Conserve Water for Food

High School Educational Resources

Background

The food science discipline encompasses all scientific aspects of the development, production, processing, packaging, and distribution of foods. Food scientists study the biology, chemistry, and engineering design for food systems to enhance product safety, quality, stability, nutritive value, accessibility, affordability, and sustainability. These efforts apply to food for both humans and companion animals.

Food safety is paramount and widely realized in the United States. However, illnesses occur due to unintentional contamination that can occur throughout production, processing, and final consumer handling. The U.S. Centers for Disease Control and Prevention (CDC) estimates 48 million foodborne illnesses occur in the U.S. annually.

Foodborne illness is typically characterized by gastroenteritis, symptoms of which include nausea, vomiting, diarrhea (may be bloody), abdominal pain, and flu-like symptoms, although some foodborne microorganisms and their toxins can affect other bodily systems including the hepatic, renal, reproductive, and neurological systems. Illnesses can be short-lived and self-eliminating; however, some can be severe and result in hospitalization, long-term sequelae, or even death depending on individual vulnerability, exposure, and pathogen characteristics.

Many of the microbial pathogens associated with foodborne illness can be found in the intestinal tract and fecal waste of infected humans and animals. Foodborne pathogens are often zoonotic, meaning they can be transmitted between humans and other animals. Some microorganisms that cause disease in humans may be carried asymptomatically by an animal. Foodborne pathogens are generally transmitted the fecal-oral route, meaning pathogens are shed in the feces of an infected individual and enter the next individual through the oral cavity, generally through consumption of fecally-contaminated food or water. Bacteria, viruses, and parasites can persist in food, water, and the environment for days to months to even years depending on the conditions and microbial characteristics. Bacteria can replicate to increase in number in food and environmental matrices that support their growth. Conversely, viruses and parasites can persist in the environment, but they grow and replicate only in hosts.

Scientists have shared interest and responsibility for food safety to minimize disease transmission cycles involving humans, animals and the environment – a One Health approach to interdependent wellbeing.

Pathogens can be inadvertently introduced to food products through infected food handlers, contaminated food contact surfaces, and contaminated environmental sources such as soil and water. Foods that do not receive a proper terminal microbial inactivation treatment such as thermal processing may be particularly vulnerable for transmission of pathogens. For example, raw agricultural commodities contaminated with microbial pathogens have been associated with foodborne illness outbreaks caused by bacteria, parasites, and virus such as *Escherichia coli* O157:H7, *Cyclospora cayetenensis*, and human norovirus, respectively. To minimize risks of contamination, guidelines such as Good Agricultural Practices (GAPs) and regulations such as the Produce Safety Rule (PSR) of the Food Safety Modernization Act (FSMA) have been instituted for the production of produce. One of the regulatory requirements includes evaluation of the microbiological quality of water used to irrigate food crops.

Sources of irrigation water can include ground water and surface water (lakes, ponds, streams), although availability of these traditional water resources have become strained due to droughts and contamination. As a result, research efforts to safely and sustainably recycle water for food production has become a research priority.

In order to evaluate the quality of water to be used for irrigation of food crops, environmental water is collected and transported to a laboratory to be tested for the presence of bacteria typically found in the intestinal tracts of humans and other animals. The bacteria that are quantified are known as fecal coliforms and include *Escherichia coli* (*E. coli*). There are many types of *E. coli*. The bacterial species includes generic *E. coli* which is part of a healthy intestinal microbiome and does not harm the host; whereas other strains, such as *E. coli* O157:H7, can cause severe illness. Fecal coliforms are often quantified in water tests as an indication of potential fecal contamination of water; however, their presence does not necessarily indicate that pathogens are present in a water sample. Analyzing water for the presence of pathogens requires more extensive and time-consuming laboratory tests.

Various treatments are evaluated for reducing microbial contamination of irrigation water at the point of use. Treatments may improve water quality by removal of microorganisms, such as filtration of water through various matrices, or by inactivation of microorganisms, such as through disinfectants or non-thermal methods.

High School Educational Resources

Advancing the understanding of the issues surrounding the safety and availability of water and the consequent impact on the food supply is essential to developing science-literate community members who can affect positive change through personal and professional action. Issues surrounding the safe reuse of water for agriculture support educational concepts taught in secondary education. Educational resources prepared by CONSERVE for the high school community include animations, simulations, interactive investigations, presentations, digital narratives, infographics, glossary, and questions to exercise and evaluate student knowledge gained from utilization of these resources.

- **Animations**
  - ***Water, Food & Our World***
    https://www.youtube.com/watch?v=ShYjTA-2sVk (3 minutes, 52 seconds)
    This animation provides an overview of the sources, types, and uses of water. The animation also addresses the need to conserve and appropriately reuse water for food production due to increases in demand and shortages of clean water. Research efforts underway to address these challenges are presented.

  - ***Humans & Food Are Part of the Water Cycle***
    https://www.youtube.com/watch?v=-Q0NmSugRVo (2 minutes, 38 seconds)
    This animation provides an overview of historical and current water uses for irrigation of food crops. The animation addresses the water cycle, water sources, and water recycling for sustainable agriculture.

- **Presentations**
  - ***Food and Water Safety for One Health***
    This presentation provides an overview of topics related to: 1, public health impacts of foodborne illness; 2, microbiology basics; 3, food microbiology and control strategies; 4, surveillance for foodborne illness; 5, foodborne illness outbreak investigations; 6, sources of food contamination; 7, water as a critical resource; 8, food safety and environmental water connection; and 9, changing needs and response for water resources.

  - ***Foodborne Illness Outbreak Investigation***
    https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/Appendix-3-JMBE-Shearer-Kniel-Conserve-Outbreak-Investigation-Presentation-Individual-Exercise.pdf

    https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/Appendix-4-JMBE-Shearer-Kniel-Conserve-Outbreak-Investigation-Presentation-GroupActivity.pdf
    These presentations accompany the Foodborne Illness Outbreak Investigations that can be conducted by students in groups or individually. The presentations provide a brief introduction to the topic, guidelines to complete the investigations, and visuals to support class discussion after completion of the investigations.

- **Food Safety and One Health – Foodborne Illness Outbreak Investigations**
  - **Interactive Group Investigation**
    https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/Appendix-2-JMBE-Shearer-Kniel-Conserve-Interactive-Group-Outbreak-Investigation.pdf
    The foodborne illness outbreak investigation provides an interactive, problem-based approach to learning about food safety and One Health in the context of a

real-life scenario. The group investigation features activities to organize, graph, perform computations, and draw conclusions about data related to epidemiology, laboratory, traceback, recall, environmental risk assessment, and prevention efforts of an investigation. The investigation features gaming elements including text, visual, and manipulative-based data clues that, when successfully interpreted, generate a three-digit numeric code to unlock a preset, programmable combination lock. The group format also exercises communication and other teamwork skills among students as well as communication with the larger class through group presentations. Students are further prompted to consider and discuss thoughts on aspects related to their investigation phase; some of the topics may not have a single correct answer based on current scientific knowledge or technologies.

- **Individual Investigation**
  https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/Appendix-1-JMBE-Shearer-Kniel-Conserve-Outbreak-Individual-Exercise.pdf
  The foodborne illness outbreak investigation provides a problem-based approach to learning about food safety and One Health in the context of a real-life scenario. The individual investigation features activities and illustrations to organize, graph, perform computations, and draw conclusions about data related to epidemiology, laboratory, traceback, recall, environmental risk assessment, and prevention efforts of an investigation.

- **Simulations**
  - ***Water Sampling Simulation***
    https://conserve.nmsu.edu/
    This virtual laboratory exercise guides the student through the process of collecting water samples from various sources (pond, stream, canal, water treatment facility) in different regions of the United States. Concepts addressed include location selection, sampling handling protocols, sample analysis, and data handling. The animation also addresses the need to conserve and appropriately reuse water for food production due to increases in demand and shortages of clean water. Research efforts underway to address these challenges are presented.

  - ***Water Testing Simulation***
    https://conserve.nmsu.edu/
    This virtual laboratory exercise guides users through analysis of water samples for the presence of microorganisms as an indication of water quality and potential exposure to fecal material. Exercises include water sample dilutions, set up and use of a water filtration apparatus, transfer of filter to agar, sample incubation, enumeration of coliform bacteria, and related calculations. The water testing simulation emphasizes the importance of personal protective equipment, equipment sterilization and assembly, handling of laboratory instruments,

microbiological testing protocols, calculations and data interpretation. The animation provides an overview of historical and current water uses for irrigation of food crops and addresses the water cycle, water sources, and water recycling for sustainable agriculture.

- **Glossary:** ***Recycled Water and Related Terms Relevant for Agriculture***
  https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/CONSERVE_RecycledWater_Agriculture_Terms.pdf
  This 5-page glossary provides definitions for terms related to types of water and water treatment technologies, processes and products as related to agriculture.

- **Infographics**
  - ***Evolutionary Water Systems***
    https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/CONSERVE-Infographic-Timeline-Water-Systems.pdf
    This infographic provides an historical perspective and timeline on water transport, reclamation, and policy.

  - ***Revolutions in Urban Water***
    https://www.udel.edu/content/dam/udelImages/canr/pdfs/anfs/conserve/Revolutions-Urban-Water-infographic.pdf
    This infographic provides historical perspective on societal efforts to obtain and render water safe for human use.

- **Digital Narratives**
  - ***Water Research – Virus Detection***
    https://drive.google.com/file/d/106hlB4ih-pwyRTCGim7hwhsmV65jB4Eq/view
    This digital narrative (less than 4 minutes) features a student researcher who describes and demonstrates the purpose and approach for research in which water samples are collected and analyzed for the presence of virus to evaluate the microbiological safety of the water.

  - ***Water Research – Parasite Detection***
    https://drive.google.com/file/d/1NiU8w3BWjloKlh9ljli01fDrlQDLTaGE/view
    This digital narrative (less than 4 minutes) features a student researcher who describes and demonstrates the purpose and approach for research in which water samples are collected and analyzed for the presence of parasites to evaluate the microbiological safety of the water.

Education Content Standards Supported

- **Science (Next Generation Science Standards)**
  - High School Life Sciences: Interdependent Relationships in Ecosystems.
    - HS-LS1-1. Mathematical and/or computational representations to support explanations of factors that affect ecosystems
    - HS-LS2-2. Mathematical representations of populations in ecosystems
    - HS-LS2-6. Effects of changing conditions on ecosystems
    - HS-LS2-7. Design, evaluate, and refine a solution for reducing impact of human activity on the environment
    - HS-LS2-8. Evaluate the evidence for the role of group behavior on survival and reproduction
    - Science and Engineering Practices
    - Cross Cutting Concepts
- **Mathematics (Common Core)**
  - High School: Reason abstractly and quantitatively
- **Social Studies**
  - Geography: Ecosystems, human modification and response to natural environment
  - Civics: Structure and purpose of government

Learning Objectives

The educational resources support cross-curricular instruction on issues surrounding the availability and safety of environmental water needed for food production. This resource will support student understanding of the following:

1. The importance of fresh water from environmental and recycled water sources for production of food crops
2. The roles of environmental water, plants, animals, and microorganisms in disease transmission
3. The generation and use of data to inform decisions related to provision of safe irrigation water

Lesson Essential Concepts

1. Water is critical for food production and is obtained from environmental water bodies such as streams and ponds as well as reclaimed water sources.
2. Contaminated and untreated irrigation water can transfer hazardous biological agents to human food.
3. Environmental water is sampled and tested prior to use for irrigation of food crops.
4. Irrigation water must meet microbiological standards for use on food crops.
5. Technology is used to reduce microbial contamination of irrigation water.
6. Actions by scientists, society leaders, and all individuals can impact the safety and availability of water needed for agriculture.

Acknowledgement

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2016-68007-25064. Any opinions, findings, conclusions, or recommendations expressed in the publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.