



Nutrient Management Technical Note No. 7

Reducing Risk of E. coli O157:H7 Contamination

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Reducing Risk of *E. coli* O157:H7 Contamination

Introduction

The purpose of this technical note is to provide important aspects of the contamination of foodstuffs with *E. coli* O157:H7. The bacterium *E. coli* O157:H7 (the suffix refers to biochemical compounds found on the bacterium's surface) is of particular concern due to its hardiness and severe consequences if ingested. This feces-transmitted microorganism has been causing illness since 1982 and its increased occurrence around the world has become a public health concern. In this technical note, the organism's health impact on humans will be presented. Our understanding of this organism is rapidly developing; therefore, while this technical note provides some background, more recent references should be sought out as well. Modes of potential contamination will be presented along with ways the Natural Resources Conservation Service can reduce potential vectors of contamination.

E. coli O157:H7 Health Impact on Humans

Escherichia coli is a species of bacteria that normally live in the intestines of humans and warm-blooded animals. While most strains of *E. coli* are harmless, the O157:H7 strain can cause severe diarrhea, severe kidney failure, and can break down the lining of the intestine in humans. Other disease-causing strains of *E. coli* that have been found in the U.S. are

O26:H11 and O111:H8. Illness can be caused by only a few cells (as few as 10 to 100 cells) of the O157:H7 strain. Recreational water quality standards typically allow for approximately 100 *E. coli* per 3 ounces of water. The *E. coli* that is monitored in recreational waters is not specific to this toxic strain. Consequently, surface waters considered safe for recreational use could still pose a serious threat to human health.

When *E. coli* O157:H7 attaches to the gut wall of infected people, it produces hemorrhagic colitis. It produces a powerful toxin that can cause severe kidney failure and can break down the lining of the intestine. Typical symptoms of infection include nausea, severe abdominal cramps, watery or very bloody diarrhea, and fatigue. Most people infected with *E. coli* O157:H7 get better within 5 to 10 days without treatment.

However, the disease can progress quickly to cause severe consequences in susceptible people, especially young children, the elderly, and those with weakened immune systems. Infection with *E. coli* O157:H7 is diagnosed by detecting the bacterium in the stool. *About one-third of laboratories that culture stool still do not test for this strain, so it is important to request that the stool specimen be tested on sorbitol-MacConkey agar for this organism.* All persons who suddenly have diarrhea with blood should get their stool tested for *E. coli* O157:H7.

The Center for Disease Control and Prevention, <http://www.cdc.gov/>, estimates 73,000 cases of infection with *E. coli* O157:H7 resulting in 61 deaths occurring in this country each year. The first reported outbreaks of illness occurred in 1982. First, undercooked hamburger meat was identified as the carrier. Now it is recognized that many other foods and sources also are carriers, including salami, raw milk, lettuce, spinach, untreated water, drinking or swimming in sewage contaminated water, ground beef, unpasteurized apple juice and cider, deer jerky, produce from manure-fertilized fields and gardens, and root crops, especially young seedlings like radish and alfalfa sprouts, as well as green onions. Transmission can also occur by infected persons who do not wash their hands.

Potential Sources and Factors Affecting Risk of Contamination

Like all bacteria, the survival and growth of *E. coli* O157:H7 in foods are dependent on the interactions of numerous factors, including temperature, pH and water availability. The *E. coli* O157:H7 strain is very hardy and can survive for extended periods in water and soil, in dry conditions, and under frozen and refrigerated temperatures. The strain can also adapt to acidic conditions. It can be destroyed by thorough cooking or pasteurization. Consumers should always practice safe food handling and preparation measures.

Tracking the origin of *E. coli* O157:H7 in a specific outbreak is difficult for several reasons. Water tests can only detect the presence of the bacteria, not its concentration. In addition, it can easily contaminate other foods it comes in contact with and it is difficult to detect; often the bacteria die off in culture, a step needed for positive ID. Laboratory sampling may detect the organisms in a sample and then, shortly after, no organisms may be detected. DNA

fingerprinting or ribotyping is used in some watersheds as a multiple source technique but is expensive. Determining the source(s) requires a comprehensive, multi-partner, multi-state initiative and can be time-consuming and expensive.

Research investigations are continuing to try to determine the sources of *E. coli* O157:H7 in the watershed to table continuum. A recent literature review (Stuart, 2006) indicates scientific studies largely agree that exposure of crops to untreated livestock waste and the use of improperly composted manure are the most likely sources of *E. coli* O157:H7 on cropland. Irrigation, runoff, and flood water contaminated with fecal matter may also pose significant risks. It is important to know the sources of water and to avoid contact between crops and contaminated water. Direct contact with domestic cattle and/or their feces is another source of pre-harvest contamination. The prevalence of food-borne human pathogens in wildlife is generally very low, but is higher for wildlife that eat or live around human and livestock waste, such as gulls or rats.

Risk from Manure Application and Animals

Root crops and leafy vegetables have the greatest risk of infection from manure application to soil. They can also become contaminated through direct or indirect contact with infected cattle, deer, and sheep. *E. coli* O157:H7 is most prevalent in ruminant animals in general and in cattle in particular (both beef and dairy). Other known carriers include birds (including gulls, pigeons, starlings), insects, raccoons, squirrels, and most recently, pigs. While the bacteria do not appear to make these animals sick, the animals carry and shed the bacteria in their feces. Wildlife that have contact with contaminated animals, manure, soil, or plant material can spread the pathogen across the landscape where these animals roam.

E. coli O157:H7 may be only a transient member of the bacterial flora of a cow, colonizing cattle from 1 to 2 months, rather than being a long-term resident. The organism is found in cattle more frequently after May 1 and is more common in cow heifers 3 to 18 months old. *E. coli* O157:H7 is more common in larger herds.

Research has shown that cattle on grass pastures have little or no O157:H7 in their rumens or gut. Whereas cattle finished on corn are more easily contaminated. This has to do with rumen pH. Cattle fattened on corn showed no toxic *E. coli* after two weeks on grass.

Pathogens have been shown to be transferred from manure to the surface of crops on contaminated soil particles. Once on the surface of the crop, pathogens can persist for up to 150 days. *E. coli* O157:H7 can survive for more than six months in the soil.

Risk from Irrigation and Drainage Water

Irrigation water can be a prime source of contamination, with potential sources of contamination, including improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff. Waterborne bacteria can enter leaves through stomata. When *E. coli* O157:H7 was introduced into flowers of cucumber, tomato, and strawberries, the subsequent fruits were contaminated. When introduced on seed, *E. coli* O157:H7 became internalized in cress, lettuce, radish, and spinach seedlings, but was not recovered within the tissues of mature plants. Entry through roots and translocation through plant has been shown to be unlikely, even with pathogen inoculation and root damage. However, the potential for this absorption of the pathogen has not been completely ruled out. The probability of contamination of the spinach and lettuce plants appears to be greater when they are exposed to the pathogen just prior to harvest

as compared to exposure at early or mid-stages of growth. Sprinkler versus drip, flood or furrow irrigation appears to pose a greater risk for contamination. Improper reuse of non-chlorinated dairy wastewater for irrigation of leafy and root vegetables also poses a substantial risk. Reuse of drainage water from infected fields poses a potential source of contamination. The *E. coli* bacteria can persist in sediment in drainage and irrigation canals as well as in feedlots.

Human contamination or inadequacies at water treatment plants have been implicated in almost all large-scale outbreaks. The potential does exist for contamination of water with pathogens from agriculture, warranting a proactive approach for reducing this and all sources in watersheds. Human contact with contaminated water, whether swimming, fishing, or drinking, can transmit the pathogen to humans.

Reducing Risk of Contamination

In 1998, the Food and Drug Administration (FDA) published the Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables, also referred to as the Good Agricultural Practices (GAPs) guide. It addresses microbial food safety hazards and good agricultural management practices common to the growing, harvesting, washing, sorting, packing, and transporting of most fruits and vegetables sold to consumers in an unprocessed or minimally processed (raw) form. It is voluntary guidance which can be used by both domestic and foreign fresh fruit and vegetable producers to help ensure the safety of their produce.

According to the GAPs guide, areas that are considered risk potential for microbial contamination of produce include: agricultural water (for irrigation or crop protection sprays), wild and domestic animals, worker health and hygiene,

production environment (use of manure, irrigation, previous land use, use of adjacent land), post-harvest water quality (water used to wash or cool produce), and sanitation of facilities and equipment.

FDA focused on the farm and packing facilities because of a need to raise awareness about food safety at these stages of the supply chain. FDA's 2004 Produce Safety Action Plan, however, recognizes that contamination can happen at any point in the supply chain.

Individual states and EPA have water quality standards and regulations; however, the high expense of monitoring can prevent optimal quality assurance. With increasing outbreaks in recent years, it is recognized that more must be done to protect the consumer's food safety from farm to table.

The strain's low infectious dose, survival under adverse conditions, and potential for extreme disease severity require successful risk reduction strategies from source to table. NRCS strategies focus on reducing and controlling the pathogen, in the watershed, farm, and field.

Watershed Approach

The NRCS technical report (Rosen, 2000 a), *Waterborne Pathogens in Agricultural Watersheds*, provides comprehensive information on waterborne pathogens, including *E. coli* O157:H7. <http://www.wsi.nrcs.usda.gov/products/nutrient.html>. The report includes sources, characteristics, transport pathways, and potential measures for the control of pathogens from agricultural sources. This report details a multi-barrier approach which can help control pathogen transport and proliferation. The four control points are: pathogen import to the farm (intended to prevent the initial infection by these organisms); cycle of pathogen amplification or proliferation in the animal operation; waste

management; and pathogen export or transport from the farm.

Comprehensive watershed plans focusing on all potential sources of pathogen contamination are the recommended course of action for those watersheds which provide the greatest risk to food safety. These plans typically involve multiple partners, including state and federal agencies, universities, producers and consumers, with each contributing. EPA's total maximum daily load program requires state responsibility to implement EPA's criteria and identify violations, including bacterial exceedances, and to implement watershed measures to correct these. Watershed restoration action strategy plans, required for EPA Non-point Source (319) project funding should already be underway or completed for identified priority watersheds.

Farm and Field Approach

Operators need to consider the impact of selected conservation practices on pathogen control. Many of the same conservation practices used to prevent nutrient movement from animal operations, such as leaching, runoff, and erosion control are likely to minimize the movement of pathogens. A recent study by Guber et al. (2006) concludes that pathogens move off the land in a like manner to phosphorus. If conservation practices keep phosphorus on the land and in the root zone, they should also keep pathogens on the land. Phosphorus best management practice publications have been developed relating to agricultural phosphorus in the environment and phosphorus best management practices to protect water quality. (http://www.sera17.ext.vt.edu/SERA_17_Publications.html).

NRCS resource management systems and combinations of conservation practices provide both on-site and off-site protection of resources on the field or farm. Numerous

conservation practices have a role in reducing pathogen load in a watershed, including:

- Amendments for Treatment of Agricultural Waste (591)
- Animal Mortality Facility (316)
- Composting Facility (317)
- Conservation Cover (327)
- Conservation Crop Rotation (328)
- Constructed Wetland (656)
- Cover Crop (340)
- Fence (382)
- Filter Strip (393)
- Grassed Waterway (412)
- Heavy Use Area Protection (561)
- Irrigation Land Leveling (464)
- Irrigation Water Management (449)
- Manure Transfer (353)
- Nutrient Management (590)
- Pond Sealing (521)
- Prescribed Grazing (528)
- Riparian Forest Buffer (391)
- Riparian Herbaceous Cover (390)
- Sediment Basin (350)
- Solid/Liquid Waste Separation Facility (632)
- Use Exclusion (472)
- Waste Storage Facility (313)
- Waste Treatment Lagoon (359)

Practice details are available from the NRCS Field Office Technical Guide.

Animal Feeding Operations

Comprehensive nutrient management plans (CNMP) should be developed for animal feeding operations (AFO) in priority watersheds. Effluent should be treated and manure properly composted prior to being applied to vegetable crop fields, such as spinach, lettuce and onions. Proper irrigation water management and wildlife management should also be maintained.

Phosphorus and pathogens have been shown to bypass the soil matrix to contaminate tile

discharge, particularly following application of liquid manures. Tile drains have served to better understand the problem, indicating that significant fecal coliform infiltration into well structured soil may contaminate groundwater even during modest rainfall.

Certain manure treatment systems can reduce the pathogen content of manure. Manure treatment technologies which may produce minor to major pathogen removal from liquid stream, depending on site specific conditions, include:

- high-rate aeration
- low-rate aeration
- lagoon with high-rate aeration retrofit
- lagoon with low-rate aeration retrofit
- aerobic/anaerobic zones retrofit
- lagoon with impermeable cover
- lagoon with permeable cover
- anaerobic digester with gas collection
- aerobic biofilter
- constructed wetlands
- sequencing batch reactor
- land application.

Those manure treatment technologies which may produce minor pathogen removal include: mechanical solids removal, gravity solids removal, and chemical precipitation. One or a combination of several treatment systems should be utilized to treat manure and effluent prior to land application.

Cropland

Rosen (2000 b) suggests on cropland there are two approaches that should be considered dealing with manure application to a field. If a storm event is anticipated within 24 hours, the waste material should be incorporated or injected into the soil. Incorporation in the soil allows for a reduction of potentially harmful *E. coli* organisms through soil adsorption, filtration, and attenuation from competing soil organisms. Incorporation reduces the potential for surface runoff.

When soils are dry and summer temperatures are > 75° F, surface application allows significant pathogen die-off due to exposure to UV light and desiccation.

Where compost is applied to vegetable crops in priority watersheds, a mandatory component of the nutrient management plan shall include guidance on the proper composting of manure. Improper composting can result in crop contamination. When the management goal is to reduce pathogens, the compost shall attain a temperature greater than 130° F for at least 5 days as an average throughout the compost mass. The National Organic Program has specific composting requirements for manure and other material used in compost, which should be followed by certified organic producers where more stringent than NRCS Composting Facility Standard 317.

Proper irrigation water management is another important practice to reduce pathogen risks. Appropriate source, quality, timing and distribution of irrigation water must be ensured. Capturing return flow tail water is advised so not to contaminate irrigation water downstream. Irrigation water management should also be a component of the nutrient management plan on fields where manure and effluent are applied to vegetable crops and in those priority watersheds.

Vegetated treatment systems have also been shown to reduce the presence of pathogens. Common practices in these systems include vegetated ponds or basins, grassed waterways, filter strips, and constructed wetlands. Field runoff characteristics, site conditions, buffer design, and buffer management are several factors affecting buffer effectiveness. Maintaining short vegetation height permits UV light and drying winds to reach the soil surface where the pathogens have been trapped. Physical barriers, such as fences and vegetated buffers may also be effective barriers to prevent movement of livestock and

wildlife onto fields. Wildlife management and population control are essential management techniques when wandering animals are deemed to be vectors for the spread of pathogens. Additional work needs to be done to determine and ensure the appropriate design specifications, effectiveness and impact of conservation practices on pathogens.

The GAPs guide provides recommendations to growers, packers, and shippers, several of which include agricultural water, processing water, cooling operations, manure management, animal feces management, worker health and hygiene, packing facility management, transportation, and trace back. NRCS may be called upon to provide technical assistance regarding water supply and manure management. Other actions to address contamination prevention must be addressed by the appropriate agency. NRCS personnel should be aware of the potential for their hands, clothing, shoes, or boots, and vehicles to be vectors for contamination. Appropriate protective clothing and foot covering should be used in high-risk situations. Frequent hand washing or disinfection should be routinely applied practices. Disinfectant spray should also be used on vehicles as needed in such situations.

Summary

E. coli O157:H7 is a feces-transmitted microorganism that has been causing illness since 1982 and its increased occurrence around the world has become a public health concern. Sources of this pathogen within a watershed could include irrigation water, improperly treated sewage, sewage spills, septic tanks, livestock, wildlife, and storm water runoff. Pathogens are carried with surface runoff or subsurface flows to receiving waters.

Comprehensive watershed plans focusing on all potential sources of pathogen

contamination are the recommended course of action for those watersheds which provide the greatest risk to food safety. NRCS should be a crucial partner participating in the development and implementation of these watershed plans. In this scenario, comprehensive nutrient management plans would be developed and applied for animal feeding operations in those priority watersheds. Effluent would be treated and manure composted prior to being applied to vegetable crop fields, such as spinach, lettuce and onions. Proper irrigation water management and wildlife management, complemented with vegetative and structural practices as needed to control potential on-farm pathogen sources, would also be applied and maintained. If the quality of water delivered to the producer is of good quality through a well-monitored and implemented watershed plan, the producer will be able to produce a good quality food and prevent off-site contamination in following this nutrient management plan and farm GAPs.

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