Water Supply & Sanitary Engineering (DI05006021)

Unit 3: Treatment of Water

Lecture 9: Coagulation and Flocculation Processes

GTU Diploma Engineering

Lecture Agenda

- The Problem with Colloidal Particles
- Theory of Coagulation
- Common Types of Coagulants
- Chemistry of Alum
- Rapid Mixing (Flash Mixing)
- The Flocculation Process
- The Jar Test for Optimum Dosage

The Challenge of Colloidal Impurities

- Water contains suspended, colloidal, and dissolved solids.
- Large suspended solids (like sand) settle rapidly by gravity.
- Colloidal particles (like fine clay, silt, and organic matter) are extremely small (1 nm to 1 micron).
- They have a large surface-area-to-volume ratio and possess a negative electrical charge.
- Due to electrostatic repulsion (negative repels negative), colloids remain stable and will not settle even over long periods.

Theory of Coagulation

- Coagulation is the chemical process of destabilizing these negatively charged colloidal particles.
- Chemicals called 'coagulants' (which carry strong positive charges) are added to the water.
- The positive ions neutralize the negative surface charges on the colloids.
- Once neutralized, the repulsive forces are eliminated, allowing the particles to come together (agglomerate) upon collision.

Common Types of Coagulants

- Aluminium Sulphate (Alum): The most widely used coagulant in municipal water treatment. Cheap, effective, and readily available.
- Iron Salts: Ferric Chloride, Ferric Sulphate, and Ferrous Sulphate. Form heavier flocs and work over a wider pH range than alum.
- Polyelectrolytes (Polymers): Synthetic high-molecular-weight polymers used as primary coagulants or as coagulant aids to strengthen flocs.
- Sodium Aluminate: Used for specific applications, often in conjunction with alum.

Chemistry of Alum Coagulation

- Chemical Formula: Al2(SO4)3 · 18H2O
- Alum requires naturally occurring alkalinity in the water (usually in the form of Calcium Bicarbonate) to react.
- Reaction: Al2(SO4)3 + 3Ca(HCO3)2 -¿ 2Al(OH)3 (precipitate) + 3CaSO4 + 6CO2
- The product, Aluminium Hydroxide (Al(OH)3), is a sticky, gelatinous precipitate called 'floc' that traps suspended particles.
- If natural alkalinity is low, lime (Ca(OH)2) or soda ash must be added artificially.

Factors Affecting Coagulation

- pH of Water: The most critical factor. Alum works best between pH 6.5 and 8.5. Outside this range, the floc does not form properly.
- Coagulant Dosage: Too little fails to neutralize charges; too much can reverse the charge (restabilize) or waste chemicals.
- Temperature: Cold water slows down the chemical reactions and increases water viscosity, making floc formation slower.
- Characteristics of Raw Water: High turbidity and varying organic content affect the required dose.

Rapid Mixing (Flash Mixing)

- Objective: To instantaneously and uniformly disperse the coagulant chemical throughout the raw water mass.
- Time scale: Mixing must occur in a few seconds (typically 30 to 60 seconds).
- Mechanism: Achieved using a mechanical mixer (impeller/propeller) in a small chamber.
- Why Rapid? The charge neutralization reactions occur in fractions of a second; if mixing is slow, the chemicals are wasted on a small portion of the water.

The Flocculation Process

- After rapid mixing, the water enters the Flocculation Basin.
- Objective: To gently agitate the water, causing the neutralized, micro-flocs to collide and stick together into larger, heavier macro-flocs.
- Mixing Speed: Slow and gentle (paddle speeds of 0.2 to 0.6 m/s).
- Detention Time: Typically 20 to 40 minutes.
- Warning: If mixing is too fast, the shear forces will break apart the fragile flocs!

Types of Flocculators

- Baffle Type Flocculators: Use zig-zag flow paths around baffles to create turbulence and mixing. No moving parts, but high head loss.
- Mechanical Flocculators (Paddle Type): Large horizontal or vertical rotating paddles driven by motors. Allows operators to adjust the mixing speed (velocity gradient, G).
- Tapered Flocculation: Providing higher mixing energy at the inlet and gradually reducing it toward the outlet to prevent breaking fully formed flocs.

The Jar Test

- Purpose: A laboratory procedure used to determine the optimum dosage of coagulant for the current raw water conditions.
- Procedure: Six jars are filled with raw water. Different doses of alum are added to each.
- Simulation: The jars are rapidly mixed for 1 minute, then slowly mixed for 20 minutes, mirroring the actual plant process.
- Observation: The stirrer is stopped, and settling is observed. The lowest dose that produces large flocs and clear water is selected as the optimum.

Summary

- Colloids remain suspended due to negative electrical charges.
- Coagulation neutralizes these charges using chemicals like Alum via rapid flash mixing.
- Flocculation is the gentle agglomeration of particles into heavy flocs over 20-40 minutes.
- The Jar Test is essential for determining the correct chemical dosage.