Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers

Section II

Good Agricultural Practices

Introduction

Fresh produce is consumed raw. There is no absolute kill step, such as cooking, that will preserve the fresh characteristics of the product while ensuring its safety. Nor is there a cleansing step that can remove 100% of biological and most chemical contaminates. Thus prevention of contamination during production should be the first priority in a food safety program.

Fruits and vegetables most often are grown in an open environment where there are multiple opportunities for exposure to chemical and microbiological hazards. Greenhouses or other enclosed structures offer some protection but do not eliminate the risk altogether. The major concerns of the U.S. Food and Drug Administration (FDA) priority watch list for food safety are: waste, which includes manures, manure-based soil amendments, and various organic fertilizers; water; wildlife, and; workers. This Module and those that follow address practices for reducing risks associated with these FDA concerns during the production of fresh fruits and vegetables.

Hazard Analysis

The first step in developing a GAP program is to conduct a systematic review of the production environment and all crop inputs for the purpose of identifying any hazard that may present a potential risk for contamination of the crop. For example, the presence of fecal contamination from any source is a serious hazard that potentially involves all four of the concerns on the FDA list noted above. Chemical and physical hazards also may exist. A cursory inspection by an untrained observer may not predict all site risks. Farmers should request assistance from Extension personnel experienced in GAP planning and other food safety professionals to help with the identification of potential hazards.

Growers should begin by drawing a diagram of the site and surrounding areas. This diagram will be an invaluable point of reference for all ensuing considerations of hazard analysis. The local authorities that monitor or regulate land use may be able to provide a map. Eventually an official survey map or aerial photograph may be required and is highly desirable. However, the simple exercise of drawing a crude diagram will help identify details for the farmer that otherwise might not be noted by simply looking at a map provided from another person.

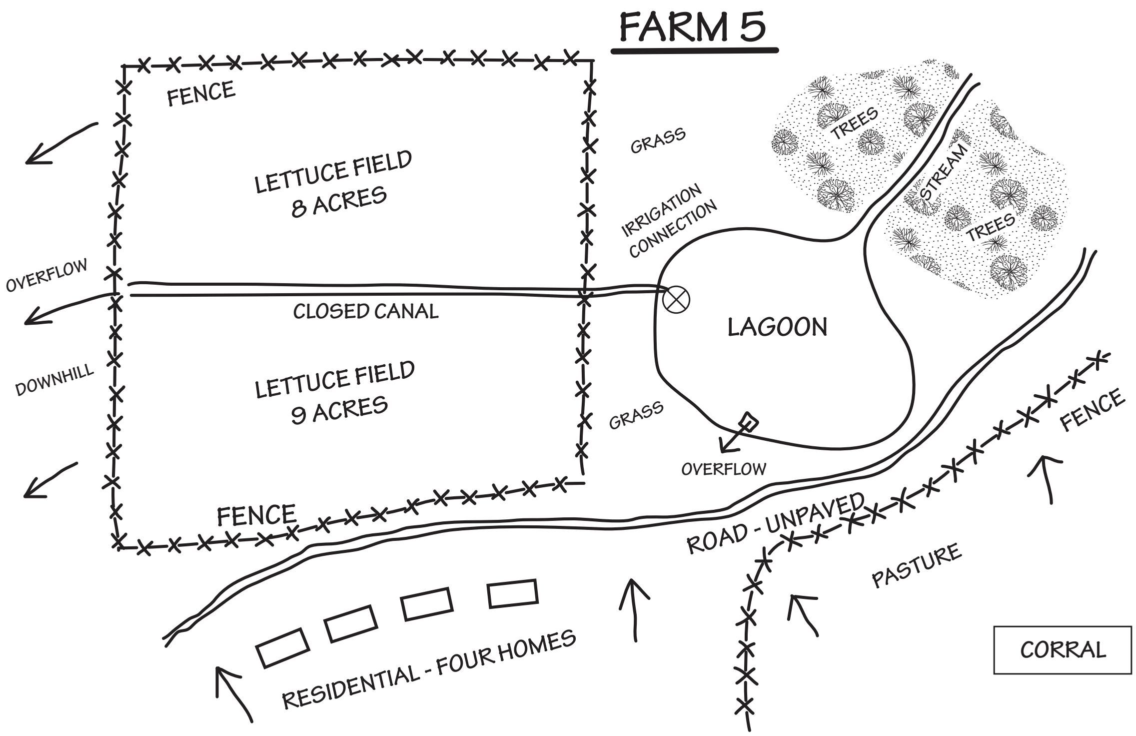
The example diagram on the next page shows the production fields, irrigation source, potential wildlife habitats, cattle production area, residential area, road, fences, and a general indication of the slope of the land. Although the diagram is crude, it contains a great deal of useful information that the grower may utilize in the development of a land management plan and food safety practices for the farming operation.

Land History

Knowledge and documentation of prior use of the land is required. Potential hazards may be undetected or unexplained (such as groundwater contamination) without this information. Additionally, knowledge of previous exposure of the site to any significant environmental event, such as flooding, gives further insight into the suitability of the site for farming.

In the event of flooding, individual assessment of each flooding event will be needed. The up-flow or land surface features and the time that has passed between floods, as well as the time that has passed since the last flood, are important. Flood prone areas generally are not suitable for fruit and vegetable production. Soil tests may be recommended after land has flooded, especially if there is an obvious hazard in the vicinity. For example, the presence of a nearby cattle operation would suggest the need for testing of pathogenic *E. coli* in fields that had flooded or were subjected to run-off from the cattle production area. Unfortunately, microbiological testing is not an absolute means of assuring that a field is safe, i.e. a negative test is not necessarily a confirmation that no pathogenic microorganisms are present. Flooding is discussed again later in the context of adjacent land use.

The potential of prior users of the land to compromise GAP presents risks to the current user. If the land was previously used for production of crops for human consumption, the farmer should search for records of past production



practices. Interviews with prior users and owners or review of municipal permits or other public records will be useful. The application of compost, raw manure or biosolids on the land is a concern, as is the use of pesticides, soil amendments or other chemicals. In the absence of records from past production cycles, soil testing for microbiological and chemical contamination is recommended.

Previous use of the land for animal husbandry can increase the risk of contamination of fruit and vegetables with pathogens commonly found in the intestinal tract of animals. Sites where barns or feedlots may have been located are of particular concern because a large number of animals would have been confined in a relatively small space. If such areas are identified, it is recommended that the soil be tested for the presence of pathogens. Factors affecting the survival of pathogens in the soil are discussed later.

Prior use of the land for non-agricultural purposes also should be investigated. Before the existence of regulations for land use that exist today, land in rural areas could be utilized in a several ways that could present hazards for production of fresh produce.

Waste management sites are of special long-term concern. Disposal of garbage containing fecal matter may inoculate soil with pathogens and, depending on the garbage contents, can provide substrate for microbiological survival for an extended period of time. Even if the waste management site was restricted to a small area, precipitation, wind, animal vectors, traffic or workers may disperse contamination over a larger area.

Industrial waste or incinerated waste can leave chemical residues that may not degrade for many years. Oil or gas extraction also may leave chemical contaminants in the soil. It is strongly recommended that soil tests for chemical contaminates be conducted prior to farming any land with questionable history.

Adjacent Land Use

Contaminants on land adjacent to cultivated fields may be dispersed into the crop production area. As noted earlier, precipitation, wind, traffic, animals and people are vehicles for the movement of contamination.

The presence of farm animals near the cultivated site increases the risk of product contamination. Barns or feedlots where animals are confined may increase risk compared to animals grazing on open pasture but all animal activity needs to be evaluated in the initial risk analysis.

Assessment of the location of the animals, their distance from the cultivated area, the nature of holding facilities, waste management and fly abatement, bird populations, drainage systems, and the direction of flowing water will help determine the potential for contamination. If the elevation of the cultivated area is lower than that of the livestock production area, there is greater risk of run-off during a storm event. It may be necessary to construct physical barriers, such as terraces or channels, to divert water away from the crop area and any surface water sources used for crop management. Animal exclusion from cultivated fields is discussed further in a later Module.

Residential communities, or even a single home, also present risks for nearby production land. Homes in rural areas usually a have septic tank and drain field which can fall into disrepair. Wastewater may run off into a production area, especially if the water reaches the soil surface due to a failure of the drain system. Household garbage or refuse also may find its way into the crop area as well as attracting animal pests.

Fences or other barriers may be needed to discourage people and domestic animals from having uncontrolled access to fields. Growers should be acquainted with their neighbors and have knowledge of the living conditions within the community. Open and amicable communication with neighbors can help the farmer prevent problems before they occur.

Persistence of Contaminants in the Soil

Chemical contaminants of an organic nature, such as pesticide residues, may gradually be degraded by sunlight, microorganisms, etc. and eventually be undetectable in soil. Inorganic chemical contaminates, e.g. heavy metals, do not degrade and their presence may preclude the use of the land for fresh produce production. A soil test will be necessary to confirm the absence of harmful residues.

Persistence of microbiological contaminants is affected by many factors, including time, temperature, relative humidity, tillage, sunlight and microbial competition in the soil. The interaction of these factors is complex and in most cases there is not an adequate amount of scientific information to allow accurate predictions for the survival time of human pathogens in the soil. This topic will be discussed in more detail in Module 3, which deals with organic fertilizers.

Site Traceability

The grower must have a system for tracing product back to the field in which it was grown and tracing forward to the buyer or receiver. A number or some type of code should be assigned to fields to facilitate traceability. Usually when the grower makes the first drawing or map of the farm, there will be obvious zones or divisions of fields within the production areas. Ditches, canals, fences, roads, well heads, or any other reasonably fixed or permanent demarcation can be used to designate the border of a field or zone. If no such lines exist, the grower must make arbitrary divisions and map these for future reference.

There are no regulations or specific recommendations regarding the size of the designated zones for traceability purposes. Common sense and practicality are the only guides for growers. The assigned code should be noted on all documents beginning with pre-plant field inspections and continuing through harvest and all subsequent handling steps until the time the product sold to the consumer. This must include identification of the harvest crew and harvest date for each lot.

Audits, Inspections and Record Keeping

Farmers today may be under constant pressure from regulatory agencies and the buyers of their products to review their production practices and keep records of all activities on the farm. This point will be reemphasized throughout this Manual.

Records of prior use of the land, the hazard analysis, pre-plant field inspections and any necessary soil tests are the minimum requirements related to soil and site selection. Growers are well served by having a thorough understanding of GAP and conducting self audits of their operations. Guidelines for self audits are available from numerous sources, including private auditing firms and public service agencies.

Summary

The four major concerns on the FDA priority watch list for food safety include waste, water, wildlife and workers.

During fruit and vegetable production there are multiple opportunities for contamination of the crop.

Growers must conduct a hazard analysis of their farm. It will useful to have input from a food safety professional to conduct this analysis.

Diagrams and maps of the production fields and adjacent areas will be invaluable to the grower.

Knowledge and documentation of prior use of the land is required. Waste disposal and animal production are two important aspects of land history that must be examined.

Adjacent land use also impacts the safety of production areas. Animal production areas and residential communities can present immediate risks to the farm.

Chemical and microbiological contaminants can persist in the soil for long periods of time and soil testing may be required to determine if land is suitable for fruit and vegetable production.

Growers must establish a system that will enable tracing of the product from the buyer or receiver to a specific production area.

Self audits and inspections will help growers to identify potential risks before they become problems for the safety of the products. Formal third-party audits may be required by buyers.

Records must be kept for all farming practices.

Introduction

Water is essential for the production of fruits and vegetables. It is used for various methods of irrigation, mixing and application of pesticides, liquid fertilizer application, frost protection, dust abatement, and evaporative cooling. Additionally, water is used by workers in the field for drinking, hand washing and cleaning of field equipment and sanitary facilities.

Water of unacceptable quality is a direct source of contamination for fresh produce. It also is an effective vehicle for the spread of contamination from one location to another. The severity of any microbiological hazard associated with poor quality water depends upon the type and number of microorganisms present and their capacity to survive and multiply on the product surface. Multiplication (growth) is not necessary for some pathogens to cause severe illness. For chemical hazards, the severity depends upon the concentration of the chemical in the water and its toxicity to humans.

The risk of contaminating a crop with water of inappropriate quality is influenced by the plant's growth habit, morphology, the type and stage of development of the crop, the time between water exposure and harvest, and perhaps other factors. In spite of these or other considerations that might mitigate risk, growers should follow the rule that water of inferior quality is unacceptable for plant production unless remedial action is taken to reduce risk to an acceptable level.

Waterborne Contaminants

The following Table lists a few examples of waterborne human pathogens that have been associated with outbreaks of illness. The list is not comprehensive.

Examples of Microbial Hazards in Water

Enterohemorrhagic *E. coli*	*Salmonella* spp
Enterovirulent *E. coli*	*Shigella* spp
Vibrio cholerae	*Gardia lamblia*
Cryptosporidium parvum	*Toxosplasm gondii*
Cyclospora cayetanensis	Hepatitis A virus

Some of the above microorganisms have the capacity to survive in water for extended periods. Water temperature is a factor in the length of time that fecal pathogens can remain viable. Below is a summary Table of some studies on the time that fecal pathogens can persist in water. Note that two of the pathogens most often associated with fresh produce contamination, *Salmonella* and *E. coli* O157:H7, both can survive at 5°C for over 9 months. Water in deep wells typically is cool. If wells are contaminated with either of these microorganisms, which can occur with flooding and run-off from nearby animal operations, pathogens can persist for extended periods. This illustrates the importance of water testing, discussed later in the Module.

Survival of Fecal Pathogens in Water

Pathogen	Frozen	Cold (5°C)	Warm (30°C)
Giardia	< 1 day	2 mo	< 3 wk
Cryptosporidium	> 1 year	> 1year	< 3 mo
Salmonella	> 6 mo	> 9 mo	> 6 mo
Campylobacter	2-8 weeks	< 2 wk	< 1 wk
Yersinia	> 1 year	> 1 year	< 2 wk
E. coli O157:H7	> 6 mo	> 9 mo	< 3 mo

Hazards Associated with Water Sources

Agricultural water comes primarily from three sources: surface water, ground water and public water supplies. Surface water includes rivers, streams, canals, swamps, lakes, ponds and man made reservoirs. Ground water comes from wells, which may be open or capped and may vary considerably in depth. Public water systems, e.g. municipal water, also are utilized and in this case the water quality is monitored and adjusted by the municipality. An additional water source, rainfall, is still the sole supply of water in some parts of the world. Hazards associated with these different water sources are discussed in the order of decreasing risk.

Surface water is presumed to be the source at greatest risk of contamination. Its microbial content may vary dramatically from thousands of organisms per milliliter in some sources to only minimal presence in other sources. Rainfall tends to reduce the numbers of microorganisms in smooth waters due to a natural purifying process. However, in some areas, rainfall has been shown to be the major factor in acute increases in contamination due to run-off from land surfaces. Regardless of the source, one can never assume that untreated surface water will have microbiological quality similar to municipal water or some other treated supply.

Contamination of surface waters may be permanent, cyclical or intermittent. Potential sources of biological contamination include raw human and animal wastes, sewage water discharges, pollutants from recreational use and adjacent land utilized for animal production, manure storage or waste disposal. Children in and around the fields and inadequate restroom and hand washing facilities that might drain into water are of particular concern. Wildlife is an additional source of contamination that is very difficult to monitor or control. Rodents, birds, reptiles, amphibians and even insects all are potential carriers of human pathogens and all are attracted to water. Restricted animal access to water is one way to reduce contamination risk and is addressed in Module 4.

Chemical hazards also may exist in surface water. These were covered in some detail in the previous Module on soil and site selection. When chemical contaminants are present in the soil they can eventually find their way into water. Nitrate run-off, improper disposal of pesticide containers, and run-off of petroleum products from roadways or from in-field repair of equipment, etc. are potential hazards of concern.

Flowing surface water in a river, stream or canal may travel long distances before it is utilized for crop production. It is important to identify upstream sources of potential contamination to this flow. Elimination of the contamination may involve sediment trapping or modification of the flow pattern, which is relatively simple with canals but may be much more complicated in a natural setting. If the contamination source cannot be eliminated, suitable treatment is required before using the water for agricultural purposes. Verification of the treatment method also is required and is discussed later in this Module.

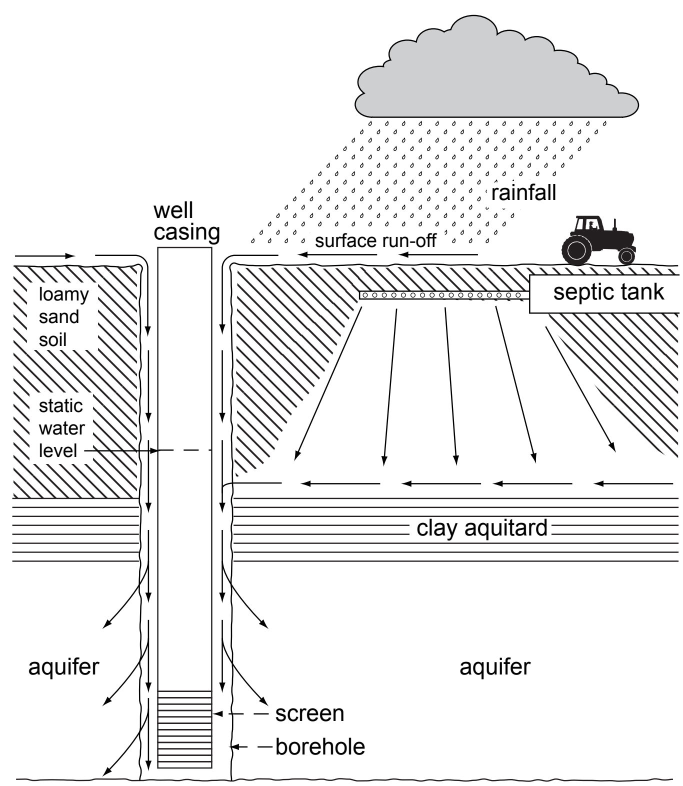
Ground water is generally believed to be less likely than surface water to be contaminated with pathogens. As water filters through layers of soil, clay and rock the organic content is reduced before it reaches the sub-surface reservoir. Testing of well water has verified that this usually is true. However shallow, old or improperly constructed wells may become contaminated with chemicals or microbes from the surface water intrusion.

It is well beyond the scope of this Manual to present all of the engineering considerations that factor in to the design of a well. However, growers should be aware of potential hazards associated with wells when developing their GAP program. The graphic below depicts a well that is not properly constructed.

Note first that the well casing has not been properly installed, i.e. the outer perimeter of the casing is not sealed. Rather, the area around the casing is packed with gravel or some other porous material. Flooding, either from heavy rainfall or from other surface water sources that ingress into the field, facilitates movement of contaminants to the well head where they can flow directly into the aquifer below.

Another serious hazard is the location of a septic tank and drain field near the well. Contaminated water percolates to the clay layer, moves laterally to reach the well casing and finally moves downward to pollute the aquifer. A general

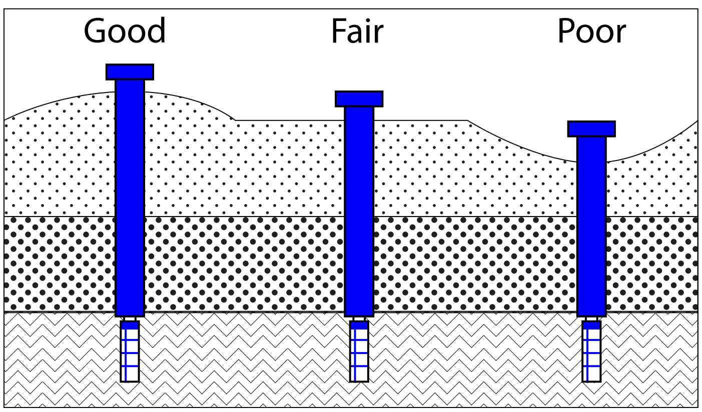
Illustration of an Improperly Designed Well and Several Potential Hazards



recommendation is to locate septic systems at least 100 feet from a well head, but in this example this distance may not be sufficient because of the potential lateral movement of sewage water underground along the clay layer. The contamination described here is permanent unless the septic system is excavated and removed and the casing is sealed to an adequate depth. These types of remedial actions are costly and may not be entirely effective in the short term because of the persistence of pathogens in the soil.

The handling of pesticides, fuel or other chemicals near this well site also would present a hazard as these substances can enter the aquifer in the same manner described for biological hazards. The well location should be noted before mixing, applying, storage or disposal of pesticides.

The location of the well relative to the elevation of surrounding land also is an important consideration as shown in the following graphic. Ideally a well head would be located in an area that is of higher elevation than the surrounding area, labeled as Good. If the well head is in a low area, labeled as Poor, surface water is more likely to accumulate around the well and percolate downward.



Well sites require maintenance. The area should be clean and free of debris. The well casing, seals and caps should be inspected regularly to be certain that they are in good repair. When repairs are needed, those should be performed in a manner that does not contaminate the water below. The activities of people on the ground surface can be a hazard for the aquifer. Workers may need to use oil or other solvents or perhaps temporary toilets are brought to the site. Animal presence presents a risk of fecal contamination. These hazards must be controlled to protect the well water.

Municipal water is a source that presumably does not present hazards although it also should be tested periodically. However, misuse of municipal water can be an issue and is discussed later.

All water sources should be inspected and tested regularly for the potential hazards noted previously. All monitoring procedures should be described in the relevant SSOP and records of the inspection, tests, unusual occurrences or repairs should be maintained.

Hazards Associated with the Use of Water

Agricultural water quality requirements and the severity of potential hazards can vary depending on the purpose for which the water is used, the degree of contact the water has with the edible portion of the plant, the growth habit and surface properties of the crop and the time that elapses between water contact and harvest. In this discussion we describe the various uses of agricultural water in some detail, identify potential hazards associated with water use, and offer suggestions for managing those hazards. Every farm is different and growers must tailor their water management plan to suit their particular operations, region and climate.

Concurrent with water use considerations, GAP includes soil and water conservation practices such as channel construction, drain control structures, diversion tanks, etc. Terraces, vegetation strips and other physical barriers should be considered in the event of run-off from the cultivated fields. This is an especially important topic for farms that are located near other farms or near natural bodies of water. Under ideal conditions, growers will be able to produce their crops with minimal impact upon the surrounding environment.

Irrigation

Irrigation is defined as the controlled application of water for the purpose of providing the moisture levels needed for appropriate development of the plant. Irrigation may be applied to the open field, within an enclosed structure such as a greenhouse, or in the case of containerized production, water is typically applied in low volume directly to the container.

There are various methods for irrigation which growers will select according to the environment, water source and availability, climate, soil characteristics, type of crop and cost. Different methods present different concerns for product safety. Quality of the water may dictate the preferred method of irrigation delivery. In general, methods that result in contact between water and the edible portion of the crop present the highest risk of contamination.

Overhead irrigation is sometimes referred to as sprinkler irrigation, although not all types of sprinklers are necessarily overhead. Water is delivered through a pressurized network of pipes to sprinklers, nozzles, or jets which spray the water into the air to fall upon the plants. This is, in effect, a simulation of rainfall. Obviously a relatively high volume of water is required. Much of the water can evaporate before reaching the soil and is wasted, particularly during dry windy weather. Plants are drenched, so the quality of water is an important concern because water of poor quality directly contaminates the crop.

Micro-sprinklers, as the name implies, are small sprinklers that typically are only a short distance above ground. They can spray water over a circumference of a meter or more and are most commonly used for vine or tree fruits because they can be placed under the canopy of the plants. Since water is applied close to the ground, less volume is required compared to overhead systems and typically there is little contact between the fruit and water.

Trickle, or drip, irrigation is applied through emitters or holes installed in tubes that may be placed along the surface of the ground or may be buried near the root zone of the growing plants. In vegetable production, drip tubes may be placed on top of the soil, installed sub-surface below the root zone, or used in combination with plastic mulch so that all of the water is effectively trapped in the soil. This is the most efficient means of irrigation. Water is not lost directly to the air and a low volume of water will satisfy the needs of the plant. With sub-surface placement, except in rare exposed areas, water does not come into contact with fruit or vegetables growing above ground so that the microbiological quality of the water is of less concern than with irrigation methods mentioned previously. The cost of tubing, emitters and plastic mulch is high but crop yields also may be higher. The cost of waste disposal can be a factor. Drip irrigation is a component of precision farming and managers must take care to meter precise amounts of water into the soil.

Surface, furrow or flood irrigation is the direct application of water to the soil surface either through furrows or by controlled flooding of the entire field. Various applications of these methods are employed for fruits, tree nuts and vegetables. Direct contact with the edible portion of the plant is minimal, as with furrow irrigated staked tomatoes, or there is no contact at all in the case of tree fruits and nuts. However, any contamination in the water is widely distributed over the soil which becomes a concern if the product itself is ever brought into contact with soil by farm operations or workers. This is a concern for tree nuts that may fall onto the soil.

Seep irrigation is the controlled delivery of water from canals that are in close proximity to the field. Water seeps from the canal through the soil to reach the root zones of growing plants. The depth of the water in the canals must be controlled carefully in order to provide adequate amounts of irrigation without water-logging the soil and creating an anaerobic environment for the roots. The irrigation water, theoretically, would never reach the soil surface or come in contact with the edible portion of the plant. In addition, depending on soil properties, significant filtering of bacteria and parasites (viruses to a lesser extent) will occur as the water seeps through the soil.

Hazards associated with irrigation are influenced by the water source and quality, the amount and frequency of application, the irrigation method, soil drainage properties, and the time that elapses between irrigation and harvest. Growers should consider all of these points in the development of their SSOP for agricultural water use. Records should be kept of the amount and purpose of water used, the dates of applications and any unusual occurrences such as breaks in main water lines causing localized flooding. These records may be a legal requirement, particularly in areas of limited water supply.

Frost Protection and Evaporative Cooling

Untimely frost or freezing weather, typically in the spring of the year, may require that plants be protected from damaging cold. Overhead irrigation is applied and a layer of insulating ice forms on the plant. Due to the heat released by freezing, the temperature underneath the ice remains at or near 32°F (0°C) while the air temperature above the plant may be several degrees below freezing. Strawberries and some species of citrus are two crops that can tolerate this freeze protection strategy.

During very hot weather, overhead irrigation may be used to cool plants that are very sensitive to heat. As the water evaporates from the plant surface it will reduce the surface temperature (evaporative cooling).

Water quality is of utmost concern in frost protection and evaporative cooling. If fruits are present they are literally bathed in the water. Typically, well water of high quality is used for these production management practices.

Pesticide Mixing and Application

Potable water is strongly recommended for the mixing and spray application of pesticides and foliar nutrients. When chemicals are applied directly through irrigation systems the process is sometimes called chemigation or fertigation. Outbreaks of illness have been associated with the use of inappropriate quality water for pesticide application because the edible portion of the plant is directly exposed to water. The presence of soluble foliar nutrients may enhance the growth of microbes that reside on the product surface.

Pesticide applicators should be trained and certified to handle chemicals. Spray drift and run-off from the field can injure workers or other crops that are near the application area. Excess chemicals on the product are a food safety hazard. Careful attention to dosage rates, re-entry and harvest intervals, etc. is required. Growers must follow label instructions. This is an absolute requirement for farming. Pesticide concerns are addressed later in Section IV.

Backflow Prevention

Once water has been removed from its source and is on its way to the crop, care must be taken to ensure that there is no backflow of water to the source. This can be achieved with the use of air-gaps or backflow prevention devices.

Backflow prevention is required by law in the U.S. and it should be practiced by all growers. Regular inspection of devices by a certified professional is required to ensure that they are functioning properly. A certificate of the inspection must be kept in the farming records.

Microbiological Testing of Agricultural Water

The most common source of microbiological contaminants in agricultural water is fecal material. Most of the bacteria in the feces of humans and other warm blooded animals are not pathogenic to humans. They are simply released into the environment with feces and cause no harm. However, relatively high numbers of fecal bacteria in the environment are an indication that pathogens are more likely to be present.

Routine testing for specific pathogenic bacteria, such as *E. coli* O157:H7 or *Salmonella*, is not generally appropriate unless there is some history of contamination to justify these tests. A more practical approach is to test for the indicator bacteria such as generic *E. coli*. If these counts become elevated then more specific tests may be justified. Unfortunately, tests for fecal bacteria indicators are too often a poor indicator of fecal pathogens and do not reveal the presence or confirm the absence of pathogenic viruses or parasites. This is a significant limitation of water testing programs.

Microbiological determinations are time consuming and obviously add to the cost of farming. They are not practical for daily monitoring activities but periodic testing can help identify changes and trends in the microbial load in water, e.g. for understanding seasonal variations of the source and tracking the safety of water. Once growers become accustomed to seeing that their water is of a certain quality based on test results, they will more readily identify results that are unusually high, take steps to determine the source of contamination and make adjustments in management practices to minimize risk.

Testing, whether process testing (verifying antimicrobial dose) or microbiological assessments, is the only means of verifying that a water treatment is effective. It is essential to keep all records of water tests. These will be useful in the event of an outbreak of illness. The SSOP should require that growers document the frequency of testing, the location of sampling, and the results of every test.

Growers should keep in mind that the microbiological characteristics of water may vary with the time of year and source of the water. Warm temperatures are conducive to bacterial population growth so higher counts might be expected in surface water in the summer compared to winter. Further, surface water is expected to have higher bacterial counts than ground water so growers should not necessarily be alarmed if they compare surface water tests to well water tests.

High counts in ground water would be a cause for concern and investigation of potential contamination sources would be appropriate, as discussed earlier with regard to well water. However, it is important to note that general or total bacterial populations are not the currently accepted criteria for assessing safety. Though not perfect, irrigation standards are based on levels of generic *E. coli*. The World Health Organization (WHO) maintains an international standard of 1000 fecal coliform bacteria / 100 ml water for unrestricted irrigation, a level unacceptable in the U.S. It is prudent for growers to acquire at least a basic understanding of microbiology as it relates to farming practices.

For drinking water, the maximum contaminant level (MCL) for total coliforms in water is zero, although EPA defines potable water in 40 CFR Part 141.63 as having <2 MPN generic *E. coli* / 100 ml water.

There is no existing MCL recognized for agricultural water. Some commodity groups have established specific recommendations for audit metrics that could eventually be a matter of law. It is useful to growers to keep abreast of developments in this area.

At the time of this writing, the California Leafy Greens industry has adopted for irrigation water the most restrictive level of the U.S. Environmental Protection Agency (EPA) guidelines for microbial quality of recreational water (intended for full body contact) as a standard (40 CFR Part 131.41c). The metric for indicator *E. coli* is 126 most probable number (MPN) / 100 ml water derived from a rolling average of five test results in a specified period. There is a contingency plan that requires additional testing in the event that a single test reveals counts that exceed a higher number, which varies depending on foliar or non-foliar contact. The important point for now is for growers to be aware that the global industry is moving from less specific voluntary GAPs programs to more prescriptive or mandatory requirements for some food safety program components, particularly for water use.

Other commodity groups are expected to adopt the leafy greens guideline. The California Tomato Farmers and the Florida Tomato Committee are two organizations that currently require members to conform to the leafy greens metric for irrigation water and to employ water testing to confirm compliance.

Frequency of testing is another issue that has been left to the interpretation of growers. Testing recommendations currently vary with the water source. For a closed system such as a deep well, one annual test at the beginning of the season should be sufficient. An uncovered well, open canal, reservoir or other surface water has a recommended testing frequency of every three months. A significant environmental event, such as flooding, is justification for additional testing. For public water systems, records from the municipality or district should be obtained at least annually. More frequent monitoring of test results is recommended to assess problems with the distribution systems and failures of backflow prevention.

Private third-party food safety auditing firms and representatives of regulatory agencies typically ask to review water test results. Prior to scheduling an audit, growers should be aware of the expectations of the auditing firm. The expectations of produce buyers, e.g. wholesalers, supermarket chains, re-packers, etc. also should be considered as these customers are commonly placing specific requirements on growers before they agree to purchase product. Growers who keep abreast of water quality requirements will be better prepared to respond to inquiries.

Water sample collection for testing is a scientific procedure that must be carried out correctly. If growers plan to collect their own samples, the testing laboratory will provide growers with a protocol and usually will offer training for taking the initial samples. Care must be taken in collecting and handling the sample to avoid contamination from any other source. Growers will be well served by seeking professional assistance in this important exercise.

Remediation of Contaminated Water

Several options for remediation are available to growers if they find that agricultural water is of poor or uncertain quality.

They first should attempt to identify the source of contamination and take steps to prevent the problem from occurring. This may not be feasible in the case of flowing surface water that becomes contaminated far from the production fields or if the source of contamination is beyond the grower's control.

A second option is to make repairs to infrastructure that supports the water source. In the example presented earlier of a well that was potentially contaminated by surface water or by a nearby septic system, the first step would be to repair the well casing and ensure that all grouting is intact. It would then be necessary to remove the septic system, excavate contaminated soil and treat the well with appropriate sanitizers until tests verify that the water quality has been restored to an acceptable level.

Treatment of contaminated water with sanitizers also is an option. There are a number of ways to improve the microbial quality of water. This author is familiar with a system installed for the treatment of canal water that entailed four steps, or hurdles. First was filtration through sand to remove large particulate matter. The second step was additional filtration through material that removed smaller particulates. The filtered water then was passed though chambers of ultraviolet lamps. Finally the water was chlorinated. Weekly tests of the treated water were implemented to ensure that the water quality met or exceeded the EPA standard for potable water which allowed for the use of water for pesticide mixing. Chlorination and other water sanitation practices are discussed in detail in Section III of this Manual.

If remediation of a water source is not possible the grower may be forced to consider alternative water sources. For example, if available surface water cannot be treated effectively or if the treatment is too expensive, the installation of a well could be a viable alternative.

Summary

Agricultural water uses include irrigation, pesticide and liquid fertilizer mixing and application, frost protection and evaporative cooling.

Workers in the field need potable water for drinking, hand washing and for cleaning of field equipment and sanitary facilities.

Water of poor quality can be a direct source of contamination to the crop. Water also is a vehicle for the spread of contamination.

Risks associated with agricultural water use are influenced by the way water is used, the type of crop, its stage of development, the time between water exposure and harvest, and possibly other factors.

Waterborne human pathogens have led to outbreaks of illness associated with the consumption of fresh fruits and vegetables. Some human pathogens can remain viable in water for long periods of time.

Agricultural water comes primarily from three sources: surface water, ground water and public water supplies. Although any of these sources can become contaminated, surface water generally is at greatest risk for contamination.

Wells must be properly designed to prevent the introduction of contamination. Growers must be aware of potential hazards associated with wells and other water sources and take steps to mitigate risk.

Hazards associated with the use of agricultural water must be identified and controlled in a way that mitigates risk.

Irrigation methods vary in the potential risk they present to the crop. Methods that involve direct contact between water and the edible portion of the plant present the highest risk for contamination.

There are no laws or regulations governing the microbial quality of water used for irrigation, however some commodity groups have adopted the guidelines for recreational water established by EPA as a standard for irrigation water.

Water used for mixing and application of pesticides must be of potable quality.

Backflow prevention is essential to ensure that water removed from its source cannot return to the source.

Microbiological testing of water is useful for tracking changes in water quality. Common tests for fecal indicators do not correlate with the presence of viruses or parasites.

Contaminated water can be treated to reduce or eliminate biological hazards.

If the source of contamination cannot be mitigated, growers should consider alternative sources.

Introduction

Fields used for agricultural production eventually require the addition of plant nutritional supplements (fertilizers) for soil enrichment in order to maintain the productivity of the land. Fertilizers are natural or synthetic substances added to the soil or in some cases, directly to the plant, to provide the nutrients necessary for plant development. Enhancement of soil fertility will enhance the quality and quantity of fruits and vegetables grown in it.

Fertilizers are divided into two large categories, inorganic and organic, depending on the source of the material. As a chemical definition, the term organic refers to chemicals containing carbon and inorganic refers to non-carbon containing materials. For the purpose of this manual, organic refers to naturally occurring substances such as manure, compost or cover crops, while inorganic refers to synthetic fertilizers.

In the context of food safety, organic fertilizers containing animal manure or animal components present the greatest number of hazards which are the subject of most of this Module. Inorganic fertilizers are discussed briefly.

Inorganic Fertilization

Inorganic fertilizers are, in most cases, salts that are produced on a very large scale through commercial chemical synthetic processes. In the developed world the large majority of fertilization is done with inorganic materials. The products themselves generally are not a source of microbiological contamination. However they can become contaminated through the use of unclean equipment for application or by the use of contaminated water for mixing. Those hazards and GAP for controlling them are discussed in various other parts of this Manual.

Organic Fertilization

Organic fertilizers are derived from plant material, animal manure, other animal wastes (fish emulsions, blood meal, bone meal, etc.) or from sludge (biosolids) collected from municipal sewage treatment systems.

Plant materials from a number of sources may be utilized. Culled fruits and vegetables from packinghouses, waste such as peel or pulp from produce processing facilities or municipal green waste all can be converted to fertilizers.

Animal manure is in abundant supply, discussed in Section I, and is a rich source of organic fertilizers if properly handled. Much of this Module will focus on hazards associated with the use of manure.

Municipal biosolids also are a source of organic material for fertilizers but their use is generally discouraged because of the presence of heavy metals or other toxic chemical or pharmaceutical contaminants that can be found in municipal waste. An additional concern is the potential presence of human pathogens, especially viruses that may not be inactivated during the processing of waste at the sewage treatment plant. Although biosolids can be used safely under some circumstances, it is common to find that their use is specifically prohibited in SSOP for fertility programs in the production of fruits and vegetables.

When properly treated, organic fertilizers offer many advantages to farmers and to society in general. For farmers, organic material adds nutrients to the soil and improves soil structure as well. For society, organic farming presents an option for the utilization of waste that otherwise poses a source of contamination to our environment.

Hazards Associated with Animal and Human Waste

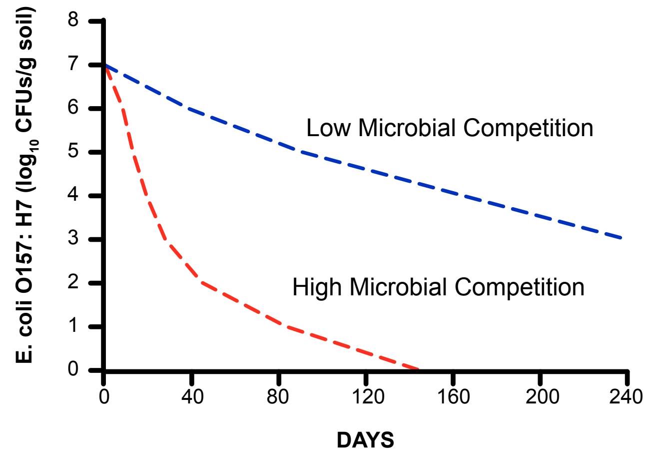
The feces of animals and humans are rich in microbes, some of which can cause illness in humans. Strains of *Salmonella*, *Shigella*, *Cryptosporidium*, *Enterococcus*, *E. coli* and other bacteria have been isolated, as well as viruses such as Hepatitis. One of the most infectious microorganisms in animal manure is *E. coli* O157:H7 which resides in the intestinal tract of ruminant animals such as cows, sheep and deer.

Proper treatment of manure, usually by composting (discussed later), can inactivate bacterial pathogens. The survival of viruses and protozoa in compost has not been clearly determined. If composting or other treatments are inadequate, or if no treatment is used, the risk of contamination of fruits and vegetables can be extremely high.

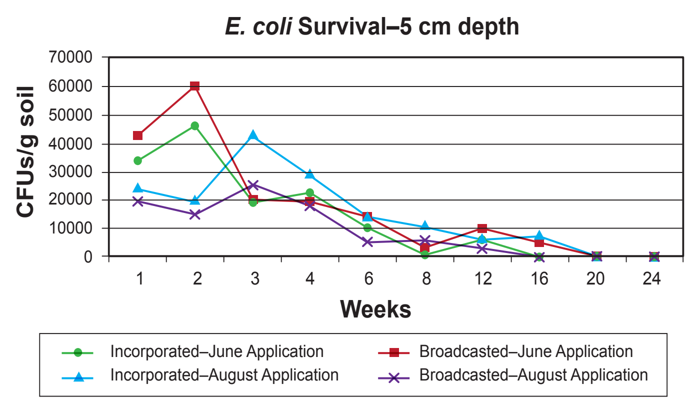
Although raw manure is never recommended for use as fertilizer, in many parts of the world it is commonly applied. If it is used, it should be incorporated into the soil during preparation and significantly prior to planting. The population of pathogens in the soil will be reduced over time and the rate of reduction is influenced by a number of environmental and management factors to be discussed. In some studies pathogens have survived in the soil for as much as one year so the maximum amount of time should be allowed between manure application and planting. Raw manure should never be applied to produce intended for fresh consumption during the cultivation period. Continued application of untreated manure to land may increase pathogen populations and extends the time that pathogens are present.

Survival of microbes in the soil and their potential transfer to the edible portion of crops depends on the soil pH, water status, method of application of the organic material, effectiveness of composting or other inactivating treatments, presence of competing microbes and predators in the soil, tillage practices that allow for aeration and exposure to sunlight and probably other factors. Research studies have provided valuable insight into the persistence of pathogens in the soil but the results of those studies vary widely, making accurate farm-specific recommendations difficult.

The graphic below illustrates the influence of microbial competition in the soil on the survival of *E. coli* O157:H7 in manure applied to the soil. Low Microbial Competition indicates that the soil was autoclaved to kill competing microbes before application of the manure. High Microbial Competition indicates that soil was not autoclaved so that the natural flora in the soil was present at the time of manure application. Note that in autoclaved soil (Low Microbial Competition) the pathogen was recovered after 240 days. In soil with High Microbial Competition the population of *E. coli* O157:H7 decreased rapidly during the first 40 days and in general survived only half as long compared to treatment of the autoclaved soil. Management practices such as soil fumigation that reduce microbial competition may actually prolong the life of pathogens if manure is applied after fumigation.



Other studies with *E. coli* survival in the soil have not yet yielded results that have been useful for management of manure. An example is found in the following graph depicting work that was reported from Canada. Liquid manure from a dairy cattle operation was applied to soil at two different times of year in either June or August. The application methods were broadcasting over the soil surface or by incorporation into the soil by plowing. At weekly intervals samples of soil were removed at a 5cm depth and the *E. coli* enumerated. Note that the bacteria survived from 8 to 20 weeks and there was no clear effect due to the method of application or the time of year that the manure was applied. Soil temperatures in Canada are typically cooler than in other farming regions and this may have obscured treatment differences.



Example data for the survival of *E. coli* from liquid dairy manure applied to soil.

Stratton, et al. 2002. ASAE Paper no. 022058.

Results of several additional studies are summarized on the following page that show the expectations for survival of either *E. coli* O157:H7 or *Salmonella* in soil, manure or other places in the environment.

The main point to be inferred from these studies is that survival of human pathogens in the environment is

	E. coli O157:H7			*Salmonella*	
Soil	**Manure**	**Other**	**Soil**	**Manure**	**Other**
50 to 150 days or more	5°C – 70 days 22°C – 56 days 37°C – 49 days Slurry: 21 to > 70 days Feces: > 90 days	Water: 222 to 257 days *E. coli* O157:H7 found to persist for 120 days in water trough sediments Feed: *E. coli* O157:H7 has been shown to proliferate in moist feeds	Surface or incorporated – 300 days or more	Feces of carrier cows – 159 days Slurry 10°C 132 days 20°C 57 days 30°C 13 days	Pasture 91 to 231 days

unpredictable. Pathogen survival is influenced by many variables, the easiest of which to manage is time. Avoiding the use of raw manure reduces risks, so methods for inactivation of pathogens should be employed prior to manure application.

Treatments to Reduce Microbiological Risks in Organic Fertilizers

Composting

Composting can be one of the most effective and economical methods of converting plant material and animal or human waste into organic fertilizer or soil amendments. It is a natural process in which bacteria and fungi break down organic matter into stable humus that can be utilized by plants. The fermentation that occurs during composting generates heat and various chemicals which, if properly managed, can reduce or eliminate biological hazards.

The principles of composting are quite simple. Naturally occurring microorganisms in the organic matter are provided with a balanced diet, water and oxygen to sustain their growth and promote their action upon organic materials. A small amount of nitrogen fertilizer may be added to the compost pile to supplement the nutritional requirements of the composting microbes. Ideally a C:N ratio of 25-30:1 optimizes the composting process.

The microorganisms need a moist, but not saturated, environment. A moisture range of 40 to 60 % in the pile is ideal. Excess water will cause the pile to become anaerobic and too little water slows microbial growth. Aerobic microbes, which are more effective for fast composting than anaerobic microbes, utilize oxygen and will function most effectively if the compost pile is turned periodically to allow aeration (see active composting below). Anaerobic composting may generate compounds that are toxic to many seedling plants.

A temperature in the range of 130 to 150°F should be generated inside the compost pile. Heat energy accumulates as a result of microbial action. Thermophilic (heat loving) bacteria, which are particularly effective for composting, will thrive in this temperature range. Thus the heat produced by bacteria promotes their own growth which in turn speeds the composting process and reduces or eliminates human pathogens.

Composting treatments can be divided into two groups: passive and active.

Passive composting treatments require very little inputs. Organic waste is simply held under natural conditions. The piles are not turned and oxygen is depleted, resulting in anaerobic conditions that slow the composting process. Given enough time, environmental factors, i.e. temperature, ultraviolet radiation and humidity, inhibit the growth of pathogens and eventually kills them.

The disadvantage of passive composting is that much time is required and it is difficult to know when the pathogens are finally killed. The amount of time needed depends upon the climate, region and season, as well as the type of manure or waste being used. Because of these many uncertainties passive composting treatments are not recommended.

Active composting treatments are those in which the compost pile is managed to create conditions that speed the process of decomposing waste. This is an artificial process in the sense that environmental conditions are controlled. Active composting is the most widely used treatment in agricultural industries.

Active treatment involves frequent turning of the material to maintain adequate oxygen levels within the pile. Moisture levels are monitored and water is added when necessary to maintain levels within the optimum range. Nutrients may be added to obtain the ideal C:N ratio, mentioned earlier, for microbial activity. Temperature also is monitored and when the pile stops heating the composting process is complete. Carbon dioxide and ammonia levels may also be monitored to determine completeness and curing stability. Under ideal conditions the high temperatures generated will kill 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 elimination of pathogens. The presence of *E. coli* and *Salmonella* are generally used as indicators. If these pathogens are present the compost should not be applied to crops without additional treatment. Composting is considered adequate if tests for fecal coliforms are <1,000 MPN / gram compost and *Salmonella* tests are < 3 MPN / 4 grams compost. Some current GAP programs consider these standards too permissive and, in addition specify a larger sampling mass for pathogen analysis.

Guidance for the development and management of a composting facility is available from the USDA Natural Resources Conservation Service (NRCS), from FAO, and from the Cornell University GAP websites.

Heat Treatments

Pasteurization with steam or dry heat effectively disinfects compost. Clearly the cost would be substantial for the utilization of heat treatments on a large scale. However, some industries have developed cost effective strategies. One example is the use of heat treated, pelletized poultry manure by the organic leafy greens industry.

Fumigation

Various fumigants or other volatiles (such as ammonia) can effectively kill pathogens. Fumigation presents occupational hazards which are discussed later in Section IV on the handling of pesticides.

GAP for the Manufacture, Storage and Application of Compost

To assure that pathogenic microorganisms do not contaminate fruits and vegetables and, ultimately, the consumers, it is necessary to implement a GAP program for the manufacture, storage and application of compost.

Manure should be isolated for treatment. The location for raw manure storage should be a reasonable distance from areas of treatment, finished compost, and production areas. Scientists have not identified with certainty what this distance should be, but the elevation of the facility relative to surrounding areas, run-off, the prevailing wind direction and the potential for farm traffic that might carry contaminant to the crop fields all are considerations for choosing a location. Barriers or some type of physical containment will help reduce risk. Composting can be achieved in an open area but managers must give special consideration to potential spread of contamination by wind or rain. Also consider the potential for re-contamination of the area by wildlife, birds or rodents, or by the introduction of fresh uncomposted material to the piles.

Contamination of water sources near the composting area is a concern. Ideally, treatments would be conducted on a concrete floor to reduce the risk of leaching into groundwater. Piles would be covered either by a roof or with sheets of plastic to reduce the risk of recontamination by wildlife and dispersal by wind. These practices also reduce risk of run-off into sources of surface water or onto surrounding fields.

Equipment used to handle raw manure should be thoroughly cleaned before it is used with finished compost or in a production field. Pressure washing and the use of an appropriate sanitizer is recommended. Likewise, personnel who handle manure or compost should not enter fields or be involved in harvesting or packing operations until proper attention has been given to clothing, footwear, protective gear and personal hygiene.

Compost should be applied prior to planting or in the early stages of growth. Ideally it would be incorporated into the soil. It should not be applied when the fruits or vegetables are near maturity or at harvest time. Always maximize the time between application and harvest. It is a violation of GAP to apply compost in a way that allows direct contact with the edible portion of the plant.

Consider the type of crop being produced. Crops grown at ground level, such as leafy greens or cantaloupe melons, would be at greater risk than fruit growing on a tree. Growers must exercise good judgment and common sense in the application of organic fertilizers.

The use of manure and compost teas, although discouraged, is popular with some organic and conventional producers. The same precautions that exist for dry compost application should be exercised with even more stringency for the application of teas.

SSOP and Record Keeping

Individuals or companies that practice composting should have detailed SSOP for each part of the process. Record keeping is a critical component of the SSOP. Following are a few examples of essential records. Depending on the specific operation additional records may be required.

The origin, composition and amount of organic material must be noted. If different types or sources of waste are utilized all of these data must be recorded. The specific method of treatment must be identified along with the location of the facility and dates that the treatment was initiated and terminated. If an active composting treatment is used the dates of turning the material are recorded. Times and temperatures are logged periodically throughout the process. Any unusual event occurring during treatment or storage, such as flooding, must be recorded. Results of microbiological analyses and the service laboratory providing the results should be available. Finally, the person managing the operation and contact information for the responsible individual should be stated on all record sheets.

If purchasing compost from a supplier, all of the above record-keeping should be presented in a Certificate of Analysis (COA) provided at the time of delivery and copies maintained by the grower for at least three years.

Summary

Fertilizers are natural or synthetic substances that provide nutrients that are necessary for plant growth and development.

Inorganic fertilizers are, in most cases, salts that are produced by commercial synthetic processes and pose relatively low food safety risks to crops.

Organic fertilizers are naturally occurring substances derived from manure, compost, cover crops, biosolids or waste from packing or processing operations.

Organic fertilizers offer many advantages when properly treated to reduce or eliminate food safety risks.

The feces of animals and humans may contain pathogens that pose significant food safety risks that must be controlled through appropriate treatments.

The survival of pathogens in soil or in compost are influenced by temperature, pH, water status, effectiveness of composting or other inactivating treatments, methods of application and tillage, type of crop and time.

Composting is a natural process in which bacteria or fungi decompose organic matter into stable humus than can be utilized by the plant.

Passive composting relies on natural conditions to gradually break down organic matter which requires a relatively long period of time.

Active composting involves the active manipulation of the environment to control and speed the composting process.

Safety of compost may be further enhanced by heat sterilization or by fumigation.

Microbiological analysis of compost is recommended to ensure that the process has been effective for the inactivation of microbes.

The accepted standard for microbial quality is to reduce the population of fecal coliforms to <1,000 MPN / gram and *Salmonella* to <3 MPN / 4 grams.

A detailed GAP program should be implemented for the manufacture, storage and application of compost.

GAPs should include steps to ensure that contamination from compost is not transferred to sources of water or to production fields.

SSOPs should be developed for compost manufacture and handling. Record keeping of all steps in compost operations is an essential component of SSOPs.

Introduction

In fresh produce operations the term "pest" applies to all organisms that negatively impact the quality and safety of produce, directly or indirectly. Animal pests that present food safety hazards during crop production are the primary concern for this Module. Pest control for postharvest facilities is covered in Section III.

All animals including mammals, birds, reptiles, amphibians and invertebrates (insects, slugs, snails, etc.) are considered potential sources or vehicles for contamination of fresh produce with pathogens. Their surfaces, e.g. hair, feathers, skin, and mouthparts can harbor large numbers of pathogens, which may also reside internally in their respiratory and gastrointestinal systems. Exclusion of animals from production areas is the only effective means of eliminating these hazards but this is not a realistic expectation. Minimizing risk by limiting intrusion is a practical goal but still difficult to achieve consistently.

Non-crop vegetation and dense weeds may also represent a hazard as they provide habitat and likely harbor insects, birds and vermin. Farmers deal with these pests more in the context of the limitations they place on productivity and quality rather than as food safety hazards. Chemical controls (pesticides) are addressed in Section IV.

Hazards Commonly Associated with Animals

Feces are considered the major source of pathogenic microorganisms from animals. Microbiological hazards associated with feces are discussed in detail in various Sections throughout this manual.

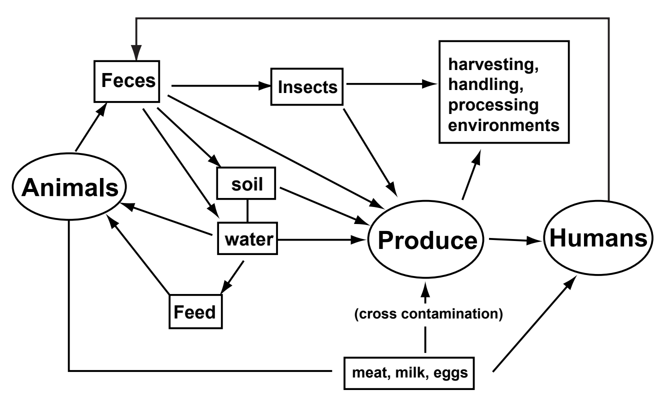
Some bacteria are commonly associated with animal skin. These include *Salmonella*, *Staphylococcus* and *Streptococcus*. Chickens and other domestic birds may harbor these pathogens on their feathers. Wild birds, reptiles and amphibians are common carriers of *Salmonella*, which has been isolated from these animals in numerous scientific investigations. Animals also can carry more opportunistic pathogens (typically not as serious as *E. coli* O157:H7, *Shigella* and *Salmonella*) and spoilage microorganisms. These reduce the quality and shelf life of fresh produce by causing decay.

Workers who handle animals must practice personal hygiene and clean their clothes and footwear before they work in fruit and vegetable fields or in packinghouses to avoid contaminating the product. It also is important to recognize that animal handlers are at direct risk of contaminating themselves. In commercial animal production some diseases have been identified as occupational illnesses because of the exposure that workers have on a daily basis. Illnesses have occurred in people who touch animals in petting zoos or other settings and then touch their food or mouths without washing their hands properly.

Physical damage inflicted by animals to the surface of fruits and vegetables immediately reduces quality. The damage also serves as a point of entry for human pathogens and spoilage microorganisms which multiply readily on the nutrients available from within the product. It is clear that GAP for the production and handling of fresh produce must include steps for the exclusion of animals from the environment.

Entry and Distribution of Pathogens in the Food Supply

This graphic illustrates several ways that contamination from the feces of animals can reach food and then be spread though the food handling system (modified from Beuchat, 1996).



Feces from humans and domestic or wild animals can contaminate the soil, water or be carried by insects. These are indirect routes to the contamination of produce. Insect vectors and birds are a special concern because of their mobility. They may feed on feces, animal feed stockpiles, or on contaminated produce and carry pathogens to any point in the harvesting, handling or processing environment.

A direct route also exists from feces to produce if the feces are deposited directly on the product by wild animals or birds in the field. There has been at least one suspected case of wild hogs having directly or indirectly acquiring *E. coli* O157:H7 from close interactions with cattle. This in turn contaminated the feces of the hogs before they deposited their own feces in produce fields. Another example is rodents that carry zoonotic pathogens from chicken houses to adjacent crops.

In a food preparation context, cross contamination of produce can occur with improper handling of meat, milk or eggs. Outbreaks of illness have been associated with this type of cross contamination occurring in restaurants, as well as with wholesale distributors that improperly store or co-mingle food products.

Ultimately, if the contaminated produce is eaten by humans, an outbreak of illness can be the result. Other scenarios for the spread of contamination certainly exist, but this graphic is a clear depiction of known risks associated with indirect or direct contact between animals and food.

The most critical principle of GAP is clearly illustrated in the above discussion. Prevention of contamination is essential for the assurance of food safety. Once pathogens have entered the food handling chain there is little that can be done, short of cooking, to eliminate the risk.

Classification of Animal Hazards

Some animals pose greater risks than others. Formal risk analysis is beyond the scope of this Module, but we can make some classification of animals based on their potential for being reservoirs or carriers or pathogens, as follows:

Primary reservoirs include cattle, deer, and pigs. Animals in this group have a very high likelihood of carrying pathogens of high concern internally and special effort should be made to exclude them from fruit and vegetable production areas. Calves in particular are known to shed pathogens with their feces at a relatively high rate.

Secondary reservoirs include horses, goats, sheep, cats, dogs, rabbits, rats, gulls, geese and other birds. Animals in this group perhaps pose less risk than the primary reservoirs. Larger domestic animals can be excluded and the smaller ones should be excluded from fields to the extent possible.

Transient carriers are those animals that do not have resident populations of a pathogen and are not commonly infected but may carry a pathogen in or on their bodies. Almost any animal, including humans, can be considered a transient carrier.

Mechanical vectors are animals that seldom are infected with pathogens but if exposed to contamination they can physically move it to another host. Slugs, nematodes, insects and Canada geese are examples of demonstrated mechanical vectors.

Animal Control and Exclusion

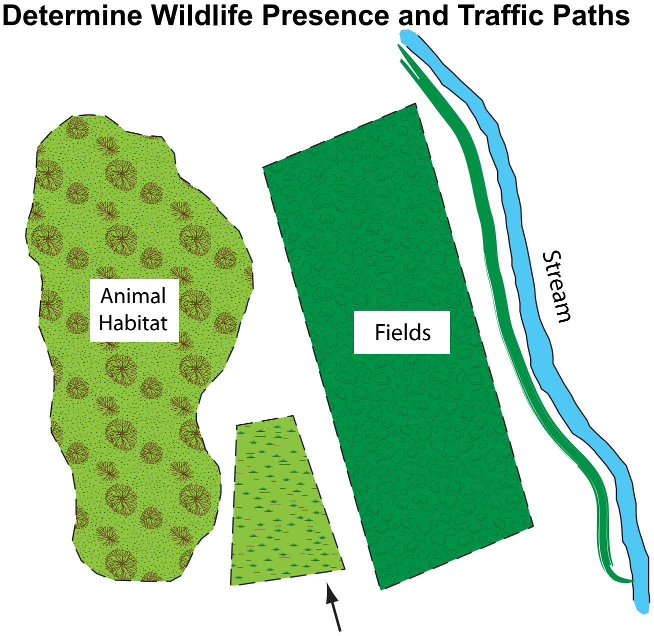
There are several methods for controlling animal and other pest incursions. None of them are completely effective but they all decrease the risk to varying degrees.

The direct control of animal populations by depredation (killing) is an option in some specific cases. Controlled hunting of hogs, deer and other wild animals may be permitted in some locations. The use of chemical controls such as baits or poisons may also be an option, but be aware that some animals, particularly rodents, can carry poison baits to fields or packing areas, potentially exposing produce to the chemical hazard. Growers must be aware of local regulations governing the elimination of animals before exercising any of these methods. Dispose of dead or trapped animals promptly to avoid attracting other animals to the area.

Fields and surrounding areas should be kept clean and free of garbage that will attract any type of animal pest in the area. Workers who eat near fields must be provided a means for disposal of food garbage and they must be trained to follow company protocols for taking breaks and disposing of garbage. Do not leave unused equipment, trailers, etc. around fields so that animals can seek shelter under such items.

Evaluation of the need to remove harborage areas around fields is recommended. The environmental impact of such measures should be considered as it influences run-off, etc. Many crops are grown in close proximity to wildlife habitat. Buffer zones around the field from which vegetation is removed can help discourage animals from making a home next door to the field. The effectiveness and necessity of this practice or the extent of vegetation removal is highly dependent on the type and natural behavior of animals in the area. Recent research is beginning to bring the practice of wide plant-free buffer zones into question. For example, some rodents don't venture into crops in close proximity to their natural habitat and others are not deterred from crop intrusion by plant-free zones. Small isolated fields, shown below, may be at greater risk for animal incursion than other areas because there might be less human and machine traffic that would discourage animal entry. In addition, as represented in the graphic, fields that are positioned between habitat and a water source may become a corridor for animal traffic.

Determine Wildlife Presence and Traffic Paths



Construction of fences or other physical barriers is the most common method of both large and small animal exclusion. If it is not possible to fence the entire farm, growers should evaluate the fields for indications of animal traffic patterns and construct fences strategically to interrupt the pattern of movement. Frequent inspection of fences is required. Local or regional wildlife protection regulations must be considered prior to constructing barriers. Hogs are particularly destructive and can often find a way around, under or through the best made fence. Deer can leap over most fences with ease.

Animals are attracted to water and water is needed for bacterial pathogen growth. Growers should limit the presence of water to only that needed for agricultural purposes. Areas of the farm with standing water should be drained. Watershed quality protection regulations or incentives may dictate that on-farm run-off retention and sediment settling ponds or impoundments be established. These may represent a conflict for growers with GAP audit criteria. No clear solution to this problem is currently available.

Deterrent devices are available commercially and some can be constructed by the grower. Propane cannons can be set to automatically discharge at a particular frequency to scare birds. Farmers are creative in the construction of scarecrows to mimic the presence of a person in the field. Unfortunately these methods lose their effectiveness after birds or other animals become accustomed to the noise or the presence of a scarecrow that cannot move about the field.

Some growers utilize domestic animals (dogs) to deter wild animals. Though this may be effective, most third-party auditing services will consider the presence of a domestic animal an immediate food safety risk and use that as a basis for a failure of the audit. Inspectors from regulatory agencies also view this as a serious violation of GAP. It is recommended not to allow domestic animals in fields.

Animal exclusion is one of the most difficult tasks facing growers in their GAP programs. There is no easy solution because practically all control measures are temporary, primarily cosmetic, and may create other concerns such as with the use of poison bait stations. All animal control methods employed should be stated in the SSOP for the farm's food safety program and must be documented.

Field Inspections

Frequent inspections of production areas are required to determine if exclusion methods are effective. Check the condition of fences, traps and bait stations. Non-poison bait (feeding) stations such as attractant-impregnated wax blocks may be used to monitor rodent presence and pattern of intrusions. Test deterrent devices to determine if they are working properly. Look for the presence of feces and for injury to the crop caused by feeding animals. Record the time and dates of inspections and keep these records in an appropriate location.

Summary

All animals are considered sources or vehicles for the contamination of fresh fruits and vegetables with pathogens.

Feces are considered the major source of pathogens associated with animals.

Workers who come in contact with animals must give special attention to personal hygiene before they work in fresh produce fields or handling facilities

Animals are sources of spoilage microorganisms as well as human pathogens. Physical injury of products caused by animals is a point of entry for these microbes.

Once microbiological contamination has entered the food production or handling environment, it can be transmitted to humans in many different ways.

Prevention of this contamination is the key to an effective GAP program.

Different types of animals differ in the degree of risk they pose to fresh produce. However all animals should be excluded from the production and handling environment as much as reasonably possible.

Animal and pest incursion may be controlled by various methods, including elimination, trapping, baiting, poisoning, by the construction of fences and barriers or by the use of deterrent devices.

Growers must be aware of local regulations governing animal control practices before implementing any method.

Fields and surrounding areas should be clean and free of food waste. Harborage areas should be reduced to the extent possible without causing environmental concerns.

Domestic animals should not be permitted in production and handling areas.

Frequent inspections of fields should be conducted and records kept of the inspections.

Introduction

The responsibility for reducing or avoiding contamination during primary production falls heavily on agricultural workers. Healthy people are more productive than those that are ill and are less likely to contaminate food and fellow workers. Numerous food safety hazards are identified throughout this manual, but ultimately it is the people who work with food that are the key to the assurance of food safety. This Module focuses on personnel and their role in the prevention of illness.

Hazards Associated with Personnel Practices

There are numerous routes for the transmission of disease. Sick or infected people can infect other persons directly through personal contact. They may also contaminate objects with their hands, such as a doorknob or money, which are then touched by others who become infected. When infected or ill persons touch food or food contact surfaces, the risk of causing illness in consumers is dramatically increased. Outbreak investigations have shown that just one identified infected person handling food has caused regional and multi-illnesses due to distribution and consumption of the contaminated product.

People themselves can be hazards. There are several pathogens for which humans are the only reservoir. Categories of biological hazards identified in Section I included bacteria, viruses and parasites. Each of these groups contains pathogens that reside, only infect, or must reproduce in people. Bacterial pathogens specific to humans include *Shigella* and *Salmonella* typhi. Viral pathogens include hepatitis virus A and Norovirus. One parasite, *Cyclospora*, is believed to be sourced from humans although the research is still preliminary. Any pathogen from any source may potentially be transmitted by people once contact is made.

Employees who feel sick should be trained and encouraged to report their condition to their supervisor. Workers may be reluctant to report illness because if they are not working they may not be paid. Managers should be trained to recognize the obvious symptoms of illness and they must be vigilant in the detection of employees who may be ill. Workers who are experiencing diarrhea, vomiting, dizziness, abdominal cramps, jaundice or who have open or exposed wounds or sores should not be allowed to perform tasks in which they contact food or food-contact surfaces. Employees who make frequent trips to the toilet or exhibit any other behavior indicative of illness should be questioned about their health. Frequent absenteeism may also be an indicator of illness. Detection of ill workers is an extremely important component of a GAP program.

Some pathogens can infect people without causing illness. These carriers of the pathogen who do not show symptoms (asymptomatic) may still have the capacity to shed the microorganisms that directly or indirectly find their way onto food. Controlling the spread from asymptomatic carriers is very difficult because even they do not know they are infected.

There are two specific considerations for personal hygiene that are of critical importance. First, the fecal-oral route of transmission of pathogens must be interrupted. Second, proper handwashing is essential in order to prevent the transfer of pathogens. All other components of GAP are important, but food industries cannot achieve the goal of food safety assurance if they fail to focus adequate attention on these two concerns. The health and hygiene of workers is critical for success.

Health Care for Workers

Ideally agricultural workers should have access to a preventative health care system. Once an employee is diagnosed with illness, he or she should not be allowed to return to work until they have clearance from a licensed healthcare worker. Unfortunately we do not live in an ideal world and the exclusion of sick employees from the workplace remains a significant challenge for managers.

A first aid kit with supplies for treating injuries should be readily available at the work site. The kit should contain at a minimum, adhesive bandages for small injuries, other larger bandaging supplies, hydrogen peroxide and disposable gloves. The simple procedures for cleaning, disinfecting and covering a wound should be included in employee training. Disposable gloves should be used to cover bandages on the hands or fingers. Procedures used to treat injured workers should be documented. Training exercises also should include instructions for reacting to the contamination of product, packaging materials and other food contact surfaces in the event they are exposed to blood or bodily fluids. Training must be documented.

Records should be kept of any medical report, particularly if it involves gastrointestinal or other illnesses. This information will be useful in the event that traceback of a disease outbreak leads to a specific work site.

Handwashing and Personal Hygiene

The easiest and most effective food safety practice that every company can implement is handwashing. Handwashing is considered a basic procedure that children learn at an early age. However, each person has a different background and may either have a different concept of proper handwashing or fail to fully exercise that knowledge. Therefore, personnel should be well trained in proper handwashing technique no matter how simple or basic the procedure appears to be.

The proper technique involves wetting the hands with water, applying soap and vigorously scrubbing the whole surface of the hand, around and under the nails and between the fingers for at least 20 seconds. After these steps, the hands are thoroughly rinsed with clean water and dried with a disposable paper towel. To avoid recontaminating clean hands, a paper towel should be used to turn off the water faucets and open exit doors. Paper towels should be disposed of in an appropriate garbage receptacle.

Hand sanitizers may be applied after washing. A number of hand sanitizing products are available, but it is critical that managers emphasize that the use of sanitizers is not a substitute for washing, e.g. we cannot sanitize filth. Recent research has shown that some viruses are not inactivated by some sanitizers so the effectiveness of sanitizer use is questionable.

Handwashing should be practiced at the beginning of the work day and after breaks, going to the toilet, eating, drinking, smoking, sneezing, coughing, touching skin or wounds, touching floors, dirty surfaces or equipment, handling cleaning materials or handling agricultural chemicals. In general, any time a worker uses hands for something other than their assigned tasks, handwashing is required.

Visitors to the fields or handling facilities, including produce inspectors or buyers, should follow the established hygiene and safety practices. Managers in particular should follow all practices to set an appropriate example for the workers. Signs describing appropriate handwashing procedures, using clear graphic icons to accommodate language or literacy issues, should be placed in strategic locations such as near toilets or at the entrance to a restricted work area as a reminder to everyone.

In order to facilitate proper handwashing, potable water, soap and single-use paper towels must be provided for all employees and visitors. Stand-alone handwashing stations located in convenient areas in the fields and packinghouses will encourage use. Handwashing policies are useless without the resources to implement the practices.

In addition to handwashing workers should bathe regularly, wear clean clothes, keep their fingernails short and clean, and use hairnets if the company policy requires them. In the same way that dirty hands can result in product contamination, so can dirty clothes and an unclean body.

Several tools are available to trainers to demonstrate the consequences of poor personal hygiene. The Glow-Germ demonstration is recommended for the classroom because it is simple and provides a quick result for the class to see. This involves placing a harmless powder or lotion on the hands and asking the participants to rinse or wash for varying lengths of time. The material that is not removed is visible under the “black light”. Residue on doorknobs or clothing can also be observed.

Gloves

Glove use generally is not mandatory or necessarily better than bare hands in agricultural production operations. If a company determines that gloves should be used by some specific workers, it should specify the policy in the SSOP and take steps to ensure compliance. If the company has a policy and the practice is not implemented, auditors and inspectors will note this as a serious deficiency in the GAP program.

Gloves are not a substitute for proper hand washing and other hygienic practices. This must be clearly understood by workers and supervisors. Hands should be thoroughly washed before putting on gloves. When properly used, gloves are an effective means of preventing contamination of food and protecting employees. However gloves can be a means of spreading contamination if they are not changed or disinfected after a potential contamination.

If gloves are used, the disposable kind (plastic, latex, etc.) are better than multiple use gloves since frequent replacement of gloves can help assure cleanliness and reduce the potential for growth of microorganisms on wet or dirty gloves. Gloves should be changed any time that 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 cleaning materials or agricultural chemicals.

Sanitary Field Stations

Historically agricultural field workers did not have access to toilet facilities. They simply had to find a location within or near the fields, perhaps with some privacy or perhaps not. Obviously if there were no toilets there also were no handwashing facilities.

Today in practically all developed countries there are laws that require that toilets be made available to workers. The number of toilets must be adequate for the number of workers in the field. Generally the rule is that there must be at least one toilet for each 20 workers of the same sex. If male and female workers are present in the same work area toilets should be designated by gender.

Toilets must be accessible to personnel, within 400 meters (1,300 feet) or less than a 5 minute walk from the work site. The more accessible the toilets are, the more likely that workers will use them. Access should be permitted at any time a worker needs to use them, not just during break periods.

Toilets should not be positioned within the production area. Although there are no laws stating the distance from the production field, some third-party auditing firms stipulate that the distance must be at least 50 feet from cultivated plants.

Toilets should be cleaned regularly and should be supplied with hygienic (toilet) paper. Workers should be trained to deposit used paper inside the toilet and not on the floor where it might be inadvertently transferred into the field. Records of cleaning and replenishment of toilet supplies must be kept. Workers are more likely to use a facility that has been serviced than one that is dirty. All workers should be trained to report dirty facilities to the person in charge of having them cleaned.

Most audit guidelines stipulate that the presence of toilet paper or human feces in or around a production field results in an automatic failure of the audit. Inspectors from regulatory agencies also view this as a serious violation of GAP. Managers must inspect fields and the perimeter for signs of non-compliance with these rules. Evidence of non-compliance should be cause for an immediate training session for the workers.

Toilets should be constructed in a manner that does not pose a risk for contamination of the field or nearby water supplies. It is recommended that they be positioned not less than 400 meters (1,300 feet) from sources of agricultural water, e.g. wells, canals, reservoirs, etc. This is a particularly difficult recommendation to comply with when fields are relatively small and surrounded by canals for furrow irrigation.

Portable toilets should be positioned so that trucks that service the units have easy access and present low risk for contaminating the crop. Ideally the servicing of portable units would be conducted away from the fields to reduce the risk of contaminating soil, water or workers in the event of spillage. Training for procedures employed for responding to accidental spills, including the company policy for limiting contact with impacted areas, should be stated in the SSOP. All training must be documented.

Permanent toilets should be connected to suitable septic drainage system, discussed earlier in Module 2 on Agricultural Water.

Toilets should be accompanied by hand wash stations. These should be supplied as described earlier. Water used for handwashing (gray water) should be captured and disposed of away from the production area. Tanker trucks or other containers used to transport water to the field station should be emptied periodically, preferably daily, and cleaned and disinfected to reduce the possibility for the formation of biofilms on the interior surfaces of water tanks or the plumbing system.

Appropriate signage instructing workers on proper sanitation in the field should be placed in strategic locations to remind personnel of these important practices. The signs on the following page were developed by the National GAPs Program in the U.S. In addition to signage and frequent training, many companies have found it useful to station full time workers near the sanitary facilities

Posters provided by the Cornell University Good Agricultural Practices Program

to replenish supplies throughout the day and to remind workers that they must comply with GAP.

Drinking Water

Companies have a moral, ethical, and in most countries, a legal obligation to provide workers with a safe supply of drinking water. Workers with access to water are less likely to suffer heat exhaustion or develop other illnesses that could lead to contamination of fresh produce.

Water for human consumption must be potable, i.e. free of microorganisms or chemical contaminants that can jeopardize the health of the person drinking the water. Standards for potable water quality have been established in most countries. The microbiological standard is that a test of 100 ml of water must confirm that no fecal coliforms or *E. coli* are present. Chemical standards vary with location and typically a maximum allowable limit is set for specific chemicals.

Coliform bacteria are present in the environment and are not normally harmful. However, if a total coliform test reveals that one or more coliforms are present in 100 ml of drinking water, additional testing should be conducted to determine the source of the contamination and the effectiveness of the treatment process to purify the water for human consumption. A thorough inspection of the water source, treatment method and distribution system should be conducted periodically to identify potential sources of contamination with documentation of the inspection.

All three groups of microbiological hazards discussed earlier (bacteria, viruses and parasites) have been associated with contaminated water. Bacterial pathogens have included *E. coli* O157:H7, other pathogenic or toxigenic *E. coli*, *Salmonella*, *Listeria*, *Campylobacter* and *Shigella* species. Viruses have included Hepatitis virus A and norovirus. Parasites include *Giardia lamblia*, *Cryptosporidium* and *Cyclospora cayetanesis*. The presence of any of these microorganisms, with the exception of *Listeria*, generally is an indication that fecal contamination has occurred.

The three most common sources of drinking water in descending order of risk are: treated surface water that comes from rivers, canals, lakes reservoirs. etc.; ground water from below the surface, including wells that require pumping or springs from which water flows naturally to the surface, and; municipal water from a city water treatment facility. Municipal water is preferred over other sources, but water from practically any source can be treated to make it potable.

It is beyond the scope of this Manual to discuss all of the treatment strategies to make potable water. Various methods are available to remove organic and inorganic contaminants but filtration followed by disinfection are perhaps the most common practices. Filtration media include sand, diatomaceous earth, and membranes of various designs. Disinfection methods include chlorine, chlorine dioxide, ozone and ultraviolet light. Each of the methods listed has some limitations. For example, generally acceptable levels of chlorine disinfectants are not effective against *Cryptosporidium* which has been implicated in some outbreaks of illness associated with the consumption of fresh produce. Ozone is very effective against *Cryptosporidium* but has no residual effectiveness in a water distribution system. Boiling is an effective method for killing microorganisms but it may not have an effect on chemical contaminants.

Ideally, drinking water would be treated immediately before consumption. There are different systems available that employ chlorine or ozone injection, ultraviolet light or micro filtration. In a field setting it may not be practical to utilize equipment of this nature.

The efficacy of any method or combination of methods must be verified by microbiological testing before the water is made available for human consumption.

Once water has been treated and the potable quality has been verified, additional precautions must be taken to ensure that re-contamination does not occur. Frequent monitoring is required to verify that the water supply, treatment processes and distribution systems are in good working order and functioning properly. Water storage or transport tanks or other containers should be cleaned and sanitized frequently, ideally on a daily basis. They should be closed at all times and stored out of the sunlight or excessive heat. Disposable cups should be provided and each worker should use a different cup.

Records must be kept of microbiological or physical evaluations of drinking water. Simple sensory evaluations (color, odor and taste) should be conducted on a daily basis. Any unusual observation requires that water be discarded and replaced with a suitable supply. If the water is sourced from a municipal supply, authorities should be notified of the irregularity.

Worker Hygiene Training Program

Employers can provide training and other resources to educate workers, but in the end, the effectiveness of the program relies on the workers' understanding and implementation of personal hygiene and safety practices. The quality of the overall food safety program is related directly to the quality of the worker training program and the value that workers place on the training provided.

Management must provide workers with information about acceptable practices, ensure that the information is understood and set an example for workers to follow so the importance of the practices is clear for all personnel. An SSOP should be developed for worker training that includes a detailed description of the behavior that is expected of all employees and the benefit to them personally.

All employees including supervisors and full-time, part-time and temporary personnel should participate in the training program. Commitment of managers and other company administrators to GAPs is essential in order for employees to fully understand the importance and participate willingly in the GAP program.

The level of knowledge required should be set according to the type of operation, responsibilities and type of activities in which the employee participates. Demonstrations of procedures are usually more effective than verbal instructions. Pictorial training for critical steps may be essential where language is a barrier.

Training should be in the language or dialect of the employees to ensure comprehension. Trainers should be sensitive to cultural aversions and ingrained practices when planning and delivering a training session and find an appropriate way to overcome these obstacles. Worker training is a challenging exercise but it is essential to an effective GAP program.

Training should be reinforced on a regular basis. Managers must be observant of the day to day practices of workers and conduct refresher trainings any time the need arises. Such training may be directed to an individual or to a group of workers who have similar responsibilities.

Records of all training activities should be kept. Workers who participate in training should sign a dated record sheet that is kept in an appropriate location. Third party auditors and representatives of regulatory agencies routinely ask to inspect training records.

Summary

The health and hygienic practices of employees is one of the most critical components of GAP because of the capacity for workers to transmit pathogens to other workers.

Proper handwashing must be practiced by all employees in a fresh produce operation.

Workers who are ill should be excluded from tasks that require them to touch food or food contact surfaces.

Workers who are ill should report their condition to their supervisor. Managers should be familiar with the obvious symptoms of illness and question workers who exhibit symptoms.

Ideally agricultural workers should have access to a health care system, should be familiar with first aid for minor injuries and should have access to first aid kits.

Every company should establish a glove use policy in their SSOP and take steps to ensure compliance with the policy.

Gloves and hand sanitizers are not substitutes for proper handwashing practice.

Workers should bathe regularly, wear clean clothes, correctly use toilet facilities, keep their fingernails short and clean, and use hairnets if the company policy requires them.

Training in the above practices should be conducted at the time of hire and frequent reinforcement training conducted thereafter.

Records of training and other critical health and hygiene practices must be kept.

In general, any time workers use their hands for something other then their assigned tasks they should wash their hands.

Visual aids and demonstrations are more effective training tools than simple explanations.

Managers and visitors to fields and facilities must practice the same personal hygiene steps that are expected of workers.

Workers must use sanitary field stations. The presence of human feces in or near a production field is reason for failure of a third-party audit and is viewed by regulatory inspectors as a serious violation of GAP.

Toilets must be conveniently accessible to workers. Toilets must be clean and supplied with hygienic (toilet) paper.

Hand wash stations must be near toilet facilities and must be supplied with potable water, soap, paper towels and a receptacle for disposal of towels.

Portable toilets must be cleaned and handled in a manner that does not pose a risk for contamination of the crop, field or workers. Permanent toilets must be connected to a proper septic system.

Signage for toilet use and handwashing policy should be strategically located.

If necessary, full time workers may be stationed near field sanitation units to ensure that workers comply with company policy for personal hygiene.

Companies are obligated to provide workers with an adequate supply of potable water for drinking.

The microbiological quality of drinking water should be verified by testing.

The possibility of produce contamination is related directly to the quality of the worker training program, the availability of resources to practice proper hygiene, and the employees' acceptance of the importance of their actions.

An SSOP should be developed for worker training that includes a detailed description of proper hygienic practices.