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E. coli, Water Quality, Food Safety, and Human Health

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What is *E. coli*?

Escherichia coli, better known as *E. coli*, is a type of fecal coliform bacteria commonly found in the intestines of animals and humans (Figure 1). This bacterium lives and grows naturally in the gastrointestinal tract of humans and animals, but if the wrong type of *E. coli* gets into the wrong place in the body, such as the kidneys or blood, it can lead to severe illness, with symptoms including nausea, vomiting, diarrhea, and fever – possibly leading to hospitalization (U.S. Dept. of Health and Human Services 2018). It is difficult to control *E. coli* bacteria because they are carried within all of us, and they are so small they cannot be seen by the naked eye without a microscope (Ingerson and Reid 2011). These bacteria are shed in feces and people become infected when they unknowingly consume food or water contaminated with *E. coli;* hence the way *E. coli* is spread is termed the "fecal-oral" route of transmission.

Figure 1. *E. coli* - Gram-negative, facultative anaerobe, rod prokaryote; with multiple flagella and fimbriae. *E. coli* can cause urinary tract infections, diarrhea and can lead to kidney damage in extreme cases. (Dennis Kunkel Microscopy, Inc./Visuals Unlimited, Inc.)

While most *E. coli* are considered harmless, there are specific types (also called "strains") that are pathogenic, meaning that they can cause disease in humans. Harmful types of *E. coli* are classified into the following groups: Enterotoxigenic (ETEC), Enteropathogenic (EPEC), Entertohemorragic (EHEC) and Enteroinvasive (EIEC) (Table 1). The ETEC, EPEC, and EIEC groups are all generally transmitted through contaminated food and water (Gerba et al, 2009 and Vieira et al, 2007). A well-known type of EHEC is *E. coli* O157:H7, a particularly dangerous strain known to contaminate foods, such as produce and beef, and has also been implicated in outbreaks in which irrigation water was identified as the source of contamination.

Table 1. Groups of *E. coli*

Group of *E. coli*	Modes of Transmission	Disease
Enterotoxigenic (ETEC)	Food or water ingestion	ETEC causes diarrhea without fever. It is common in infants and is often the cause of travelers' diarrhea
Enteropathogenic (EPEC)	Food or water ingestion, direct and indirect human contact	EPEC causes watery, sometimes bloody diarrhea. It is a common cause of infantile diarrhea in underdeveloped countries.
Enterohemorragic (EHEC)	Food/ingestion, direct or indirect human contact	EHEC strains cause bloody diarrhea and can sometimes damage the kidneys and progress to the potentially fatal hemolytic uremic syndrome (HUS). EHEC has caused many large food-borne outbreaks worldwide; O157:H7 is the best known strain.
Enteroinvasive (EIEC)	Food and water ingestion	EIEC causes watery, dysentery like diarrhea. Fever is another common symptom.

E. coli in Water and on Food

Preventing food contamination and human infection from *E. coli* requires control measures at all stages of the food production continuum: from agricultural production, to processing, manufacturing, transporting, storing, and preparation of foods in both commercial establishments like restaurants as well as domestic environments, such as your home (The Hartford Loss Control Department 1998). Although contaminated ground beef has been the most common cause of *E. coli* poisoning, contamination can also occur at any number of points along the food production continuum (CDC 2018). Fruits, vegetables, and water are other common sources of contamination. The focus of this publication is to inform readers about the impacts of *E. coli* bacteria in water on food safety and human health.

The presence of *E. coli* in water is a strong indication of recent human sewage or animal waste contamination. It is important to note that *E. coli* and waste can get into water by many different ways. For example, during heavy rainfall and snow melt, *E. coli* may be washed into creeks, rivers, streams, lakes, or irrigation canals (Griffith et al 2003, Roslev and Bukh 2011) from the land surface. Other means of release of *E. coli* into water include failing septic systems, recreational activities (where *E. coli* wash from human skin into water bodies), and local land use practices (for example fertilizers like manure, livestock, and concentrated feeding operations). Human and animal sources of fecal contamination represent a serious health risk because there is a high likelihood that their waste contains pathogenic *E. coli* strains. Cattle, swine, birds, and other wildlife also carry zoonotic pathogens, meaning that bacteria in their feces can be transmitted from animals to humans, causing disease. Therefore, waste of any animal is of high concern.

In 2006, a major *E. coli* outbreak occurred in the United States. The Center for Disease Control and Prevention (CDC) confirmed 199 illnesses and three deaths associated with baby spinach (CDC 2006). Other *E. coli* outbreaks have occurred since 2006, many of which have been associated with leafy greens, sprouted vegetables, and beef products (CDC 2018). Whenever an outbreak is detected, the U.S. Food and Drug Administration (FDA) and CDC officials work with patients to identify common foods consumed, to aid in tracing the outbreak to the food source. Once the source is identified, the FDA and CDC work with local departments of agriculture, irrigation water managers, growers, agronomists, and food processing facilities to ensure that the cause of the outbreak is eliminated.

How do we keep water and food safe?

Because contaminated water poses such a large threat to human health, water managers and regulatory agencies utilize tests to tell us if our water is safe for its intended use. As mentioned above, *E. coli* is commonly used to indicate that fecal contamination is present in water. Although, we do not want to find *E. coli* in our water, these bacteria can be easily quantified using simple methods. The *E. coli* are generally reported in colony forming units (CFUs), with one CFU equal to a single, viable bacterium that is capable of causing infection. Detection

Figure 2. Raw Product Testing for *E. coli* bacteria (Photo Credit: Dr. Channah Rock)

of these bacteria in water means that fecal contamination has occurred and suggests that other enteric pathogens (such as Salmonella or Cryptosporidium) may be present. This also means that humans and animals should not come into contact with the contaminated water until the presence of *E. coli* is no longer detected or is at the allowable level for the intended use (Table 2). At that point, the water is considered safe.

Numerous federal and state governmental agencies, as well as growers of fresh produce, test irrigation water quality (as well as raw product, Figure 2) to determine if it is safe. As stated earlier, *E. coli* is currently the most reliable indicator of fecal bacterial contamination of surface waters in the U.S. according to water quality standards set by the United States Environmental Protection Agency (EPA). Water quality testing is normally based on the concentrations of *E. coli*; this applies to water that is consumed for drinking, as well as for wastewater that has been treated and then recycled for irrigation purposes and/or discharged to surface waters. Rivers that are used for recreation, such as fishing and swimming, are also required to meet certain levels of *E. coli* or they can be deemed "impaired" (Rivera and Rock 2011).

Table 2 outlines the acceptable levels/concentrations of *E. coli* based on the various categories of water use. The concentrations of *E. coli* used in regulation are based on assessment of the volume of water a person consumes during different practices

Table 2. Level of *E. coli* permitted for Different Uses of Water (ADEQ 2016; FDA 2017; and EPA 2008, 2012) ✶ *fecal coliform organisms,* ✦***geometric mean*** *is a type of* ***mean*** *or* ***average****, which indicates the central tendency of the water source.*

Water Use	Acceptable Level of *E. coli* cfu per 100mL
Drinking Water (Municipal Supply)	Zero
Surface Water Full-Body Contact (Swimming)	✦Geometric Mean of 126 Single Sample Maximum 235
Surface Water Partial-Body Contact (Fishing, boating, etc…)	✦Geometric Mean of 126 Single Sample Maximum 575
A+ Recycled Water (Irrigation of food crops)	Zero in 4 of last 7 samples ✶Single Sample Maximum 23
Agricultural Water (Produce production)	✦Geometric Mean of 126

and the likelihood the person would become sick after coming into contact with the contaminated water if it contained pathogenic *E. coli*. It makes sense that, in circumstances where the contact or ingestion of the water is high (swimming or drinking) the concentration of the *E. coli* that is deemed acceptable is lower. Likewise, in situations where contact with the water is minimal (irrigation), the levels of *E. coli* considered acceptable may be higher because there is a lower risk of a person becoming sick (Soller et al, 2010).

Two of these categories are partial-body contact (PBC) and full-body contact (FBC). According to the EPA, partial-body contact means the human body comes in contact with surface water used for recreational activities, but not to the point of full-body submergence (EPA 2012). Alternatively, full-body contact means the human body is completely underwater as is the case in swimming or other recreational activities (EPA 2012).

Additionally, the FDA recently passed regulations entitled: *Standards for Growing, Harvesting, Packing and Holding Produce for Human Consumption*, that establish science-based minimum standards for the safe growing, harvesting, packing, and holding of produce on farms. This is part of the implementation of the FDA Food Safety Modernization Act (FSMA) and it applies to produce that is consumed raw and does not receive commercial processing that would adequately reduce the presence of microorganisms of public health significance (FDA 2013). The goal of FSMA is to reduce foodborne illness associated with the consumption of contaminated produce, and though FSMA guidelines focus on standards around many growth and handling practices related to produce safety, they specifically include the quality of agricultural water used for irrigation. FDA defines agricultural water as "water that is intended to, or likely to, contact the harvestable portion of covered produce or food-contact surfaces" (FDA 2013).

One key area within FSMA that applies to water quality is the Produce Safety Rule (PSR), which requires growers to initially establish a Microbial Water Quality Profile (MWQP) for each agricultural untreated water source used for irrigation. The water quality profile is based on the levels of generic *E. coli* in agricultural (pre-harvest) water. An initial MWQP must be established with a minimum of 20 water samples collected as close to harvest as possible over a period of at least 2 to a maximum of 4 years (FDA 2017). If water quality does not meet FSMA standards, growers are required to implement mitigation strategies including treating the water to reduce the levels of *E. coli* bacteria, allowing for bacteria to die-off in the field before harvest (prescribed number of days outlined in the PSR), or discontinue use of the water source. By establishing a MWQP, growers are proactively managing their water sources to better understand water quality and to aid in sustaining a safe food supply and public health protection.

What can you do in your community to protect water quality and keep food safe from contamination?

Numerous activities that occur in your community can ultimately impact water quality and indirectly, food safety. Here are some ways you can help keep rivers, lakes, streams, and irrigation canals protected from contamination with *E. coli* bacteria:

- Learn about your local water sources, including groundwater and surface water
- Identify ways you can help prevent polluted runoff from your home, ranch, or farm
- Pick up pet waste in and around your neighborhood

- Keep domestic animals and/or livestock out of waterways (or reduce their exposure)
- Properly maintain your septic system and have it inspected when appropriate
- Join a local watershed group or volunteer organization active in environmental issues in your community
- Volunteer during clean-up events targeting pollution near surface waters
- Do not throw trash into rivers, lakes, and streams, or irrigation canals (while the trash may not contain fecal matter or waste, it may attract wild or domestic animals which may introduce fecal contamination near water bodies and cause contamination)
- When camping or hiking, properly dispose of waste and trash to reduce the attraction of animals

Water is a very precious resource; by doing our part to protect water sources we can ensure benefits to future generations and to the safety of its users.

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