# Good Agricultural Practices –
# Summary of Guidance on Irrigation Water Quality

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Summary

Under certain circumstances, irrigation water used for fruit and vegetable crops can be a potential source of contamination with microbial pathogens that cause human illnesses. This document reviews guidelines on irrigation water quality and practices that have been described in Good Agricultural Practices (GAPs) guidance documents in recent years. It is important to note that, in most cases, these GAPs guidance documents do not carry any force of law or contract, and serve merely as recommended best practices for the industry. Further, the GAPs guidance contained in most of these documents is generic and does not provide quantitative metrics for producers to target. Concerning potential food safety risks associated with irrigation water sources and practices, several factors are important. These include, among other factors, the nature of the crop being produced, the source of irrigation water, the method and timing of irrigation, and other potential sources of microbial contamination in the immediate vicinity or watershed. Producers of fresh and minimally-processed fruits and vegetables should complete a risk assessment to determine potential hazards associated with their irrigation water sources and practices, and implement strategies to minimize the risk of microbial contamination of their produce.

## Introduction

Foodborne illness outbreaks associated with fresh fruits and vegetables continue to be a significant concern for the produce industry. Most of these outbreaks have been traced to contamination of fresh produce with microbial pathogens arising from either animal or human feces. In some cases, this fecal contamination occurs via poor practices, such as fertilizing produce fields with untreated manure or inappropriately treated compost. However, in many cases, contamination of produce with microbial pathogens occurs through indirect mechanisms of contamination. These indirect contamination mechanisms often involve the transmission of microbial pathogens to produce items via contaminated water. This contamination can occur through irrigation of produce fields with contaminated water or from using contaminated water for application of pesticide and other chemical sprays, or this contamination can occur when washing produce in packing facilities after harvest. It is essential that fresh produce growers and packers consider the potential hazards associated with water that comes into contact with the edible portion of produce both in the fields and in packing operations. This is particularly important for produce that is consumed raw, as once produce becomes contaminated with microbial pathogens it is virtually impossible to remove this contamination with washing alone.

FDA Good Agricultural Practices Guidance and USDA AMS Auditing Program

Since the mid-1990s, it has become apparent that foodborne illness outbreaks associated with fresh produce have developed into a significant problem in the United States. Every decade since the 1980s, outbreaks associated with fresh produce have been detected much more frequently, and these outbreaks tend to be larger in scope than in previous years. Reasons for this increase in numbers and sizes of outbreaks are multi-factorial, but include elements such as a) increased complexity of the produce distribution system wherein produce items could be distributed nationally (or even globally) from a single farm or packing operation, b) increased surveillance and reporting capacity of the public health system, thereby increasing the likelihood of detecting outbreaks when they occur, c) increased numbers of persons having particular susceptibility to foodborne illnesses (e.g. elderly persons, persons with weakened immune systems), d) increased virulence of microbial pathogens which commonly cause human illnesses, and e) other unidentified factors.

In response to these trends, in 1997 the US Food and Drug Administration (FDA) began developing guidance on “Good Agricultural Practices” (GAPs) for fruit and vegetable producers that would reduce the likelihood of produce contamination. This ultimately resulted in the October 1998 publication of the FDA “Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables” (hereafter referred to as the “FDA GAPs Guide”). The FDA GAPs Guide recognized the critical importance of the safety of water used in both pre- and post-harvest applications for ensuring the safety of fresh produce. This was clearly articulated in Principle 4 of the FDA GAPs Guide, which stated “*Whenever water comes in contact with produce, its source and quality dictates the potential for contamination. Minimize the potential of microbial contamination from water used with fresh fruits and vegetables.*” However, it is important to note that the FDA GAPs Guide was designed to provide only broad-based, generic guidance on GAPs for fresh produce, not to serve as a formal regulation or as the basis of an auditable standard.

More recently, in response to requests from the produce industry, the United States Department of Agriculture (USDA) Agricultural Marketing Service (AMS) developed a “Good Agricultural Practices and Good Handling Practices Audit Verification” program. This program was established to provide a mechanism whereby, on a fee-for-service basis, USDA AMS inspectors would conduct audits of produce growing and packing operations to assess compliance with provisions of the FDA GAPs Guide and other food safety and food defense criteria. Since its inception, the USDA AMS Fresh Produce Audit Verification System has steadily grown, and recently became a requirement for producers wishing to sell products to the USDA School Lunch Program.

Given the critical importance of pre- and post-harvest water safety to ensuring the safety of fresh produce, as was acknowledged in the FDA GAPs Guide, it was predictable that the USDA AMS Fresh Produce Audit Verification System would contain several elements on water safety. However, from the standpoint of irrigation water safety, there are only four elements in the USDA AMS Audit Checklist which specifically address irrigation water safety. These elements are in the “Water Usage” section of Part 1 (Farm Review) of the USDA AMS Audit Checklist, and are:

#15 – What is the source of irrigation water (Pond, Stream, Well, Municipal, Other…Specify)?
#16 – How are crops directly irrigated (Flood, Drip, Sprinkler, Other….Specify)?
#17 – Water quality is known to be adequate for the crop irrigation method and/or chemical application.
#18 – If necessary, steps are taken to protect irrigation water from potential contamination.

In subsequent sections of this document, I will review recommendations from the FDA GAPs Guide and other relevant GAPs guidance documents which pertain to these four elements from the USDA AMS Audit Checklist.

FDA GAPs Guide, 1998

Although the FDA GAPs Guide has not been amended since being published in 1998, it is notable that there has been relatively little improvement in the scientific basis for recommendations on irrigation water safety and application procedures in subsequent years. As was noted in the FDA GAPs Guide, water can be a carrier of many microorganisms including pathogenic strains of *Escherichia coli*, *Salmonella* spp., *Vibrio cholerae*, *Shigella* spp., *Cryptosporidium parvum*, *Giardia lamblia*, *Cyclospora cayetanensis*, *Toxiplasma gondii*, and the Norwalk and hepatitis A viruses. Many of these organisms can cause human illness even when present in foods in very low numbers.

Several factors influence the potential for irrigation water to contaminate produce with microbial pathogens. These factors include the water quality (presence and concentrations of microbial pathogens), characteristics of the fruit or vegetable crop which is being irrigated (does the crop grow at or below the ground surface, or off the ground), how the irrigation water is applied (drip or trickle, flood, or overhead irrigation), and when the irrigation water is applied relative to development of the edible portion of the crop and the time of harvest. In general, the quality of irrigation water is most critical when it is in direct contact with the edible portion of the fruit or vegetable crop, especially close to the time of harvest.

The quality of irrigation water drawn from surface water sources such as ponds, lakes, streams or rivers can vary greatly. This is particularly true for surface waters that are subject to intermittent, temporary contamination events such as wastewater discharge and runoff from upstream livestock operations. In some cases ground water quality may be vulnerable to contamination by surface waters, as in the case of wells that have unprotected well-heads or damaged casings. Practices to help ensure adequate water safety may include ensuring that wells are properly constructed and protected, treating water to reduce microbial loads, or using alternative application methods that minimize water-to-produce contact.

*General considerations for irrigation water safety discussed in the FDA GAPs Guide:*

- Identify the source and distribution of water used and be aware of its relative potential for being a source of pathogens.

  It is generally assumed that groundwater is less likely to be contaminated with high levels of pathogens than surface water.

- Maintain wells in good working condition.

  Growers with older wells, or who have other reasons for concern about the condition of their well and possible contamination, may want to have their well examined by a water quality expert.

- Review existing practices and conditions to identify potential sources of contamination.
  Agricultural water can become contaminated, directly or indirectly, by improperly managed human or animal waste. Contamination with human waste may occur from improperly designed or malfunctioning septic systems and sewage treatment facility discharges. Examples of potential sources of contamination from animal waste are animal pasturing in growing areas, manure storage adjacent to crop fields, leaking or overflowing manure lagoons, uncontrolled livestock access to surface waters, wells, or pump areas, and high concentrations of wildlife.

- Be aware of current and historical use of land.
  Agricultural water is frequently a shared resource, and in some regions may come from surface waters that travel some distance before reaching the produce growing area. Although growers do not have control over all potential risks to water safety in their watershed, when evaluating irrigation water quality they should consider questions such as:
    - What is the prevalence of animal production in the region?
    - Do feedlots, animal pastures, and dairy operations in the region use fences or other barriers to minimize animal access to shared water sources?
    - Is manure applied to land by many farms in the region?
    - Do local rainfall patterns and topography impact the likelihood of contaminated runoff from these operations reaching surface waters?
    - Are controls generally in place to minimize contamination of agricultural waters from other farm or animal operations?

- Consider practices that will protect water quality.
  Good agricultural practices may include protecting surface waters, wells, and pump areas from uncontrolled livestock or wildlife access to limit the extent of fecal contamination. Soil and water conservation practices such as grass/sod waterways, diversion berms, runoff control structures, and vegetative buffer areas may help prevent polluted runoff water from contaminating agricultural water sources and produce crops.

- Consider irrigation water quality and use.
  There is general scientific agreement that irrigation practices that expose the edible portion of plants to direct contact with contaminated water may increase microbial food safety risks, especially for those crops and regions where irrigation is likely to occur close to harvest. To the extent feasible, growers should follow good agricultural practices that minimize the potential for contaminated water to contact the edible portion of the crop. Where available and appropriate, growers may want to consider low volume sprays, drip, furrow, or underground irrigation as part of their overall program. Conversely, if knowledge or testing indicates water quality is good (such as water from properly constructed wells or municipal water supplies), the risk of water serving as a direct source of microbial contamination is low, regardless of the type of irrigation system used. Further, for some crops, such as root crops or low growing crops, it may not be possible to effectively minimize contact between irrigation water and the edible portion of the crop.

*Microbial testing of agricultural water as discussed in the FDA GAPs Guide:*

The following discussion is derived directly from the 1998 FDA GAPs Guide.

"There are a number of gaps in the science upon which to base a microbial testing program for agricultural water and microbial testing of agricultural water may be of limited usefulness. Growers concerned about water quality should first focus their attention on good agricultural practices (such as manure management and runoff controls) to maintain and protect the quality of their water sources. Growers interested in testing the microbial quality of agricultural water sources may want to consider the following:

- Growers may elect to test their water supply for microbial contamination on a periodic basis, using standard indicators of fecal pollution, such as *E. coli* tests, which may be performed by commercial, State, or local government laboratories. However, bacterial safety of water does not necessarily indicate the absence of protozoa and viruses.
- Where agricultural water comes from public sources, information on microbial analysis of the water may be available from the local water authority.
- Water quality, especially surface water quality, can vary with time (e.g., seasonally or even hourly), and a single test may not indicate the potential for water to be contaminated. Furthermore, testing water may not reveal specific pathogens if they are present in low numbers. However, appropriate microbiological testing may be useful for confirming water quality concerns in extreme situations (e.g., polluted water source) and in assessing the effectiveness of certain control programs (e.g., clean-up of well water).
- Growers can consult local water quality experts, such as state or local Environmental Protection or Public Health agencies, extension agents or land grant universities, for advice appropriate for individual operations."

Food Safety Begins on the Farm: A Grower's Guide, 2000

In 2000, researchers and Extensionists from Cornell University summarized available GAPs guidance in a publication titled "Food Safety Begins on the Farm: A Grower's Guide." Much of the guidance contained in this document mirrors that in the 1998 FDA GAPs Guide and will not be re-stated here. However, the Cornell publication also included some additional generic guidance on irrigation water quality and testing recommendations. The following sections are excerpts from the publication.

*Irrigation Water Quality and Methods:*

Municipal water and potable well water provide the lowest risk for irrigation purposes. However, using these water sources is often not feasible due to field location and size. Surface water is the most common source for irrigation on fruit and vegetable farms. Ideally, upstream neighbors keep animals out of waterways and prevent feedlot runoff from entering streams. Working with local watershed committees to better understand watershed areas and promoting stewardship of these waterways can improve irrigation water quality for all farms and further reduce microbial risks on the farm.

*Irrigation Water Testing:*

Depending on the source of irrigation water, different testing frequencies are recommended. Properly sample water and send the samples to a reputable laboratory for analysis of fecal coliforms. The presence of fecal coliforms indicates that water may have been contaminated with manure and harmful pathogens. Although standards for irrigation water have not been examined in recent years, there are currently two recommendations for evaluating microbial water quality.

- The Environmental Protection Agency (EPA) established a standard for reclaimed water (treated effluent) used on nonprocessed fresh produce of less than 2.2 fecal coliforms per 100 milliliters (mls) of water. This is considered free of pathogens for nonpotable agricultural purposes. If higher densities of fecal coliforms are detected, it is suggested that growers do not use overhead irrigation.
- Researchers from the University of California concluded in earlier research on irrigation water quality that 1,000 fecal coliforms in 100 mls of water was acceptable based on survival studies of several pathogens on produce.

This broad range of recommendations highlights the need for more research. Until recommendations specific to surface water are developed and tested, use these guidelines to interpret farm water test results. Water quality may be more important for water that comes in direct contact with the edible part of the plant, especially close to harvest. Awareness of irrigation water quality will assist in the selection of irrigation practices that minimize the risks of spreading pathogens to fresh produce.

Below are recommendations for testing water sources. For additional information or local recommendations, consult a county or state Cooperative Extension Service educator.

- Municipal water: Acquire test results from the local water authority annually.
- Well water: Test biannually and treat the well if fecal coliforms are present. If the well casing is secure and well-maintained, and if livestock and manure storages are excluded from the well recharge and pumping area, then the risk of contamination is greatly reduced.
- Surface water: Test quarterly in warm climates such as California, Florida, Texas and other southern states. Test three times during the growing season in northern climates such as New York, Pennsylvania, and Michigan – first at planting, second at peak use, third at or near harvest.
- Keep records for all water tests. If water test results indicate the presence of fecal coliforms, filtering the water or using settling ponds can reduce these counts in surface water systems. If a well is contaminated, it can be chemically treated to reduce fecal coliform counts.

Irrigation Method:

- Use drip irrigation whenever possible. This method minimizes the risk of crop contamination because the edible parts of most crops are not wetted directly. Plant disease levels also may be reduced and water use efficiency is maximized with this method.
- Microbial risks in overhead irrigation are minimized by using potable water. Maintaining wells and treating them if fecal coliforms are present ensures clean water for irrigation. If surface water is used for overhead irrigation, examine the source of the water and be aware of upstream uses of that waterway. By applying overhead irrigation in the morning, water use efficiency is maximized and leaf drying time reduced. Rapid drying and ultraviolet light will reduce survival of both plant and human pathogens on crops.

- Consider not applying overhead irrigation within one week of harvest, if drawing from surface water source.
- Keep records of application methods, rates, and dates.

California Leafy Greens Marketing Agreement, 2007

More than 20 foodborne illness outbreaks in the U.S. have been traced to leafy greens (e.g. lettuce, spinach, etc.) in recent years. In response to a large-scale, national outbreak in 2006 associated with fresh spinach, producers in California pursued development of a marketing agreement which included specific food safety provisions. The first version of these food safety provisions, titled "Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens" was finalized in March 2007. The most recent revision of this document was finalized in June 2008.

The California Leafy Greens Marketing Agreement (LGMA) incorporates science-based food safety practices with mandatory government inspections by USDA-trained auditors. Audits of participating growers – both scheduled and unannounced – are conducted under the program to assess compliance with food safety practices. As of August 2009, approximately 120 farmers, shippers and processors, representing over 99% of the volume of California leafy greens, have voluntarily signed onto the Marketing Agreement. Arizona leafy greens growers also joined in this process in 2007, and there currently is an effort to make the requirements under the LGMA applicable nationally to all growers of leafy greens (refer to the National Leafy Greens Marketing Agreement at: http://www.nlgma.org/index.php).

The food safety provisions underpinning the LGMA are, to the greatest extent possible, presented with quantitative metrics. For example, the LGMA Food Safety Guidelines include specific requirements for microbiological indices for irrigation water, proper composting of soil amendments, and acceptable buffer zones for adjacent land uses such as animal grazing or feeding operations, etc.

The provisions of the LGMA apply only to growers of leafy greens who have signed on to the program. At the current time, this only includes growers from California and Arizona. However, I have included excerpts from the LGMA Food Safety Guidelines as an example of a metrics-based GAPs standard.

The following is the (slightly edited) section from the LGMA Food Safety Guidelines ("Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens") on Water Usage.

*The Best Practices Are:*

- A water system description shall be prepared. This description can use maps, photographs, drawings or other means to communicate the location of permanent fixtures and the flow of the water system (including any water captured for re-use). Permanent fixtures including wells, gates, reservoirs, valves, returns and other above ground features that make up a complete irrigation system should be documented in such a manner as to enable location in the field. Water sources and the production blocks they may serve should be documented.
- Water systems that convey untreated human or animal waste must be separated from conveyances utilized to deliver irrigation water.

- Use irrigation water and water in harvest operations that is of appropriate microbial quality for its intended use. [Note: The LGMA document contains metrics specific for this. This metric specifies that irrigation water used for foliar application should be tested for generic *E. coli*. The detection of generic *E. coli* at levels ≤126 Most Probable Number (MPN)/100 mL (rolling geometric mean n=5) and ≤235 MPN/100mL for any single sample will trigger additional testing and assessment activities to determine the acceptability of the crop.]
- Perform a sanitary survey prior to use of water in agricultural operations and if water quality microbial tests are at levels that exceed the numerical values set forth in the metrics. [Note: The procedures for the sanitary survey are outlined in an appendix to the LGMA document.]
- Test water as close to the point-of-use as practical, and if microbial levels are above specific action levels, take appropriate remedial and corrective actions.
- Retain documentation of all test results and/or Certificates of Analysis available for inspection for a period of at least 2 years.

*Other Considerations for Water:*

- Evaluate irrigation methods (drip irrigation, overhead sprinkler, furrow, etc.) for their potential to introduce, support or promote the growth of human pathogens on lettuce and leafy greens. Consider such factors as the potential for depositing soil on the crop, presence of pooled or standing water that attracts animals, etc.
- When waters from various sources are combined, consider the potential for pathogen growth in the water.
- For surface water sources, consider the impact of storm events on irrigation practices. Bacterial loads in surface water are generally much higher after a storm than normal, and caution shall be exercised when using these waters for irrigation.
- Use procedures for storing irrigation pipes and drip tape that reduce or eliminate potential pest infestations. Develop procedures to provide for microbiologically safe use of irrigation pipes and drip tape if a pest infestation does occur.
- Reclaimed water shall be subject to applicable state and federal regulations and standards. Use of this water for agricultural purposes must meet the most stringent standard as defined by the following: state and federal regulation or metrics of this document.

## Additional Comments and Summary

Certain fruits and vegetables have historically been implicated in numerous foodborne illness outbreaks which likely resulted from contact with contaminated water (either irrigation or processing water). Examples of these commodities include leafy greens, green onions and scallions, tomatoes, melons, raspberries and mangoes. Producers of these and other commodities which have been implicated in foodborne illness outbreaks need to be particularly diligent in assessing potential food safety risks associated with their production and packing processes.

Although well water in general should be safe, it is critical that the wells be assessed for proper construction, integrity of the wellhead, and be tested at least annually to ensure that the source is not contaminated with potential pathogens. In cases where water is drawn from wells to recharge irrigation ponds, the potential risk of this irrigation water should be treated the same as surface water.

Growers should conduct their own risk assessments to determine potential hazards associated with their irrigation practices. These risk assessments should consider an overall assessment of risks presented by activities in the surrounding area and watershed (e.g. presence of concentrated animal feeding operations), the nature of the commodities produced, the source of irrigation water, the method of irrigation the timing of irrigation relative to harvest, and other factors. The following table summarizes several of the factors producers should consider.

Summary Table of Potential Risk Factors for Microbial Pathogen Contamination of Fresh Produce

| Factor | Increases Potential Risk | Minimizes Potential Risk |
|---|---|---|
| Fruits and vegetables which grow in soil (e.g. carrots) or at the surface (e.g. leafy greens, strawberries, celery) | X | |
| Tree fruit or other fruits and vegetables which grow off the ground | | X |
| Trellising/Staking of plants prone to drooping to the ground (e.g. tomatoes) | | X |
| Irrigation water source – municipal water | | X |
| Irrigation water source – properly constructed, maintained and tested well | | X |
| Irrigation water source – surface water (pond) | X | |
| Irrigation water source – surface water (river or stream) | XX | |
| Irrigation water application – drip (trickle) irrigation | | X |
| Irrigation water application – furrow or flood irrigation (if not contacting fruit or vegetable crop) | | X |
| Irrigation water application – overhead spraying | X | |
| Irrigation timing – stop irrigation (if method allows contact of water with edible portion of crop) at least one week (or perhaps longer) prior to harvest of fruit or vegetable crop | | X |
| Use only potable water for chemical applications to crop | | X |
| Livestock/Wildlife activity in close proximity to fruit or vegetable fields | X | |
| Livestock/Wildlife activity in close proximity to irrigation water recharge area | X | |

Finally, it is important to consider that research on irrigation methods, water sources, potential hazards, and interactions of these hazards continues to be conducted. As scientists learn more about factors influencing the food safety risks associated with specific irrigation practices, recommendations undoubtedly will continue to change. Producers should, to the extent practicable, stay abreast of current recommendations from government, Extension, producer organizations, and other authoritative sources.

For example, the US Food and Drug Administration issued new draft guidance documents to minimize microbial food safety hazards for three commodities – leafy greens, melons, and tomatoes – on July 31, 2009. I a press release issued to coincide with the new draft guidance documents, FDA Commissioner Margaret Hamburg stated “These guidances embody the Obama Administration’s and FDA’s prevention-oriented food safety strategy. They will be made final as soon as possible after public comment, and will be followed within two years by enforceable standards for fresh produce.”

References

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