of these requirements have been discussed earlier in this module.

Additional Resources:
- U.S. EPA Antimicrobial Products Registered with the EPA as Sterilizers.

Follow the Label!
- Always read and follow label instructions
- You must use the product only as labeled
  - Direct contact with produce vs. food contact surface
- You should use the correct amount of antimicrobial product (in ppm or other measurement)
- Understand factors that affect efficacy
  - Temperature, pH, sunlight, and how it is affected by organic load

Always read and follow label instructions. You must use the product only as labeled. Direct contact with produce vs. food contact surface. You should use the correct amount of antimicrobial product (in ppm or other measurement). Understand factors that affect efficacy: Temperature, pH, sunlight, and how it is affected by organic load.

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Each sanitizer will have its own specific approach to monitoring.

Some monitoring can be done automatically through in-line systems that both monitor and inject sanitizer when necessary.

§ 112.43(b) requires that those subject to the rule must monitor any water treatment at a frequency to ensure the treated water is consistently safe and of adequate sanitary quality and/or meets the relevant microbial quality criteria, as applicable.

- For any treatment method, including use of sanitizers, growers covered by the rule must monitor at a frequency sufficient to maintain sanitizer concentration and pH at effective levels under their operating conditions.

- For example, if the sanitizer level drops 30 minutes into a run and it is only being monitored once every 2 hours, this is not frequent enough monitoring and the monitoring frequency may need to be increased.

- If growers have any questions about monitoring sanitizers, they should contact the sanitizer supplier.

- ORP meters are another option for monitoring the effectiveness of sanitizers in water (described in the Oxidation Reduction Potential slide, optional).
62 Additional Information

- This slide is optional.
- Oxidation Reduction Potential “is the potential (voltage) at which oxidation occurs at the anode (positive) and reduction occurs at the cathode (negative) of an electrochemical cell... an oxidizing chemical pulls electrons away from the cell membrane, causing it to become destabilized and leaky. Destroying the integrity of the cell membrane leads to rapid death” of microorganisms, including pathogens. (Suslow 2004)
- ORP can be used to determine the amount of sanitizer to add to water to reach the ideal voltage of 700–825 mV.
- ORP works well with chlorine, but does not work well with hydrogen peroxide or peroxyacetic acid treatments.

Additional Resource:

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- These are just suggestions for Standard Operating Procedures (SOPs) that could be developed to aid in postharvest water management—there may be others that could be used, depending on the type of operation and activities being done on the farm.
- SOPs should be shared during worker training programs so workers know exactly how to do jobs critical to postharvest water management.

Examples of SOPs for Postharvest Water Management

- Monitoring and adding antimicrobial product
- Monitoring and modifying pH
- Monitoring water and pulp temperatures
- Monitoring turbidity and changing/adding water
- Calibrating thermometers and sensors

Notes:

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With monitoring in place, it is important to consider when it might be necessary to use corrective actions. Here are a few scenarios where corrective actions may be necessary to protect the safety of the produce.

- Example #1: Monitoring indicates water sanitation procedures are NOT working properly. Recordkeeping sheets may show that growers have used much more of the sanitizer product than they were expecting, which might indicate the automatic dispenser is not functioning or a worker is not measuring properly. This may require retraining workers or calibrating equipment.

- Example #2: A worker notices a problem with the dosing meter while they are working. It is very important that workers feel empowered to speak up and report things that seem wrong or out of place. The farm should investigate the report and determine if a corrective action is needed.

- Example #3: A review of recordkeeping sheets indicates monitoring is not happening on the set schedule. Growers should re-check monitoring practices such as if computer records are not being saved properly or if a worker is not logging their tasks properly.

- These scenarios might mean that growers need to re-treat the water with additional sanitizer, test water sources again for proper sanitizer and pH levels, evaluate whether the water could pose a food safety risk to any produce that it touched, or retrain workers. The important thing is to follow up when something goes wrong so that it is less likely to happen again!
Recordkeeping is important to make sure all tasks are completed properly and on schedule.

Records can help keep track of how much sanitizer is being used, how the sanitizer responds to different organic loads and types of produce, and even how well the equipment and system is functioning to keep water safe.

Recordkeeping allows employees to document tasks they have completed (in real time) and for management to see monitoring practices are being completed.

Proper management and review of records can help identify trends or problems over time. Records that are never reviewed have less value because management is not benefiting from the recordkeeping investment.

§§ 112.50(b)(1) through (9) requires that those subject to the rule must establish and keep the following records that are relevant to postharvest water, specifically:

1) The findings of the inspection of the agricultural water system in accordance with the requirements of § 112.42(a).

2) Results of any analytical tests conducted on agricultural water to comply with FSMA Produce Safety Rule provisions.

3) Scientific data or information growers rely on to support the adequacy of the methods used to satisfy §§ 112.43(a)(1) and (2) for water treatment.

4) Documentation of the results of water treatment monitoring as required by § 112.43(b).

5) Scientific data or information relied upon to support the microbial die-off or removal rate(s) that were used to determine the time interval (in days) between harvest and end of storage, including other activities such as commercial washing, as applicable, used to achieve the calculated log reduction of generic *Escherichia coli* (*E. coli*), in accordance with § 112.45(b)(1)(iii).
6) Documentation of actions taken in accordance with § 112.45. Provision § 112.45 describes measures to take if agricultural water does not meet the safe and of adequate sanitary quality for intended use requirement in § 112.41 or the numerical criteria in § 112.44.

7) Annual documentation of the results or certificates of compliance from a public water system as outlined in §§ 112.46(a)(1) or (2), as applicable.

8) Scientific data or information that were relied upon to support any alternative established and used on the farm in accordance with § 112.49.

9) Any analytical methods you use in lieu of the method that is incorporated by reference in § 112.151(a) (U.S. EPA Method 1603 modified mTEC).

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**Summary**

- Postharvest water management can help prevent a small contamination event from becoming a BIG one
- For harvest and postharvest uses, use only water that has no detectable generic *E. coli* in 100 mL water sample
- Consider adding a sanitizer to postharvest water
- Develop SOPs for key water management steps
- Monitor key variables of both the water and any sanitizer used to ensure postharvest water quality
- Take corrective actions when needed
- Keep detailed records

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**Notes:**