Lecture 8: Water treatment processes

(Jan 27th 2015)

by Dr. Arun Kumar (arunku@civil.iitd.ac.in)

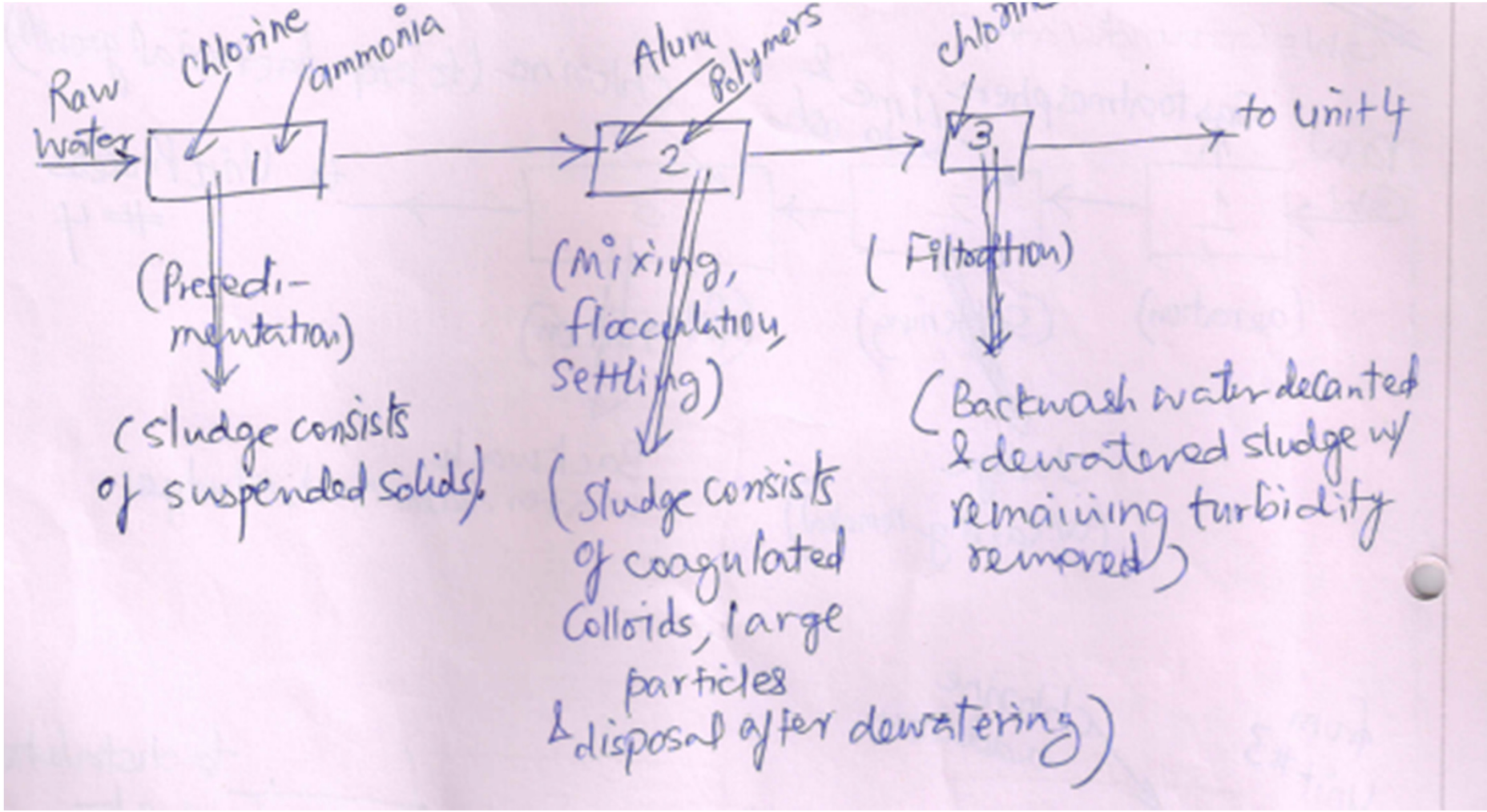
Objective: Understand functioning of different unit processes for water treatment

Courtesy: Dr. Irene Xagoraraki (Michigan State University, East Lansing, USA)

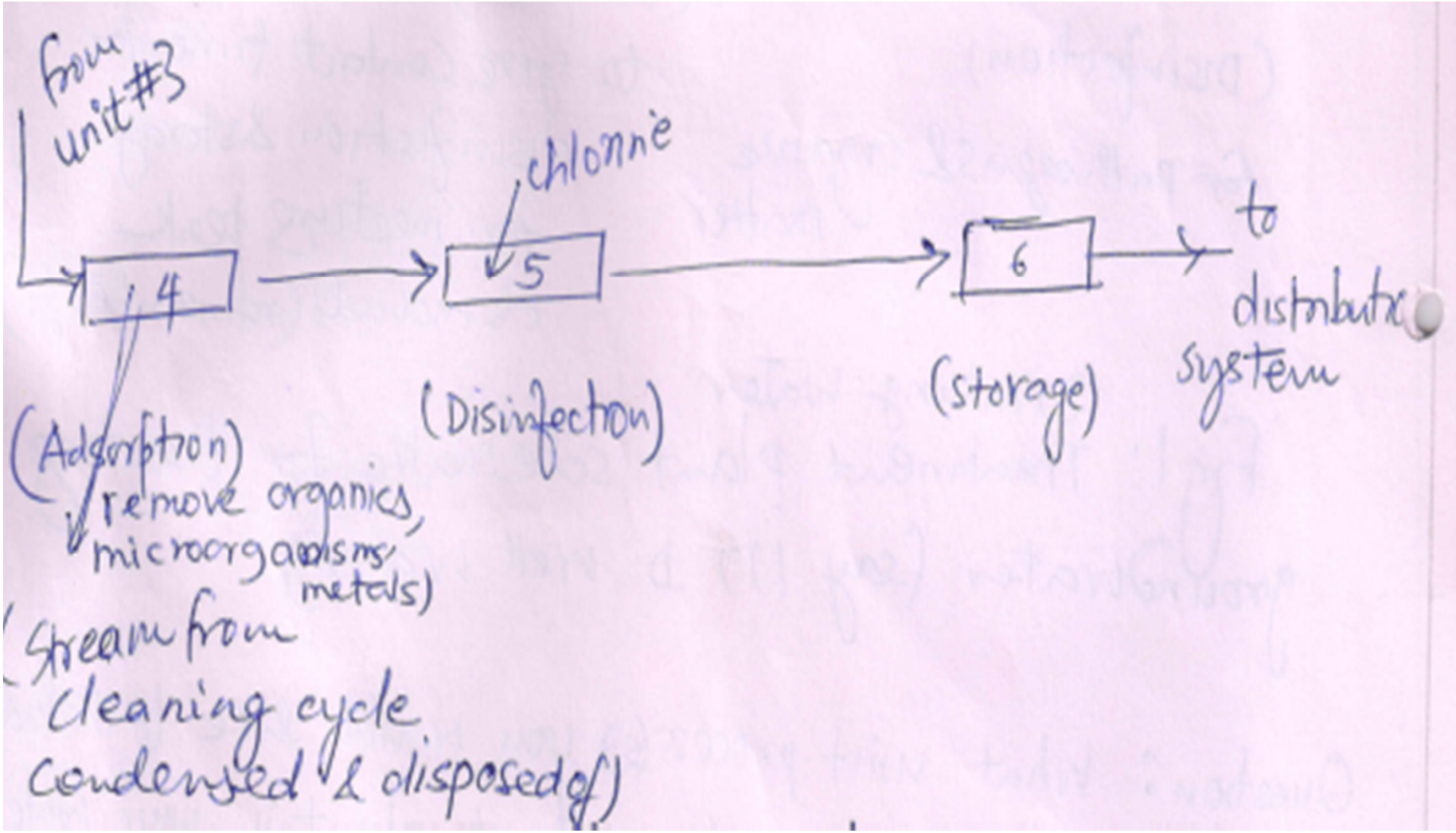
Previous lecture re-cap

- 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 → Drinking water



Example 2 schematic contd.



Treatment schematic (SW→ Potable drinking water)

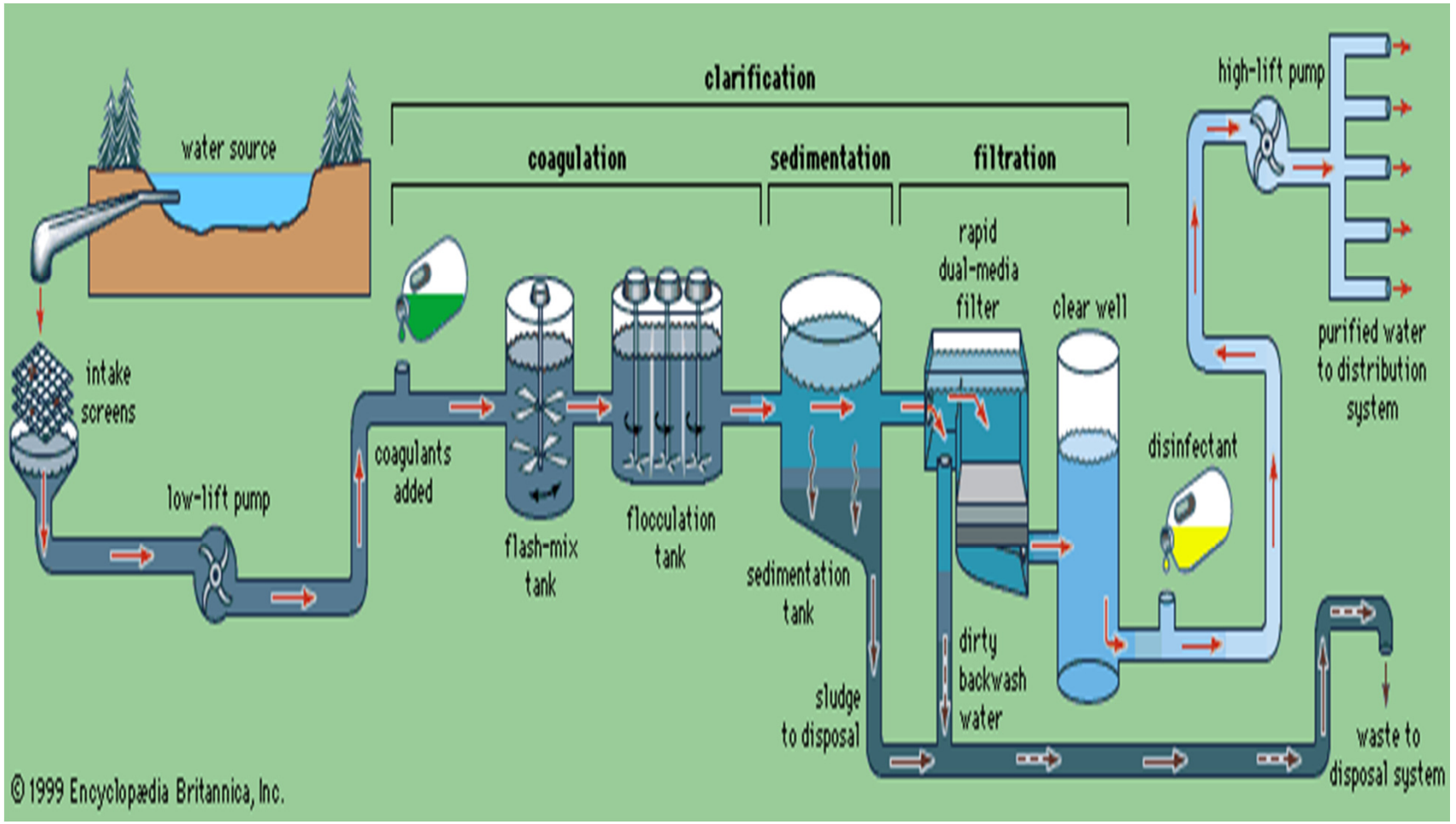
- Sequence of unit processes: pre-sedimentation →mixing, flocculation, settling→filtration→adsorption →disinfection

- 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

(SW→ Potable drinking water) *contd..*

- Chlorine is added in sedimentation and filtration tank to avoid microbial growth
- Chorine is used as a oxidizing agent as well as a disinfection solution.

Surface Water Treatment



Conventional Surface Water Treatment

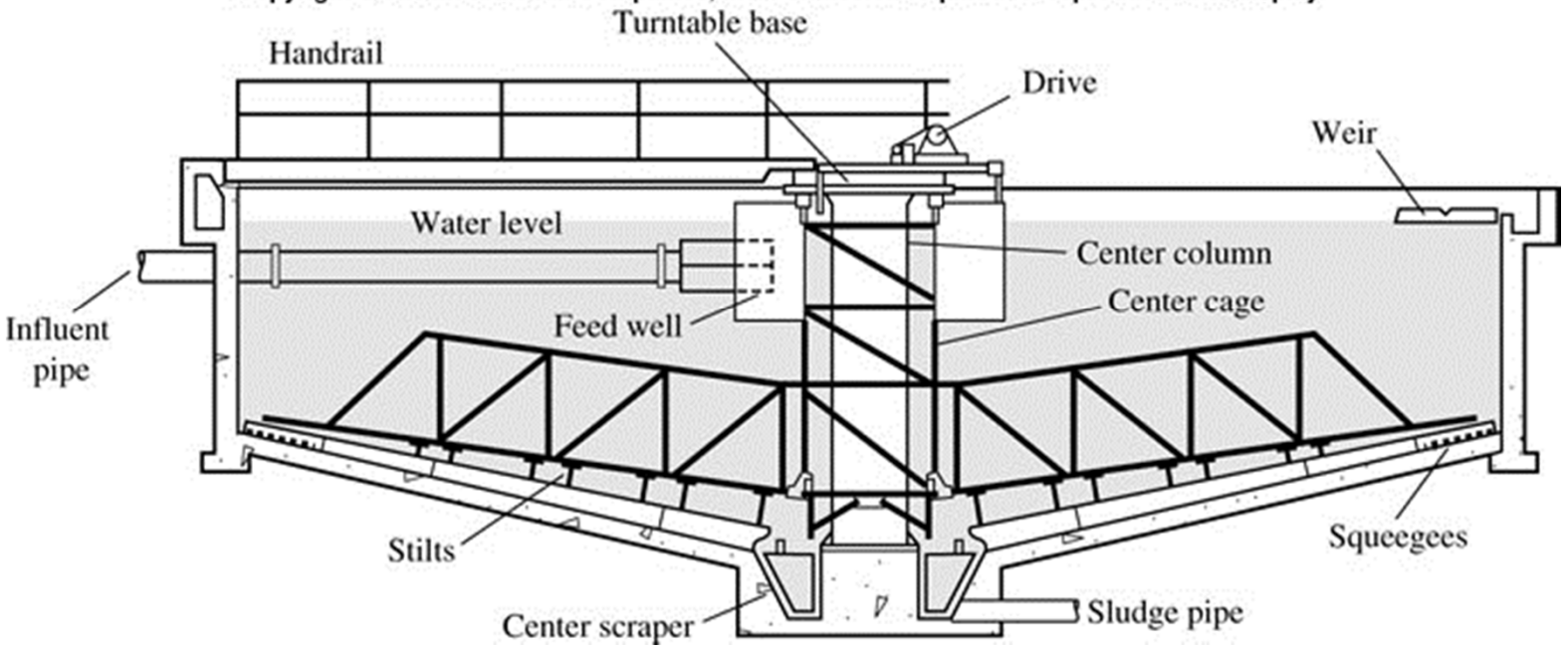
- Screening (remove relatively large floating and suspended debris)
- Rapid-mix (mixing water with chemicals that encourage suspended solids to coagulate into larger particles that will settle easily)
- Flocculation (gently mixing water and coagulant allowing the formation of large particles of floc)

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



Method1. 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.

Method1. 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.

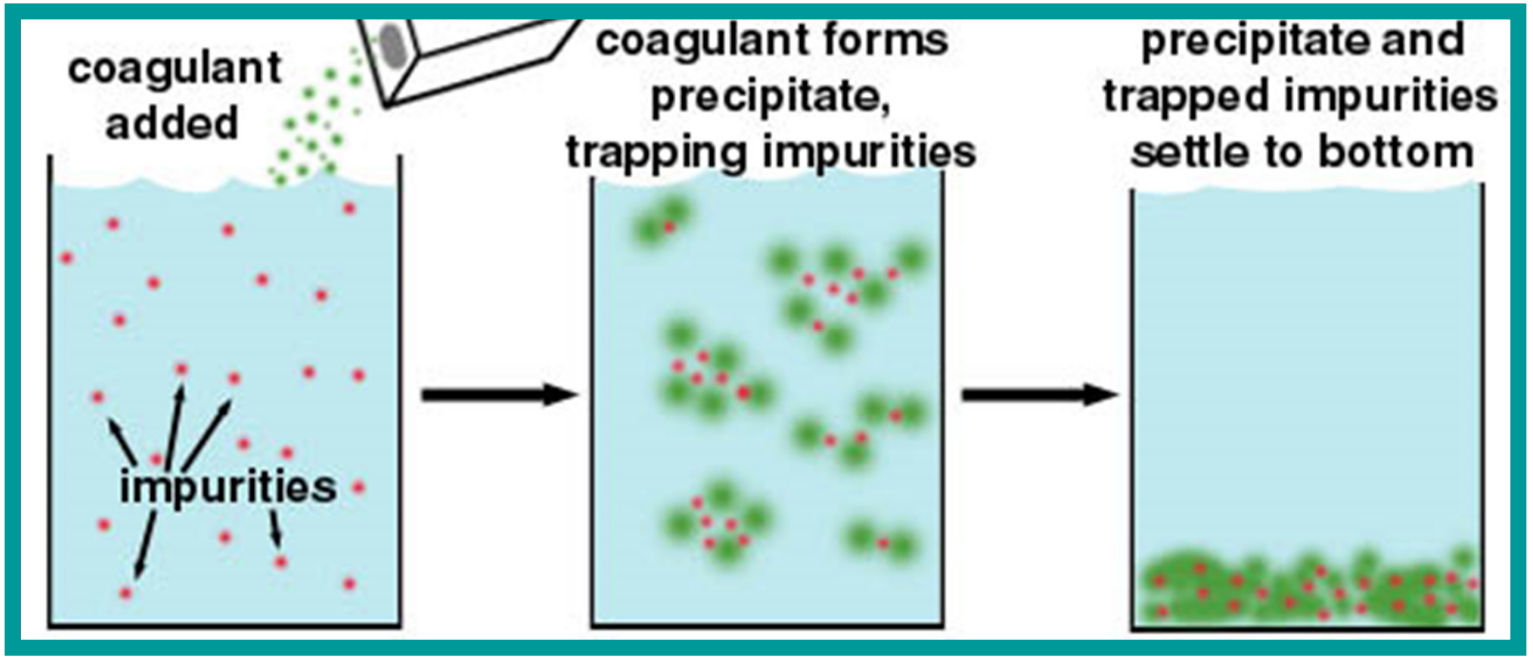
Sedimentation

- Time for settling = column depth/settling velocity at steady state
- Some particle take less time and some particles take longer time to settling.
- if t_design>t_settling, particles remove 100%. All patcies now constitute to solid waste.
- if t_design<t_settling, particles do not remove 100%. Remaining particles go to next unit in treatment plant scheme.

Method 2. Coagulation-Flocculation-Sedimentation

Some coagulants:
aluminum sulfate,
ferric sulfate
ferric chloride

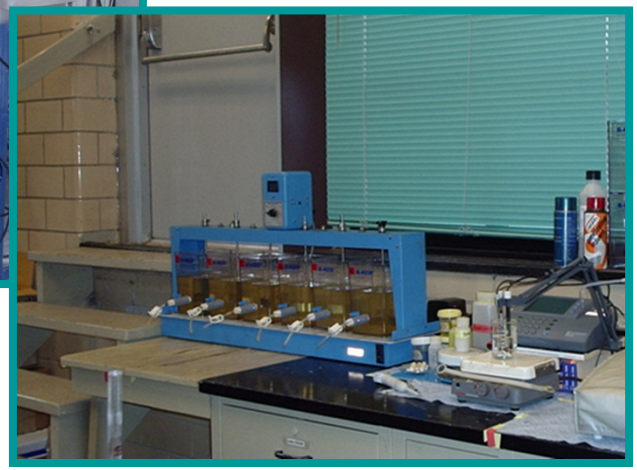
Some coagulant aids:
activated silica
clay
polymers



Coagulation-Flocculation-Sedimentation

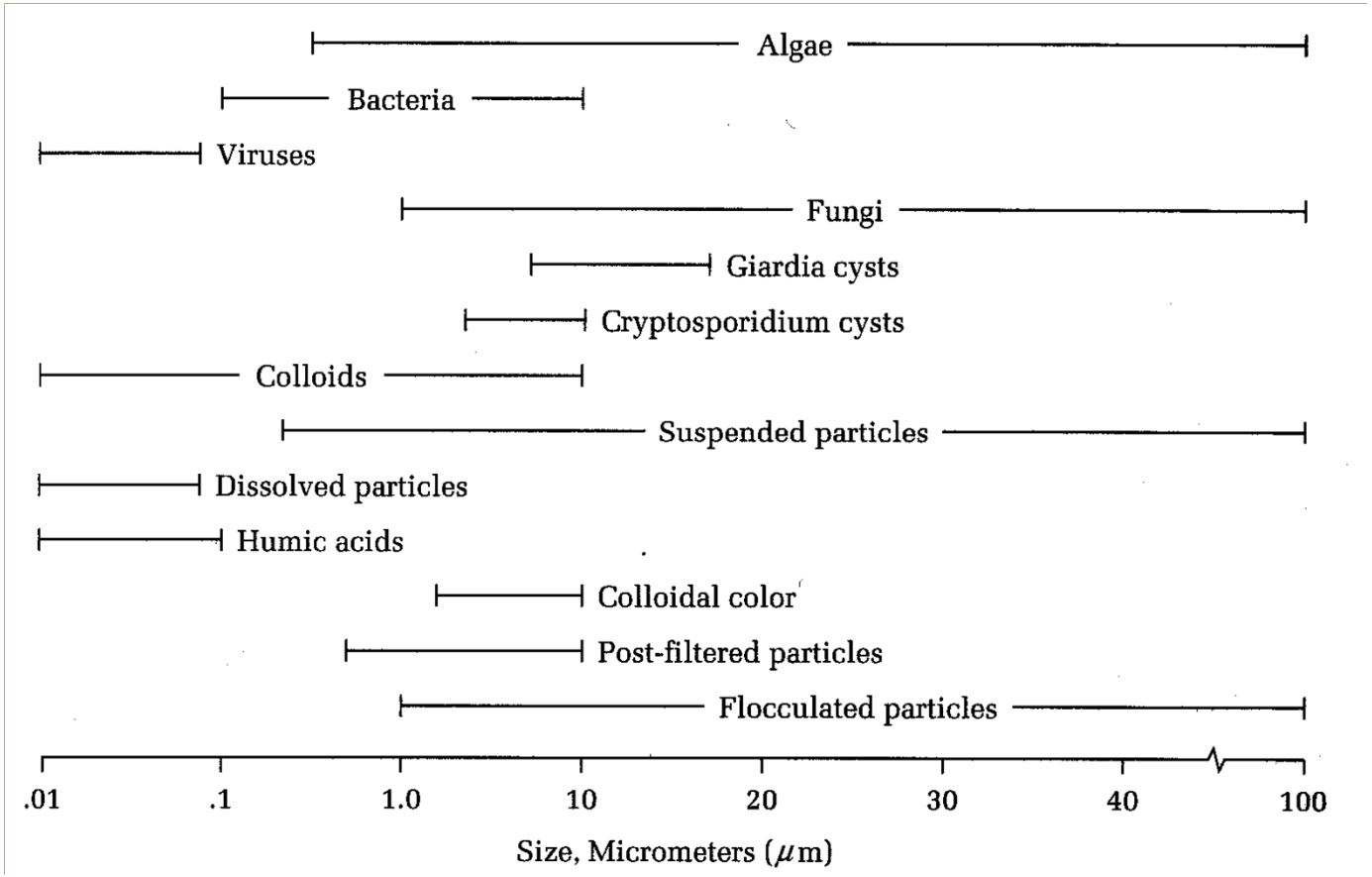
Full-scale

Pilot-scale



Bench-scale

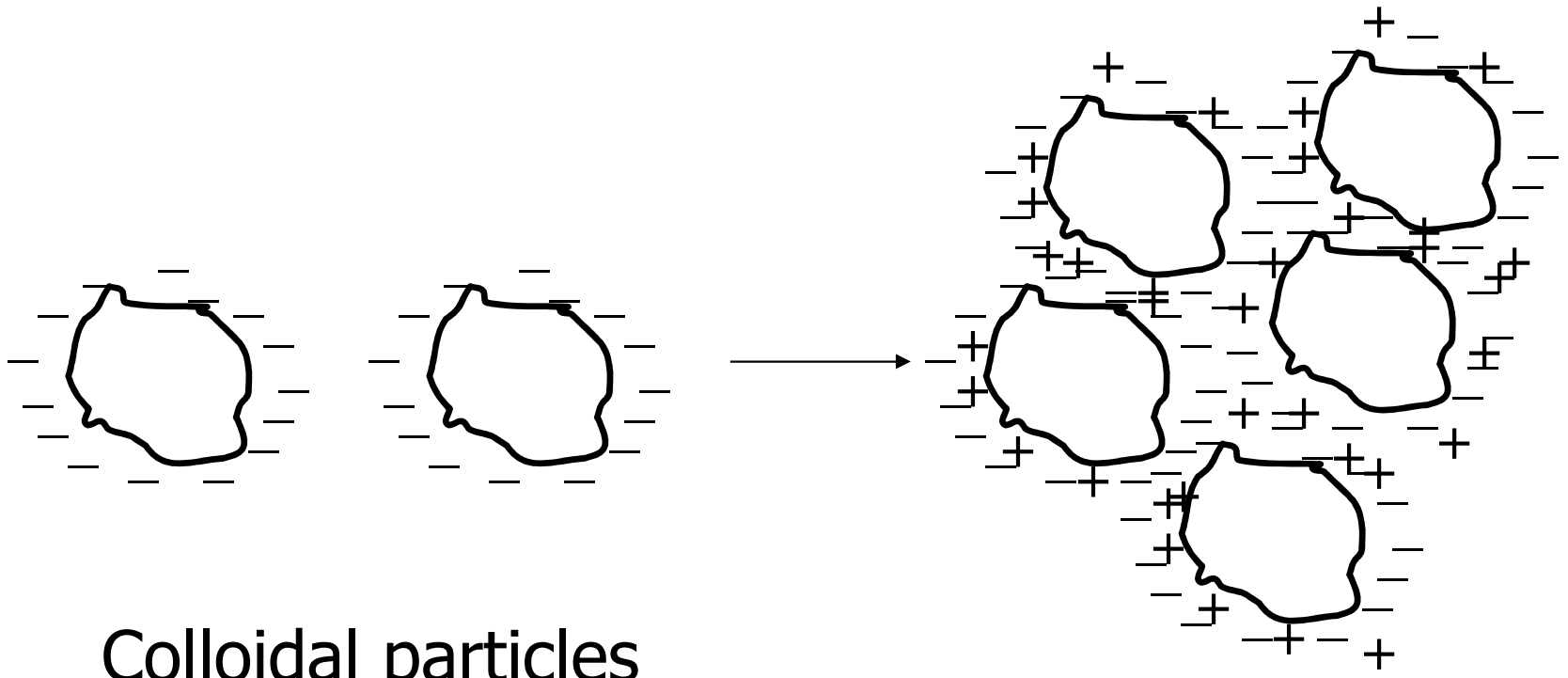
Sizes of Particles in Water



Method2. 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)

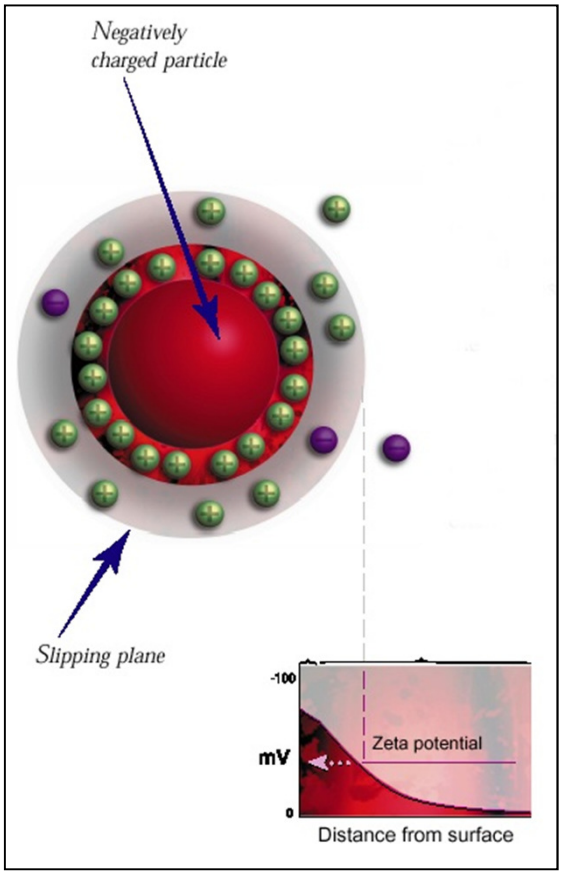
floc
(1 - 100 μm)

Method2. 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)

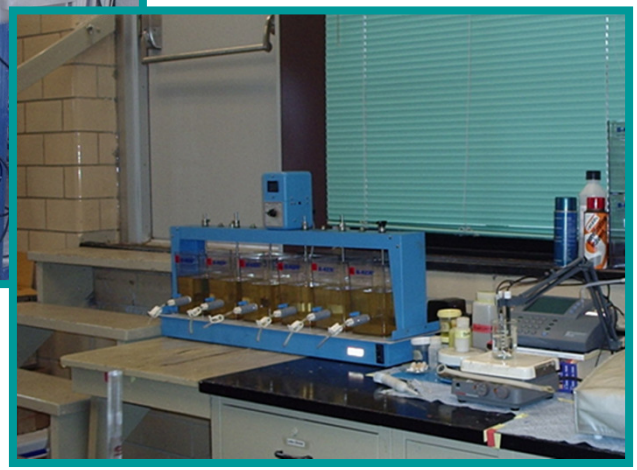


Picture Source: Malvern Instruments, Zeta-Meter Inc.

Coagulation-Flocculation-Sedimentation

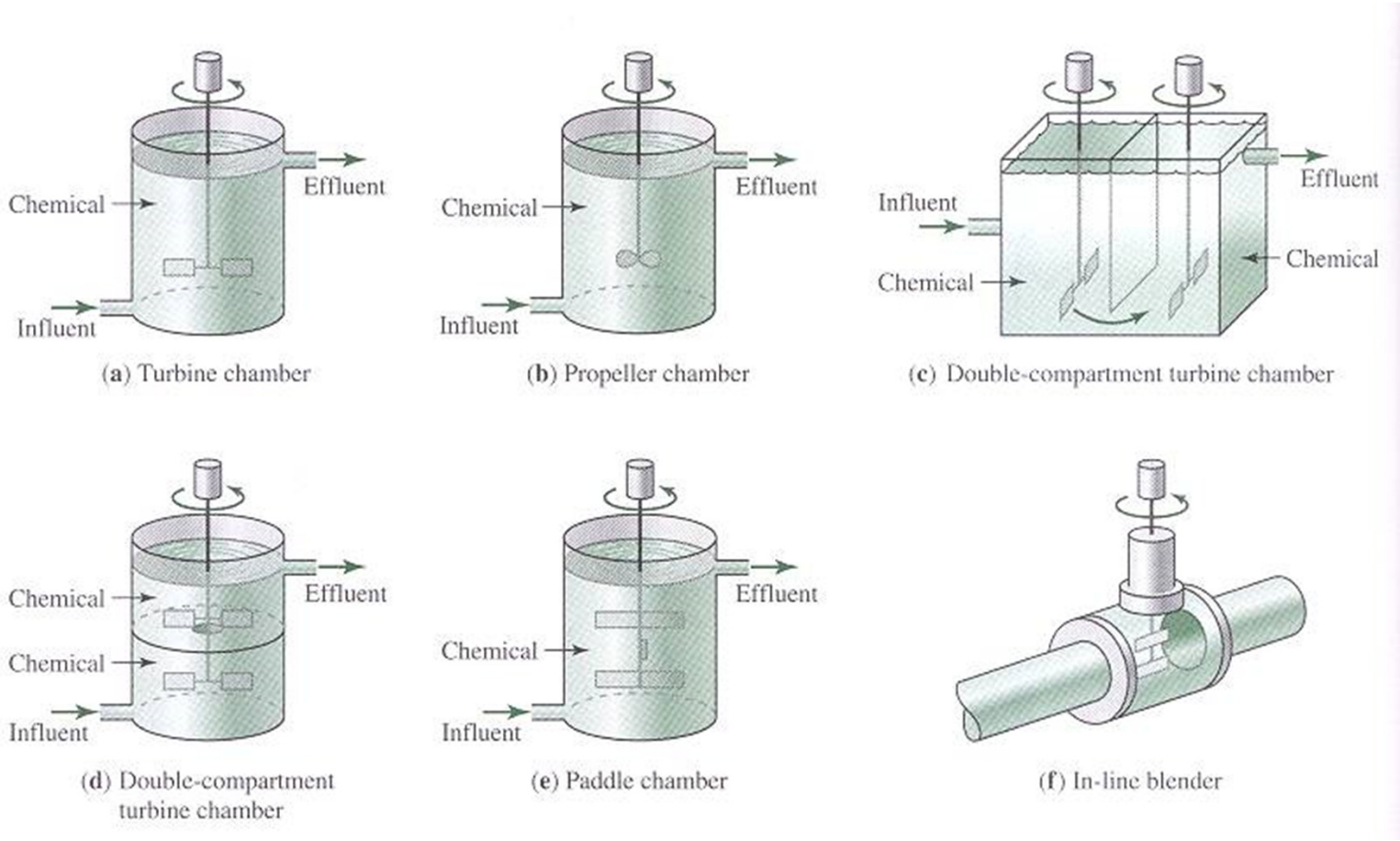
Full-scale

Pilot-scale

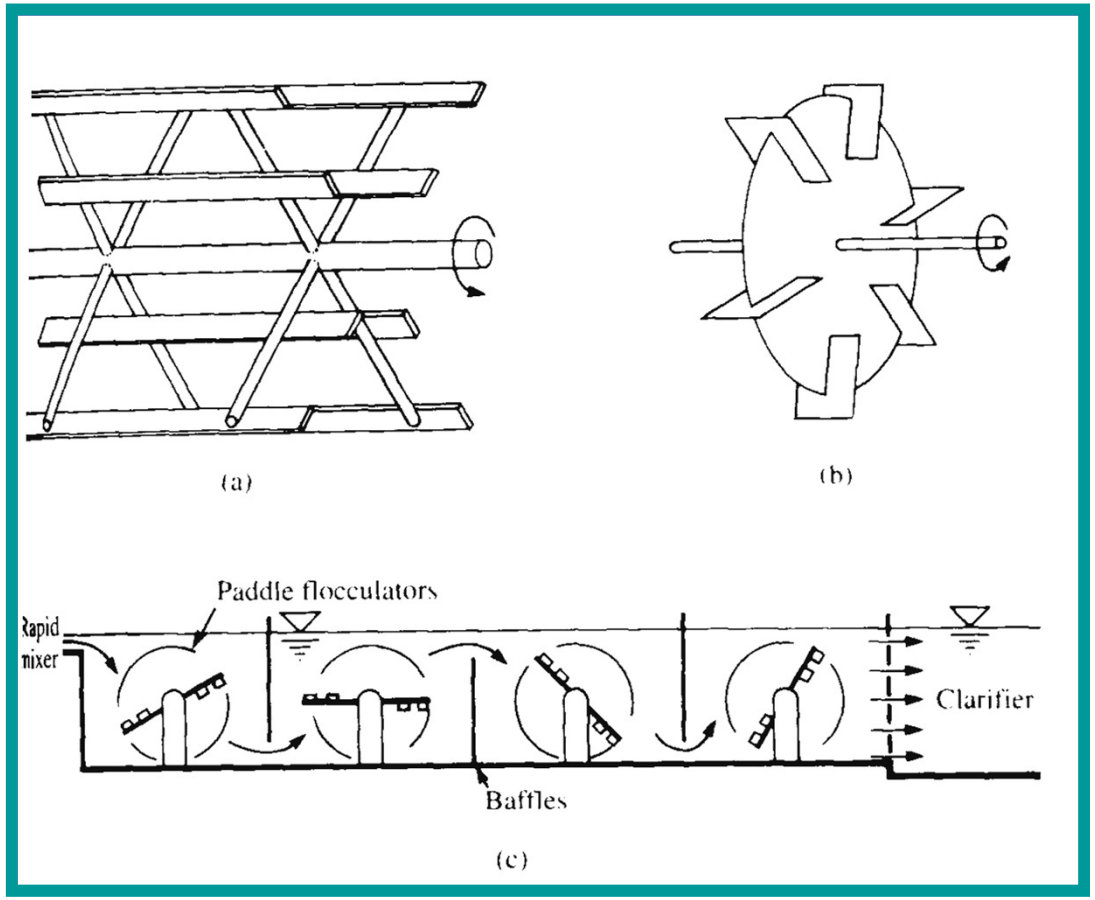


Bench-scale

Rapid Mixing

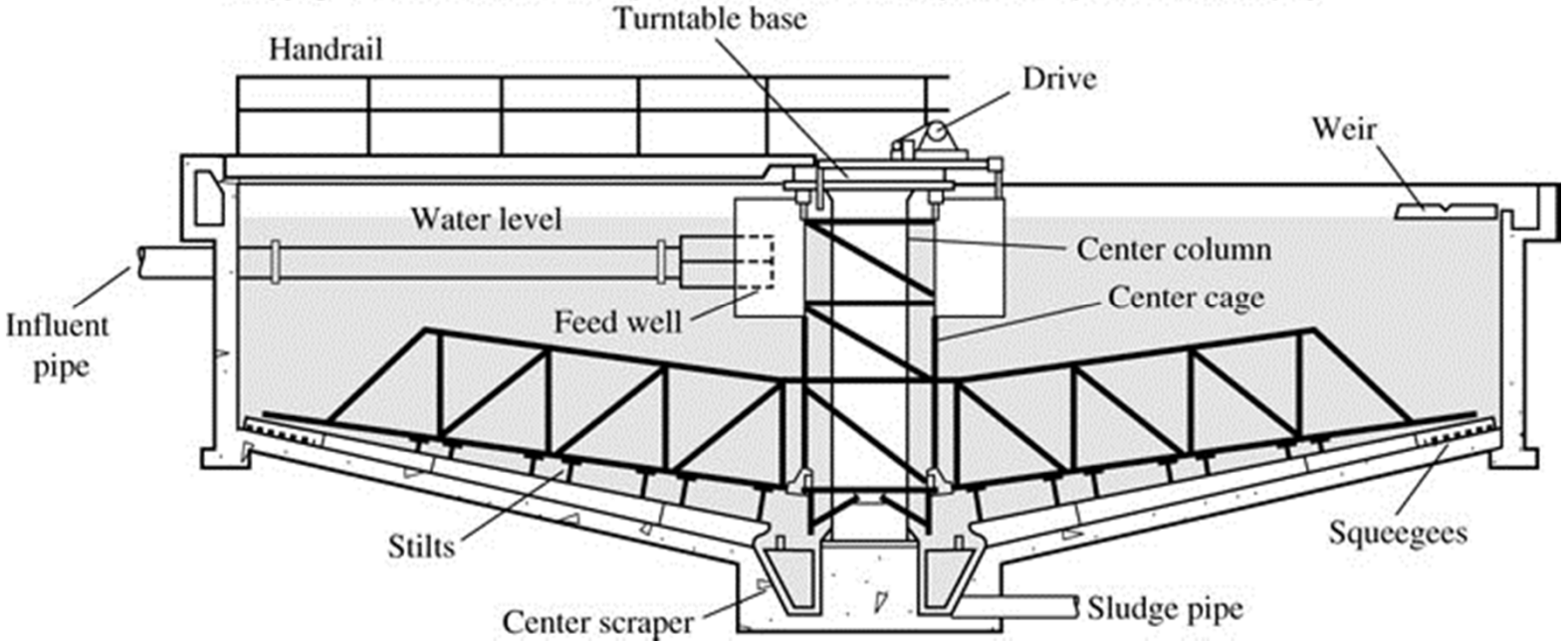


Flocculation



(Source: Water Supply and Pollution Control, 5th ed. W. Viessman, Jr. and M.J. Hammer, Harper Collins College Publ. 1993)

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 → Discharge water to river

- Sequence of unit processes: stabilization tank→sedimentation →biological process→secondry settling → nitrifier unit→denitrifier unit →disinfection→discharge water suitable for river
- Function of unit processes: making incoming flow rate uniform →solid removal→breakdown of organic compound →settling of microbial biomass →removal of ammonium ions →removal of nitrate ions →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.