Overview
Bacteria are ubiquitous, single-cell organisms. Pathogenic bacteria are excreted by infected humans or animals. Their waste can then enter source waters through point discharges like sewage overflows or sewage systems that are not working properly. Bacteria can also come from non-point discharges, such as polluted stormwater runoff and agricultural runoff. Water supplies may be more vulnerable to such contamination after flooding or due to deteriorating infrastructure.

In contrast to traditionally regulated bacterial pathogens, opportunistic bacterial pathogens (e.g., *Legionella*, Nontuberculous mycobacteria) can be found in a wide range of natural and artificial environments (e.g., water, soil, building/home water systems). Also, the primary modes of exposure (e.g., inhalation, aspiration) for these pathogens differ from traditionally-regulated pathogens such as ingestion.

Pathogenic bacteria may cause respiratory disorders and gastrointestinal disorders that range from mild gastroenteritis to severe diarrhea. In most cases the impacts are self-limiting. Those people with weakened immune systems may experience more severe and longer-lasting impacts, which in some cases could be fatal.

Testing for Bacteria
Because pathogenic bacteria usually occur in low concentrations and each requires a unique microbiological isolation technique, coliform bacteria are tested for because they are easier to detect and can indicate the possibility of other microbial contamination. The four indicators
most commonly used are total coliforms, fecal coliforms, *E. coli*, and enterococci.

Culture-based techniques are the most common testing methods for opportunistic pathogens. However, there is not currently a standardized testing method for opportunistic pathogens.

Regulations Related to Bacteria in Water

**Surface Water Treatment Rule (SWTR)**

This rule applies to the physical removal of microbial contaminants by filtration for all water utilities that use surface water or groundwater under the direct influence of surface water (EPA 2015b). The purpose of this rule is to prevent waterborne diseases caused by viruses, *Legionella*, and *Giardia lamblia*. The rule requires having sufficient treatment to reduce the source water concentration of *Giardia lamblia* by at least 99.9% (3-log removal). At the entrance of the distribution system, ≥0.2 mg/L of disinfectant concentration is required, and a detectable concentration must be maintained throughout the distribution system. There are no regulatory limits specific to *Legionella*, but the EPA believes that if *Giardia lamblia* is removed or inactivated, then *Legionella* will be controlled.

**Ground Water Rule (GWR)**

This rule was passed to enhance protection against microbial pathogens and applies to water utilities that use groundwater (which may be susceptible to fecal contamination). The rule relies on four risk-based strategies, including sanitary surveys, triggered source water monitoring, corrective action for systems with deficiencies or contamination, and compliance monitoring (EPA 2015a).

**Total Coliform Rule (TCR)**

This rule applies to all public water systems. It sets public health goals and legal limits for the presence of total coliforms in drinking water and details the type and frequency of water testing required based on the size of the water utility. Revised Total Coliform Rule (RTCR) was passed to reduce implementation burden and to improve rule effectiveness. The key provisions of the RTCR include:

- Maximum contamination level (MCL) for *E. coli*
- Acute violation based on *E. coli* study
- Assessment and corrective action required based on monitoring results
- Seasonal system requirements, including identification, start-up procedures, and monitoring (EPA 2016)

**Treatment and Control**

Bacteria can be physically removed by conventional water treatment processes, including coagulation, flocculation, sedimentation, and filtration. However, bacteria can pass through the filtration process due to their small size (most bacteria cells are about 0.5 to 1 µm in diameter by 1 to 2 µm long). Therefore, it is important to add a chemical disinfection process as a final barrier at the end of the treatment system. All common disinfectants such as chlorine, chloramines, and UV can effectively inactivate bacteria with sufficient dose and contact time.
Three mechanisms of Coliform Occurrence in Treated Drinking Water:
1. Coliforms breaking through the treatment process from the source water supply
2. Coliform regrowth, typically in biofilms
3. Coliforms from recontamination of treated water within the distribution pipeline system

Treatment processes must be designed to address the specific needs of the individual utility. A single treatment process rarely solves all problems, and in some cases, can lead to other water quality or operational problems. Disinfectants such as chlorine, chlorine dioxide, and chloramines may contribute to the formation of disinfection by-products such as tri-halomethanes and haloacetic acids, which are regulated by the EPA. UV and ozonation systems, while effective, require significant energy and must be well maintained to ensure proper inactivation of targeted organisms.

Controlling opportunistic bacterial pathogens is not yet well understood. Chemical disinfectants, increased hot water temperature, frequent flushing of unused water lines, regular cleaning of faucets and shower heads, and replacement of fittings that are old and encrusted with scale build-up are currently recommended to control opportunistic pathogens.

References

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