Water Treatment – Disinfection

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Module 1: Design Fundamentals & Risk Management

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** source water risks and the necessity of a multi-barrier treatment approach.
- **Identify** key regulatory requirements for disinfection efficiency and compliance under SI 278 of 2007.
- **Select** appropriate disinfection technologies based on source water characteristics and required inactivation levels.

Executive Summary: The primary objective of water treatment is the inactivation or removal of pathogenic microorganisms through a "source-to-tap" risk management approach. Effective disinfection requires a multi-barrier strategy that integrates upstream physical removal with validated chemical or physical inactivation to ensure water is both safe (meets standards) and secure (managed risks).

Scope and Technical Objectives

The goal of modern disinfection is to provide rigorous pathogen control while maintaining compliance with water quality parameters, particularly **Disinfection By-Products (DBPs)**. This manual update previous standards to reflect advances in risk-based modeling and alternative technologies like **Ultraviolet (UV) radiation**.

Licensed PEs must focus on three pillars of modern water engineering:

- **Risk-Based Approaches:** Moving from reactive testing to proactive Water Safety Plans (WSPs).
- **Multi-Barrier Integration:** Recognizing that disinfection efficiency is dependent on upstream processes like coagulation and filtration.
- **Alternative Technologies:** Utilizing UV and ozone to address chlorine-resistant pathogens like *Cryptosporidium*.

💡 **Design Tip:** While this manual focuses on disinfection efficacy, always consult the Safety, Health and Welfare Act 2005 and specific Material Safety Data Sheets (MSDS) for the handling and storage of hazardous treatment chemicals.

Regulatory Framework (SI 278 of 2007)

The EC (Drinking Water) (No. 2) Regulations 2007 transpose Council Directive 98/83/EC into Irish law. These regulations apply to all water intended for human consumption, including supplies > 10 cubic meters/day or serving > 50 persons.

Key Compliance Mandates

- **Point of Compliance:** For distribution networks, compliance is measured at the consumer's tap.
- **Wholesomeness:** Water must be free from any microorganisms or substances that constitute a potential danger to human health.
- **Disinfection Verification:** Regulation 13 mandates that the efficiency of disinfection treatment is verified and DBPs are kept as low as possible without compromising safety.

⚠️ **Safety Constraint:** There are no international "indicator" standards for *Cryptosporidium*. Per SI 278, engineers must investigate for *Cryptosporidium* if a source influenced by surface water fails compliance for *Clostridium perfringens*.

Disinfection Technologies

Selecting a disinfectant involves balancing biocidal power against the formation of potentially harmful by-products.

Primary Disinfectants and Constraints

- **Chlorine (Gas or Sodium Hypochlorite):** The global standard. Provides a stable residual but forms **Trihalomethanes (THMs)** and **Haloacetic Acids (HAAs)**.
- **Chloramination:** Using monochloramine for distribution. It is a weaker disinfectant than free chlorine but much more stable and produces fewer THMs/HAAs.
- **Ozone:** High oxidation potential; excellent for micro-pollutant removal. Main constraint: Formation of **Bromate**.
- **Chlorine Dioxide:** Effective across wide pH ranges. Main constraint: Formation of inorganic **Chlorite** and **Chlorate**.
- **UV Irradiation:** Superior for *Cryptosporidium* inactivation. Does not provide a residual; must be used with a secondary chemical disinfectant.

The Multi-Barrier & Risk-Based Approach

The EPA follows the WHO **Drinking Water Safety Plan (DWSP)** approach, categorizing supplies as:

1. **Safe:** Meets quality standards during routine testing.
2. **Secure:** A management system is in place to identify and mitigate all potential risks.

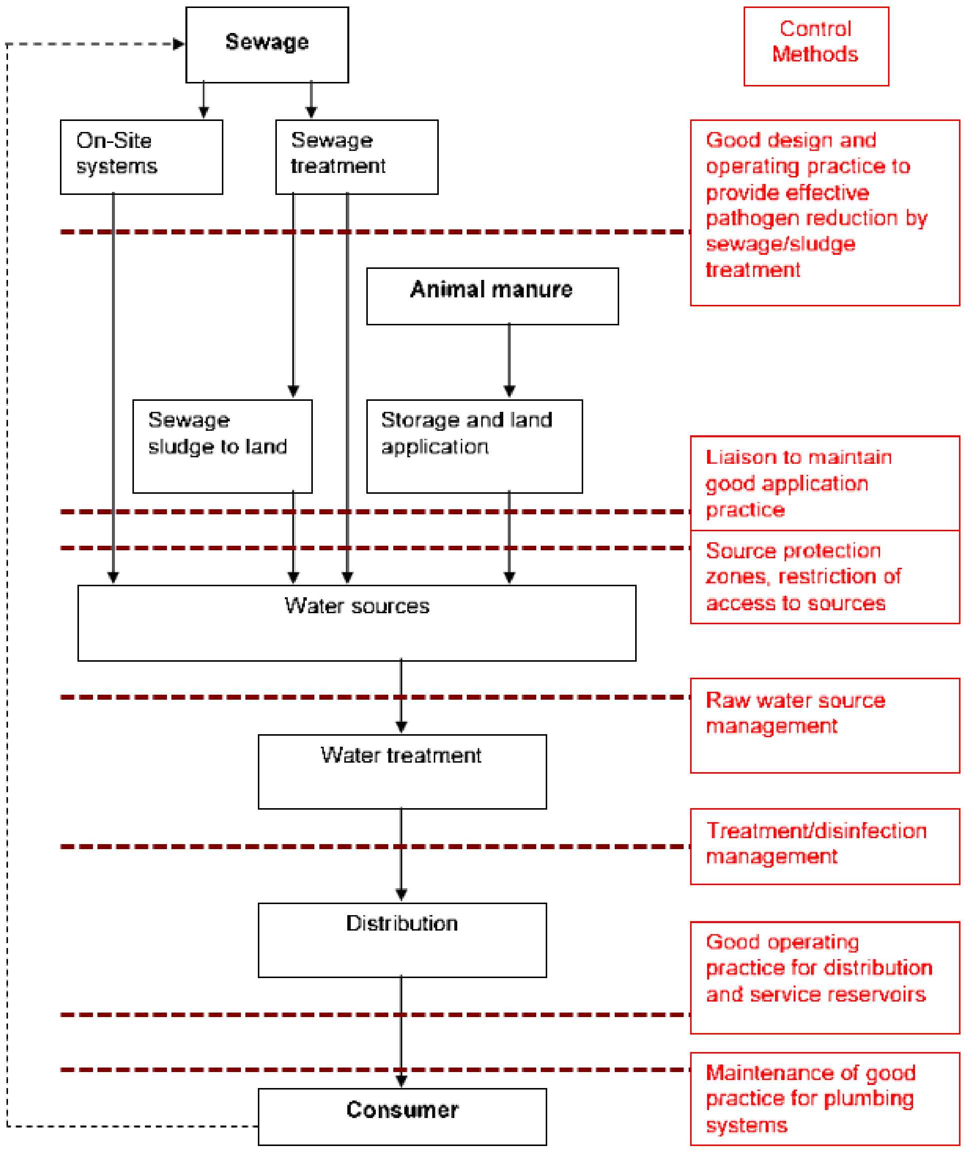

Figure 1.1: Sources and control of faecal contamination from source to tap

Upstream Process Contributions

- **Coagulation & Flocculation:** Essential for removing organic precursors (THM/HAA precursors) and shielding pathogens from disinfectants.
- **Filtration Ripening:** The initial period of a filter run ("ripening") carries higher microbial risk. Consider "filter-to-waste" protocols.
- **Backwash Recycling:** Recycling filter backwash can concentrate pathogens. Ensure recycle flows pass through all conventional treatment processes.

🧮 **Calculation Note:** In the US EPA Surface Water Treatment Rule (SWTR), treatment plants must achieve specific "log removal credits" (e.g., 3-log or 99.9% for *Giardia* and 4-log or 99.99% for viruses). Engineers should aim for similar performance metrics to ensure robust disinfection.

Principles for System Selection

When selecting a disinfection system, evaluate the following site-specific factors:

1. **Source Risk:** Clarity, organic content (TOC), and microbial burden.
2. **Inactivation Requirements:** Determine the necessary dose based on the toughest pathogens present.
3. **Pre-treatment Adequacy:** Ensure turbidity and color are reduced to levels that do not interfere with disinfectant demand or UV transmittance.
4. **Contact Time (Ct):** Verify that the tank geometry and flow rates provide the required "Concentration x Time" for chemical agents.
5. **Verifiability:** The system must allow for continuous monitoring and recording of performance (Regulation 13).

Checkpoint Quiz

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1. **Under the DWSP approach, a water supply is defined as "secure" when:**
   a) It passes all parametric tests for three consecutive months.
   b) A management system is in place that identifies and manages all potential risks.
   c) It utilizes at least three different chemical disinfectants.
   d) The source water is 100% groundwater.

Answer: (b). Security is defined by the management system and risk identification, not just testing results.

2. **Which disinfection technology is specifically noted for its effectiveness against *Cryptosporidium* but lacks a residual for distribution?**
   a) Sodium Hypochlorite
   b) Monochloramine
   c) UV Irradiation
   d) Chlorine Gas

Answer: (c). UV provides excellent inactivation for protozoa but requires a secondary disinfectant for the distribution network.

3. What is the primary engineering concern regarding the "ripening period" of a filter?

a) High energy consumption during startup.
b) Potential for microbial breakthrough due to higher turbidity.
c) Excessive chemical demand for pH adjustment.
d) Damage to the filter media from high initial flow rates.

Answer: (b). The ripening period is a high-risk phase where filtered water quality is lower, potentially allowing pathogens to pass.