

TESTING AGRICULTURAL WATER FOR FRUIT AND VEGETABLE PRODUCTION AND POSTHARVEST HANDLING



Why Should I Test my Water?

Water is used throughout fruit and vegetable production and postharvest handling for cooling, frost protection, irrigation, fertigation, protective sprays, handwashing, washing produce, as well as cleaning and disinfecting equipment and produce contact surfaces. Water can harbor harmful bacteria, such as *Salmonella* and *E. coli* O157:H7, which can cause foodborne illnesses. When contaminated water is used in crop production, there is a risk that these pathogens may contaminate produce. Given its widespread use during production and in postharvest applications, any contamination of water can result in subsequent produce contamination, capable of causing large numbers of people to become ill when the produce is consumed. For these reasons, it is imperative to evaluate how water is used within your farm and develop a plan for testing water so that you can control associated risks.

The Produce Safety Rule

This publication covers best practices for managing risks associated with water, but there has also been a lot of focus on water standards included in a new Food and Drug Administration (FDA) federal regulation. The formal name of the rule is *Standards for the Growing, Harvesting, Packing and Holding of Produce for Human Consumption* but is commonly referred to as the Produce Safety Rule, or PSR. The full text of the regulation can be found in the Code of Federal Regulations in Title 21, Part 112 (FDA 2015). The PSR requirements for agricultural water, defined as “the water used in growing, harvesting and packing covered produce where water is intended to, or is likely to, contact covered produce or food contact surfaces,” are outlined in Subpart E, § 112.41–112.50. The PSR states that “all agricultural water must be safe and of adequate sanitary quality for its intended use” (§ 112.41). In order to assist farms which must comply

with the PSR, this publication also covers pertinent points which should be considered for regulatory compliance.

Managing Risk within the Farm— Production Water

There are several factors which drive risk connected to water used during production. The following factors impact risk associated with agricultural water used preharvest on a farm:

The number of foodborne pathogens present in the water. It is highly unlikely that you will know if pathogens are present in your water. This is because it is not recommended that growers spend valuable resources to detect foodborne pathogens in water given their sporadic nature and typically low populations. As an alternative mechanism for evaluating risk, it is recommended that you monitor water for indicator microorganisms. Indicators are present at much higher populations, which can be effectively monitored. As the number of indicator microorganisms present in water increase, the likelihood of a pathogen being present also increases. Therefore, when trending the populations of indicator microorganisms within a water source, you can effectively evaluate the risk associated with those sources. Since the vast majority of foodborne pathogens are associated with fecal contamination, it is best to monitor for a bacterium common to feces known as generic *Escherichia coli* (*E. coli*), which is the most common type of indicator organism that is evaluated for agricultural water.

Surface water contamination. Surface water is more likely to be contaminated by foodborne pathogens present in the environment. This is because it is influenced by runoff as well as exposed to the environment where it can easily become contaminated with feces. As defined by the PSR § 112.3(c), surface water “means all water

open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors that are directly influenced by surface water.” Groundwater, including that found in a well, is much less likely to be a source of microbial contamination if properly installed and capped to prevent surface water contact.

Influence of surface runoff. Water is very effective at moving microorganisms. As water moves, it is likely to carry environmentally present foodborne pathogens and indicator organisms. For these reasons, surface water, which is highly influenced by runoff, is at the greatest risk of contamination. Examples would include tailwater (the excess water that drains back into a pond, canal, or other body of water after irrigation) or rainwater draining into bodies of surface water. Because fecal contamination is a common source of foodborne, pathogenic bacteria, special attention should be paid to proximities between domestic or wild animals and bodies of surface water. Any water runoff from these areas can easily carry these pathogens and deposit them into the agricultural water. Surface water can be managed to mitigate these risks. The most common approaches include maintenance of riparian zones, whose vegetation and absorbent soils help mitigate microbial contamination, construction of ponds so that they are not subject to runoff, and inclusion of diversion ditches to protect surface water from runoff.

Water delivery method. Water that touches the portion of the crop that will be eaten should be scrutinized to a much greater extent than water that does not. For those crops with edible portions growing above ground, application of irrigation water in a manner that does not contact the crop (e.g., drip tape) is preferred.

Timing of water application. The phyllosphere (aboveground portion of plants) is fairly inhospitable to foodborne pathogens which are exposed to stressors such as UV light, desiccation, and other microorganisms which are better suited for surviving on plants. For these reasons, foodborne pathogens die off over time once deposited on a plant surface. Therefore, the quality of water applied closer to the time of harvest can play a larger role in produce contamination as the microorganisms will not be exposed to these stressors for as long and may not die off to the same extent.

Understanding how these risk factors affect agricultural water will help you to develop water application strategies that best fit with the production recommendations and decrease food safety risks.

Mapping the Water on your Farm and Inspecting the Farm’s Water System

In order to account for the water used on your farm, it is recommended that you construct a map documenting distribution. This will give you, your farm team, and any other parties an easy overview of agricultural water use within your operation. This also makes documenting water collection sites and location of maintenance events much easier.

It is a good idea to inspect the agricultural water system used on your farm at the beginning of the growing season and periodically throughout production. The PSR requires that you inspect the water system at least once annually at the beginning of the growing season to identify hazards (§112.42). The PSR states that the following items should be considered when conducting the review:

1. The nature of each agricultural water source (e.g., ground, surface water).
2. The extent of the farm’s control over each water source.
3. The degree of protection of each water source.
4. Use of adjacent and nearby land.
5. The likelihood of introduction of food safety hazards to agricultural water by another user before it reaches the farm.

If any deficiencies are found during an agricultural water inspection, they must be corrected. During the review, you should inspect distribution systems and their components (backflow devices, piping, reviewing and inspecting water distribution systems). Open irrigation systems should also be inspected and be kept clear of debris, trash, and domesticated animals.

What water sources do I test?

Testing improves on-farm hazard assessment and provides assistance for understanding when mitigation strategies should be adopted. Any water source used for irrigation, cooling, frost protection, pesticide, herbicide, and fertilizer application should be tested. The PSR requires testing of any water not from a municipality that will touch the edible portion of produce or a food contact surface.

If using municipal water, the local municipality or health department will be able to provide a water quality report documenting microbial water quality. A copy of this report should be maintained in your

records. It may also be a good idea to take at least one water test annually to make sure the municipal water is not becoming contaminated at some point within your farm.

How many Water Tests Should I Take?

This is a hard question to answer given the complexity of how on-farm agricultural water is used. Ultimately, buyer audit requirements and PSR requirements will set the minimum number of water samples which a farm must collect. Most produce safety experts would recommend taking as many samples as possible if using surface water given the many factors which contribute to its microbiological quality.

The PSR has specific requirements regarding frequency of agricultural water used during growing that differ from water quality requirements used during and after

harvest for handwashing and cleaning or disinfecting food contact surfaces. Table 1 summarizes the required frequency of water tests described in the PSR (§112.44). Surface water must be sampled the most frequently, and untreated surface water is prohibited from being used in any harvest or postharvest activities. As previously discussed, this is due to the highly variable nature of microbial populations in surface water. On March 18, 2019, the FDA released a final rule to extend compliance dates for all requirements of Subpart E an additional two years (FDA 2019). As shown in Table 2, the largest farms would begin sampling water in the 2022 growing season. The FDA is considering requirements within Subpart E during this time and may ultimately alter some aspects through rule making or guidance. Therefore, it is important that growers not make drastic changes to their water sampling programs to gain compliance ahead of schedule and stay engaged to see what the FDA ultimately decides for Subpart E requirements.

Table 1. Produce Safety Rule requirements for agricultural water testing frequency based upon water types¹.

Water Source	Initial or Annual	Number of Tests ²
Agricultural water used during growing		
Surface Water	Initial	20 tests over the first two to four growing seasons
	Annual	5 tests every season after the initial profile is established
Groundwater	Initial	4 tests in first growing season
	Annual	1 test every season after the initial season
Public Water	N/A	No requirement for testing. Maintain copy of public water report or testing results
Agricultural water used during and after harvesting, handwashing, and food contact surface cleaning and disinfecting³		
Groundwater	Initial	4 tests in first growing season
	Annual	1 test every season after the initial season
Public Water	N/A	No requirement for testing. Maintain copy of public water report or testing results

¹ Agricultural water requirements are discussed in Subpart E of the PSR. On March 18, 2019, the FDA issued a final rule extending compliance dates for PSR water testing requirements for covered produce other than sprouts 84 FR 9706. With extended compliance dates, the largest farms must begin collecting samples by the 2022 growing season.

² Testing must occur during growing season prior to harvest.

³ Use of untreated surface water is prohibited.

Table 2. Produce Safety Rule proposed extended compliance dates for Subpart E.

Business Size ¹	Extended Compliance Date
All other businesses (>\$500K)	January 26, 2022
Small businesses (>\$250K–500K)	January 26, 2023
Very small businesses (>\$25K–250K)	January 26, 2024

¹ Business size is based upon the average annual monetary value of produce sold during the previous three-year period.

How do I Analyze the Results?

The results of these tests will be analyzed to determine two criteria: (1) the Geometric Mean (GM) and (2) the Statistical Threshold Value (STV) to develop a Microbial Water Quality Profile (MWQP). The GM and STV are analyzed annually to update the MWQP. The Produce Safety Alliance has created a factsheet describing the steps required to calculate the GM and STV titled *Geometric Means, Statistical Threshold Values, and Microbial Die-Off Rates* (Bihn et al. 2017). There are also tools which can calculate the GM and STV from the water testing values you provide. The Western Center for Food Safety (2019) has created an Excel spreadsheet which can be used for calculating the GM and STV for both surface water and groundwater sources. The University of Arizona has created an Ag Water App (2021) that is also capable of calculating these values for surface water. Both tools can be accessed through the Western Center for Food Safety at <https://www.wcfs.ucdavis.edu/resources/>.

What are the Thresholds for *E. coli* in Agricultural Water?

Auditing schemes will have specified standards for preharvest and postharvest water. As an example, the Global GAP version 5.2 Integrated Farm Assurance Standard states that all water must have less than 1,000 colony forming units (CFU) per 100 mL of generic *E. coli* for preharvest uses and no detectable *E. coli* per 100 mL in postharvest application (Global GAP 2019). It is important to understand what the

water testing criteria are for any good agricultural practices (GAP) scheme your farm will need to adhere to for buying requirements.

The PSR states that the GM must be at or below 126 CFU per 100 mL, and the maximum STV allowed is 410 CFU for all agricultural water used during growing (Table 3; §112.44). For all agricultural water used during and after harvesting, handwashing, and food contact surface cleaning and disinfecting, a much more conservative threshold of no detectable generic *E. coli* per 100 mL has been established.

When do I Test?

Water should be tested throughout the growing season, with samples collected as close to harvest as possible.

What Tests Should I have Conducted on my Water?

Many times growers will only analyze a water sample for the population of *E. coli*. However, there are other parameters that can be useful for both general production and food safety which should also be understood.

1. ***E. coli***: You will want to quantify the generic *E. coli* in a 100 mL sample of water. Results should be reported as the number of CFU per 100 mL or alternatively as most probable number (MPN) per 100 mL. It is important to specify the actual value and not just the presence or absence of bacteria.

Table 3. Produce Safety Rule GM and STV criteria for agricultural water used during production.

Geometric Mean (GM)	Statistical Threshold Value (STV)
Maximum 126 CFU generic <i>E. coli</i> per 100 mL	Maximum 410 CFU generic <i>E. coli</i> per 100 mL

Any of the seven methods listed below can be used for meeting the water testing requirements of the PSR. It is important to make sure that the lab you select to conduct water testing uses one of these methods. The method will also be included in the results reported from the lab.

- **Membrane filtration methods**
(values reported as CFU/100 mL):
 - mTEC agar (EPA method 1603)
 - mTEC agar (EPA method 1103.1, standard methods 9213D, and ASTM 5392-9)
 - MI agar (EPA method 1604)
 - mENDO/NA-MUGagar (standard methods 9222B followed by 9222G)
 - mColiBlue 24 agar (Hach method 10029)
- **Most probable number methods**
(values reported as MPN/100 mL):
 - Colilert (Idexx method, using Quantitray 2000)
 - Colilert 18 (Idexx method, using Quantitray 2000)

2. **Conductivity:** Conductivity is the measurement of the ability of water to conduct an electric current and an indicator of the salinity or mineral content of water. Large changes in conductivity readings also can be an indicator of pollution.
3. **Turbidity:** This is a measurement of the suspended particulate matter in the water that interferes with the passage of a beam of light through the water. Materials that contribute to turbidity are silt, clay, organic material, or microorganisms. The higher the turbidity of water, the greater the surface area of particles for bacterial growth.
4. **pH:** This is the measurement of the hydrogen-ion concentration in the water. Low pH in water is caused by acids, acid-generated salts, and dissolved carbon dioxide. High pH results from carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates. For water samples with less than 6.5 or greater than 8.5 pH, additional tests should be performed to determine the cause of abnormal values. Be aware that for water with a pH lower than 6.5, there is potential for corrosion on plumbing, pumps, or storage tanks.

How do I Take a Sample?

These are general guidelines. If the testing lab you plan to use has a specific protocol make sure to follow it.

1. Contact the testing laboratory and have them send you a water sampling kit.

2. Supplies to have on hand (Figure 1):
 - Marker for labeling bottles.
 - Sterile sampling bottles (one bottle for *E. coli* and another if testing for other parameters). These will be part of the sampling kit received from the lab.
 - Cooler.
 - Ice or ice packs.
 - Sealable plastic bag.
 - Shipping labels, if mailing to the lab.
 - Tape, for securing any labels.
 - Sampling pole (optional, helpful for surface water sources).
3. Locate the best sampling area. It is recommended that samples should be taken as close to point of use as possible. This can be directly from irrigation equipment in the field or from the water source itself. If taking a sample from the water source, make sure it is a representative sample by choosing an area that is: (1) near where the pump draws the water, (2) clear of debris and vegetation, and (3) undisturbed.
4. Write farm name, water source, date, and time of sample on the bottle or the bottle cap (Figure 2, page 6).
5. Remove bottle lid. Do not touch inside the bottle or cap to avoid contamination.



Figure 1. Water sampling supplies: cooler, ice or ice packs, sampling bottles, marker, Ziploc bag, tape. (Photo by: Annette Wszelaki.)



Figure. 2
 Sampling bottle properly labeled with name, date, time, and type of water source.
 (Photo by: Annette Wszelaki.)

6. Fill bottle with water.

- If taking a sample from irrigation equipment, make sure to (1) let the water run at least five minutes before collecting your sample and (2) do not let the lip of the bottle come in contact with the equipment.
- If sampling surface water, take sample near the middle of the source or several feet from the side of the river, stream, or pond. Also, take the sample well below the water surface, as deep as possible without scraping the bottom of the source. Take care NOT to collect floating debris or scrape the sides or bottom of the source while sampling—any of which may contaminate the sample.

7. Replace lid.
8. As a precaution, double check the bottle label to ensure accuracy.
9. Place the bottle in a plastic bag that can be sealed to act as a secondary container in case of leaks.
10. Immediately place in cooler on ice or ice packs. This must be done within 15 minutes of collection.
11. Deliver samples to the lab within six hours of collecting the sample. Notify the lab a day prior to sampling and delivery, so they can be prepared to receive your sample. If shipping your sample to the lab instead of delivering it in person, be sure to ship the sample “overnight.”

Bringing it Together

It is important to develop a plan for assessing risk posed by water used on your farm and outline any actions you may want to proactively take to manage this risk using the approaches discussed in this publication. Many times, part of that management plan will include testing for indicator microorganisms to assess the safety of the water applied during growing, harvesting, and postharvest. Agricultural water standards and buyer requirements are continually changing, so it is important to stay abreast of new requirements so you will be prepared for carrying out your plan of action annually for your farm.

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