Water Supply & Sanitary Engineering (DI05006021)

Unit 3: Treatment of Water

Lecture 11: Filtration Processes

GTU Diploma Engineering

Lecture Agenda

- Purpose of Filtration
- Mechanisms of Filtration
- Filter Media (Sand & Gravel)
- Slow Sand Filters (SSF)
- Rapid Sand Filters (RSF)
- Comparison: SSF vs. RSF
- Filter Cleaning (Backwashing)
- Operational Troubles (Mud balls, Air binding)

Purpose and Mechanisms of Filtration

- Purpose: To remove fine flocs, colloidal matter, bacteria, and color that did not settle in the clarifier.
- Mechanism 1: Mechanical Straining - Particles larger than the voids between sand grains are physically caught.
- Mechanism 2: Sedimentation - Tiny particles settle on the surface of the sand grains inside the filter bed.
- Mechanism 3: Flocculation - Particles collide and stick together within the pore spaces.
- Mechanism 4: Biological Action - A sticky layer of harmless bacteria forms on the sand, consuming organic matter and trapping pathogens (Schmutzdecke).

Filter Media

- Sand: The primary filtering medium. Must be hard, durable, free of clay, and chemically stable.
- Effective Size (D10): The sieve size through which 10% of the sand passes by weight. Controls the hydraulic performance.
- Uniformity Coefficient (Cu = D60/D10): Indicates how uniform the sand grains are. Lower Cu means more uniform size.
- Gravel: Placed at the bottom to support the sand layer and prevent it from washing into the underdrain system. It is graded in layers (coarsest at the bottom).

Slow Sand Filters (SSF)

- The oldest form of water filtration.
- Filtration Rate: Very slow, about 100 to 200 liters/m2/hour.
- Media: Uses fine sand (Effective size 0.2-0.3 mm) and a deep bed.
- Pre-treatment: Does not require coagulation; raw water must have low turbidity (usually plain sedimentation is enough).
- Biology: Relies heavily on the biological 'Schmutzdecke' (dirty skin) layer on the top surface to remove 99% of bacteria.

Cleaning Slow Sand Filters

- Process: When head loss becomes too high (clogged), the filter is drained.
- Scraping: Laborers manually scrape off the top 1.5 to 3 cm of dirty sand (the Schmutzdecke) using flat shovels.
- Frequency: Cleaned every 1 to 3 months, depending on raw water quality.
- Ripening: After cleaning, the filter must run to waste for a few days until the biological layer regrows.
- Limitations: Labor-intensive and cannot handle highly turbid water.

Rapid Sand Filters (RSF)

- The standard for modern municipal treatment.
- Filtration Rate: Extremely fast, 3000 to 6000 liters/m2/hour (30 times faster than SSF).
- Media: Uses coarser sand (Effective size 0.45-0.7 mm) to allow high flow.
- Pre-treatment: Mandatory! Water must undergo coagulation, flocculation, and sedimentation before entering the RSF.
- Mechanism: Depth filtration. Particles penetrate deep into the sand bed, not just the surface.

Underdrain System in RSF

- Functions:
- 1. Collect filtered water uniformly across the entire bottom of the filter.
- 2. Distribute high-pressure wash water uniformly during backwashing.
- Types: Pipe and lateral systems (perforated pipes), porous plates, or nozzle/strainer systems.
- Design Importance: If wash water is not distributed evenly, it will cause 'boils' and disrupt the gravel layers, destroying the filter.

Cleaning RSF: Backwashing

- Indicator: Cleaned when 'Head Loss' reaches a limit (e.g., 2.5 meters) or turbidity breaks through.
- Process: Reversing the flow of water. Clean water is forced upwards through the underdrains at a high velocity.
- Fluidization: The upward flow lifts and expands the sand bed by 20-50%, causing grains to rub together, scrubbing off the dirt.
- Wash Troughs: The dirty wash water overflows into suspended troughs and is drained away.
- Frequency: Typically every 24 to 48 hours. Takes only 10-15 minutes.

Comparison: SSF vs. RSF

Concept 1	Concept 2
Filtration Rate: SSF is slow (100-200 L/m2/h); RSF is fast (3000-6000 L/m2/h).	
Space Required: SSF needs massive area; RSF is compact.	
Pre-treatment: SSF needs none/little; RSF requires full chemical coagulation.	
Cleaning: SSF is scraped manually every few months; RSF is backwashed mechanically every 1-2 days.	
Bacterial Removal: SSF is excellent (98-99%); RSF is good (80-90%), meaning RSF strictly requires post-disinfection.	

Operational Troubles in RSF

- Mud Ball Formation: If backwashing is inadequate, dirt and coagulant stick to sand grains, forming heavy mud balls that sink and clog the filter.
- Air Binding: Dissolved gases release due to negative pressure in the filter bed, forming air bubbles that block water flow and reduce capacity.
- Sand Cracking: Shrinkage of the sand bed creates cracks where raw water can bypass the media, leading to poor effluent quality.
- Solution: Proper backwash velocity, use of surface wash/air scour, and maintaining adequate water depth.

Summary

- Filtration removes particles through straining, sedimentation, and biology.
- Slow Sand Filters are large, natural biological filters cleaned by scraping.
- Rapid Sand Filters are compact, high-rate physical filters cleaned by backwashing.
- RSF is the industry standard but requires strict pre-treatment and post-disinfection.
- Next Lecture: Disinfection - the final barrier to ensure water is biologically safe.