Drinking Water Pathogens, Their Indicators, and Their Control
A Reference Resource

Prepared for use in PSU Course **ESR/CE 410/510, Water Wqulaity Problem Solving**
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A Pathogen Primer

Pathogens are microbes that cause disease. They include a few types of bacteria, viruses, protozoa, and other organisms. Some pathogens are often found in water, frequently as a result of fecal matter from sewage discharges, leaking septic tanks, and runoff from animal feedlots into bodies of water. Infections by pathogens associated with water-borne illnesses also can occur through non-drinking water means such as recreational activities (e.g., swimming and water slides), person-to-person contact (e.g., diaper changing, unwashed hands), and consumption of food.

Total Coliforms are a group of closely related, mostly harmless bacteria that live in soil and water as well as the gut of animals. The extent to which total coliforms are present in the source water can indicate the general quality of that water and the likelihood that the water is fecally contaminated. Total coliforms are currently controlled in drinking water regulations (i.e., Total Coliform Rule) because their presence above the standard indicates problems in treatment or in the distribution system. EPA requires all public water systems to monitor for total coliforms in distribution systems. If total coliforms are found, then the public water system must further analyze that total coliform-positive sample to determine if specific types of coliforms (i.e., fecal coliforms or *E. coli*) are present. EPA is increasing protection from pathogens in surface water systems as part of the Interim Enhanced Surface Water Treatment Rule, which becomes effective in December 2001.

Cryptosporidium is a single-celled microbe in a group generally known as protozoa. Cryptosporidium is commonly found in lakes and rivers, especially when the water is contaminated with sewage and animal wastes. Cryptosporidium may cause a disease, *cryptosporidiosis*, when ingested. Cryptosporidiosis symptoms include diarrhea, nausea, and/or stomach cramps. Symptoms can range from mild stomach upset to life threatening disease in those who are immunocompromised (e.g., people with severely compromised immune systems). Individuals who are severely immunocompromised may include those who are infected with HIV/AIDS, cancer and transplant patients taking immunosuppressive drugs, and people born with a weakened immune system. Cryptosporidium has caused several large waterborne disease outbreaks of gastrointestinal illness, most notable in the city of Milwaukee, Wisconsin. Moreover, Cryptosporidium has been a contributing cause of death in some immunocompromised people.

Data are not adequate to determine how most people become infected. For example, we do not know the importance of drinking water compared to other possible sources of Cryptosporidium, such as exposure to the feces of infected persons or animals, sex involving contact with feces, eating contaminated food, or accidentally swallowing contaminated recreational water.

Current testing methods cannot determine with certainty whether Cryptosporidium detected in drinking water is alive or whether it can infect humans. In addition, the current method often requires several days to get results, by which time the tested water has already been used by the public and is no longer in the community's water pipes.

Oocysts are part of the life-cycle of some Cryptosporidium. In this stage, the Cryptosporidium can infect humans and other animals. Cryptosporidium, especially in the oocyst form is very resistant to disinfection, and even a well-operated water treatment system cannot ensure that drinking water will be completely free of this parasite. Current EPA drinking water standards were not explicitly designed to assure the removal or killing of Cryptosporidium.

EPA regulates Cryptosporidium in drinking water, through the new Interim Enhanced Surface Water Treatment Rule which mandates treatment technologies and watershed protection (see discussion of this rule below.) The effectiveness of treatment technologies is used to judge how well removal works since direct measurement of pathogens in treated water is not feasible. This requirement becomes effective in December 2001. Many large water systems already voluntarily take actions for greater control of Cryptosporidium and other microbial contaminants.

Giardia lamblia (commonly referred to as Giardia) are single-celled microbes in a group known as protozoa. When ingested, they can cause a gastrointestinal disease called giardiasis. Giardiasis is a frequent cause of diarrhea. Symptoms may include diarrhea, fatigue, and cramps. Waterborne giardiasis may occur as a result of disinfection problems or inadequate filtration procedures. Cysts are a stage in the life-cycle of some Giardia. In this stage, the Giardia can infect humans and other animals. EPA regulates Giardia in drinking water by requiring water systems that use surface water or ground water under the direct influence of surface water to disinfect and/or filter their water so that at least 99.9% of Giardia are rendered harmless or physically removed. The effectiveness of treatment technologies are used to judge how well removal works since direct measurement of pathogens in treated water is not feasible.

Protozoa are microscopic, usually single-celled microbes which live in water and are relatively large in comparison to other microbes. Protozoa eat bacteria, and many are parasitic.

Viruses, including hepatitis A virus, rotaviruses, and Norwalk and other caliciviruses, are microbes that can cause illness. EPA regulates viruses in drinking water by requiring water systems that use surface water (or ground water under the direct influence of surface water) to treat their water to ensure that 99.99% of viruses are rendered harmless or physically removed.

Regulation and Contol of Pathogens

Drinking Water Standards for Regulated Contaminants. Through the Safe Drinking Water Act (SDWA), Congress requires EPA to regulate contaminants which may be health risks and which may be present in public drinking water supplies. Passed in 1974, and revised in1986 and 1996, SDWA extends public health protection to America's drinking water consumers.

Under SDWA, EPA sets legal limits on the levels of certain contaminants in drinking water. The legal limits reflect both the level that protects human health and the level that water systems can achieve using the best available technology. Besides prescribing these legal limits, EPA rules set water-testing schedules and methods that water systems must follow. The rules also list acceptable techniques for treating contaminated water. SDWA gives individual states the opportunity to set and enforce their own drinking water standards if the standards are at least as strong as EPA's national standards. Most states and territories directly oversee the water systems within their borders.

What Regulations Control Pathogens? One of the key regulations the EPA has developed and implemented to counter pathogens in drinking water is the **Surface Water Treatment Rule** (SWTR; published 29 June 1989, effective 31 December 1990). The rule sets non-enforceable health *goals*, or Maximum Contaminant Level Goals (MCLGs), for Legionella (causes Legionnaire's disease), Giardia, and viruses at zero because any amount of exposure to these contaminants represents some health risk. In establishing legal limits for contaminants in drinking water, EPA can set either a legal limit (MCL) and require monitoring for the contaminant in drinking water, or, for those contaminants that are difficult to measure, EPA can establish a treatment technique requirement. Since measuring disease-causing microbes in drinking water is not considered to be feasible, EPA established a treatment technique in this rule.

Among its provisions, the rule requires that a water system, using surface water or ground water under the direct influence of surface water as its source, have sufficient treatment to reduce the source water concentration of Giardia and viruses by at least 99.9% and 99.99%, respectively. The SWTR specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, residual disinfectant concentration, and disinfectant contact time conditions.

The adequacy of the filtration process is established by measuring turbidity (a measure of the amount of particles) in the treated water and determining if it meets EPA's performance standard. Some public water supplies that have pristine sources (such as Portland and New York City) may be granted a waiver from the filtration requirement. These supplies must provide the same level of treatment as those that filter; however, their treatment is provided through disinfection alone. The great majority of water supplies in the United States that use a surface water source filter their water.

To assure adequate microbial protection in the distribution system, water systems are also required to provide continuous disinfection of the drinking water entering the distribution system and to maintain a detectable disinfectant level within the distribution system. The distribution system is a series of pipes that delivers treated water from the water treatment plant to the consumer's tap.

According to EPA's 1993 study, compliance with this rule costs about $534 million each year for testing and upgrading treatment systems. Most of this cost is spread among the 10,200 systems (serving 48 million people) which would need significant upgrades in equipment.

Total Coliform Rule. When the news media announce a "boil water emergency," reporters often speak of a "total coliform violation." Coliforms are a group of bacteria, most of which are harmless. At first glance, it might seem strange that a harmless group of bacteria such as coliforms could cause such commotion. But like police tape and chalk outlines, coliform bacteria are often found at the scene of a crime even though they are not themselves criminals. The presence of *any* coliforms in drinking water suggests that there may be disease-causing agents in the water.

The Total Coliform Rule (published 29 June 1989/effective 31 December 1990) set both health goals (MCLGs) and legal limits (MCLs) for total coliform levels in drinking water. The rule also details the type and frequency of testing that water systems must do. In the rule, EPA set the health goal for total coliforms at *zero*. Since there have been waterborne disease outbreaks in which researchers have found very low levels of coliforms, any level indicates some health risk.

EPA also set a legal limit on total coliforms. Systems must not find coliforms in more than five percent of the samples they take each month to meet EPA's standards. If more than five percent of the samples contain coliforms, water system operators must report this violation to the state and the public.

When a system finds coliforms in drinking water, it may indicate that the system's treatment system is not performing properly. To avoid or eliminate microbial contamination, systems may need to take a number of actions, including repairing the disinfection/filtration equipment, flushing or upgrading the distribution system, and enacting source water protection programs to prevent contamination.

If a sample tests positive for coliforms, the system must collect a set of repeat samples within 24 hours. When a routine or repeat sample tests positive for total coliforms, it must also be analyzed for fecal coliforms and Escherichia coli (E. coli), which are coliforms directly associated with fresh feces. A positive result to this last test signifies an acute MCL violation, which necessitates rapid state and public notification because it represents a direct health risk.

The number of coliform samples a system must take depends on the number of customers that it serves. Systems which serve fewer than 1000 people may test once a month or less frequently, while systems with 50,000 customers test 60 times per month and those with 2.5 million customers test at least 420 times per month. These are minimum schedules, and many systems test more frequently.

EPA's 1993 study indicated that the annual costs associated with this rule, all of which are monitoring costs, are approximately $135 million. These costs are spread among all 173,000 public water systems in the country.

More Regulations:
The latest round of rules, particularly dealing with Cryptosporidium is discussed in another reading posted on the course home page entitled **Microbial and Disinfection Byproduct Rules**.