# SECTION II
# GOOD AGRICULTURAL PRACTICES*



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# SECTION II

## Good Agricultural Practices

### Introduction*

Produce may become contaminated with pathogens anywhere in the farm-to-table chain. If produce becomes contaminated, there is no process other than thorough cooking to ensure elimination of the pathogens. Since cooking is not appropriate for produce bound for fresh markets, prevention of contamination is imperative to assure a safe product.

The use of Good Agricultural Practices (GAPs) during growing, harvesting, sorting, packaging, and storage operations for fresh fruits and vegetables is key to preventing pathogen contamination. Key areas of concern when implementing a GAP program are prior land use, adjacent land use, water quality and use practices, soil fertility management, wildlife, pest, and vermin control, worker hygiene and sanitary facilities, and harvesting and cooling practices.

The following modules provide a look at these operations and the GAPs associated with each. The intent of this manual is not to cover every detail of each operation in the production and handling of fresh produce but rather to educate on the importance of the topic and to use pertinent examples to illustrate some concerns. Because of the diversity of agricultural production practices and commodities, procedures recommended to minimize microbial contamination will be most effective when these general concepts are adapted to specific operations.

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# Module 1
# Soil and Water

## Learning Outcomes

- ***Participants should be able to identify the potential for produce contamination resulting from current and prior uses of the soil.***

- ***Participants should be able to recognize the potential for produce contamination associated with water quality and use practices.***

## Practical

- ***Laboratory Exercise: Water as a Contamination Agent***

## Additional Resources

- ***Part III – Disinfecting Contaminated Wells***

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In order to reduce risks associated with the production of fresh fruits and vegetables, it is necessary to first assess the potential hazards in the production environment. Once the potential sources of produce contamination have been identified, practices should be implemented to reduce or eliminate them.

For example, human and animal feces are one of the most important sources of contamination of soil and water. This contamination can be easily spread to fresh produce. When assessing the possible produce contamination associated with a production site, it is important to look at the potential for fecal contamination and, if it exists, to determine steps to eliminate this hazard source.

## Soil

Agricultural land and land that has been used for activities other than agriculture can be contaminated with pathogenic organisms or toxic chemical substances. Obtaining a history of the prior use of the land is important because it helps identify these potential hazards. In addition, the failure of prior users to follow Good Agricultural Practices can offer risks of contamination to produce grown on the soil.

Visual II.1-1

**Identification Of Hazards Associated With Soil History**

As part of a Good Agricultural Practice (GAP) program it is necessary to identify possible sources of microbial and chemical contamination associated with the prior use of land that it is being used for agricultural production.

It is important to obtain information about the previous use of the land where agricultural production is taking place. This can be done through interviews with prior owners, a review of municipal permits or from other sources. This background information can help in the identification of situations that can increase the risk for fresh produce contamination (FDA, 1998).

Visual II.1-2

**Cultivated Land Information**

Important information that needs to be obtained about the history of the land includes if the land has been used:

- For animal feeding
- For domestic animal production
- 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, industrial waste or if mineral residues exist on the site
- For barns and/or if farm animals are being produced on land adjacent to or a short distance from the cultivation site.

Other information that should be obtained include if 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 animal feeding or domestic animal production can greatly increase the risk of contamination of fruit and vegetables with pathogens commonly found in the intestinal tract of animals. The potential for contamination from this source is related to the time that has passed since the land was used for animal feeding or production. The risk of contamination will also be influenced by conditions such as atmospheric temperature, sunlight and relative humidity.

The presence of barns or farm animals 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 currents flowing near these areas will help determine the potential for contamination. In some instances it may be necessary to create physical barriers or channels to divert water which may carry contamination from the animals.

When the land has been used for garbage disposal or as a waste management site, it may contain decomposing organic matter and, perhaps, fecal material.

Depending on the garbage contents, soil microbial loads can be extremely high and the soil may also contain harmful chemicals or toxic contaminants.

Land that has been used for mining or petroleum extractions can be contaminated with heavy metals or hydrocarbons. Even if the contamination is located on a small portion of the land, factors such as rainfall and subterraneous water flow should be evaluated. Analysis of toxic substances in the soil and a review of the environmental compliance of the extraction operation are recommended when the ground history indicates a high risk for chemical hazards.

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

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

Visual II.1-3

**Current or Prior Use of Adjacent Land**

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

The land owner or operator should research both the present and prior use of adjacent lands to identify potential produce contamination and precautions that need to be taken to prevent contamination of fresh produce in the field.

Contamination from areas away from the actual growing area can reach produce through a variety of means including water or wind flow, and workers, vehicles, or equipment moving from one area to another.

## Water Resources and Irrigation Practices

Visual II.1-4

Water used in the production of fruits and vegetables can be a source of pathogen contamination and dissemination.

During agricultural production of fruits and vegetables, water is used for numerous activities in the field, including irrigation and pesticide and fertilizer application (FDA, 1998). Other water uses during produce handling include cooling, washing, waxing and transportation. In addition to activities where water comes in direct contact with produce, field and packing shed workers use water for drinking and hand washing.

Visual II.1-5

Water used in agricultural activities can be contaminated with pathogenic bacteria that may cause severe health problems to consumers.

It can be a source of and vehicle for biological hazards such as:

| | |
|---|---|
| Enterohemorrhagic and Enterovirulent ***Escherichia coli*** | ***Salmonella spp*.** |
| ***Vibrio cholerae*** | ***Shigella spp*** |
| ***Cryptosporidium parvum*** | ***Gardia lamblia*** |
| ***Cyclospora cayetanensis*** | ***Toxisplasm gondii*** |
| Norwalk virus | Hepatitis A virus |

Such microorganisms are associated with gastrointestinal diseases that, in severe cases, can cause death.

Poor quality water may be a direct source of contamination and also an important vehicle for spreading microorganisms in the production field (Bern et al., 1999). Every time water comes in direct contact with fruits or vegetables, the possibility of contaminating the produce with pathogens exists. This includes water used for produce production, fresh produce washing, 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.

Visual II.1-6

The chances of contamination of fruits and vegetables with microorganisms present in water can increase depending on factors such as:

- Product growth stage
- Type of crop
- Time between water application and harvest
- Water and product handling practices

In addition to the quality of the water other factors that can increase the risk of contamination of produce by water include the stage of development and type of crop, the time between the contact of the produce with the water and harvest, and other water and produce handling practices. Fruits and vegetables with large surface areas, like leafy vegetables, or those where the surface structure allows pathogens to adhere easily are at a greater risk of contamination from water. This risk can be further increased when the contact with contaminated water takes place near harvest time or during post harvest handling.

**Potential Produce Contamination Associated with Water Sources**

Visual II.1-7

Usually, water for agricultural uses comes from***:***
- Surface sources such as rivers, streams, and reservoirs
- Ground water from wells (open or capped)
- Public water systems such as those provided by towns or other municipalities

Among the most common sources of agricultural water are surface rivers, streams, open canals, etc. Other sources include reservoirs such as swamps, lakes, tanks, ground water from wells (open or capped) and, occasionally, public water systems.

Surface and reservoir sources vary considerably in their microbial content. Microbial loads of surface water range from several thousand organisms per milliliter after a rainfall to a relatively low number after auto purification, a normally occurring process in smooth waters.

Surface waters can be exposed to temporary or intermittent contamination. This contamination can come from raw human and animal wastes, sewage water discharges, and water coming from adjacent lots dedicated to animal production or other contamination. Surface water generally flows some distances before it reaches the crop. It is important to identify upstream sources of contamination to this flow. Elimination of this contamination may involve modification of the water’s route or the introduction of intervention methods, such as filters.

Visual II.1-8

> Water destined for agricultural production can easily become contaminated with human and/or animal feces.
>
> To protect water sources:
> - Keep animals and children out of the fields;
> - Provide field workers with properly constructed and maintained restrooms or sanitary mobile units;
> - Properly develop wells and water systems.

Water destined for agricultural production can easily become contaminated with human and/or animal feces. 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. Water contamination with human fecal material also can occur if wells and water systems are not properly developed, if septic systems fail or have deficiencies in their design, and from discharges that come from 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 and minimization of potential contamination by wildlife should be the goal.

Visual II.1-9

> Ground water may be contaminated by a variety of biological and chemical hazards, which include:
> - Bacteria, viruses, parasites, and protozoans
> - Domestic waste
> - Nitrate nitrogen
> - Synthetic organic chemicals
> - Heavy metals
> - Petroleum residues
> - Combustion products from roadways

It is generally believed that ground water is less likely than surface water to be contaminated with pathogens since ground water generally loses much of its bacterial and organic compound content after filtration though rock and clay layers. (Buttler et al, 1993). The bacterial content of ground water may vary from a few to a few hundred organisms per milliliter. However, under certain conditions, such as with shallow, old, or improperly constructed wells, the potential for contamination of ground water by surface water is a great risk.

Prevention of well contamination begins with proper placement 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 well pumping on groundwater movement, and susceptibility of the site to flooding.

Both soil and slope characteristics make well location tricky. The following standards apply to the placement of wells (Engel et al., 1998):

- The well should be located away from septic tanks, sewage disposal areas (such as a drain field), and other sources of contamination such as feed lots, manure piles, chemical storage, chemical mixing areas, dumps or landfills, fuel storage tanks, storm sewers, privies, or refuse dumps. Separating the well from a contamination source may reduce the chance of pollution, but it does not guarantee that it 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 extra precautions to protect it must be planned. Floodwater can easily carry bacteria, oil products, and pesticides from one place to another.
- Surface drainage should be planned to run water away from the well on all sides. Up-slope drainage should be diverted away from hillside wells. A well 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.
- The well should be located above (higher in grade) disposal areas if possible. Surface land slope does not always indicate the direction a pollutant might flow once it gets into the ground. Groundwater often moves toward surface streams and lakes, but the aquifer supplying water to the well may be deep below the surface, and its slope may be different than the land surface. Finding out about groundwater movement on a farm may require special monitoring equipment.

Once the well site is selected and the well is in place, proper maintenance is important to assure the well water does not become contaminated. The well site should be kept clean and well casings, seals and caps should be maintained to prevent surface water and contaminants from entering the well. It is also important to consider that ground water is not inactive. Rain, snowmelt, or interchange with surface waters usually recharges a well. Because of this, human activities can lead to contamination of ground water.

Pesticide handling in the vicinity of wells may result in chemical contamination of ground water. The location of wells should be considered when mixing, applying, storing and disposing of pesticides. Vegetation or other barriers should be established as guard zones to help limit contact between the chemicals and water sources (Nesheim, 1993).

Visual II.1-10

**Summary of GAPs to Prevent Contamination of Water Sources**

- Identify the primary and secondary sources of water, and be conscious of sources for possible pathogen contamination.
- Identify sources of water shared with grass-lots, feed-lots and dairy farms.
- Take necessary measures to prevent animal access to crop fields, water sources and other related areas.
- Be aware of uncontrollable wildlife vectors and treat water accordingly.
- Identify if any adjacent fields are using untreated animal manure as fertilizer.
- Avoid manure storage near the crop fields.
- Identify topography of the landscape, its effect on water flow and the rainfall pattern of the region.
- Provide maintenance to water storage tanks.
- Periodically verify water quality by submitting samples for microbiological testing. Tests for standard indicators of fecal pollution, such as ***E.coli*** can be performed but do not necessarily indicate the absence of protozoa and viruses.

Good agricultural practices also include the use of soil and water conservation practices, such as channel construction, drain control structures, diversion tanks, vegetation barriers, etc., which act as physical barriers in the event of a contaminated water run off.

### Hazards Introduced by Irrigation Practices

Visual II.1-11

**Irrigation**

Controlled application of water to the land or field with the purpose of providing the moisture levels required for the appropriate development of the plant.

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

Visual II.1-12

**Irrigation methods commonly used include:**
- Surface (furrow or flood)
- Overhead (sprinklers)
- Trickle (drip or buried)
- Micro-sprinklers

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

- Surface (furrow or flood) – where soil surface is used as a conduit for water that is allowed to pond on the ground 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, to fall onto the plants and soil in an artificial "rain".
- Trickle irrigation - the slow, frequent application of water to the soil though emitters placed at or near the root zone of the plants. The term trickle irrigation is general, 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. Subsurface or buried irrigation is the application of water below the soil surface.
- Micro-sprinklers – are a cross between sprinkler and trickle irrigation. These systems use low-volume sprinkler heads located about 1 foot 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 of ground cover or under trees. Their low-volume spray does not reach high into the air so plant material not growing close to the ground is not directly exposed to the water.

Irrigation methods are selected according to the environment, water source, climate, soil characteristics, type of crop, and cost. The type of irrigation system chosen is important to product safety since this determines the amount of contact between the irrigation water and the produce. In general, the quality of water in direct contact with the edible portion 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 portion of the crop (FDA, 1998).

Visual II.1-13

**Hazards associated with irrigation practices are influenced by:**

- Water source and quality
- Amount of water applied
- Irrigation program
- Irrigation method - degree of contact with the edible portion of the fruit or vegetable
- Soil drainage properties
- Time to harvest date

The closer to harvest irrigation occurs, the greater the chance for survival of pathogens and for the presence of residual chemicals on the produce. Irrigation methods, like drip system, where the contact between water and plant is minimized, are generally less likely to lead to fresh produce contamination, however, the use of good quality water is still important. Sprinklers offer a greater degree of contact between the edible portion of the fruit or vegetable and the water. Therefore, a greater risk of produce contamination may occur. With these systems, the use of good quality water and the proper use and maintenance of the equipment is especially important.

Visual II.1-14

**Chemigation**

Refers to the application of fertilizer or pesticides through irrigation systems.

Water used for the application of pesticides and foliar fertilizers can be a source of microbial contamination. For this reason, the microbiological quality of the water used for these activities should be considered.

In addition to biological hazards, water also can contain chemical contaminants. When chemigation systems are not properly designed, they can result in serious ground water contamination, increasing the risk of chemical contamination of fresh produce. Safety equipment is available that can prevent back-flow and subsequent groundwater contamination (Olexa, 1991). This equipment is relatively inexpensive and can prevent serious hazards.

Additional safeguards against contamination during chemigation include training and certification of applicators and water analysis at the source and at locations near the water source. In addition, it is important to identify the runoff direction, if runoff takes place. In the case of fertilizers, it important to know the plant toxicity of the specific fertilizer and to pay close attention to calculated and recommended dosage rates and schedules of application (Olexa, 1991).

**Agricultural Water Microbiological Testing Procedures**

Visual II.1-15

- Microbiological testing is used to track safety, not for daily monitoring activities.
- It is important to document the frequency and results of each water test for comparison purposes. Changes may help identify problems.
- These records would become very important in the event of a microbiological outbreak investigation.

Microbiological determinations are time consuming so are used to track safety trends, not for daily monitoring activities. They are generally used to verify that the appropriate preventive measures are in place. Microbiological analyses are generally performed as indicators of contamination, especially for the verification of cleaning programs for tanks, wells, or when contamination from a specific source or event is suspected.

Proper records of water microbiological quality are an important good agricultural practice. It is important to document the frequency and results of each water test since changes in results may identify problems.

Testing for specific pathogenic bacteria in water may be inappropriate. They could be present in very small amounts and thus not detected. Furthermore, microbiological characteristics of water can vary considerably depending on such factors as the water source, season, and sampling time. Since waterborne disease is usually the result of fecal contamination of water supplies, it is more efficient to determine if fecal contamination is present than to actually look for the presence of pathogens.

The fecal indicator bacteria are used to identify when fecal contamination of water has occurred. The fecal indicator bacteria are natural inhabitants of the gastrointestinal tracts of humans and other warm-blooded animals. These bacteria are released into the environment with feces and, in general, cause no harm. However, relatively high numbers of fecal indicator bacteria in the environment, suggest an increased likelihood of pathogens being present as well. In the United States, coliform bacteria serve as the indicator organisms for fecal contamination.

Visual II.1-16

Laboratory assays commonly performed to determine the quality of water for agricultural usage include:

- Total and fecal coliform bacteria
- Enumeration of ***Escherichia coli***

To test if the water being used in agricultural production is contaminated with fecal material, the recommended laboratory tests should look for the presence of fecal coliform bacteria, specifically ***E. coli***.

Visual II.1-17

MCL (Maximum contaminant level) for total coliforms in drinking water is <u>Zero</u>

An MCL does not exist for agricultural water, however growers are urged to minimize all hazards over which they have control.

The maximum contaminant level (MCL) for drinking water for total coliform/E.coli is zero (U.S. EPA, 2001b). An MCL does not exist for agricultural water, however growers are urged to take a proactive part in minimizing sources of microbial contamination over which they have control. If wells or water sources are contaminated with these organisms, possible alleviation measures include disinfecting with chlorine or another disinfectant or filtration of the water source. Part III in the Additional Resources section gives general procedures for disinfecting contaminated wells.

Visual II.1-18

| **Source** | **Possible Water Testing Frequency** |
|---|---|
| Closed system, under the ground or covered tank | One annual test at the beginning of 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) |

The type of water source will determine the recommended 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 developed. With open systems, like uncovered wells, open canals and ponds, testing every three months is recommended to track the water's safety. Additional testing should be considered after a significant event that might cause water contamination such as heavy rain or flooding.

Visual II.1-19

**Water Sample Collection**

- <u>Sterile</u> sample containers should be obtained from the testing laboratory because containers may be specially prepared for a specific contaminant.
- Sampling and handling procedures will depend on the specific water quality concern and should be followed carefully.
- If water has been chlorinated, the presence of residual chlorine or other halogens can prevent the continuation of bacterial action. To prevent this occurrence, sodium thiosulfate should be added to the collection tube.
- If the water is collected from a tap, the water should be allowed to flow for 1-3 minutes before the sample is taken.
- The sample should be analyzed as soon as possible and no more than 30 hrs after its collection.
- Samples should be kept cool (<10$^{o}$C) during transportation from the source to the laboratory.

When testing water, care should be taken in collecting and handling the sample to assure the integrity of the sample, to avoid contamination during the sampling process and to assure changes do not take place in the sample after it is collected. Some water conditions and/or treatments can affect tests for microorganisms so samples must receive special treatment if these conditions exist. For example, if water has been chlorinated, the presence of residual chlorine or other halogens can prevent the continuation of bacterial action. To prevent this occurrence, sodium thiosulfate should be added to the collection tube. Basic considerations for the collection of water samples (U.S. EPA, 2000) are described in the visual above, however, precise procedures should be obtained from the testing laboratory being used to assure appropriate samples.

## 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 (GAP) program it is necessary to identify possible sources of microbial and chemical contamination associated with the prior use of land that it is being used for agricultural production. Use of adjacent land is also important and should be investigated.

3. Every time water comes in direct contact with fruits or vegetables, the possibility of contaminating the produce with pathogens exists. This includes water used for produce production activities like irrigation and chemical application, fresh produce washing, in packaging facilities and during transportation. The quality of water used to produce ice for cooling and other produce handling operations is also important since this can be a 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 type and amount of microorganisms in the water and their capacity to survive on the produce.

5. Water destined for agricultural production can easily get contaminated with human and/or animal feces. 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. The maximum contaminant level (MCL) for drinking water for total coliform/E.coli is zero. If wells or water sources are contaminated with these organisms, possible alleviation measures include disinfecting with chlorine or another disinfectant or filtration of the water source.

# Module 2
# Organic and Inorganic Fertilizers

## Learning Outcomes

- ***Participants should be able to identify potential produce contamination associated with the use of organic and inorganic fertilizers.***
- ***Participants should be aware of recommended composting procedures for manure.***

## Practical

- ***Laboratory Exercise: Water as a Contamination Agent***

## Additional Resources

- ***Part IV – Composting Facility***

Visual II.2-1

**Fertilizer**

Natural or synthetic substance added to the soil or plants to provide them with the necessary nutrients for plant development.

Fields used for agricultural production generally require the addition of plant nutritional supplements for soil enrichment. Fertilizers are natural or synthetic substances that are added to the soil or plants to provide them with the nutrients necessary for plant development. The use of fertilizers is a common practice to increase the soil quality, and consequently, the quantity and quality of the fruits and vegetables grown in it.

Visual II.2-2

**Categories of Fertilizers**

Fertilizers can be divided into two large categories:
- Organic
- Inorganic

Fertilizers can be divided into two large categories, organic and inorganic, depending on the source of the material.

## Organic Fertilizers

Visual II.2-3

Raw materials commonly used for the production of organic fertilizers include:

- Animal manure
- Post-harvest material
- Organic waste
- Biosolids/sludge (human waste)

Organic fertilizers are derived from plant material or animals. They are obtained by the conversion of animal manure, post-harvest material or organic waste into compost. When properly treated, organic fertilizers can provide many advantages to public health because their production eliminates waste material that otherwise would constitute a source of bacterial contamination.

### Associated Risks

Visual II.2-4

**Hazards Associated with Animal Manure**

- When fecal material is used for fertilizer without proper treatment, there is danger of contamination of fruits and vegetables with pathogenic bacteria.
- These bacteria can cause gastrointestinal and other illnesses in humans.
- Survival of viruses and protozoa in composted manure has not been clearly determined.

Human and animal fecal materials are important sources of microbiological contamination of produce. Organisms linked to these sources include Salmonella, anaerobes such as, ***Enterococcus,*** and other intestinal bacteria. One of the most infectious organisms prevalent in animal manure is ***E. coli*** O157:H7 that usually comes from the fecal material of ruminants like cows, sheep, and deer. Other significant hazards found in human and animal fecal material include ***Salmonella*** and ***Cryptosporidium*** (FDA, 1998).

Animal manure and solid biological waste may provide safe, effective fertilizer when properly treated. If the treatment is inadequate, or if no treatment is used, the risk of contamination of fruit and vegetables with pathogenic microorganisms is extremely high. The rate of survival of contaminants in manure and their transfer to crops depends on a number of factors. These include soil type, manure application rate, soil pH, composting method and time of application.

Continued application of untreated manure on a site could lead to extended pathogen survival and buildup which increases the risk of both contamination at that site and the spread of contamination to nearby sites.

In addition to microbial hazards, the use of solid biological waste on land can also introduce chemical hazards, such as heavy metals and toxic organic compounds. These materials may accumulate to levels that will be harmful to plants grown on the land. Another harmful effect from improperly treated manure is decreased water quality due to the release of oxygen demanding substances, suspended solids, and nitrogen.

**Treatments to Reduce the Risks**

Visual II.2-5

**Composting**

Composting is a natural, biological process by which organic material is broken down and decomposed.

Because the fermentation process generates a lot of heat it reduces/eliminates biological hazards in organic matter.

To convert organic waste into safe fertilizers (compost), practices should be followed to reduce the presence of pathogenic bacteria. Composting is a natural, biological process by which organic material is broken down and decomposed. The composting process is carried out by bacteria and fungi which ferment the organic material and reduce it to a stable humus. Because the fermentation process generates a lot of heat it reduces/eliminates biological hazards in organic matter.

The principles of composting are quite simple -- just provide the microorganisms with an environment conducive to their growth -- a balanced diet, water and oxygen (Merka et al., 1994):

- The microorganisms best at composting are aerobic (require oxygen). During the composting process oxygen is used up quickly by microorganisms inside the compost pile. Aerating the compost pile allows oxygen to be resupplied to these microorganisms so that the composting process continues at a rapid rate.
- Composting microorganisms thrive in moist, but not soggy, conditions. Desirable moisture levels in the composting materials should be 40 to 60 percent. Too much water can cause the compost pile to become anaerobic; too little will prevent microorganisms from reproducing to adequately high numbers.
- A temperature in the range of $130^{o}$ to $150^{o}$F should be generated inside the compost pile. These high temperatures are produced by the biological activity

of the microorganisms that are breaking down the organic material in the pile and are beneficial to the composting process. High temperatures enhance the growth and reproduction of thermophilic (heat loving) bacteria that are especially good at digesting organic material. The heat produced by the microorganisms not only contributes to their own growth, but also speeds up the decomposition process and helps in killing pathogenic microorganisms.

The USDA´s Natural Resources Conservation Service (NRCS) has prepared guidance on the development and use of a composting facility. This document is included as Part IV of the Additional Resources section of this manual.

Visual II.2-6

Composting treatments can be divided in two groups:
- Passive
- Active

Composting treatments can be divided in two groups, passive treatments and active ones.

Passive Composting Treatments

Visual II.2-7

**Passive Composting Treatments**

Passive treatments are based on maintaining organic waste under natural conditions. Environmental factors such as temperature, humidity and ultraviolet radiation, given enough time, encourage the composting process and a reduction in the numbers of pathogenic microorganisms.

Passive treatments are based on maintaining organic waste under natural conditions. The compost piles are not turned and free oxygen in the piles is quickly used up, resulting in anaerobic conditions in the pile, slowing the composting process. However, environmental factors, such as temperature, humidity, and ultraviolet radiation, given enough time, inhibit the growth of pathogenic organisms and eventually destroy them.

The biggest obstacle to this approach is that it takes a long time to significantly reduce the number of pathogens in the material and determining the time required for this process to take place is difficult. The amount of time needed depends on the climate, region and season, as well as the source and type of manure and organic waste used. Due to these uncertainties, passive composting treatments are not recommended.

Active Composting Treatments

Active treatments are those in which piles of materials are managed so that conditions are created to speed up the process of converting waste materials to compost. Active treatment to convert organic material into compost is the treatment most widely used by farmers.

Visual II.2-8

Active Composting Treatments

- Artificially induce the environmental conversion of waste to compost.
- Compost piles are turned frequently or other aeration is provided to maintain adequate oxygen (aerobic) conditions.
- Temperature and moisture levels of the pile are monitored and supplements are added as necessary
- When properly applied, these treatments require less time than passive treatments to reach the required microorganism reduction level.

With active composting compost piles are turned frequently or other aeration is provided to maintain adequate oxygen (aerobic) conditions within the pile. Temperature and moisture levels of the pile are monitored and supplements are added as necessary to obtain optimum moisture and proper carbon:nitrogen ratio for complete composting. The composting process is complete when the pile stops heating. Under appropriate conditions, the high temperature generated during the fermentation process destroys most of the pathogens in a relatively short time

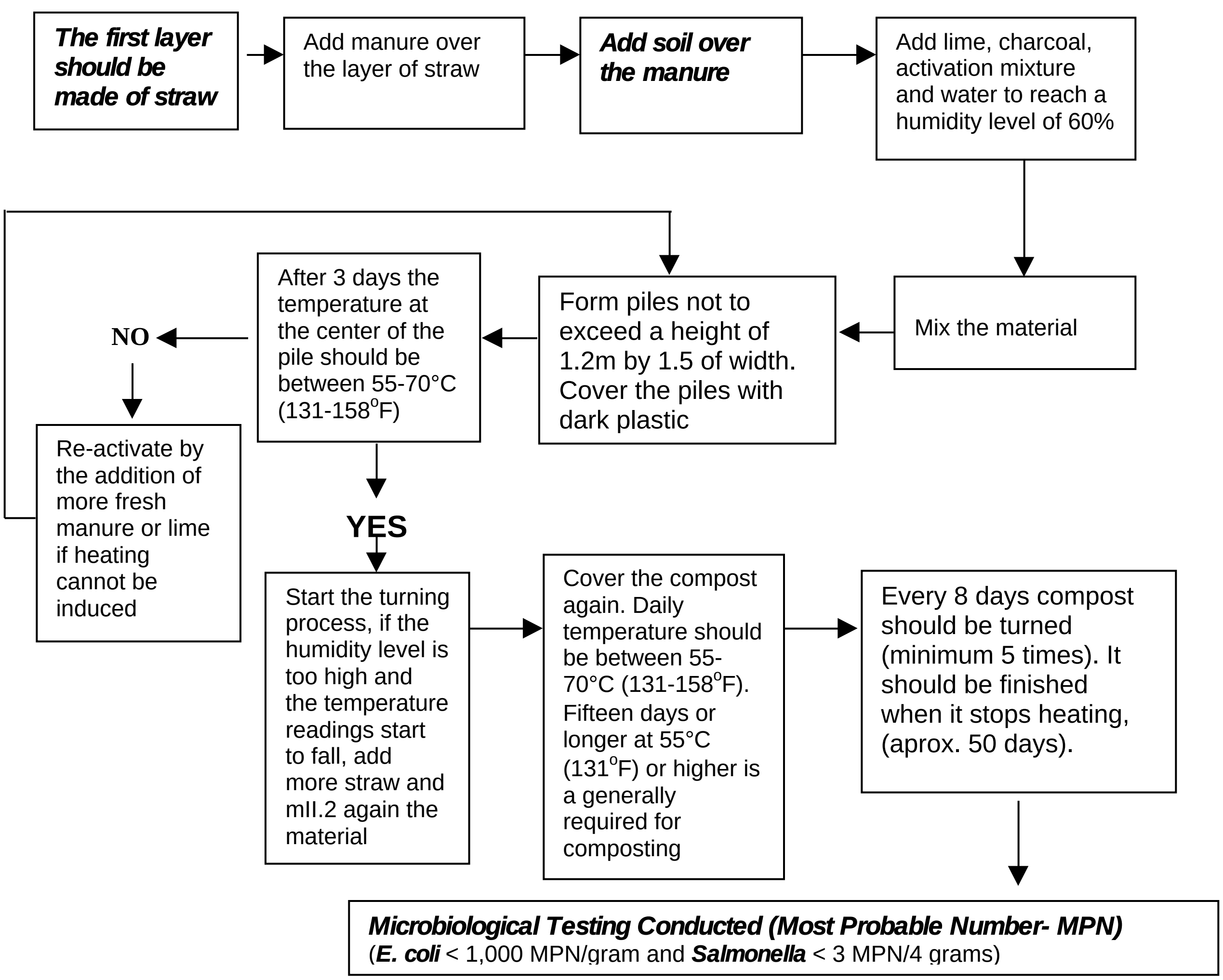
Microbial analysis of the compost may be performed to determine if the procedure was effective in the eliminating pathogenic bacteria. The presence of ***E. coli*** and ***Salmonella*** are generally used as indicators since, if they are still present in the compost, the organic fertilizer should not be applied to crops and additional treatments of the fertilizer are needed.

Additional active treatments such as pasteurization, drying with heat, anaerobic digestion, stabilization with alkalis, aerobic digestion or a combination of these may be applied to speed the composting process.

Figure1. Manure Composting Procedure currently being recommended by the Fresh Produce Safety Committee of the State of Guanajuato, Mexico (CESAVEG) (Ballesteros-Sandoval, 1999)

Composting Materials:
- ✓ 1000 kg of fresh cow manure (other sources include pig, chicken, veal and other farm animals). Large agglomerations should be broken down.
- ✓ 10 stacks of hay (150 kg) - they could be made of wheat straw or from alternative sources such as corn, sorghum, green remains from harvest, or organic waste (paper and cardboard)
- ✓ 50 kg of sieved soil. It should not contain glass, plastic or metals.
- ✓ 10 kg of ground charcoal
- ✓ 2 bags of lime (45.4 kg)
- ✓ Activator: 5 kg of molasses or sugar can be used. It is mixed in solution with baker's yeast
- ✓ Clean water
- ✓ Turning instruments
- ✓ Water hose
- ✓ Thermometer

Active composting is generally performed away from the production site, protected from the sun, wind and animals.



## Good Agricultural Practices in the Management of Organic Fertilizers

To assure that pathogenic microorganisms do not reach fruits and vegetables and, ultimately, the consumers, it is necessary to follow certain practices when manufacturing organic fertilizers, during their application and during harvest.

Visual II.2-9

**Hazards Associated with Manure Treatment and Storage Location**

- The location for storage and treatment of animal manure should be away from the produce production areas.
- Barriers or some type of physical containment should be used as part of the manure storage areas to prevent contamination of produce or production areas by pathogens spread by rain wash, subterraneous water flow or wind spread from the stored manure.
- Contamination of ground water supplies can be minimized if animal manure is stored on a cement floor or in special holes lined with clay.
- Manure piles should be covered with plastic or other materials and/or stored under a shed since rainfall on manure piles can result in run-off containing pathogenic bacteria that can contaminate fields, equipment, etc.
- The minimum distance from the manure storage facility to the production field depends on many factors, such as the configuration of the plantation fields, land slope, existing barriers to entrap water, and the possibility of bacterial spread by wind or rain.
- Treated manure should be kept covered and away from waste and garbage to prevent recontamination by birds or rodents.

Manure should be confined for treatment. The location for storage and treatment of animal manure should be far away from the produce production areas. Barriers or some type of physical containment should be used as part of the manure storage areas to prevent contamination of produce or production areas by pathogens from the stored manure spread by rain wash, subterraneous water flow or wind spread. Contamination of ground water supplies can be minimized if animal manure is stored on a cement floor or in special holes lined with clay. Rainfall on manure piles can result in run-off containing pathogenic bacteria that can contaminate the fields, equipment, etc. so manure piles should be covered with plastic or other materials and/or stored under a shed.

Equipment (tractors) that comes in contact with untreated manure can be a source of produce contamination. Equipment should be cleaned with high pressure water or vapor before it is allowed in the production areas. In a similar way, personnel handling manure should not go into the production fields without proper hygiene.

Treated manure should be kept covered and away from waste and garbage to prevent recontamination by birds or rodents. It should be maintained away from the plantation fields and separated from product packaging material so it will not contaminate the fresh produce, water sources or packaged produce.

Visual II.2-10

**Precautions for the Application of Organic Fertilizers**

- Properly treated organic fertilizer should be applied pre-planting or in the early stages of growth of the plant. It should be applied near the roots and covered with soil.
- Organic fertilizers should NOT be applied when the fruit or vegetable is nearing maturity or harvest.
- Maximum time should be allowed between the application of organic fertilizers and harvest of the product.
- It is also suggested that crops on adjacent fields be grown in a way that organic fertilizers are not applied near a field that is already cultivated or near its harvest time.

Properly treated organic fertilizer should be applied prior to planting or in the early stages of plant growth. It should be applied near the roots and covered with soil. Organic fertilizers should NOT be applied when the fruit or vegetable is nearing maturity or harvest. Maximum time should be allowed between the application of organic fertilizers and harvest of the produce. It is also suggested that crops on adjacent fields be grown in a way that organic fertilizers are not applied near a field that is already cultivated or near its harvest time.

To properly assess the severity of the risk of biological contamination, the type of fruit or vegetable that is being produced should be considered.

Visual II.2-11

Commodity specific considerations in determining the risk of disease from contamination with organic fertilizers:

- Characteristics of the crop (i.e. leafy vegetable vs. tuber) and mode of consumption
- Physical contact of the edible portions of fruits or vegetables with the ground
- Shape and texture of the fruit or vegetable

Produce that grows in or on the surface of the soil is more susceptible to contamination. Produce that grows close to the ground also is more easily contaminated by the splash of water during rain or irrigation. Fruits and vegetables that are produced on plants where they are not in direct contact with the soil are not as susceptible to contamination provided they are not dropped on the ground. The risk of contamination increases if the characteristics of the fruit or vegetable make it easy for dust or bacteria to adhere to their surface.

**Untreated Animal Manure**

Visual II.2-12

> The use of untreated animal manure (without composting) in the production of edible produce results in a greater risk of contamination than treated manure and is NOT recommended.

The use of untreated animal manure (without composting) in the production of produce results in a greater risk of contamination than treated manure and is NOT recommended.

Although raw manure is never recommended for use as a fertilizer, in some regions, it is used. When untreated manure is used, it should be introduced into the ground during soil preparation and prior to planting. Microorganisms in the soil may reduce the number of pathogenic organisms in the manure, however time is a critical factor. The manure should be incorporated into the soil and the ground turned periodically to facilitate pathogen reduction. A maximum amount of time should be allowed between application of manure and planting. The amount of time that pathogenic bacteria can survive in manure is unknown but some researchers estimate that, depending on environmental conditions, the survival period can extend to a year or more.

Applying untreated animal manure (without composting) on the fields during the cultivation period is not recommended.

**Recommended Controls and Records**

Keeping complete records of fertilizer preparation and use is part of a Good Agricultural Practices program.

Visual II.2-13

**Suggestions for information to record:**

- Origin of the organic material (Source and physical make-up of composted material)
- Date compost process started
- Treatment applied
- Turnings of windrows (minimum 5 times)
- Temperatures during composting (daily temperature readings of 55°C (131°F) or higher recommended).
- Times at 55°C (131°F) or higher for windrow composting.
- Amount used
- Place of application
- Date of the application
- Method of application
- Person responsible for the application
- Microbiological Testing Conducted (Recommended: ***E. coli*** <1,000 MPN/gram and ***Salmonella*** < 3 MPN/4 grams) [MPN= Most Probable Number]

Information should be kept about the preparation of the organic fertilizer, including the source of the material, details of the composting procedures, and the results of microbiological tests on the composted material. Information on the dates, amounts and methods of applying the fertilizer as well as the person responsible for the application should also be maintained. These records will help verify that appropriate steps were taken to assure safety of the produce and will be useful if a traceback is required.

## Inorganic Fertilization

Inorganic fertilizers are obtained via commercial chemical processes. Although the products themselves are generally not a source of microbial contamination, care should be taken to assure that contamination is not introduced through the use of contaminated water to mix the products or unclean equipment used in their application.

## Summary

The following table identifies points to consider when assessing the safety of fertilizer selection and treatments.

| **Evaluating Contamination Risks of Fertilization**<br>"Organic and Inorganic Fertilization" | |
|---|---|
| **Use of the following**<br>Organic Fertilizers yes no<br>Inorganic Fertilizers yes no | **Type of product being cultivated:** |
| **Origin of the Organic Matter**<br>Animal manure<br>Animal type _______________<br>Post-harvest waste<br>Organic waste<br>Sewage sludge/biosolids | **Type of composting treatment**<br>Passive<br>Active Which one?<br>______________________<br>None |
| **When are the fertilizers applied?**<br>Before planting/during preparation of the ground<br>During production<br>After harvesting | Do you have microbiological tests and/or records that indicate that the organic fertilizer has been treated to reduce pathogens? yes no |
| 1. Is there a direct contact between edible portion of the fruit or vegetable and the ground? yes no<br>2. Does the product morphology facilitate biological contamination? yes no | |
| Appropriate measures taken in the following areas to reduce risks at the production site<br>Adequate storage of manure<br>Adequate use of equipment or tractors.<br>Adequate traffic control through the field | |

# Module 3
# Animal Exclusion and Pest Control

## Learning Outcomes

- ***Participants should understand the potential for produce contamination associated with animals in the production areas.***

- ***Participants should understand recommended practices for pest and vermin control.***

## Practical

- ***Experiments Using Artificial Germs: How Germs are Spread II***
  ***Germs and Produce***

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### Animal Exclusion

All animals including mammals, birds, reptiles and insects are considered vehicles for contamination with pathogenic organisms. A large number of microorganisms can be found on the surface of animals (hair, feathers, hide, etc.) and in their respiratory and gastrointestinal systems.

Visual II.3-1

Feces are usually considered the major source of pathogenic organisms from animals. However:

- Some pathogenic bacteria commonly associated with animal skin include ***Salmonella***, ***Staphylococcus,*** and ***Streptococcus.***
- The feathers and other parts of domestic birds also can be contaminated with these organisms.
- Wild birds, reptiles and amphibians are a potential sources of ***Salmonella.***

Feces are usually considered the major source of pathogenic organisms from animals (Murray et al., 1995). However, since animals are in contact with the soil, manure and water, they can easily pick up contaminants from these sources on their hide, paws, hair, etc.

In addition to foodborne pathogens, animals can carry many spoilage microorganisms, which can greatly reduce the quality and shelf life of fresh produce. Quality deterioration also can be accelerated by physical damage to the surface of the fruit or vegetable caused by animals, birds and insects. In addition to lowering quality, the wounded surfaces become an open door to pathogenic and spoilage organisms, greatly increasing the risk of contamination of the internal portions of the produce.

Visual II.3-2

> All animals should be kept away from production and handling areas (agricultural fields, storage facilities, packaging areas, machinery, etc.) to prevent the contamination of fresh fruit and vegetables with biological hazards that can harm the consumer.

Domestic animals, such as pets and livestock, and wild animals are all potential sources of contamination of produce and should be kept out of production areas. The risk of contamination is greatly increased when there are large numbers of wild animals near the production field. This includes animals such as crows, migratory birds, bats, etc. The presence of these animals is common when there are large forests, rivers and/or prairies around the field. In such cases, there are a number of different measures that can be implemented to exclude animals from the fields.

Visual II.3-3

**Keeping Animals Out of Production Areas**

To reduce the presence of animals in the production areas it is important to follow common sense practices such as:

- Maintaining domestic and farm animals away from the fruit and vegetable production fields (vineyards, orchards, etc.) and establishing physical barriers or vegetation to prevent entry of wild animals. These precautions are especially important near harvest time.
- Field workers should not be allowed to bring dogs, cats or other domestic animals into the field, packaging areas or storage facilities.
- Dead or trapped animals such as birds, insects, rats, etc., should be disposed of promptly to avoid attracting other animals. Proper disposal procedures are to bury or incinerate the animal.

Domestic and farm animals offer as much risk of produce contamination as wild animals. All animals, including pets, should be kept away from produce production and handling areas. Dead or trapped animals should be disposed of promptly to avoid attracting other animals. Proper disposal procedures are to bury or incinerate the animal.

The maintenance of animal-free areas, such as cleared land, around the production site is also an important control. Farmers often use homemade devices to repel animals. In many cases, these are very effective. These devices range from scarecrows, to water guns, traps, and physical barriers. When selecting an animal exclusion method it is important to consider the country's environmental and animal protection laws.

Visual II.3-4

**Cleaning Considerations for Surrounding Areas**

- Keep the grass short to avoid the presence of rats, reptiles and other pests.
- Keep all areas free of garbage.
- Remove all unnecessary equipment - old and broken equipment can provide protection for rats and insects.
- Remove nests from fields and buildings

The topic of sanitation standard operating procedures (SSOPs) will be discussed in detail in Section III. However there are a few considerations regarding animal exclusion that are also related to good cleaning practices. All areas where produce is grown and handled should be kept clean and free of garbage, unused equipment or situations that might encourage animals to inhabit the area.

Visual II.3-5

**Animals and Water**

- Since animals are attracted by water, the presence of water in the field and packing building should be limited to that needed for specific uses
- In the packinghouse, surfaces and floors should be kept clean and as dry as possible to avoid the availability of water for bacterial and pest growth.
- Water tanks and storage containers should be capped to prevent animal access to water sources.

Since animals are attracted by water and water is needed for bacterial growth, the presence of water in the field and packing building should be limited to that needed for specific uses. In the packinghouse, surfaces and floors should be kept clean and as dry as possible to avoid the availability of water for bacterial and pest growth. Water tanks and storage containers should be capped to prevent animal access to water sources.

## Pest Control

Visual II.3-6

Insects and rodents are the pests most commonly found in food handling facilities

Insects (cockroaches, flies, etc.) and rodents are the pests most commonly found in food handling facilities. Rats and mice not only cause significant losses of fresh produce but also damage buildings. In addition, they can contaminate fresh produce with parasites and other diseases. Rodent feces and urine can contaminate produce since they can contain microbial pathogens.

### Pest Control Programs

Visual II.3-7

**Pest Control in Fresh Produce Operations**

- In fresh produce operations the term "pest" applies to all organisms that can contaminate fruit and vegetables during field production, packaging, storage and distribution.
- Insects, microorganisms, wild animals and weeds (which can also harbor insects, vermin, etc.) should all be considered in a pest control program.
- This program should also extend to the packinghouse, storage facilities and transportation vehicles.

In fresh produce operations the term "pest" applies to all organisms that can contaminate fruit and vegetables during field production, packaging, storage and distribution. This includes insects, microorganisms, wild animals and weeds (which can also harbor insects, vermin, etc.). All of these should be considered when implementing a pest control program.

Although cleaning is an important step for controlling pests, it is also important to implement a pest control program. Many produce packaging operations prefer to use professional pest control services. However, packinghouse personnel play an important role in detecting when a pest problem exists. Therefore it is recommended that an in-house pest control program be implemented to prevent fresh produce contamination.

Pest control programs should include a series of scheduled inspections to identify situations that can encourage the introduction of pests, identify the presence of pests and quantify their number.

Visual II.3-8

**Important Components of a Pest Control Program**

- Periodic inspection of facilities to identify pest outbreaks and/or contamination with animals and to identify pests, including insects, rodents, and wild and domestic animals.
- Scheduled inspection activities that include all areas of the operation/facility.
- Identification of the type(s) of pests and quantification of their numbers.
- Record keeping of all the inspections performed, indicating dates and problems that were observed with specific information on the identification of the pest detected and corrective actions taken.
- Verification of the effectiveness of corrective and preventive actions included in the company's pest control plan.
- Establishment of facility maintenance program to repair cracks and holes and to remove places where a pest can get established.

A sound pest control program will help assure pests are not a problem in the produce production and handling areas. Records should be kept of all inspections, pests identified and pest control treatments used. These records will aid in determining that pest control methods were appropriate for produce protection. It is also important to verify the effectiveness of corrective and preventive actions. This documentation can save time, money and help prevent small problems from becoming large ones.

Facility maintenance is important in controlling pests. Repairing cracks and holes will help keep pests from entering while eliminating places where pests can get established discourage them from becoming permanent residents.

## Common Pest Control Procedures

Pest control can be accomplished by either non-chemical or chemical methods, or through a combination of both (Table II.3-1). When selecting a pest control method, choose one that is approved for local, regional and/or national level use and then apply it appropriately.

Table II.3-1. Summary of control measures used to prevent or lessen the crop damage caused by pests (U.S. EPA, 2001c).

| METHOD | DESCRIPTION |
|---|---|
| BIOLOGICAL CONTROL | Uses living organisms for pest control. Biopesticides fall into 3 major classes:<br>(1) Microbial pesticides contain a microorganism (e.g., bacterium, fungus, or virus) that generally attacks a specific pest.<br>(2) Plant pesticides are substances that plants produce from genetic material that has been added to the plant.<br>(3) Biochemical pesticides are naturally-occurring substances that control pests by non-toxic mechanisms (e.g., pheromones).<br><br>Some plant growth regulators are naturally-occurring biopesticides. Biological control also includes the release of parasitic and predaceous insects to control insect pests or weed species. |
| PLANT RESISTANCE | Crop plants are bred to produce varieties that resist insects and other pests. Crop plants are also genetically altered to allow them to withstand herbicides so that only weed species are killed when treated with chemical pesticides. |
| CULTURAL METHODS | Methods include crop rotation, soil tillage, use of trap crops, change in planting or harvesting time, intercropping with other crops or with varieties which repel pests. |
| MECHANICAL AND PHYSICAL METHODS | Techniques such as collecting pests with traps, suction devices or by hand, using fire, heat, cold, sound, barriers or screens. |
| CHEMICAL METHODS | EPA defines conventional pesticides as synthetic chemicals which are intended to prevent, destroy, repel or mitigate any pest, or intended for use as a plant regulator, defoliant or desiccant. |
| INTEGRATED PEST MANAGEMENT (IPM) | IPM is a pest management approach that uses all available pest control methods, including but not limited to the judicious use of pesticides, to optimize a crop's ability to resist the pest with the least hazard to man and the environment. |

**Pesticide Use and Misuse**

Visual II.3-9

**Pesticides**

Pesticides are used to protect crops and stored grains, control household pests and nuisance insects, and eliminate vectors (organisms that carry pathogens from one host to another) of human and animal diseases.

Pesticides are used to protect crops and stored grains, control household pests and nuisance insects, and eliminate vectors (organisms that carry pathogens from one host to another) of human and animal diseases (U.S. EPA, 2001c). They are toxic (poisonous) chemicals used to control pests. Classes of pesticides are commonly named after the pests that they help to control (insecticides control insects; herbicides control weeds; fungicides control fungi; and rodenticides control rodents).

Since pesticides can be extremely harmful, they should be applied, handled and stored in accordance with the instructions given on the label or on the manufacturer's safety data sheet for the product. Because of the potential health hazards associated with pesticides, application rates should be controlled to limit the amount of residues on produce and only pesticides approved for use on a specific product or in food processing facilities should be used.

Visual II.3-10

Registration of a pesticide is a scientific, legal and administrative process to enable authorities to control quality, use levels, labeling, packaging and advertising. Data required for registration include:

- chemical and physical properties
- effectiveness
- toxicity for assessment of human health hazards
- prediction of environmental effects

Pesticides used on products for import into the U.S. must be registered with the Environmental Protection Agency (U.S. EPA, 2001c). Registration of a pesticide is a scientific, legal and administrative process through which EPA examines the chemical and physical properties of the pesticide, it’s effectiveness, its potential for causing toxic human health effects, and environmental effects resulting from its use. The producer of the pesticide must provide data from tests done according to EPA guidelines when seeking registration. Registration enables authorities to control quality, use levels, efficacy claims, labeling, packaging and advertising. Registration also helps to ensure that the interests of end-users are well protected.

Pesticides should be used only on crops for which they are registered. The use of pesticides on other crops or at inappropriate levels can result in produce being refused for importation thus leading to significant loss of income for growers, packers and shippers.

Selection of Pesticides

Visual II.3-11

- A particular pesticide should be used only for the purposes or crops that it was approved for, and only under authorized conditions, doses and intervals.
- The use of unauthorized pesticides is a common barrier to international trade.

Pesticides should be used only when needed and only in the amounts that will adequately control pests. Minimizing the amount of pesticide used reduces costs and helps to protect the environment (Nesheim, 1993). The pesticide label is the ultimate source of information for determining the proper application rates for a specific pesticide. It is recommended that growers document and verify that the pesticides used come from certified distributors, and that competent authorities approved their usage.

Pesticide Handling

Pesticide handling should be controlled through every phase of use from acquisition through storage to use in the fields. It is very important that the persons in charge of handling these products carefully follow the instructions printed on the label or on the information page that usually accompanies the product (Material Safety Data Sheet- MSDS).

Pesticide Application in the Field

The instructions for application of a particular pesticide should be read carefully before using the product. Information such as restrictions for its use, application rates, approved doses, number of applications and minimal intervals between applications should be carefully considered.

Pesticides can be applied in liquid, solid, or gaseous forms. It is important to follow label instructions for the mixing, loading and handling of the specific pesticide being used and the actual conditions of use. The amount of pesticide concentrate needed to treat a specific site should be carefully calculated. The water used to prepare pesticides should be free of pathogenic organisms.

Special attention should be paid to spray equipment, pumps and nozzles used to apply pesticides. To minimize the potential for over or under treatment, accidents and spills, they should be calibrated for accuracy and checked frequently for malfunctions. Spray equipment should be regularly washed to prevent possible contamination of fruits or vegetables with compounds not authorized for that commodity and to avoid accidentally overdosing.

Warning signs should be posted on fields that have recently been treated with pesticides to prevent workers or visitors from inadvertently coming in contact with treatment chemicals. Such signs should only be removed after the established re-entry period into the field has passed so that residual levels are at an acceptable level.

Pesticide Storage

The amount of pesticide on hand should be kept to a minimum by buying only what is needed for the season or for the specific application.

Visual II.3-12

The pesticide storage facility should:
- Be properly identified
- Be away from children, animals, and all water sources
- Be away from all water sources
- Have a concrete floor to facilitate clean up in the event of a spill or leak.

All pesticides should be stored safely away from children, animals, and anyone who might misuse them (U.S. EPA, 2001c). Pesticides should be stored in clearly labeled containers; storage in the original containers is preferable. Containers should be kept in a safe storehouse that is well ventilated and can be closed off to prevent unauthorized entry. The storehouse should be located away from populated areas, on well-drained land, and away from domestic water supplies. It should be constructed with non-combustible material, and have a leak-proof floor and emergency exits. Any pesticide spillage should be cleaned thoroughly with large amounts of water. Pesticides and food should never be transported in the same vehicle.

Pesticide Residues

Visual II.3-13

Maximum Residue Limit (MRL) - the maximum level of residue that is legally permitted to remain in or on a crop in commerce.

High levels of pesticide residues on crops may be a hazard to humans who eat the produce. To regulate pesticide residues, a legal limit known as the maximum residue limit (MRL) is developed for each pesticide (U.S. EPA, 2001c). The MRL is the maximum level of residue that is legally permitted to remain in or on a crop in commerce. This limit is used to provide reasonable assurance that no adverse effects to the consumer will result over a lifetime of dietary exposure. Although strict adherence to MRLs might not be feasible for some countries because of economic constraints, those countries relying on food export profits should monitor for and comply with these MRL levels in order to maintain credibility as responsible exporters.

Pesticide Disposal

Instructions and restrictions on pesticide disposal are available from the product's manufacturer and may also be established by local environmental regulators. These should be followed. Empty pesticide containers should be washed multiple times, then returned to the supplier or taken to an appropriate place for disposal (Nesheim, 1993). Excess spray and rinse water from equipment cleaning can be sprayed on sites or crops listed on the label. Never dispose of pesticides or pesticide containers in unused wells or near water sources. Empty, properly rinsed pesticide containers can be disposed of at most sanitary landfills. In view of the persistent, volatile nature of many pesticides, disposal by burning or burying on the farm is discouraged.

Training and Documentation

Visual II.3-14

Records of pesticide handling training activities should include:

- Employee's name
- Experience or hire date
- Position or job performed by the employee
- Date of training
- Training topics
- The institution responsible for training and instruction records or certificates
- Signature of trainer

Thorough training of personnel responsible for using and applying pesticides is critical. They should be aware of the dangers that can result from improper use of the product. They also should be trained in the use of safety equipment and application devices. Field workers should be reminded that adverse health effects caused by pesticides are often not noticeable in the short term, but can develop over time if exposure is not reduced.

The producer or person responsible for the pesticide application should have the following information:

- Technical data sheets on the pesticides to be used
- Pesticide permits issued by authorized regulatory organization. If the product is not listed as authorized for the crop being treated, it should not be used.

Visual II.3-15

A pesticide record sheet should contain information on:

- Crop data (variety, planting date, product code, etc.)
- Name of pesticides used
- Place of application
- Dosage
- Application dates
- Period of time before harvest
- Name of the person responsible for the application
- Date of last equipment calibration

A producer should critically evaluate the need for a pesticide and, when possible, use alternate methods of pest control. Careful records should be kept on pesticide usage and should include the information listed on the visual above (Buttler et al, 1993).

For a more information on considerations when selecting and using pesticides, the U.S. Environmental Protection Agency Technical Information Package (TIP) – Pesticide Use and Disposal (available via the Internet at www.epa.gov/oia/tips/pestint.htm) is recommended. This document was prepared to provide on-line information for international audiences on key environmental and public health issues related to pesticide use and to provide a summary of pertinent technical publications, databases, models, websites, and software programs related to this issue.

## Summary

1. All animals including mammals, birds, reptiles and insects are considered vehicles for contamination with pathogenic organisms that can cause illness and death. In addition to foodborne pathogens, animals can carry many spoilage microorganisms, which can greatly reduce the quality and shelf life of fresh produce.

2. Animals, both domestic and wild, should be kept away from production and handling areas (agricultural fields, storage facilities, packaging areas, machinery, etc.) to prevent the contamination of fresh fruit and vegetables with pathogens that can cause illness and death. The maintenance of animal-free areas, such as cleared land, around the production site is an important control.

3. Good sanitation is key to controlling animals and pests in produce production and handling areas. All areas where produce is grown and handled should be kept clean and free of garbage, unused equipment or situations that might encourage animals to inhabit the area.

4. In addition to cleaning procedures it is important to implement a pest control program. Pest control programs should include a series of scheduled inspections to identify situations that can encourage the introduction of pests.

5. Pest control can be accomplished by either non-chemical or chemical methods, or through a combination of both. When selecting a pest control method, choose one that is approved for local, regional and/or national level use and then apply it appropriately.

6. Pesticides are used to protect crops and stored grains, control household pests and nuisance insects, and eliminate vectors (organisms that carry pathogens from one host to another) of human and animal diseases. Because of the potential health hazards associated with pesticides, application rates should be controlled to limit the amount of residues on produce and only pesticides approved for use on the produce or in food processing facilities should be used.

7. Good quality water should be used for mixing and applying pesticides to minimize the risk of microbial contamination of produce.

8. Pesticides used on produce for import into the U.S. must be registered with the U.S. Environmental Protection Agency.

9. High levels of pesticide residues on crops may be a hazard to humans who eat the produce. To regulate pesticide residues, a legal limit known as the maximum residue limit (MRL) is developed for each pesticide. Countries relying on food export profits should monitor for and comply with these MRL levels in order to maintain credibility as responsible exporters.

# Module 4
# Worker Health and Safety

## Learning Outcomes

- ***Participants should recognize the relationship between worker health and hygiene and food safety.***

- ***Participants should recognize the key components of a worker hygiene training program.***

## Practical

- ***Laboratory Exercise: Handwashing Demonstration***
  ***GloGerm Handwashing***

Visual II.4-1

**Relationship between Worker Health and Hygiene**

- Assuring worker health both increases worker productivity and aids in preventing potential microbial contamination of crops
- An infected employee (showing symptoms or not) can easily contaminate fresh produce if they don't practice good hygiene such as washing their hands after sneezing, touching hair or other body parts, or using the restroom.

Assuring worker health increases worker productivity and aids in preventing potential microbial contamination of fruits and vegetables. An infected employee (showing symptoms or not) can easily contaminate fresh produce with microbial pathogens if they don't practice good hygiene such as washing their hands after sneezing, touching hair or other body parts, or using the restroom. These pathogens can then be transmitted to consumers who handle or eat the contaminated produce.

Visual II.4-2

General symptoms that flag an employee with the potential for causing microbial contamination of produce include:
- Diarrhea
- Vomiting
- Dizziness
- Abdominal cramps
- Exposed or open wounds
- Hepatitis or jaundice (yellow color of the skin)

Employees with gastrointestinal distress or open wounds can contaminate fresh fruits and vegetables through handling. General symptoms that flag an employee with the potential for causing biological contamination of produce include diarrhea, vomiting, dizziness, abdominal cramps, exposed or open wounds, hepatitis or jaundice (yellow color of the skin).

Persons that do not show any symptoms of disease can transmit microbial pathogens. Many microorganisms can be "guests" in the human body without evidence of disease and can be spread to others by the human "hosts".

Visual II.4-3

- Workers should be trained to report any disease symptoms to supervisors.
- Sick employees should not participate in activities that involve direct contact with the fresh produce or with packaging material until they have clearance from a licensed healthcare provider.

Supervisors should train workers to recognize disease symptoms and to report any appearance of symptoms. Workers with symptoms of disease should be assigned to activities that do not involve contact with the produce. Supervisors should be provided with training on pathogens and disease symptoms so that they are able to make judgements regarding the best actions for dealing with ill employees. Workers removed from produce handling tasks because of illness should not be returned to these jobs until they provide written medical documentation from a licensed healthcare provider stating that they are free of the infectious agent that is suspected of causing their symptoms or causing foodborne illness, or stating that the symptoms experienced result from a chronic noninfectious condition.

Visual II.4-4

**Health Programs**

- Ideally, agricultural workers should have access to a health care system.
- Employers should provide fruit and vegetable handlers with a training program on good food handling and hygiene practices

Ideally agricultural workers should have access to a health care system. It is also important for employers to provide fruit and vegetable handlers with a training program on good food handling and hygiene practices. The possibility of produce contamination is directly related to the quality of the worker training program. This training should be reinforced constantly. Demonstrations of procedures are usually more effective than simple verbal instructions. Feedback to the trainer is important to assess the effectiveness of the training. Like with any food safety assurance program, commitment of administration to the program is essential.

Visual II.4-5

**Worker Hygiene Training Program**

- Proper hygiene procedures should be established and included in hygiene and health training programs. All employees including supervisors, temporary personnel, part-time and full time workers should participate in these activities.
- The level of knowledge required should be set according to the type of operation, responsibilities and type of activities in which the employee participates.
- Training should be in the language/dialect of the employees to ensure comprehension and trainers should consider cultural aversions and ingrained practices when planning training.

Proper hygiene procedures should be established and included in hygiene and health training programs. All employees including supervisors, temporary personnel, part-time and full time workers should participate in this training.

The level of knowledge an employee should achieve will vary according to the type of operation and the responsibilities and type of activities in which the employee participates. In order to ensure employees comprehend and implement the training, it should be in the language/dialect of the employees and trainers should consider cultural aversions and ingrained practices of the trainees when planning training.

Visual II.4-6

**First-Aid Kit**

A first aid kit should be kept near the production site. It should contain:
- adhesive bandages
- hydrogen peroxide
- bandages
- gloves
- other wound protecting material.

Any worker with exposed wounds that can directly contaminate fresh produce should have these wounds properly disinfected and covered before participating in production and handling activities. A first aid kit with supplies for treating worker injuries should be readily available at the work site. The simple procedures for disinfecting and covering a wound should be included in employee training. Disposable gloves should be used to cover bandages, adhesive bandages and other objects that could easily fall into the product. Procedures used to treat injuries of workers should be documented.

When properly used, gloves are an effective way of preventing contamination and protecting the employee. However, gloves can become a means of spreading pathogens when they are not appropriately disinfected or changed after a potential contamination (e.g. using the bathroom or answering a phone). It should be clearly understood by workers and supervisors that the use of gloves is not a substitute for handwashing or other good hygiene practices.

If gloves are used, the disposable kinds (latex, plastic, etc) are better than multiple use ones since frequent replacement of gloves can help assure cleanliness and reduce the potential for growth of microorganisms in wet/dirty rubber gloves. Gloves should be changed anytime bare hands would be washed. This includes after using the restroom, smoking or eating, taking a break, covering coughs or sneezes, touching skin or wounds, touching floors or other dirty surfaces or equipment, or handling or mixing agricultural chemicals or cleaning materials.

Proper records should be kept on training activities, medical reports, and gastrointestinal disease reports. In this way the health of personnel can be assessed and corrective actions can be implemented to minimize the risk of produce contamination. Such records will also be useful to facilitate a traceback of a disease outbreak (See Section IV, Module 2).

## Drinking Water

Water for human consumption should be potable - that is, free of microorganisms and/or chemical substances that can jeopardize the health of the person consuming it. Ensuring the availability of potable drinking water for field workers can minimize the risk of them developing disease and consequently contaminating the fresh produce.

Visual II.4-7

**Pathogenic microorganisms that can be present in contaminated water include:**

- ***Escherichia coli*** O157:H7; Salmonella; Shigella spp.
- Hepatitis A and Norwalk viruses
- Parasites such as ***Giardia lamblia***, ***Cryptosporidium*** and ***Cyclospora cayetanesis***

Contaminated drinking water may contain pathogenic organisms such as hemorrhagic ***Escherichia coli, Salmonella,*** and Shigella. Other microbiological contaminants include viruses such as Hepatitis A and Norwalk virus and harmful protozoa such as ***Giardia lamblia, Cryptosporidium and Cyclospora cayetanesis***. The presence of these organisms in water is generally associated with fecal contamination.

Coliform bacteria are common in the environment and are not normally harmful. However, the presence of these bacteria in drinking water indicates that the water may be contaminated with harmful organisms. If the total coliform test on a sample of drinking water is positive (1 or more coliforms per 100 mL of water), either a fecal coliform test or an ***Escherichia coli*** test should be performed to determine if the coliform bacteria found are of fecal origin. Positive results on either of these two tests is a strong indication that the water may be contaminated with fecal material. Since potable water should be free of total and fecal coliform bacteria and ***E. coli***, an investigation of the water treatment and distribution system is advised following a positive test which indicates their presence. In addition, water should be boiled as a precaution. Most countries have regulations about the microbiological characteristics of drinking water, and they also include maximum permissible levels of chemical substances and heavy metals.

To prevent contamination, it is important that water used for hand washing should be drinking water quality.

Visual II.4-8

**Common Sources of Drinking Water**

- **Treated surface water** that comes from rivers, creeks, canals, lakes and reservoirs (i.e. lakes, ponds, etc).
- **Ground water,** which comes from underneath the surface and generally is pumped up and out for use (i.e. well water) or flows naturally to the surface (i.e. spring water).
- **Municipal system** which comes from a city water treatment plant

Untreated surface water is more likely than ground water to contain pathogenic microorganisms because of the possibility of direct contamination with animal feces or sewage run-off from adjacent land or higher locations.

Drinking water should be of higher quality than that used for agricultural processes. It is recommended that water used for human consumption be from municipal sources only. When this is not an option, water treatment systems are needed.

Major water treatment processes include filtration, disinfection, and treatment to remove organic and inorganic contaminants (U.S. EPA, 2001a). Often before filtration, processes are used to clean up the water by removing solids and turbidity. These processes may include chemical addition, rapid mixing, coagulation and flocculation, and sedimentation. Filtration to remove the remaining solids as well as microorganisms like ***Giardia*** and ***Cryptosporidium*** can be accomplished using conventional filtration systems (e.g., rapid sand, slow sand, diatomaceous earth, or membrane) or through cartridge filtration systems.

The three most commonly used disinfection technologies are chlorine, ozone, and chloramines (U.S. EPA, 2001a). Other disinfectants that may be used include chlorine dioxide and ozone. Unfortunately chlorine-based formulations are not effective against ***Cryptosporidium*** which has been implicated in some foodborne outbreaks from fresh produce. Additional research is needed to determine the efficacy of ozone and other alternative treatments being developed (WGWC, 1997). Regardless of the water treatment system used, it is necessary to verify the quality of the water to determine if it is adequate for human consumption.

Visual II.4-9

***Precautions for handling drinking water in the fields and packing areas***

- Water supply systems should be in good condition and operating properly (requires constant monitoring)
- Water should be stored in clean, previously sanitized containers and tanks
- Water containers should be washed and sanitized on a daily basis
- Water storage containers should be closed at all times
- Container should be kept away from the sun and excessive heat
- Disposable cups should be provided and each person should use a different cup

If drinking water is stored in tanks or other devices before consumption it is important to clean the storage containers frequently. It also is recommended that drinking water be treated before consumption. There are different systems on the market to treat drinking water just before use. Some examples are chlorine injection units, microbiological filters and ultra-violet light treating units.

Constant monitoring is needed to assure supply systems for drinking water in the fields and packing areas are in good condition and operating properly. This water should be stored in clean, previously sanitized containers and tanks that are washed and sanitized on a daily basis and closed at all times. Water storage containers should be kept away from the sun and excessive heat. Disposable cups should be provided and each person should use a different cup.

Visual II.4-10

- Frequent microbiological and physical evaluation should be performed on drinking water when the water is being stored or treated on site.
- Simple organoleptic evaluations (color, odor and taste) of water should be performed as part of the daily monitoring procedures.
- If any of the water quality tests indicate the quality is not adequate, the water should be replaced to reduce the chances of infection and the proper authorities should be notified of the problem.

Frequent microbiological and physical evaluation should be performed on drinking water when the water is being stored or treated on site. Records of these evaluations should be part of the sanitation program and kept as evidence of the effectiveness of the water treatment and distribution systems. If municipal water is used, records from the municipal water system should be obtained and kept as record of the quality of the water being supplied.

Simple organoleptic evaluations (color, odor and taste) of water should be performed as part of the daily monitoring procedures. If any of the water quality tests indicate the quality is not adequate, the water should be replaced to reduce the chances of infection and the proper authorities should be notified of the problem.

### Worker Hygiene Practices and Sanitation Facilities

The responsibility for reducing or avoiding contamination during primary production falls heavily on agricultural workers. Employers can provide training and other resources to educate workers, but, in the end, the effectiveness of the program relies on the worker's understanding and implementation of personal hygiene and safety practices. Therefore, management should provide workers with information about acceptable hygiene practices, ensure it is understood and send a clear signal to workers about the importance of these practices.

Visual II.4-11

**Personal hygiene of agricultural workers is important to minimize contamination. Some of these basic practices include:**

- Regular bathing
- Using toilets even in the fields (Portable units should be provided in locations without a municipal sewage system. Units should be maintained in a condition to encourage their use.)
- Washing hands in the correct manner and after any possible contamination
- Wearing clean clothes
- Using hairnets
- Keeping nails clean and short

Some of basic hygiene practices that should be used by agricultural workers to minimize produce contamination include:

- Regular bathing
- Using toilets even in the fields (Portable units should be provided in locations without a municipal sewage system. Units should be maintained in a condition to encourage their use.)
- Washing hands in the correct manner and after any possible contamination
- Wearing clean clothes
- Using hairnets
- Keeping nails clean and short

Visual II.4-12

**Correct hand washing procedure**

1. Wet hands with warm water then vigorously apply soap, rubbing hands together for 20 seconds
2. Scrub the whole hand surface, including the back, wrists, between fingers and under nails
3. Rinse thoroughly with warm running water
4. Dry hands with paper towels
5. Turn off water faucet using a paper towel
6. Open the exit door with a paper towel then dispose of the towel in the provided container

Note: When nails contain accumulated dirt, scrub them with a nail brush (the nail brush is usually used at home since it is a personal item)

Handwashing is considered a basic procedure that children learn at an early age. However, each person has a different background and a different concept of proper handwashing. Therefore, personnel should be well trained in these practices no matter how basic they sound.

The proper technique for washing hands involves wetting hands with water (warm water is more effective), soaping and vigorously scrubbing the whole surface of the hand, under the nails and between the fingers for at least 20 seconds (Martínez-Téllez et al., 2000). After these steps, the hands are thoroughly rinsed and dried with disposable paper towels. To avoid recontaminating clean hands, a paper towel is used to turn off water faucets and to open exit doors.

Visual II.4-13

**Hand washing is required:**

- At the beginning of the work day
- After going to the restroom
- After smoking or eating
- After breaks
- After sneezing, coughing or touching the nose
- After touching or scratching the skin or wounds
- After touching dirty equipment and utensils
- After touching trash on the floor or after handling waste material
- After touching or handling fertilizers, pesticides, chemicals or cleaning materials

Hands should be washed after using the restroom, smoking or eating, taking a break, covering coughs or sneezes, touching skin or wounds, touching floors or other dirty surfaces or equipment, or handling or mixing agricultural chemicals or cleaning materials. Paper towels and toilet paper should be disposed of properly. Toilets and hand washing stations should be inspected frequently to ensure their cleanliness and the availability of soap and paper products. Neatness of the installations should be part of the sanitation program and should be accurately documented. Trashcans should be provided, and workers need to be instructed to deposit trash and food items in the appropriate containers.

It also is important that produce inspectors, buyers and other visitors follow the established hygiene and safety practices. Signs indicating proper hand washing and trash disposal procedures are recommended to prevent contamination of doorknobs and other surfaces by visitors. Supervisors and the workers themselves should be asked to report dirty sanitary facilities or other situations that may be a source of contamination.

Visual II.4-14

**Basic requirements for sanitary field stations:**

- Toilets should be connected to an evacuation or sewage system adequately constructed to avoid contamination of fields, water sources or product.
- Sanitary stations should be in good, clean and sanitary. They should have clean water, soap and paper towels.
- There should be an adequate number of toilets for the number of employees working. It is recommended that there be at least one toilet for every 20 persons of the same sex.
- Toilets should be accessible for the personnel. This means close to their working area - at a maximum distance of 400 meters (1,300 feet) or a 5 minute walk.
- Toilet facilities should be separated from the water sources (at least 400 meters (1,300 feet) away).
- Water stations with potable water for drinking should be in place during the harvest season.

Toilets located in the fields should not be close to water sources or in places where rain can wash out contaminants or cause spills. Any inadequate sanitary facility increases the risk of contamination of the water, soil, produce and the working personnel. Maintenance and servicing of toilets should be performed away from the field to protect soil, water, and workers in case leaks or spills occur.

The more accessible the sanitary stations are, the greater the probability that they will get used. Use of these facilities by workers should be permitted whenever it is necessary, not just during break periods. This practice reduces the possibility of urination or defecation in the woods near the fields.

Providing sufficient toilet paper also is very important. Toilets and hand washing stations should be cleaned and inspected regularly and periodically checked for adequate supplies. Provisions should be made to dispose of handwashing rinse water away from the field to avoid produce contamination. Containers used for water transport and storage should be periodically emptied (preferable daily), cleaned and disinfected. Potable water bottles should be replaced regularly.

## Summary

1. Assuring worker health both increases productivity and aids in preventing potential biological contamination of crops since an infected worker can transmit many biological pathogens to fruits and vegetables. An infected employee (showing symptoms or not) can easily contaminate fresh produce if

they don't practice good hygiene. Workers with symptoms of disease should be assigned to activities that do not involve contact with the produce.

2. Water for human consumption should be potable - that is, free of microorganisms and/or chemical substances that can jeopardize the health of the person consuming it. Ensuring the availability of potable drinking water for field workers can minimize the risk of them developing disease and consequently contaminating the fresh produce.

3. The three most commonly used disinfection technologies for water are chlorine, ozone, and chloramines.

4. Personal hygiene of agricultural workers is important to minimize contamination. Management should provide workers with information about acceptable hygiene practices, ensure it is understood and send a clear signal to workers about the importance of these practices. Some of these basic practices include:
   - Regular bathing
   - Using toilets even in the fields (Portable units should be provided in locations without a municipal sewage system. Units should be maintained in a condition to encourage their use.)
   - Washing hands in the correct manner and after any possible contamination
   - Wearing clean clothes

5. Toilets located in the fields should be properly maintained and supplied. They should not be close to water sources or in places where rain can wash out contaminants or cause spills. Maintenance and servicing of toilets and disposal of hand washing rinse water should be performed away from the field in case leaks or spills occur. Any inadequate sanitary facility increases the risk of contamination of the water, soil, produce and the working personnel.

# Module 5
# Harvesting and Cooling

## Learning Outcomes

- ***Participants should be aware of food safety considerations related to produce harvesting and to cooling practices.***

## Practical

- ***Experiment: Product Integrity and Produce Contamination***
  ***Fruit Spoilage Demonstration***

## Additional Resources

- ***Part V - Storage Conditions for Fruits and Vegetables***

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### Safety Hazards Associated with Harvesting

Most fresh fruits and vegetables are extremely perishable. The safety and quality of the produce when it reaches the retail market is strongly influenced by the safety and quality of the produce at harvest. Additional factors that affect safety and quality of fresh produce at market include handling, storage temperature, transportation conditions and the time period between harvest and retail marketing.

Maintaining safe, high quality produce with an adequate shelf life depends on both the pre-harvest factors discussed in earlier modules and the control measures taken throughout the distribution chain. This chain begins with harvesting the produce.

Visual II.5-1

**Harvesting Procedures**

- Mechanical
- Manual

The selection of a harvesting procedure will depend on the produce characteristics. Mechanical harvesting is recommended for produce that can withstand physical handling (i.e., carrots, potatoes and radishes). It is generally used to harvest produce destined for the processing industry.

For commodities destined for the fresh market, integrity and appearance are important. Therefore, manual harvesting is widely used for these products. This is especially true for commodities such as lettuce, berries, grapes, peppers, apples etc. that can be damaged easily. With manual harvest, worker hygiene is especially important since there is a great deal of hand contact with the product that could lead to produce contamination. Proper sanitation of harvest tools is also critical to produce safety.

Visual II.5-2

**Physical damage caused by mechanical harvesting methods may lead to:**

- Water loss
- Increased respiration rate
- Initiation of ethylene synthesis
- Production of undesirable colors (browning)
- Penetration of microorganisms (both foodborne and plant pathogens)

Damage during mechanical harvest can lead to a number of undesirable changes in produce. Most fresh fruits and vegetables are harvested manually, since this can minimize damage and also allows for sorting by size and other desirable produce characteristics during harvest. Training and supervision of field workers is important to maximize yields and minimize damage to the produce.

Microbial contamination of fresh produce can occur easily during harvest. This contamination may result from contact with field workers and from the physical environment of the produce. Environmental contaminants include the soil, water, air, hands, containers, etc. Preventing contamination of produce with pathogens is critical, since their presence increases the risk of illness in those consuming the produce.

## In-field Packaging Operations

Visual II.5-3

**Recommendations for products packed in the production field:**

- All workers involved in field packing operations should be encouraged to follow good hygiene and sanitation practices
- Avoid the direct contact of packages, containers or products with the soil.
- All containers, baskets or empty boxes should be clean and free from visible signs of dirt, oil/grease and chemical contaminants
- Packing containers should be stored in a clean dry place away from the field and should be transported and handled with the same sanitary considerations

Some products like grapes and strawberries are not cooled or washed. They are packed in the field immediately after harvest. Packing in the field generates a situation where contamination can occur easily. All workers involved in field packing operations should be encouraged to follow good hygiene and sanitation practices. Containers and packing materials should be handled with care and kept clean and free from dirt and contaminants. (Procedures described in Section III for maintenance, cleaning and sanitation of containers and packaging materials should also be followed by in-field packaging operations).

## Post-Harvest Water Quality

Water is key to a number of postharvest operations. It is used in dump tanks to reduce physical injury to produce as field containers are emptied onto a packing line. It may be used for rinsing at any point on a packing line. In hydrocoolers, cold water is used as a drench or in tanks to remove field heat from fruits and vegetables. It is needed for mixing of solutions of waxes and/or fungicides. Finally, hot water treatment is a quarantine measure used for insect pest control in some commodities.

Water quality is important in reducing contamination during post-harvest cooling, washing and sanitizing operations. The water used for post-harvest operations should be potable and free of disease-causing organisms. Water taken and used directly from rivers or holding ponds should not be used for postharvest washing or cooling.

Visual II.5-4

Some U.S. EPA specifications for drinking water include:

| Property | Specification |
|---|---|
| Total Coliforms | 0 CFU[1]/100 ml |
| Fecal Coliforms | 0 CFU/100 ml |
| ***Cryptosporidium*** | 0 mg/ml |
| ***Giardia lamblia*** | 0 mg/ml |
| Turbidity | 5 NTU[2] |
| pH | 6.5 to 8.5 |

[1]CFU = Colony forming units
[2]NTU = Nephelometric turbitiy unit

As indicated by the FDA (1998), processing water should be of such a quality that it does not contaminate produce. Water quality consistent with U.S. EPA requirements for drinking water, or similar standards is recommended since water that meets the microbial standards for drinking water is considered “safe and sanitary.” In addition to confirming pathogens are not present in the water, it is also useful to look at levels of turbidity and pH since these are indicators of conditions that might effect the presence of pathogens in the water. Turbidity is a measure of water cloudiness and indicates water quality and filtration effectiveness. Higher turbidity levels are often associated with higher levels of pathogenic organisms (U.S. EPA, 2002). A pH less than 8 is preferable for effective disinfection with chlorine (WHO, 1996).

Visual II.5-5

**Examples of practices to reduce the risk of contamination of produce by post-harvest processing water:**

- Perform periodic water sampling and microbial testing.
- Follow appropriate guidelines for packinghouse water sanitation.
- Change water as necessary to maintain sanitary conditions (this requirement needs to be determined for each operation).
- Clean and sanitize water contact surfaces, such as dump tanks, flumes, wash tanks and hydrocoolers as often as necessary to ensure the safety of produce.
- Install backflow devices and legal air gaps to prevent contamination of clean water with potentially contaminated water.
- Routinely inspect and maintain equipment designed to assist in maintaining water quality, such as chlorine injectors, filtration systems, and backflow devices.

Pathogens present on freshly harvested fruits and vegetables accumulate in water handling systems such as dump tanks, flumes and hydrocoolers in which the water is recirculated (Sargent et al., 2000). Even healthy looking produce coming in from the field can harbor large populations of pathogens, particularly during warm, rainy weather. When fruits and vegetables are immersed in water containing pathogens, they can become infected.

Many postharvest contamination problems result from the incorrect use of sanitizers in packinghouse dump tanks and hydrocoolers (Sargent et al., 2000). Whenever produce is dumped into water or washed with recirculated water that is not maintained properly there is a good probability that produce contamination will occur.

Maintaining water sanitation usually involves the addition of an approved sanitizer to the water. Sanitizers such as sodium hypochlorite, calcium hypochlorite or liquid chlorine are frequently used to prevent the accumulation of pathogens. Many packers routinely add chlorine to their water handling systems. A 50-200 ppm chlorine concentration can destroy most viable microorganisms. However higher concentrations are needed to kill spores. The effectiveness of this treatment in reducing produce contamination can be decreased or even nonexistent due to failure to follow appropriate guidelines for packinghouse water sanitation. Considerations in the use of sanitizers are discussed in Section III of this manual.

If chlorine is used to sanitize processing water, it is important to monitor the free (unreacted) chlorine concentration at all times during use. Chlorine product must be added to the water to replace the chlorine lost to reactions with organic matter, chemicals, microorganisms (known as the chlorine demand). Samples should be taken at least on an hourly basis to monitor chlorine concentration. All recirculated water should be changed on a daily basis, or more frequently if the water becomes extremely dirty due to build up of organic matter that reduces the effectiveness of the chlorine treatment. Local environmental codes must be consulted for proper disposal of chlorinated water.

Other factors which affect chlorine efficacy include the initial level of inoculum present on the fruit surface and the exposure time of the crop to the water. In the case of tomato dump tanks, the water should be heated 10°F (about 5°C) above the pulp temperature to reduce infiltration of the water (and pathogens) into the fruit. The tomatoes should not be in the tank for more than three minutes.

## Cooling Considerations

Visual II.5-6

**Eliminating Field Heat:**

- Immediately after harvest fresh produce temperature is high. To extend the shelf life and quality of fresh fruits and vegetables, products are generally cooled within 24 hrs after harvesting.
- Heat elimination is commonly applied to highly perishable commodities such as fruits.
- There are many different types of cooling systems available.

Highly perishable commodities are cooled to extend their shelf life. The cooling operation is generally for quality, however temperature control also can be used to inhibit the growth of pathogenic bacteria in the fresh produce. Products are generally cooled within 24 hrs after harvesting. Recommendations for cooling methods and optimum storage conditions for a variety of fruits and vegetables are presented in Part V in the Additional Resources section.

When possible, harvesting at night or in the early morning can minimize exposure to high daytime temperatures. The harvested crop should be collected and held in the shade with adequate ventilation. If shading is achieved by placing produce under a tree, care must be taken to prevent produce contamination by bird droppings. Under no circumstances should freshly harvested produce be left in direct sunlight or stored in containers where solar heat buildup is likely.

Visual II.5-7

**Benefits of a Produce Cooling Operation:**

- Reduction of field heat
- Reduction of respiration and ethylene production rates
- Minimization of spoilage
- Reduction of water losses
- Limitation of the growth of microorganisms

When produce are cooled promptly after harvest, the shelf-life is extended, appearance is more attractive and products are of higher quality. The amount of heat that needs to be eliminated during the cooling step depends on the weight, specific heat, and initial and final temperature of the produce.

## Commercial Cooling Methods

There are two main heat transfer mechanisms for produce cooling - conduction and convection. These are the mechanisms used to remove excessive heat from produce at the field. With conduction, the heat is transferred within a product to its coldest surface. With convection, the heat is transferred away from the surface of the product via a cooling medium such as moving water or air.

Visual II.5-8

**Common Cooling Media for Fresh Produce**

Media for reducing heat from produce include:

- Air (Room cooling and Forced air cooling)
- Water (Hydro-cooling and Package icing)

Regardless of the cooling method used, care must be taken to assure the cooling medium does not contaminate the produce.

Visual II.5-9

**Hazards Associated with Air Cooling Methods**

- Of the common commercial produce cooling methods, the ones using air and vacuum present the lowest risk for contamination. However, the air introduced in the cooling systems can represent a potential microbial hazard.
- Microorganisms found in dust and tiny water droplets can be introduced onto product using these cooling systems. Such microorganisms can come from outside dust, soil, equipment, and waste products.
- These microorganisms cannot develop in the air, but air can serve as the vehicle through which they can reach the product.

When using an air-based cooling system, it is important to maintain sanitary conditions in the facility. Special attention should be given to the air source area. The air system should be properly maintained and the filters changed regularly. Animals should be excluded from the surrounding areas, compost storage deposits should be located far from air sources, and any other pathogen sources that could potentially contaminate the air used in cooling systems should be eliminated.

Visual II.5-10

**Hazards Associated with Water and Ice Cooling Methods**

- Cooling methods using water and ice as the cooling mediums have the greatest potential for contamination of fruits and vegetables.
- Water and ice used for cooling operations are potential contamination sources. Water used in hydro-cooling systems and for ice making should be potable – i.e. free of pathogenic bacteria, protozoa and viruses.
- Ice should be made and held under sanitary conditions.

Cooling methods using water and ice as the cooling mediums have the greatest potential for contamination of fruits and vegetables. Cooling water can become a contamination problem, therefore the water should be replaced regularly (at least once a day, depending on the amount used and produce conditions). It is essential that ice used in cooling be produced from chlorinated, potable water and stored in a sanitary manner, so that it doesn’t contaminate the produce during the cooling process.

Visual II.5-11

**To reduce the possibility that water-based cooling systems will become a contamination source, it is important to:**

- Use good quality water
- Provide adequate equipment maintenance
- Consider using disinfectants in the cooling water
- Regularly monitor the concentration of disinfectants
- Maintain the sanitary condition of cooling water and ice

Water and ice used for cooling systems should be free of bacterial contamination. It is important to perform microbiological tests on water used in cooling and ice cooling systems. The most commonly used tests are for total coliforms, fecal coliforms, and ***E. coli*** since these tests are good indicators of water contamination.

The addition of chlorine derivatives to cooling water is a common practice and the use of chlorinated water to make the ice is recommended. Because chlorine loses effectiveness when it reacts with organic compounds, its concentration should be monitored frequently. A 50-200 ppm chlorine concentration can destroy most viable microorganisms. However higher concentrations are needed to kill spores. It is important to place a water settling and filtration device in the cooling water treatment system to remove organic material.

Cooling equipment should be cleaned and inspected frequently. Maintenance of equipment and use of appropriate sanitary procedures is critical to assuring the safety of the produce.

Visual II.5-12

**Important Considerations Regarding Water Temperature and Microbial Infiltration**

- Pathogens present on freshly harvested fruits and vegetables accumulate in water handling systems such as dump tanks and flumes in which the water is recirculated.
- For some commodities (e.g. apples, celery, mangoes and tomatoes), it has been observed that when the warm fruit or vegetable is placed in cold water a pressure differential is generated that results in infiltration of the water into the product.
- This is an important issue because contaminants in the water can get drawn into the interior of the commodity where they are protected from further disinfecting treatments.

Pathogens present on freshly harvested fruits and vegetables accumulate in water handling systems such as dump tanks and flumes in which the water is recirculated (Sargent et al., 2000). For some commodities (e.g. apples, celery, mangoes and tomatoes), it has been observed that when the warm fruit or vegetable is placed in cold water a pressure differential is generated. This creates a suction effect that results in infiltration of the water into the fruit.

More research is needed to identify the commodities that can experience cooling water infiltration and to document the practical importance of this issue. Although definitive solutions to this problem have not been established, the use of good quality water for cooling is critical to assuring produce safety. Procedures should be in place to monitor and maintain water quality whenever water is used in produce production.

One recommendation to reduce potential produce contamination associated with water infiltration has been to adjust cooling/wash water temperature to 5°C (9 $^{o}$F) above the temperature of the flesh of the fruit (Showalter, 1993). This could be an important precaution for washing systems, however, for cooling systems it interferes with the removal of field heat. Therefore, for commodities that can have this problem, the recommendation is to cool with air or other cooling methods or to combine hydro-cooling with an initial air cooling step to minimize the temperature differential between produce flesh and water temperature. The use of disinfectants, such as chlorine, in the cooling water also could help to reduce the risks associated with pathogen internalization.

A variety of methods are used commercially to cool produce. It is important to know the principle of each cooling method so potential hazards associated with them can be identified.

Visual II.5-13

**Common Cooling Methods for Fresh Produce**

Methods for reducing heat from produce include:

- Room cooling
- Forced air cooling
- Hydro-cooling
- Package icing
- Vacuum cooling

Room Cooling

In room cooling heat is transferred slowly from the mass of a product (by convection) to the cold air being circulated around stacked containers of the produce. Room cooling is used for a wide range of commodities, but is a slow method of cooling. The slow cooling rate is a major drawback to room cooling since products are often loaded for shipment before they are adequately cooled.

The cooling rate may be speeded up slightly by increasing air circulation with larger or additional fans. However, this will add more heat (energy) to the room.
Ceiling jet cooling is a slightly faster modification of room cooling. The ceiling jets direct cold air down over the stacked produce.

Forced Air Cooling

In this method, the cooling air is pulled or pushed through produce containers, providing greater air circulation around the produce and resulting in faster cooling. This method is commonly used on such crops such as grapes, berries, and other fruits.

A faster rate of forced air cooling can be obtained by increasing the circulation rate of the cold air per unit weight of produce. This may be accomplished by a larger fan capacity or by increasing the amount of container venting through which the cooling air passes.

Vents should be designed and constructed so that the stacking strength of the containers is maintained. Reducing the number of stacks of containers through which the cooling air passes reduces the cooling time. However, this requires more space and may reduce the amount of produce cooled per unit of time (Holdsworth, 1985).

Hydro-Cooling

Hydro-cooling is a rapid cooling method that uses water showering down over the produce as the cooling medium. The method is based on the principle that a pound of water can absorb more heat than a pound of air. Hydro-cooling can only be used for commodities and shipping containers that tolerate wetting.

Hydro-coolers generally use mechanical refrigeration, high water circulation rates and a minimal water reservoir to provide fast, uniform cooling. Systems should be designed to allow daily cleaning and sanitation. Sanitation of the hydro-cooling water is critical, since it is recirculated (Sargent et al., 2000). Organisms present on the produce can accumulate in the water, inoculating subsequent produce being hydro-cooled. Chlorine concentrations of 200 ppm (free chlorine) are generally used in hydro-coolers, however chlorine has a tendency to break down so concentration should be monitored frequently. Cooling water should be changed frequently.

Hydro-cooling is used for commodities that may be cooled in bulk or in packed containers. There are two basic types of hydro-coolers:

1. Flow through - the produce moves on a conveyor belt through the shower.
2. Batch type - stationary, stacked containers of produce are showered with ice water.

With a hydro-cooler, the cooling rate can be increased by

- Reducing the water temperature (addition of crushed or flaked ice to the water reservoir)
- Increasing the water circulation rate
- Increasing the exposure of the produce to the water.

Package Icing

This is one of the oldest methods of produce cooling and is used on commodities that can tolerate contact with ice, e.g. root and stem vegetables, broccoli, and brussels sprouts**.** The direct contact of the produce with the ice provides fast, initial conduction cooling. However, as the ice melts, an air space is created between the ice and the produce, and conduction cooling stops. Subsequent cooling is by radiation and convection, both slower processes than conduction.

Conventional icing involves packing finely crushed or flaked ice over the packaged produce. An alternative process uses liquid ice as the cooling medium. This is composed of 60% ice and 40% water. Liquid ice gives a much greater initial contact between the produce and the ice and it can be applied after the boxes have been palletized. It may be used to distribute ice around the produce in the shipping containers. The amount of ice added should be adjusted to initial produce temperature, produce weight, and the expected ambient temperatures during transit.

Vacuum Cooling

In this method the produce is placed in a strong, airtight steel chamber. Air is pumped out of the chamber to reduce the atmospheric pressure, causing the water in the produce to vaporize. Cooling occurs because the heat energy for vaporization comes from the produce. The cooling rate is related to the surface area to volume ratio of the produce. Thus, loose leafy vegetables cool faster than tight-headed cauliflower or celery. This method is used primarily for cooling leafy vegetables, celery, cauliflower, and to a limited extent, sweet corn, carrots, and sweet peppers.

A disadvantage of vacuum cooling is that during cooling 1% of the produce weight (primarily water) is lost for each 5-6$^{o}$C drop in produce temperature (Holdsworth, 1985). Hydro-vacuum cooling, a patented modification of vacuum cooling, prevents this weight loss by providing a water shower at specific times during the cooling cycle. As with hydro-cooling, monitoring and maintaining water quality is important when using this process.

Although vacuum chambers may be large enough to hold entire boxcar loads of produce, most vacuum coolers are portable. They can be moved to different shipping points as the growing season progresses.

## Summary

1. Most fresh fruits and vegetables are harvested manually, since this minimizes damage and allows for sorting by size and other desirable produce characteristics during harvest. Damage during mechanical harvest can lead to undesirable changes in produce including:
   - Water loss
   - Increased respiration rate
   - Initiation of ethylene synthesis
   - Production of undesirable colors (browning)
   - Penetration of microorganisms (both foodborne and plant pathogens)

2. Microbial contamination of fresh produce can occur easily during harvest. This contamination may result from contact with field workers and from the physical environment of the produce. Environmental contaminants include the soil, water, air, hands, containers, etc. Preventing contamination is critical, since their presence increases the risk of illness in those consuming the produce.

3. Packing in the field generates a situation where contamination can occur easily if containers and materials are not handled with care. Good sanitation procedures should be followed in handling containers and packing materials to prevent produce contamination.

4. Water quality is important in reducing contamination during post-harvest cooling, washing and sanitizing operations. Pathogens present on freshly harvested fruits and vegetables accumulate in water handling systems such as dump tanks, flumes and hydrocoolers in which the water is recirculated. Water used for post-harvest operations should be potable and free of disease-causing organisms. Post-harvest water can become contaminated easily and it quickly becomes saturated with organic matter (e.g. soil, solids leaching from the fruit, etc), therefore, procedures to assure good wash water quality are critical. These include frequent filtering, changing wash water often and the use of disinfectants.

5. If chlorine is used as to sanitize processing water, it is important to maintain the free (unreacted) chlorine concentration at all times during use. Samples should be taken at least on an hourly basis to monitor chlorine concentration. All recirculated water should be changed on a daily basis, or more frequently if the water becomes extremely dirty due to build up of organic matter which can reduce the effectiveness of the chlorine treatment.

6. Highly perishable commodities are cooled to extend their shelf life. The cooling operation is generally for quality, however temperature control also can be used to inhibit the growth of pathogenic bacteria in the fresh produce.

7. When using an air-based cooling system, the air system should be properly maintained so that the air is clean and free of pathogens. Animals should be excluded from the surrounding areas, compost storage deposits should be located far from air sources, and any other pathogen sources that could potentially contaminate the air used in cooling systems should be eliminated.

8. Water used for cooling systems and to make cooling ice should be free of pathogenic contamination. Use of chlorinated water is recommended and samples should be taken at least on an hourly basis to monitor chlorine concentration.

9. Cooling equipment should be cleaned and inspected frequently. Maintenance of equipment and use of appropriate sanitary procedures is critical to assuring the safety of the produce.

## References

Ballesteros-Sandoval, V. 1999. Technical guide for the manufacture of compost. Comite Estatal de Sanidad Vegetal de Guanajuato (CESAVEG), Irapuato, Gto. Mexico.

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. Epidemiologic Studies of ***Cyclospora cayetanensis*** in Guatemala. Emerging Infectious Diseases, Vol 5. No 6.

Buttler, T., Martinkovic, W. and Nesheim, O.N. 1993. Factors influencing pesticide movement to ground water. University of Florida. Florida Cooperative Extension Service. Fact Sheet PI-2. June 1993.

CSC. 1998. Quality Assurance Program. California Strawberry Commission.

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

ERS. 2001. Irrigation systems and land treatment practices. Economic Research Service, U.S. Department of Agriculture, Irrigation and Water Use Briefing Room. Available via the Internet at http://www.ers.usda.gov/Briefing/wateruse/Questions/glossary.htm

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

Holdsworth, S.D. 1985. The preservation of fruit and vegetable food products. 1st. Ed. The Macmillian Press Ltd., London.

Martínez-Téllez, M.A., Vargas-Arispuro, I., Acedo-Félix, A. 2000. Centro de Investigación en Alimentación y Desarrollo, A.C. (CIAD), Manual para el manejo de alimentos frescos no procesados.

Merka, B, Lacy, M., Savage, S. Vest, L. and Hammond, C. 1994. Composting poultry mortalities. Cooperative Extension Service, University of Georgia. Circular 819-15. Available via the Internet at http://www.ces.uga.edu/pubcd/c819-15w.html

Murray, P., Drew, W., Kobayashi, G. and Thompson, J. 1995. Medical Microbiology. Mosby-Doyma Libros, S.A. Madrid, Spain. pp. 423.

Nesheim, O.N. 1993. Best management pesticides to protect ground water from agricultural pesticides. University of Florida, Florida Cooperative Extension Service. Fact Sheet PI-1, June, 1991.

Olexa, M.T. 1991. Agricultural chemicals and water pollution. University of Florida, Cooperative Extension Service. Fact Sheet FRE-77.

Sargent, S.A., Ritenour, M.A. and Brecht, J.K. 2000. Handling, cooling, and sanitation techniques for maintaining postharvest quality. University of Florida, Cooperative Extension Service, HS719. Available via the Internet at http://edis.ifas.ufl.edu/CV115.

Showalter, R.K. 1993. Postharvest water intake and decay of tomatoes. Hort. Technol. 3:97-98.

Solomon, K.H. 1988. Irrigation system selection. In Irrigation Notes, California State University, Fresno. January. Available via the Internet at http://cati.csufresno.edu/cit/rese/88/880105/index.html

U.S. EPA. 2000. Total Coliform Rule – Approved Methods for Coliform Assay. Office of Water, U.S. Environmental Protection Agency. Available via the Internet at http://www.epa.gov/safewater/methods/tcr_tbl.html

U.S. EPA. 2001a. Ensuring Safe Drinking Water. Technical Information Packet. U.S. Environmental Protection Agency. Available via the Internet at http://www.epa.gov/oia/tips/drinkwat.htm

U.S. EPA. 2001b. National Primary Drinking Water Standards. Office of Water, U.S. Environmental Protection Agency. Pub. EPA 816-F-01-007. Available via the Internet at http://www.epa.gov/safewater/mcl.html

U.S. EPA. 2001c. Pesticide Use and Disposal. Technical Information Packet. U.S. Environmental Protection Agency. Available via the Internet at http://www.epa.gov/oia/tips/pestint.htm

WGWC. 1997. Cryptosporidium and Water: A Public Health Handbook. Atlanta, GA. p4-1. Working Group on Waterborne Cryptosporidiosis.