Lecture 8: Water treatment processes

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Objective: Understand functioning of different unit processes for water treatment

Courtesy: Dr. Irene Xagoraraki (Michigan State University, East Lansing, USA)
Previous lecture re-cap

- Introduction of water treatment schematic concepts
- Discussion on production of water of different final usages
- Discussion on checks
  - Remove solids before removing bacteria
  - Remove solids using sedimentation process before using filtration
  - Remove organic compounds and ammonia-based compounds before disinfection
- Discussion on need for calculating solids waste produced from every unit processes and solid waste management
Example 2: River Water $\rightarrow$ Drinking water

1. Raw water
2. Chlorine, ammonia
   - (Precipitation)
   - (Sludge consists of suspended solids)
3. Alum, Polymers
   - (Mixing, flocculation, settling)
   - (Sludge consists of coagulated colloids, large particles)
   - (Backwash water decanted, dewatered sludge removed; disposal after dewatering)
4. Chlorine
   - (Filtration)
   - (to unity)
Example 2 schematic contd.

From unit #3

4 → 5 (Chlorination) → 6 (Storage) → Distribute System

(AdSORBION) (remove organics, microorganisms, metals)

(Disinfection)

Stream from cleaning cycle condensed & disposed of
Treatment schematic (SW→ Potable drinking water)

• Sequence of unit processes: pre-sedimentation → mixing, flocculation, settling → filtration → adsorption → disinfection

• Function of unit processes: solids removal → removal of ions, and solids using chemical addition → removal of smaller particles → removal of organic compounds and ions → oxidation of oxygen-demanding wastes and chemical killing of pathogens in water

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(SW→ Potable drinking water) contd..

• Chlorine is added in sedimentation and filtration tank to avoid microbial growth
• Chlorine is used as an oxidizing agent as well as a disinfection solution.
Conventional Surface Water Treatment

• **Screening** (remove relatively large floating and suspended debris)
• **Rapid-mix** (mixing water with chemicals that encourage suspended solids to coagulate into larger particles that will settle easily)
• **Flocculation** (gently mixing water and coagulant allowing the formation of large particles of floc)
Conventional Surface Water Treatment

- **Sedimentation** (flow is slowed enough so that gravity will cause flocs to settle)
- **Sludge processing** (mixture of solids and liquids collected from settling tank are dewatered and disposed of)
- **Disinfection** (ensure that water is free of harmful pathogens)
- **Distribution system protection** (residual disinfection)
Solids removal
Method 1. Sedimentation
Method 1. Sedimentation

- Solids settle based on their gravitational force (with and without externally added chemicals).
- Settling depend on solid physical characteristics (diameter, density) and medium temperature, viscosity, density, etc.

- Some solids do not interact with each other during settling (i.e., discrete particles) (no change in their size and shape). The settling is called discrete settling (Type 1 settling). Ex: settling of sand.
Method 1. Sedimentation

- Some solids interact during their settling and change their size and shape (i.e., flocculent particles) (Type 2 settling). Ex: settling of clay; bacteria.
Sedimentation

- Time for settling = column depth/settling velocity at steady state
- Some particles take less time and some particles take longer time to settle.
- If \( t_{\text{design}} > t_{\text{settling}} \), particles remove 100%. All particles now constitute solid waste.
- If \( t_{\text{design}} < t_{\text{settling}} \), particles do not remove 100%. Remaining particles go to the next unit in the treatment plant scheme.
Method 2. Coagulation-Flocculation-Sedimentation

Some coagulants:
- aluminum sulfate
- ferric sulfate
- ferric chloride

Some coagulant aids:
- activated silica
- clay
- polymers
Coagulation-Flocculation-Sedimentation

Full-scale

Pilot-scale

Bench-scale
Sizes of Particles in Water

- Algae
- Bacteria
- Viruses
- Fungi
- Giardia cysts
- Cryptosporidium cysts
- Colloids
- Suspended particles
- Dissolved particles
- Humic acids
- Colloidal color
- Post-filtered particles
- Flocculated particles

Size, Micrometers (μm)
Method 2. Coagulation-flocculation (sedimentation after chemical addition)

- Some solids take very long time to settle (size in submicron range or in nanometer range).
- Chemicals (ex: alum; ferric chloride) are added in solution to (1) increase size of particles, (2) capture them in hydroxide flocs and then precipitate them.
Coagulation - Flocculation

Colloidal particles
(0.001 - 10 µm)

floc
(1 - 100 µm)
Method 2. Coagulation-flocculation (sedimentation after chemical addition)

- Coagulation methods: (i) ionic layer compressions, (2) charge neutralization and surface complexation, (3) sweep coagulation(iv) polymeric bridging
- Ex: ferric chloride gives ferric ions (acidic pH) and ferric hydroxide (basic pH). These species work in 2 different ways to improve particle settling.
Coagulation-Flocculation

- Double Layer Compression
- Adsorption of Aluminum to Produce Charge Neutralization
- Interparticle Bridging
- Enmeshment in Al(OH)$_3$ Precipitate (sweep floc)

Picture Source: Malvern Instruments, Zeta-Meter Inc.
Coagulation-Flocculation-Sedimentation

Full-scale

Pilot-scale

Bench-scale
Rapid Mixing

(a) Turbine chamber
(b) Propeller chamber
(c) Double-compartment turbine chamber
(d) Double-compartment turbine chamber
(e) Paddle chamber
(f) In-line blender
Flocculation

(a)

(b)

(c)

Sedimentation
Question 1: GDW to Gardening water

• Which parameters do we need to remove?
• Which unit processes do we need for making gardening water from groundwater? Is the order of unit process relevant here?
• How does the schematic of treatment of GDW to Gardening water differ with that of GDW-Drinking water?
Question 2: Injection of gardening water runoff in soil: Requirements?

- Can we inject garden water runoff to soil?
- Which parameters do we measure?
- Do we need to do treatment before we can inject the water (i.e., pretreatment)?
- Will it depend on soil type, depth to water table, etc.?
Question 3: Comparison

- Why schematic for GDW→ DW and SW→ DW differ?
- Can one treatment plant treat GDW as well as SW for producing DW?
Question 4: Domestic WW to Water suitable for discharge to river

- Can you draw schematic for treating domestic wastewater to produce water suitable for discharge to river?
Answer 4: Domestic wastewater $\rightarrow$ Discharge water to river

- Sequence of unit processes: stabilization tank $\rightarrow$ sedimentation $\rightarrow$ biological process $\rightarrow$ secondary settling $\rightarrow$ nitrifier unit $\rightarrow$ denitrifier unit $\rightarrow$ disinfection $\rightarrow$ discharge water suitable for river

- Function of unit processes: making incoming flow rate uniform $\rightarrow$ solid removal $\rightarrow$ breakdown of organic compound $\rightarrow$ settling of microbial biomass $\rightarrow$ removal of ammonium ions $\rightarrow$ removal of nitrate ions $\rightarrow$ killing of microorganisms
Treatment schematic (GW→ Potable drinking water)

- Sequence of unit processes: Aeration chamber ➔ Softening unit ➔ Filtration with chlorination ➔ Disinfection
- Function of unit processes: Gas removal ➔ Cations and solids removal ➔ Solids removal ➔ Microbial removal
- Lime, soda ash and chlorine are required daily.
- Solid waste generated from softening unit and filtration unit are calculated
Next class.