Introduction to Environmental Engineering

Water Treatment

Unit Processes in Water Treatment

- Surface Water Treatment
  1. Chemical Mixing (Rapid Mixing)
  2. Flocculation
  3. Sedimentation
  4. Rapid Sand Filter
  5. Disinfection
  6. Flouridation
  7. Pumped to community

Unit Processes

- Groundwater Treatment
  1. Aeration (if necessary to release any gases)
  2. Disinfection
  3. Flouridation
  4. Pumped to community

Coagulation & Flocculation

Coagulation & Flocculation

- Coagulation
  - the chemical alteration of the colloidal particles to make them stick together
  - Hydrophilic particles – water loving – absorbs to water
  - Hydrophobic particles – water hating – does not absorb to water
    - Hydrophobic particles are negatively charged and don't like to aggregate and are hydrophobic
    - A positively charge coagulant destabilizes the negatively charged particles and brings them together.
  - Coagulants lower the negative repulsion force of colloids

Coagulation & Flocculation

- Effect of coagulants
  - Bridging

Coagulation & Flocculation

- Rapid Mixing - 20 to 60 seconds
- Flocculation Gentle mixing 20-60 minutes to aggregate the particles
- Coagulants
  - Aluminum sulfate (alum) – corrosive alone, packaged in water
  - Ferrous sulfate (ferric)
  - Ferric chloride

Coagulation & Flocculation

- Coagulant aids
  - Polyelectrolytes – long chain SOC to assist floc formation
  - Lime alkalinity addition – for $Al(OH)_3$ formation
  - pH correction: lime, sulfuric acid – for optimum floc formation

Coagulation & Flocculation

- Example
  - Traditional Surface water treatment plant
    - Suspended solids = 500 mg/L
    - Q = 36,400 m^3/day
    - Alum dose = 50 mg/L
    - 98% of Total Solids are removed by the plant.
    - Compute solids produced from plant daily.

Coagulation & Flocculation

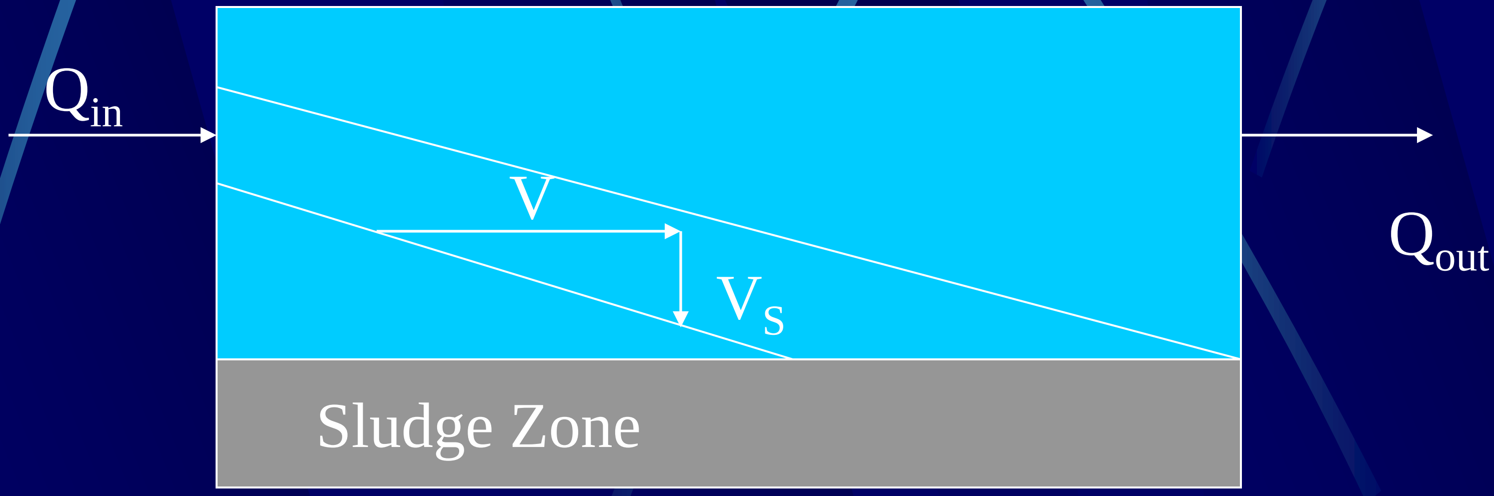
- 0.98 x 500 mg/L x 36,400 m^3/day x 1000 L/m^3 x 1g/1000mg x 1day/86,400s=
  - 206 g/s suspended solids
- Aluminum Hydroxide produced
- $Al_2(SO_4)_3 \cdot 14H_20$ + ? → $2Al(OH)_3$ + ? + ?
  - MW = 594 g/mol MW = 156 g/mol
- Ratio of $2Al(OH)_3$: $Al_2(SO_4)_3 \cdot 14H_20$ = 0.26
  - 50 mg/L x 36,400 m^3/day x 1000 L/m^3 x 1g/1000mg x 1day/86,400s = 21 g/s
  - 21 g/s x 0.26 = 5.5 g/s
  - Total Sludge = 206 g/s + 5.5 g/s = 211.5 g/s

Note: Design of rapid mixers and flocculation basins are dependent on detention time.

Settling

- When flocs have been formed they have to be separated from the water.
- Gravity Settling Tanks
  - All sedimentation tanks are modeled as plug flow reactors.
  - Rectangular or Circular design.
  - Their design is determined by the Vs of the particle size to be removed.
  - $\theta = H/V_s = L/V$
  - V_s = Stokes velocity
  - H = tank height – sludge depth
  - L = tank length
  - V = horizontal velocity

Settling



Settling

- PFR, $L \geq 2W$, $L >> H$
- Surface Overflow Rate = Vs = Q/Ap = Q/LW
- Weir overflow rate = Q/WH
  - Therefore, the settling velocity is the major design parameter
- Surface Overflow rates ≈ 20-35 $m^3/day/m^2$
- Detention times ≈2-8 hr
- Weir overflow rate ≈ 150-300 $m^3/day/m^2$

Settling

- Example
  - **Small Water treatment plant with:**
    - **Q = 0.6 m3/s inflow of the plant**
    - **Vs = 0.004 m/s (not a good assumption)**
    - **Effective settling zone, L = 20m, H = 3m, W = 6m**
    - **Can 100% removal be expected?**
  - **Surface Overflow rate, is the critical settling velocity**
    - **Vs = Q/Ap = Q/LW = 0.6 m^3/s / (20m)(6m) = 0.005 m/s**
  - **0.005 > 0.004 m/s, removal not expected**

Settling

- Can also be solved realizing settling is a problem of triangles:
- V = horizontal velocity = Weir Overflow rate = Q/WH = $0.6m^3/s$ / (6m)(3m)
- =0.033 m/s
- Vs/V = H/L'
- 0.004m/s/0.033m/s = 3m/L'   L'= 25 m, thus particles would need 25 m to be totally removed.

Filtration

- Two types of Filtration
  - Slow Sand Filtration = 0.1 to 0.2 m/h
  - Rapid Sand Filtration (Rapid Gravity Filtration) = 5-20 m/h
- In the 1930’s switch to RSF from SSF, (higher loading, less space, lower construction costs)
- However, SSF resurgence due to its removal of smaller particles.

Filtration

- Slow Sand Filter
  - Schmudzdecke – scrape off, bio growth
  - Filter runs last 3 – 6 months
  - Top of filter doing most of the work
- Rapid Sand Filter
  - Backwashing – filter runs, hours to 2 days
  - The entire filter is removing
  - Multi-media – activated carbon, garnet, sand

Disinfection

- All of the previous treatment processes remove > 90% of bacteria and viruses
- A disinfectant is used to:
  - Kill microbes fast and efficiently
  - Not kill humans or other animals
  - Last long enough to prevent regrowth in distributions systems
- Factors that inhibit disinfection:
  - Turbidity: particles shelter bacteria
  - Resistant organisms
  - NOM: form THM wit chlorine
  - Fe^{+2} and Mn^{+2}: form particles that shield bacteria

Disinfection

- Oxidizable compounds: become food for microbes in distribution system
- Commonly used disinfectants:
  - Chlorine
  - Chlorine Dioxide
  - Chloramines
  - Ozone
  - UV light