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Water Quality and Food Safety

Understanding Factors Impacting Surface Water Quality Relevant for the FSMA Produce Safety Rule

Farmers complying with the Food Safety Modernization Act Produce Safety Rule are required to take many water samples on their farms. This document reviews environmental factors that affect surface water quality test results and how farmers can reduce the impacts of these factors.

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This document reviews factors that impact the quality of surface water used to irrigate agricultural crops and might prove helpful for farmers complying with the Food Safety Modernization Act (FSMA) Produce Safety Rule (PSR) water requirements.

Food safety and preventing foodborne illness is important to farmers. In a survey about using nontraditional water sources, including reclaimed water/treated wastewater, desalinated water, return flows, and brackish waters, farmers reported that food safety and water quality concerns were the most important criteria in deciding which water source to use for irrigation (Suri et al., 2019). Safe water sources are particularly important when farmers are growing fruits and vegetables that may be consumed raw. Water can come in contact with produce at many points during the growing and handling process. Even if water appears to be clean by visual inspection, it may contain microscopic contaminants that can harm human health.

When there is concern about contaminated food in the food supply, regulators such as the U.S. Food and Drug Administration (FDA) or U.S Department of Agriculture (USDA) send recall notices requiring distributors to remove the contaminated and/or suspected-to-be contaminated products from their stores. In 2006, farmers lost $12 million in spinach sales after an outbreak of *Escherichia coli* (*E. coli*) O157:H7. A Leafy Green Marketing Agreement survey found that costs from the spinach outbreak were several times higher than the costs of complying with food safety standards (Ribera et al, 2013).

One way to try to avoid foodborne illness and avoid costly recalls is to identify possible sources of contamination on the farm, including water sources. The FDA has developed a Produce Safety Rule (PSR), as part of the broader Food Safety Modernization Act (FSMA), which will require regular water testing for agricultural water. The goal of this testing is to ensure that the water being used for these processes will not endanger human health (FDA, 2019).

Foodborne Illness: Facts and Figures

- The USDA estimates that foodborne illnesses cost more than **$15.6 billion** per year in the U.S. (CDC, 2019).
- The Centers for Disease Control and Prevention reports that **1 in 6** Americans get sick from foodborne diseases each year. Of these 48 million people that get sick, 128,000 will seek hospital treatment, and 3,000 will die (CDC, 2019).
- Between 2004-2013, the United States experienced **4,900 food** product recalls. Fruit and fruit products (excluding juice), root vegetable products, and leafy vegetable products made up nearly 8% of those recalls (Page, 2018).

Summary of FSMA PSR Water Testing Requirements

The FDA, which enforces the Produce Safety Rule, has determined that acceptable water quality will be based on the levels of generic *E. coli* detected in a series of water samples. Basing the water quality standard on multiple analyses protects producers against the natural variability of generic *E. coli* populations, which can increase or

decrease depending on changing environmental factors. These water samples must be collected for water used in different points in the production system, including water that is:

- Applied for irrigation and in direct contact with the edible portion of the plant;
- In direct contact with the edible portion of the plant during growing activities such as pesticide application or frost protection;
- In direct contact with produce during or after harvest, such as for cooling and transportation; and
- Used for handwashing during or after harvest, and/or cleaning food-contact surfaces (FDA, 2019).

Table 1 outlines the FSMA PSR water requirements for different types of water (untreated surface and untreated groundwater), different types of agricultural uses, the standards associated with the different uses, and the number of samples required for both the initial survey and after the initial survey.

From a water testing perspective, it is important to understand what factors affect bacteria levels and when to test your water to ensure a representative sample. Understanding why a water source has high bacterial levels is important in developing a water resource strategy. If certain bodies of water appear to be more susceptible to environmental factors, investigate alternative water sources. By understanding how to determine that the water being used for production and harvest meets standards, farmers can play an important role in making the food system even safer.

What is *E. coli*?

Total coliforms, fecal coliforms, and E. coli are all indicators of water quality (also known as indicator bacteria). Total coliform bacteria are a large group of microorganisms that are present in the environment and in the intestinal tract of all warm-blooded animals and humans. In general, coliform bacteria are not pathogenic (disease-causing). However, their presence in water indicates that disease-causing organisms (pathogens) could be in the water source. One sub-group of total coliforms are fecal coliforms (Figure 1). Fecal coliforms indicate that there could be feces, and associated pathogens, present in a water source. E. coli is a sub-group of fecal coliforms. Only a portion of total E. coli are pathogenic, meaning they cause illness (Figure 1).

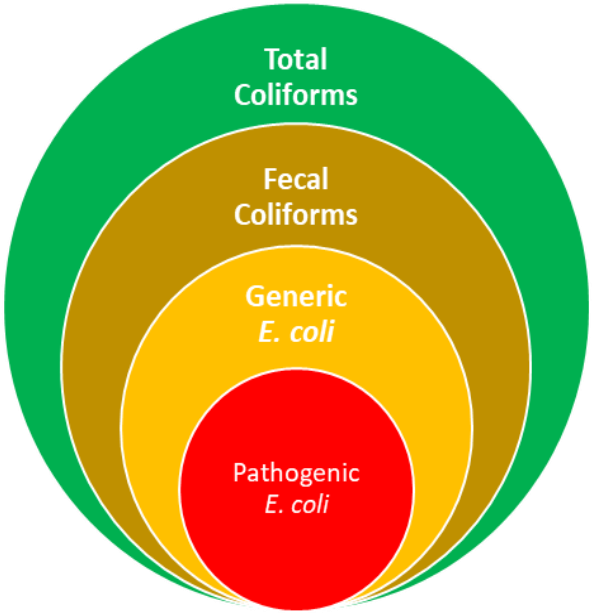

Figure 1. Relationship between total coliforms, fecal coliforms, and E. coli.

The FSMA PSR relies on tests that measure generic E. coli bacteria. Generic E. coli does not

Table 1. FSMA Produce Safety Rule Water Requirements.

Type of Water	Agricultural Use	Bacteria Tested	Standards for Use	Number of Samples Required for Initial Survey	Number of Samples Required After Initial Survey
Untreated Surface Water	Directly applied to growing produce (other than sprouts)	Generic E. coli	Geometric Mean (GM): ≤126 CFU*/100 ml** of water Statistical Threshold Value (STV): ≤410 CFU/ 100 mL of water	At least 20 samples over 2-4 years	5 samples per year
Untreated Ground Water	Directly applied to growing produce (other than sprouts)	Generic E. coli	Geometric Mean (GM): ≤126 CFU/100 ml of water Statistical Threshold Value (STV): ≤410 CFU/ 100 mL of water	At least 4 samples during the growing season or over 1 year	At least 1 sample per year
Untreated Ground Water	Washing hands during and after harvest	Generic E. coli	No detectable E. coli	At least 4 samples during the growing season or over 1 year	At least 1 sample per year
	Water used on food -contact surfaces	Generic E. coli	No detectable E. coli	At least 4 samples during the growing season or over 1 year	At least 1 sample per year
	Water used to directly contact produce (including to make ice) during or after harvest	Generic E. coli	No detectable E. coli	At least 4 samples during the growing season or over 1 year	At least 1 sample per year
	Water used for sprout irrigation	Generic E. coli	No detectable E. coli	At least 4 samples during the growing season or over 1 year	At least 1 sample per year

*CFU= colony forming unit. A colony forming unit is used to estimate the number of bacterial cells in a sample.

** 100 ml is approximately 0.5 cups.

Based on the FSMA Final Rule on Produce Safety (FDA, 2019).

necessarily cause disease in animals or humans, but it can signal the potential presence of pathogens, including Salmonella and Listeria, in water and soil. Testing for the presence of generic E. coli is a rapid, reliable, and cost-effective method to test for possible fecal contamination.

Which Factors Influence Bacteria Levels in Surface Water?

Water test results showing high bacteria levels do not always give the full picture of a particular water source's quality, especially when results are based on one sampling event or a small number of samples. A complex set of environmental

factors influence the conditions that allow bacteria to grow in water. It is difficult to pinpoint exactly which factors contribute to increased levels of bacteria, or which species of bacteria will persist or grow, especially with a limited data set.

Previous research indicates that the following factors can influence bacterial levels in water samples:

- **Turbidity** refers to the clarity of water. Water with high turbidity appears cloudier or even completely opaque. Turbidity can be temporary. For example, a clear pond may become cloudy due to precipitation transporting sediment and accompanying bacteria into water (Benjamin, et al. 2013; Draper, et al. 2016; Wilkes, et al. 2011). Animal disturbances of water and resuspension of sediment can also increase turbidity (Wilkes, et al. 2011).
- Increased **precipitation** has been found to increase the number and types of bacteria found in surface water (Wilkes, et al. 2009; Staley, et al. 2012).
- Increased frequency of **extreme rainfall events** from 2002-2012 in Maryland was correlated with greater risks of infection with Salmonella (Jiang et al. 2015).
- Increased **water temperature** can stimulate bacterial growth. Water tests conducted in summer months may have higher bacterial levels compared to testing the same water source in colder months. In other cases, higher water temperatures can cause greater competition among microbial communities, decreasing the amount of bacteria (Draper, et al. 2016; Wilkes, et al. 2011).
- **Stream flow** is associated with increased turbidity and indicator bacteria counts (such as generic E. coli) (Duris, et al. 2013), as well as greater detection of pathogens including Salmonella (Wilkes, et al. 2011).

How to Make Sure a Water Sample is Representative

While you cannot control for all the environmental factors that affect water quality, you should take water samples on days when the water source has not been stirred up by recent precipitation events or animal disturbances.

It is also important to only take water samples during months the water is actually used. For example, if you irrigate between April and October, avoid taking samples in December. This helps to ensure the water sample is representative of the water coming into contact with your crops.

What to do When a Water Source has High Bacteria Levels

If a water test shows high concentrations of bacteria, consider if any recent precipitation or animal disturbance could be a factor. The water may be unsafe to use immediately after such events, but the bacterial levels may decrease over time, particularly after a corrective action has been taken.

According to FSMA, if your water tests exceed the standards (Table 1), you need to take corrective action within one year and re-test the

water. Corrective actions include:

- Waiting to harvest until bacteria levels in the water have decreased to meet the FDA standard for irrigated crops. Use the FSMA Produce Safety Rule Online Calculator (http://agwater.arizona.edu/onlinecalc/) to determine the number of die-off days needed for sunlight to destroy bacteria after irrigation. (Note that if the standard cannot be reached within four die-off days, this corrective action cannot be used.)
- Re-inspecting your water system and correcting contamination issues.
- Treating water using an approved method (FDA, 2019).
- Consider switching to a different water source.

If the produce requires irrigation that will come into contact with the edible portion before the die-off period has concluded or before you can take corrective actions, you must use another water source.

Strategies for Water Source Selection

In the long-term, consider whether one or more environmental factors, or other sources, could be regularly causing high bacteria loads in your water source. Taking multiple samples over a longer time period is essential for determining whether or not a particular water source is appropriate for agricultural use, and any possible constraints on that source. For instance, a water source may only be safe for use during certain times of the year.

It is possible that a source of water on the farm is not suitable for agricultural use, no matter what time of year. In this case, consider using an irrigation system where the water does not contact the edible portion of the crop, like a drip irrigation system. Another option may be to grow the produce in a different field, where a different water source can be used.

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For more information about recycled water in agriculture, including fact sheets and videos, visit www.conservewaterforfood.org

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