

1. Introduction

Produce may become contaminated with hazardous agents anywhere from farm-to-table. If this occurs, special processes (washing, sorting, irradiation, etc) are required to ensure freedom from the agents. However, cooking is not appropriate for produce that will be sold fresh and prevention of contamination is imperative to guarantee a safe product. The use of Good Agricultural Practices (GAP) for fresh fruits and vegetables during growing, harvesting, sorting, packaging, and storage operations is the key to preventing contamination with pathogens. Major aspects of GAP involves prior land use, adjacent land use, water quality and usage's, soil-fertility management, wildlife, pest control, worker hygiene and sanitary facilities, and fruit harvesting and cooling practices. In this document the GAP that relate to land and water use are discussed.

2. Soil

2.1 Identification of hazards associated with soil history

As part of a GAP program, it is necessary to identify possible sources of microbial and chemical contamination associated with prior use of the land that it is being devoted to agricultural production. This can be done through interviews with previous owners, a review of municipal permits or from other sources. Such background information can help to identify any situations that increase the risk of product contamination (FDA, 1998).

2.2 Information or prior land use

Important information that needs to be obtained about the history of the land includes its

use:

- For livestock feeding
- For production of domestic animals
- As a garbage or toxic waste-disposal site
- As a sanitary waste-management site
- For mining activities, oil or gas extraction
- For the disposal of incinerated material or industrial waste possibly leaving mineral residues on the site
- For barns
- Near farm animals being produced on land adjacent to or a short distance from the cultivation site.
- Other information that should be obtained includes questions about whether the land has:
 - experienced any serious flooding;
 - been treated in an uncontrolled manner with organic or inorganic fertilizers and/or pesticides.

Prior use of the land for livestock feeding or domestic animal production can greatly increase the risk of produce being contaminated with pathogens commonly found in the intestinal tract. The potential for contamination from this source is related to the time that has passed since the land was last used for feeding or production of animals. The risk of contamination will also be influenced by environmental conditions, such as atmospheric temperature, sunlight and relative humidity.

The presence of barns or farm animals only a short distance from the cultivation site increases the risk of product contamination. Assessment of the location of the animals and their facilities and evaluation of drainage systems and water courses flowing near these areas will help determine the extent of the risk. In some instances, it may be necessary to create physical barriers or channels to divert contaminated water away from the growing site.

When the land has been used for garbage disposal or as a waste-management site, it may

contain decomposing organic matter and, perhaps, faecal material. Depending on the type of garbage, microbial loads in soil can be extremely high and the soil may also contain harmful chemicals. Land that has been used for mining or petroleum extraction can be contaminated with heavy metals or hydrocarbons. Even if the contamination is located on only a small part of the land, factors such as rainfall and subterranean water flow should be evaluated. Tests for toxic substances in the soil and a review of the extraction operation for compliance with environmental requirements are recommended when the ground history indicates a high risk of chemical hazards.

Heavy flooding also can increase the likelihood of contamination. Water run-off can introduce pathogens and chemical contaminants from region further a field. Dead animals and static water remaining after floodwaters have receded can lead to significant microbial hazards. Individual assessment of each flood situation will be needed, along with a review of the time that has passed since the flood occurred and other conditions that can mitigate or reduce the risks. When there is concern about the safety of the growing site, microbiological analyses carried out after adverse conditions have occurred (e.g. flooding or run-off) may assist in identifying any problem.

Even if investigation of prior land use indicates that it has been used solely for agricultural production, the production practices that were used should be reviewed. Improper use of organic fertilizers may result in microbiological contamination of the soil, while inorganic fertilizer and/or pesticides used improperly are more likely to cause serious chemical hazards. Chemical compounds should have been used according to label recommendations and registered for application to the crop in question.

2.3 Current or prior use of adjacent land

Information about the use of land adjacent to the production site is critical, since this helps to identify situations that can increase the risk of contaminating fresh produce with pathogenic bacteria or toxic substances. Contamination can reach produce by a variety of routes via water or wind flow, workers, vehicles or equipment.

The land owner or operator should investigate both present and prior use of adjacent land

to identify potential sources of contamination and precautions that need to be taken to protect of fresh produce in the growing field. Contamination from areas away from the actual growing site can reach produce through a variety of means including water or wind flow, and workers, vehicles, or equipment moving from one area to another.

3. Water resources and irrigation practices

During the production of fruits and vegetables, water is used for numerous purposes in the field, including irrigation and application of pesticides and fertilizers. Other uses of water during produce handling include cooling, washing, waxing and transportation.

Water used in agriculture may be contaminated with pathogenic bacteria that can cause severe health problems in consumers. It can be a source of and vehicle for biological hazards such as:

- Enterohemorrhagic and enterovirulent *Escherichia coli*
- *Salmonella serotypes*
- *Shigella spp*
- *Vibrio cholerae*
- *Giardia lamblia*
- *Cryptosporidium parvum*
- *Toxoplasma gondii*
- *Cyclospora cayetanensis*
- Hepatitis A virus
- Norwalk virus

Poor-quality water may be a direct source of contamination and also an important vehicle for spreading microorganisms on the production site (Bern et al., 1999). Each time water comes into direct contact with fruits or vegetables, there is the possibility of contaminating the produce with pathogens. This includes water used in growing produce,

for washing of fresh produce, in packaging facilities and during transportation. The severity of the hazard resulting from poor-quality water will depend on the type and number of microorganisms in the water and their capacity to survive on the produce. In addition to water quality, other factors that can increase the risk of product contamination include the stage of development and type of crop, the time between contact of the produce with the water and harvest, and other water- and produce-handling practices.

3.1 Potential for contamination associated with water sources

Water destined for agricultural use can easily become contaminated with human and/or animal faeces. It is important to keep animals and children out of the fields and to provide field workers with properly constructed and maintained restrooms or mobile sanitary units. Contamination of water with human fecal material can also occur if wells and water systems are not properly constructed, if septic systems fail or have deficiencies in their design, and from discharges leaving sewage treatment plants. Wildlife, including insects, rodents, reptiles, and birds, can carry disease. Since these are found even in the most pristine environments, absolute protection of water is difficult to achieve and minimizing of potential contamination by wildlife should be the goal.

Surface water. Surface water, like water in streams, lakes and ditches, does not fulfil the GAP criteria. Such waters are naturally contaminated with faecal material and the presence of *Salmonella*, *Listeria monocytogens* and viruses has been reported (Castillo Martín *et al.*, 1994; Nguyen-the and Carlin, 1994 and 2000)

Groundwater. It is generally believed that groundwater is less likely than surface water to be contaminated with pathogens since the ground water usually loses much of its content of bacteria and organic material after filtration through layers, of rock and clay. (Buttler *et al.*, 1993). Nevertheless, groundwater may be contaminated by a variety of biological and chemical agents. They include among others:

- Bacteria, viruses, parasites, and protozoa
- Domestic waste

- Nitrate nitrogen
- Synthetic organic chemicals
- Heavy metals
- Petroleum residues
- Combustion products from roadway construction

Well water. Preventing of well contamination of a well begins with proper siting of the well (Engel et al., 1998). The distance that the well must be from sources of contamination depends on many factors, such as geologic formations, depth of the aquifer, direction of groundwater flow, effects of pumping on groundwater movement and susceptibility of the site to flooding. Both soil and slope characteristics make the location of a well difficult. The following standards apply to the siting of wells (Engel et al., 1998):

- The well should be located away from any septic tanks, sewage disposal areas (such as a drain field), and other sources of contamination, such as feed lots, manure piles, chemical stores, chemical mixing areas, dumps or landfills, fuel storage tanks, storm sewers, field lavatories, or refuse dumps. Separating the well from a source of contamination may reduce the chance of pollution, but it does not guarantee that the well will be safe. Contaminants can come from great distances, depending on the depth of the aquifer and of the well.
- The well should be in an area free from flooding, or precautions to protect it must be planned. Flood-water can easily carry bacteria, oil products, and pesticides from one place to another.
- Surface drainage should be arranged to run water away from the well on all sides. Up-slope drainage should be diverted away from hillside wells. A well located downhill from a barnyard, a leaking tank or a failing septic system runs a greater risk of contamination than a well on the uphill side of these contamination sources.
- If possible, the well should be located above (higher in grade) disposal areas. The slope of surface land does not always indicate the direction a pollutant might flow,

once it penetrates into the ground. Groundwater often moves toward surface streams and lakes, even though the aquifer supplying water to the well may be deep below the surface, and its slope different from that of the land surface. Determining groundwater movement on a farm may require special monitoring equipment.

Once the site is selected and the well is in place, proper maintenance is important to ensure that the water does not become contaminated. The site should be kept clean and well casings, seals and caps should be maintained properly to prevent surface water and contaminants from entering the well. It is also important to realise that groundwater is not always static. Rain, snowmelt or interchange with surface waters usually recharges a well. Because of this, human activities can lead to contamination of groundwater. Handling of pesticides in the vicinity of wells may result in chemical contamination of the water.

3.2 Summary of GAP to prevent contamination of water sources

- Identify the primary and secondary sources of water, and be conscious of sources that may introduce pathogens.
- Take necessary measures to prevent access of animals to crop fields, water sources and related areas.
- Be aware of uncontrollable wildlife vectors and treat water accordingly.
- Identify any adjacent fields that are using untreated animal manure as fertilizer.
- Avoid storage of manure near crop fields.
- Establish the topography of the landscape, its effect on water flow and the rainfall pattern of the region.
- Maintain water storage tanks.
- Periodically verify water treatment and quality by submitting samples for microbiological testing.
- Tests for standard indicators of faecal pollution, such as *E.coli*, can be carried out, but do not necessarily indicate the absence of protozoa or viruses.

3.3 Hazards introduced by irrigation practices

Irrigation is the controlled application of water to the land, with the purpose of providing the moisture levels required for the healthy development of the plant. Irrigation plays a major role in achieving cultivable lands, especially in arid and semi-arid regions.

Irrigation methods commonly used include (Solomon, 1988; ERS, 2001):

- Surface (furrow or flood) – where the soil surface is used as a conduit for water that is allowed to pond on the ground, either in furrows or throughout the field. Overhead (sprinklers) – water is delivered through a pressurized pipe network to sprinklers, nozzles or jets, which spray the water into the air and allow it to fall onto the plants and soil as an artificial "rain".
- Trickle irrigation - the slow, frequent application of water to the soil through emitters placed at or near the root zone of the plants. The term 'trickle irrigation' is a general one, and includes several more specific methods. Drip irrigation applies the water through small emitters to the soil surface, usually at or near the plant to be irrigated. Sub-surface or buried irrigation is the application of water below the soil surface.
- Micro-sprinklers – are a cross between sprinkling and trickle irrigation. These systems use low-volume sprinkler heads located about 0-3 m above the ground to spray water over a wide area, when low-volume, overhead irrigation is desired. They are designed for areas where drippers are not practical, such as large areas with ground cover or under trees. Their low-volume spray does not reach high into the air, so tailed plants are less directly exposed to the water.

The choice of irrigation system is important to product safety, since this determines the degree of contact between irrigation water and the produce. In general, the quality of water indirect contact with the edible parts of produce may need to be better than that with minimal product contact. Where water quality is unknown, or cannot be controlled, growers may want to consider irrigation practices that minimize contact between water and the edible part of the crop.

With these systems, the use of good quality water and proper use and maintenance of equipment is especially important.

3.4 ‘Chemigation’

Chemigation is a combined process in which water is used both for irrigation and the application of pesticides and/or foliar fertilizers. With this process, the microbiological quality of the water used also needs to be considered. In addition to hazardous biological agents, water can contain chemical contaminants. When chemigation systems are not properly designed, they can result in serious contamination of groundwater, increasing the risk of chemical contamination for fresh produce.

Additional safeguards against contamination during chemigation include training and certification of operatives and analysis of the water at the source and at suitable locations nearby. In addition, it is important to identify the direction of any run-off. In the case of fertilizers, it is important to know of any plant toxicity and to pay close attention to calculated and recommended dosage rates and schedules of application.

3.5 Agricultural water: microbiological testing procedures

Proper recording of data on the microbiological (and chemical) quality of water used during the growing season is an important part of GAP. It is also important to document the frequency of water testing since changes in results may identify problems.

Fecal indicator bacteria are used to show when fecal contamination of water has occurred. They are natural inhabitants of the gastrointestinal tract in humans and other warm-blooded animals.

To determine whether water being used for agricultural purposes is contaminated with fecal material, the recommended laboratory tests aim to detect fecal coliform bacteria, especially *Escherichia coli*. The absence of these organisms shows that no fecal contamination has occurred.

Table 1 provides guidelines on the frequency of water testing in relation to the source of the water. The guidelines have been proposed by the California Strawberries Commission

(CSC, 1998).

Table 1. Proposed frequency for testing of water in the Quality Assurance program produced by the California Strawberries Commission (CSC, 1998).

Source	Possible water testing frequency
Closed system, underground or covered tank	One annual test at the beginning of the season
Uncovered well, open canal, water reservoir, collection pond	Every three months during the season
Municipal/district water system	Keep records from the municipality/district water system (monthly, quarterly or annual report)

It is clear that the type of water source will determine the frequency of testing (CSC, 1998). With closed, covered or underground systems, where contamination is less likely to occur, annual testing is sufficient, if the well is properly constructed. The frequency of testing is, however, debatable. Closed systems should be tested at least twice for example before and once during the growing period. With open systems, such as uncovered wells, open canals and ponds, testing every three months is recommended. Since open reservoirs are naturally contaminated by fecal material (e.g. from birds), the use of such water is questionable for fresh produce such as salad, strawberries, etc.

Additional testing should be considered after a significant event that might cause contamination of the water, such as heavy rain or flooding, and if any dead bodies are discovered in the water.

4. Summary

1. Agricultural land and land that has been used for activities other than agriculture can be contaminated with pathogenic organisms or toxic chemical substances.

2. As part of a Good Agricultural Practice program, it is necessary to identify possible sources of microbial and chemical contamination associated with the prior use of land that it is to be used for crop production. Use of adjacent land is also important and should be investigated.
3. Each time, water comes into direct contact with fruits or vegetables, there is a possibility of chemical and biological contamination of the crop. This includes water used for purposes such as irrigation and application of chemicals, fresh-produce washing, use in packaging facilities and during transportation. The quality of water used to produce ice for cooling and other operations is also important, since this can be another source of contamination.
4. The severity of the hazard resulting from poor-quality water will depend on the degree of contact between the water and the produce, the types and numbers of microorganisms in the water and their capacity to survive on the produce.
5. Water destined for agricultural use can easily become contaminated with human and/or animal faeces. It is important to keep animals and children out of the fields, and to provide field workers with properly constructed and maintained restrooms or mobile sanitary units.
6. If wells or other water sources are contaminated with coliform bacteria or *E.coli*, possible control measures include disinfecting with chlorine, or other suitable disinfectant, and filtration of the water.

References

1. Bern, C., Hernández, B., Lopez, M.B., Arrowood, M.J., Alvarez, M., De Merida, A.M., Hightower, A.W., Venczel, L., Herwaldt, B.L. and Klein, R.E. 1999.
2. Buttler, T., Martinkovic, W. and Nesheim, O.N. 1993. Factors influencing pesticide movement to ground water. University of Florida. Florida
3. Castillo Martín, A., Cabrera Jordán, J., Fernández Artigas, M., García Villanova Ruiz, B., Hernandez Ruiz, J., Laguna Sorinas J., Nogales Vargas-Machuca, R. and Picazo

- Muñoz, J. 1994. Criterios para la evaluación sanitaria de proyectos de reutilización directa de aguas residuales urbanas depuradas, Junta de Andalucía, Sevilla. Cooperative Extension Service. Fact Sheet PI-2. June 1993.
4. CSC. 1998. Quality Assurance Program. California Strawberry Commission.
 5. Engel, N, Embleton, K.M. and Engel, B.A. 1997. Well water location and condition on the farm. U.S. Environmental Protection Agency and Purdue University. Available via the Internet at <http://www.epa.gov/seahome/well/src/title.htm>
 6. <http://www.ers.usda.gov/Briefing/wateruse/Questions/glossary.htm>
 7. FDA. 1998. Guide to minimize microbial food safety hazards for fresh fruits and vegetables. U.S. Food and Drug Administration. Available via the Internet at <http://www.cfsan.fda.gov/~dms/prodguid.html>
 8. Nguyen-the, C. and Carlin, F. 1994. The microbiology of minimally processed fresh fruits and vegetables. *Crit. Rev. Food Sci. Nutr.* 34: 371-401.
 9. Nguyen-the, C. and Carlin, F. 2000. Fresh and Processed vegetables, In: “The microbiological safety and quality of foods”. B.M. Lund, T.C. Baird-Parker and G.W. Gould (Eds), Aspen Publication, Gaithersburg, pp: 620-684.

This document is partly based on the document ‘Improving the safety and quality of fresh fruit and vegetables’ produced by the University of Maryland, USA. ©2002 University of Maryland.