Ensuring pathogen removal in small-scale decentralized water supply systems

After reading this you should know/be able to:

- Identify ways pathogens can be introduced into the water system.
- Understand why stakeholders should be involved in helping to protect the supply.
- Identify the types of tests that are used to monitor pathogen concentrations in the water supply.
- Identify which small-scale water supply systems would be subject to US Environmental Protection Agency (EPA) regulations.
- Recognize the significance and limitations of surveillance data.

There are numerous ways pathogens can infiltrate a susceptible water supply system and deleteriously affect the populations served by those systems. It is the responsibility of those who manage the water supply to regularly monitor and appropriately treat their systems to ensure that lurking pathogens are removed. This technical brief will detail ways pathogens can be introduced into a small-scale decentralized water supply system, components of a susceptible system, monitoring tests, relevant USEPA regulations and the implication and limitations of using surveillance data.

Introduction

According to the USEPA, a small-scale water supply system is one that serves a population of less than 3,300 people (Ford, Rupp, Butterfield, & Camper, 2004). A decentralized system is an onsite treatment system that processes only a small volume of locally drawn water and is not part of the mainstream water supply system (Water Treatment Plant, 2010). It is their very nature of being small-scale and decentralized that places these water systems at the greatest risk for pathogenic contamination; small communities that lack access to the centralized water supply often fall short of the financial resources and access needed to prevent, treat and test their own water supplies for harmful pathogens. The CDC estimates that individual and small-scale water systems are largely responsible for the 900-1000 deaths that occur annually in the U.S. due to the consumption of water contaminated with pathogens (CDC, 2010) (Ford et al., 2004).

Fundamentals

Pathogens, or microorganisms capable of causing disease, can be introduced into the water supply in a variety of ways. Water sources near livestock farms are more susceptible to pathogenic infiltration due to the greater amounts of animal fecal waste on those sites. Seasonal changes can also affect the integrity of the water supply. Normally, water percolates down into the ground; as it does so, naturally-occurring beneficial bacteria found in the soil filters and purifies the water. After heavy rainfall and flooding, the bacteria do not have enough time to properly purify the water and normally filtered pathogens are then able to enter ground water supply (APEC, 2010).

Certain factors about the water supply and system also make it more susceptible to contamination. Surface water is more vulnerable to pathogenic contamination as compared to ground water supplies because it contains a higher concentration of dissolved solids from run-off; pathogens are attracted to these particulates and readily bind to them (Mihelcic, 2010). Surface water is also at heightened risk because the natural filtration that normally occurs for ground water supplies does not occur for surface water. An inappropriately constructed and maintained water supply, storage and/or treatment facilities can also create the opportunity for pathogenic contamination (APEC, 2010). For example, a small crack in a community well has the potential to introduce lethal pathogens into the water supply. Also, not regularly using the water system can result in stagnant water in the piping system, which is more susceptible to the formation of harmful bacterial colonies.

Operation and Maintenance

There are a variety of ways to ensure pathogen removal in small-scale, decentralized water supply systems; ways to be discussed include:

- Developing a water safety plan
- Communicating with key stakeholders
- Properly constructing community wells
- Regularly testing the supply system
- Abiding by regulations
- Monitoring surveillance data

<u>Developing a water safety plan</u>

The World Health Organization (WHO, 2005) recommends a water safety plan be created by the suppliers of water to ensure its purity and quality. There are three components to a water safety plan, which include:

- Assessment
- Monitoring
- Management

Assessment determines whether a water system can safely provide quality water from the source to the point of consumption. The next step, **monitoring**, identifies potential health hazards throughout the system. Control measures for every identified hazard and a timeline for when each action will be performed are determined. A ranked sanitation survey, which is a comprehensive inspection of the entire water-supply system (Ford et al., 2004), should be completed by those monitoring the system; this survey is used to examine where the greatest potential for pathogenic contamination exist. Survey questions should focus on different components of the system from the source to where the water is used. The most vulnerable parts of the system can then more easily be identified. The last step, **management**, consists of creating a comprehensive monitoring plan that thoroughly describes the maintenance procedures to be taken during routine monitoring and unforeseen incidents and emergencies. Communication of risks and consequences for inappropriately regulated systems should be brought to the attention of responsible staff. Staff should also be corrected (if needed) on the appropriate way to monitor and treat the water supply (WHO, 2005).

Communicating with key stakeholders

Educating stakeholders by discussing the importance of water source and supply protection is critical to preventing outbreaks. This concept is based on the notion that if people understand the consequences of mismanagement and why certain regulations are in place, they are more likely to properly manage their systems. When communicating with stakeholders, some information that could be discussed includes: how human activities may disrupt water purity, the source of the water supply, the importance of protecting the water and risks associated with improperly managing the water. Well-trained and educated staff along with appropriate educational material should be used to promote water-safety. Although not always feasible, partnering with a large-scale system for systems monitoring can reduce financial strains while promoting regular and extensive pathogenic monitoring (Ford et al., 2004).

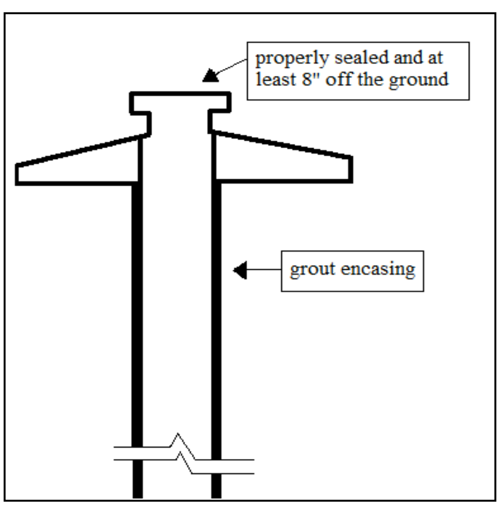


Illustration of a properly designed well

Properly constructing community wells

Properly engineering and constructing community wells can also prevent pathogenic contamination. Wells should extend at least 8’’above the ground, be encased by a protective mound and be properly sealed (Mancl, 2010). Wells should also be located at least 100 ft from non-water tight sewage lines, septic tanks, disposal systems and manure sites to prevent contamination from such sources (Oram, n.d.) (Mancl, 2010).

Regularly testing the supply system

It is of utmost importance to properly and regularly test and treat the water supply to ensure pathogen removal. Pathogens can be removed from the water using treatment procedures that may utilize chlorine, UV light and even ozone (USEPA, 2006). Although treatment of the supply is an essential component to ensuring water integrity, this technical brief is more tailored to meet the needs of those who test, rather than treat, the water for pathogens; as such, treatment procedures will not be further discussed.

Elaboration of water supply testing will now ensue with a discussion first of the proper water sampling techniques and the frequency by which testing should occur. In order to ensure an accurate representation, a consistent volume of multiple samples should be taken throughout the water system. It is imperative that once collected, the sample should be taken to the lab within 24 hours. The frequency of which tests are performed depends on the population being served by the system. Testing should be random, but increased during times of local epidemics and seasonal variations that can promote increased bacterial growth (i.e. heavy rains or flooding). Self-audits should occur at least every year and sanitation surveys at least every 5 years. Testing frequency should increase immediately after periods of stagnation, repairs made to the system and after noticeable changes in the water's smell or color. Changes in the water's turbidity, pH, temperature and chlorine residuals (if used) can also indicate potential problems with the water supply. Finally, it should be recognized that increasing sample size volume and/or testing frequency increases the likelihood of detecting lurking microbes (Ford et al., 2004).

There are three types of water supply monitoring tests that will be discussed; they include:

- Chlorine residual tests
- Fecal indicator bacteria tests
- Total fecal coliform tests

Chlorine residual monitoring is used to determine the concentrations of chlorine residuals. Absence of particular residuals can indicate bacterial growth. The water chlorine residual should be maintained at least at 0.2 parts per million (PPM) (Oram, n.d.).

The fecal indicator bacterial test, also known as the "presence/absence test" or "P/A test", is a simple, fast and inexpensive test that monitors a water sample for the presence of a particular pathogen (most P/A tests sample for the presence of *E. coli 0157:H7*). However, the test is severely limited by the fact that it can only identify whether a certain strain of bacteria is either present or absent; as such, it cannot be used to determine the concentration of tested bacteria or whether other bacterial strains are present. This test is appropriate for systems that do not typically screen positive for any bacterial contaminants; however, it is better to frequently monitor such a water supply using this relatively inexpensive P/A test, rather than occasionally monitoring the system using more expensive and detailed methods. It has also been recommended that the P/A test should monitor the water supply for the hardier pathogen, *Clostridium* instead of *E. Coli 0157:H7* (Ford et al., 2004).

The total coliform (or bacteria) test determines the level of pathogenic contamination by testing a sample for several common disease-causing strains. First, a porous filter is placed into the water supply, where it can trap pathogens. The filter is then placed in a Petri dish with bacterial media, or culture that promotes bacterial growth, for at least 24 hours at 35^{o} C. Gas levels and overall bacterial growth are measured and can provide a good estimate of the sample's overall contamination after a given length of time. The number of different bacterial strains is also determined; if there is significant contamination by many different pathogens, it is more likely the supply is contaminated by a disease-causing strain (Oram, n.d.).

Appropriate action must be taken when a positive test for a particular pathogen is found. The EPA's Maximum Contaminant Level (MCL) for bacteria in the water supply is set at 5%; meaning that a violating system has 5% or more samples testing positive for total coliforms in one month (USEPA, 2006). If the water supply tests positive for disease-causing contaminants, it should be re-sampled immediately. Given a true positive test in the second sampling, appropriate public health officials, inspectors and system operators should be contacted and informed of the level of contamination. A boil-water order, which advocates to boil water 5-10 minutes prior to use to remove any pathogens, should be immediately and regularly broadcasted through various media outlets to ensure that all those served by the system are aware of the incident and understand how to avoid becoming ill. The system must be inspected to determine the source of contamination; once the contamination source has been identified, appropriate measures to fix the system must be instated. The pipes must then be flushed and the system hyperchlorinated. Finally the system should be retested to ensure that all pathogens have been eliminated (Ford et al., 2004).

Abiding by regulations

Locally and nationally administered laws and regulations are in place to better ensure water quality and safety. Whether or not a water supply system is subject to the USEPA's regulations depends on its operational frequency, the number of people served by the system and the number of service connections to it. A system will be regulated by the USEPA if:

- It operates at least 60 days a year and serves 25 people or more or
- Has at least 15 or more service connections to it.

These systems must be monitored using the total coliform bacteria test. If a sample tests positive for pathogenic contamination, a subsequent fecal coliform or E coli. test will then be performed. As mentioned previously, the EPA's MCL for total coliforms in the water supply is set at a threshold of 5% (meaning that a violating system has 5% or more samples testing positive for coliforms in one month). It should also be noted that to avoid violations, none of the samples from water supply systems that collect less than 40 water samples per month, can test positive for coliforms. The EPA's MCL goal is zero ppm; meaning that the goal is that there is not even the slightest bacterial contamination considering the limitations of the test (USEPA, 2006).

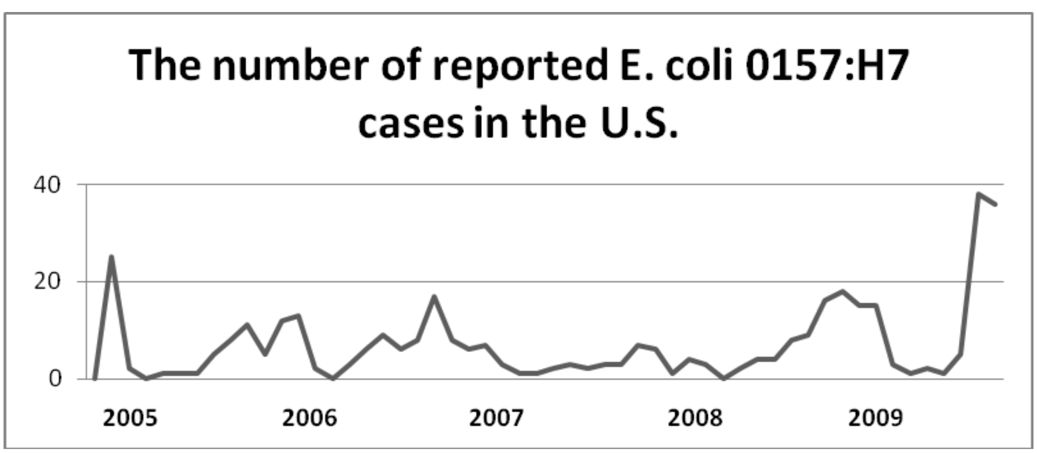
Testing frequency is subject to many factors and can include the number of people served by the system, resources available for testing and the number and occurrence of previous violations. Systems that serve between 25-1,000 people usually test their supply once a month. Although some smaller-scale water systems may not be regulated by the EPA, they may still be responsible for following locally administered regulations (USEPA, 2006).

As mentioned earlier, surface water is more likely to be contaminated by pathogens as compared to ground water stores. As a result, the USEPA mandates that systems under its authority which use surface water as a source should be regularly disinfected. However, if a ground water system tests positive for pathogenic contaminants, it too is required by the USEPA to disinfect the system (USEPA, 2006).

Monitoring surveillance data

Disease surveillance of the population served by the water supply can alert monitoring staff when the water supply has been contaminated to levels that cause human health effects. If a large cluster of similarly-diagnosed cases is occurring in a small geographically-defined area, it can become evident through surveillance that a potential outbreak is occurring. However, since the well-being of several individuals may be compromised before appropriate action is taken, this approach should not be solely relied on to determine if pathogens are present in the water system.

Surveillance data adopted from the CDC



(CDC, 2010)

Unfortunately, surveillance of water-borne disease is often a better indicator of a small-scale and decentralized water system's integrity than "routine" monitoring since monitoring in these areas often occurs too infrequently to alert staff of systematic contamination. Further, many pathogen-derived illnesses are also under-reported since the majority of those affected do not seek medical treatment; it is estimated by the CDC that only about 10% of waterborne disease gets reported (CDC, 2010). It should be noted that virulent illnesses are more likely to be picked up by surveillance measures than less lethal cases since those who are more adversely affected are more likely to seek medical intervention (Ford et al., 2004).

Further Reading

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Disclaimer

This technical brief was written by Sara Petrick, an Environmental Health graduate student at the University of South Florida, under the supervision of Dr. Mihelcic. The paper was prepared as a final assessment in the public health course: PHC 6301: Water Pollution and Treatment.

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This document was prepared for one of the following two classes at the University of South Florida (Tampa): CGN6933 “Sustainable Development Engineering: Water, Sanitation, Indoor Air, Health” and PHC6301 “Water Pollution and Treatment”. Please contact the instructor, James R. Mihelcic (Department of Civil & Environmental Engineering) for further information (jm41(at)eng.usf.edu. (learn more about our mission and development education and research programs at: www.cee.usf.edu/peacecorps).