Water Supply & Sanitary Engineering (DI05006021)

Unit 3: Treatment of Water
Lecture 12: Disinfection of Water

GTU Diploma Engineering

Lecture Agenda

- Disinfection vs. Sterilization
- Requirements of a Good Disinfectant
- Methods of Disinfection (Boiling, UV, Ozone)
- Chlorination: The Industry Standard
- Chemistry of Chlorine in Water
- Free and Combined Chlorine
- Breakpoint Chlorination Curve
- Factors Affecting Chlorination

Disinfection vs. Sterilization

- Disinfection: The process of selectively destroying or inactivating pathogenic (disease-causing) microorganisms to make water safe to drink.
- Sterilization: The complete destruction of ALL living microorganisms, pathogenic or harmless.
- In water treatment, we aim for Disinfection, not sterilization.
- Sterilization is impractically expensive for municipal scales and unnecessary since many bacteria in water are harmless.

Requirements of a Good Disinfectant

- Effective: Must destroy pathogens within a practical time frame and at reasonable temperatures.
- Safe: Must not be toxic to humans or domestic animals at the applied doses.
- Residual Protection: MUST leave a residual concentration in the water to protect against re-contamination in the distribution pipes.
- Economical: Must be cheap, readily available, and easy to transport/store.
- Analytical: Should be easy to measure its concentration in the water.

Minor Methods of Disinfection

- Boiling: Kills pathogens by heat. Excellent for households during emergencies, impractical for city supplies.
- Ozone (O3): A powerful oxidizing gas. Kills viruses faster than chlorine and removes color/odor. Drawback: Expensive and leaves NO residual.
- Ultraviolet (UV) Light: Scrambles the DNA of pathogens, preventing replication. Drawback: Leaves NO residual, and water must be completely clear for UV to penetrate.
- Potassium Permanganate: Used mainly for village wells, effective against cholera, but colors water pink/brown.

Chlorination: The Standard Method

- Most widely used disinfectant globally due to its low cost, reliability, and residual capability.
- Can be applied as:
- 1. Chlorine Gas (Cl_2): Very cheap, highly toxic gas, used in large plants.
- 2. Sodium Hypochlorite ($NaOCl$): Liquid bleach, safer to handle, used in medium plants.
- 3. Calcium Hypochlorite / Bleaching Powder ($Ca(OCl)_2$): Solid powder, used in small plants or rural areas.

Chemistry of Chlorine in Water

- When Chlorine gas dissolves in water, it forms Hypochlorous Acid (HOCl) and Hydrochloric Acid (HCl).
- Reaction: Cl2 + H2O ¡-¿ HOCl + HCl
- Hypochlorous acid (HOCl) is highly unstable and partially dissociates into Hypochlorite ions (OCl-).
- Reaction: HOCl ¡-¿ H+ + OCl-
- HOCl (Hypochlorous Acid) is the most powerful disinfecting agent. It is roughly 80 times more effective than the OCl- ion.

Effect of pH on Chlorination

- The balance between HOCl and OCl- is entirely dependent on the pH of the water.
- At lower pH (below 7), HOCl dominates (highly effective disinfection).
- At higher pH (above 8), OCl- dominates (poor disinfection).
- Therefore, chlorination is most effective in slightly acidic to neutral water (pH 6.5 to 7.5).
- If water pH is high, operators must increase the chlorine dose or contact time to compensate.

Chlorine Demand and Residual

- Chlorine Demand: The amount of chlorine consumed by organic matter, iron, manganese, and ammonia in the raw water.
- These impurities 'eat' the chlorine before it can kill bacteria.
- Residual Chlorine: The amount of chlorine left in the water AFTER the demand is satisfied.
- Equation: Applied Dose = Chlorine Demand + Residual Chlorine.
- A residual of 0.2 mg/L must be maintained in the distribution system to protect against pipeline leaks.

Free vs. Combined Chlorine

- Free Available Chlorine: Unreacted HOCl and OCl-. This is fast-acting and highly potent.
- Combined Chlorine (Chloramines): Formed when chlorine reacts with Ammonia (NH_3) in the water.
- Chloramines (NH_2Cl, $NHCl_2$) are weak disinfectants (25x weaker than free chlorine) but last a very long time in pipes.
- Some cities intentionally form chloramines to maintain a residual in massive, long distribution networks without creating taste/odor issues.

Breakpoint Chlorination

- A curve plotting Chlorine Added (x-axis) vs. Residual Chlorine (y-axis).
- Stage 1: Chlorine destroys easily oxidized compounds (Iron/Mn). No residual.
- Stage 2: Chlorine reacts with ammonia to form chloramines. Residual rises.
- Stage 3: Additional chlorine destroys the chloramines, releasing nitrogen gas. Residual drops to a minimum (The Breakpoint).
- Stage 4: Any chlorine added past the breakpoint forms Free Available Chlorine. The residual rises proportionally to the dose.

Summary

- Disinfection kills pathogens; it does not sterilize water.
- Chlorine is favored because it leaves a protective residual in the pipes.
- HOCl is the active killer, and its formation requires a pH below 8.
- Breakpoint chlorination ensures we achieve strong Free Available Chlorine.
- Next Lecture: Water Softening - addressing the chemical issue of hard water.