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Print version

CEE 371
Water and Wastewater Systems

Lecture #12
Drinking Water Treatment: Overview
Reading: Chapter 7, pp.209-210, 249-250

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Purposes for Water Treatment

- Disinfection
- Removal of Turbidity
- Removal of Color, and Tastes & Odors
- Removal of Iron & Manganese
- Hardness removal
- Protection from Toxic Organics and Inorganics

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Drinking Water Treatment Processes

- Gas Transfer (stripping)
- Oxidation
- Coagulation & Flocculation
- Sedimentation or Flotation
- Softening
- Adsorption
- Disinfection

Source Waters

- Groundwaters
  - constant quality
- Rivers
  - variable quality
    - storm events, runoff
      - increases in turbidity, pathogens, coliforms
    - Wastewater inputs
    - Agricultural runoff
    - Accidental spills
- Reservoirs & lakes
  - less variation than rivers
    - seasonal blooms of alae in nutrient rich reservoirs
    - oxygen can be depleted from bottom; causing Fe/Mn problems
    - reservoir turnover in fall & spring

Regulatory Control of Pathogens

- **General Approach**
  - **Source Water Protection, Multiple Treatment Barriers, Protected Distribution System, Monitoring of Water Quality**
- **Surface Water Treatment Rule (SWTR) – 1989**
  - **Required filtration of surface waters unless source water quality criteria met**
  - **Standards for filtered water turbidity (0.5 NTU), total coliform**
  - **Removal/inactivation (disinfection) requirements for *Giardia* and viruses**
    - ***Giardia* 3-log Removal or Inactivation (99.9%)**
      - Conventional Treatment (Clarification + Filtration): achieves 2 ½ Log Removal;
      - Thus, requires ½ Log Inactivation by Disinfection
      - If unfiltered, must have 3 Log Inactivation by Disinfection
    - **Viruses 4-log Removal or Inactivation (99.99%)**
      - Conventional Treatment (Clarification + Filtration): achieves 2 Log Removal;
      - Thus requires 2 Log Inactivation by Disinfection
      - If unfiltered, must have 4 Log Inactivation by Disinfection

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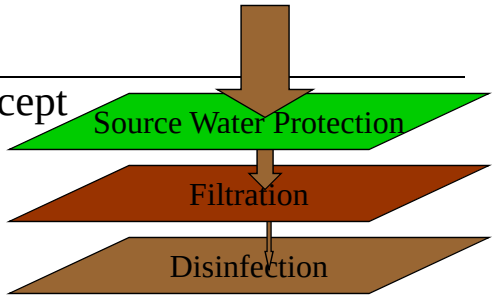
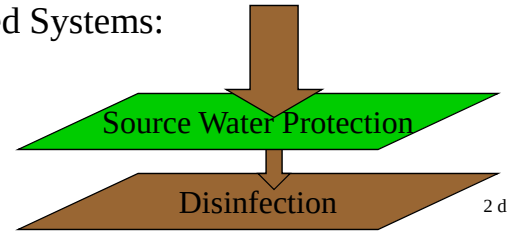
SWTR

- Multiple Barrier Concept
  - Filtered Systems:



  - Unfiltered Systems:



Including wellhead protection

2 different ones

6

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Log Removal

- **Meaning of "Log Removal or Inactivation"**
  - **Removal: remove organisms from the water**
  - **Inactivation: make organisms non-infectious by use of disinfection**
  - **Let N_0 be the number concentration of microorganisms in raw water**
  - **Let N be the number concentration of microorganisms after treatment**
  - **N/N_0 = fraction remaining after treatment**
  - **100 x $(N_0 - N)/N_0$ = percent removal (or inactivation)**
  - **Log (N_0/N) = the log removal (or inactivation)**
  - **Relation between % removal and log removal:**

% Removal	Log Removal	N, if N_0 = 10,000/L
90	1	1000
99	2	100
99.9	3	10
99.99	4	1

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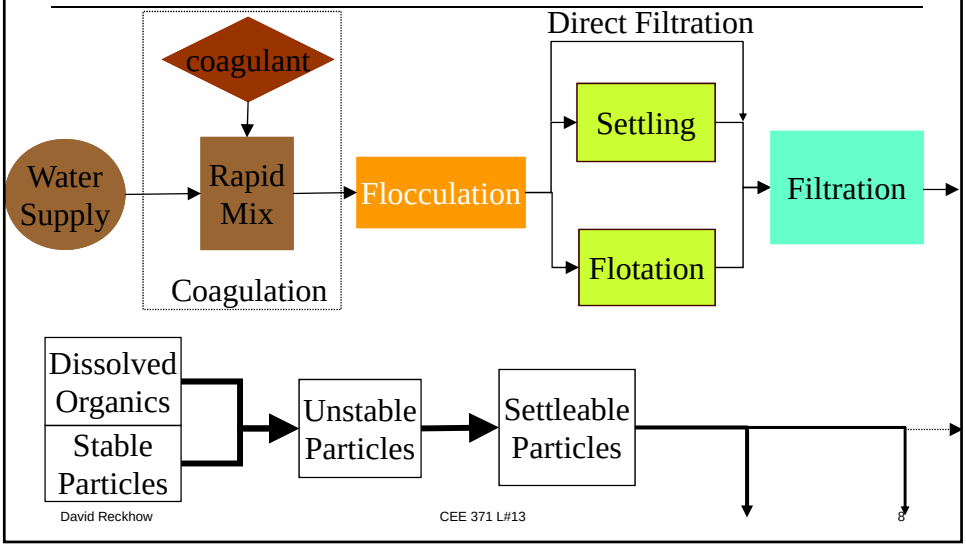
Overview of "conventional" treatment



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SWTR (cont.)

- Requirements for Filtered Supplies

Type of Filtration	Log_{10} Removal Allowed By Filtration		Remaining Log_{10} Inactivation by Disinfection	
	Giardia	Viruses	*Giardia*	Viruses
Conven-tional	2.5	2.0	0.5	2.0
Direct	2.0	1.0	1.0	3.0

- Requirements for Unfiltered Supplies
  - Meet source water quality criteria
  - Provide all Pathogen removal by Disinfection
    - 3 log *Giardia*, 4 log viruses

The TT approach, rather than MCL

Requires a certain CT

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Treatment vs Sources

- Surface water
  - Major water quality concerns
    - Pathogens
    - Turbidity
    - Color & TOC
    - Taste & odor
  - Typical treatment
    - "conventional" coagulation-filtration
    - Some use advanced treatment

Crossover is not uncommon

- Groundwater
  - Major water quality concerns
    - Fe/Mn
    - Hardness
    - Arsenic, perchlorate
    - VOCs & pesticides
  - Typical treatment
    - Disinfection only
    - Softening
    - Aeration
    - Pressure filtration

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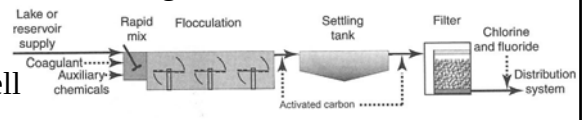
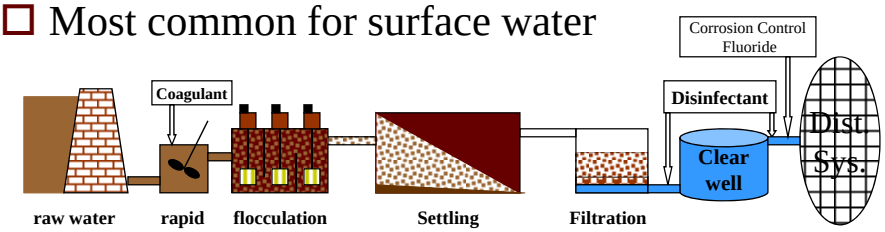
Conventional Treatment

- Coagulation & solids separation
  - rapid mix, flocculation, settling, filtration
- Disinfection
  - including clearwell for contact time



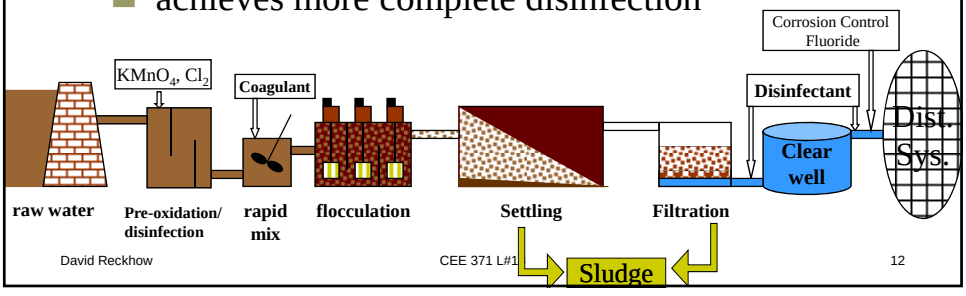
H&H, Fig 7-1, pp.210

- Most common for surface water



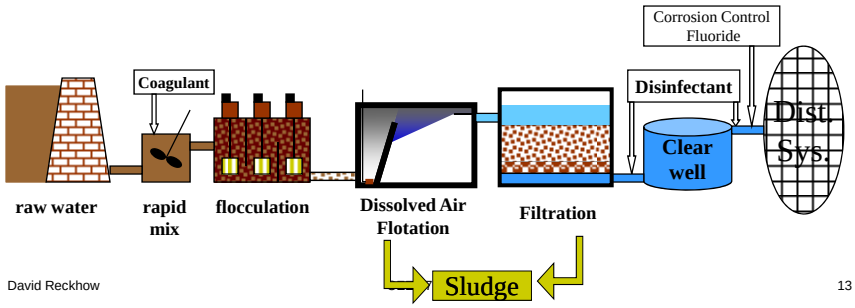
Conventional "plus"

- common to include preoxidation or pre-disinfection with conventional treatment
  - helps with removal of metals & organics by coagulation
  - achieves more complete disinfection



Dissolved Air Flotation (DAF)

- uses very small air bubbles to cause "floc" to float, instead of relying on gravity to make them sink



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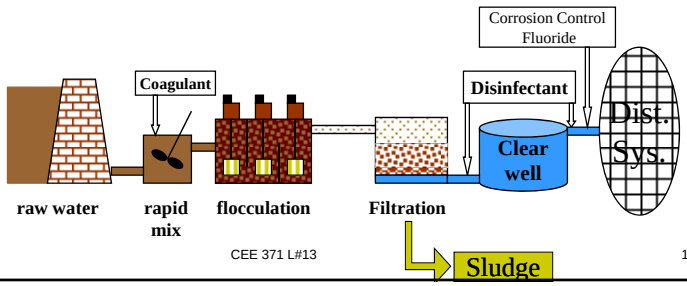
Direct Filtration

- No settling or flotation
  - goes "directly" from flocculation to filtration
  - works well for some low color, low turbidity waters



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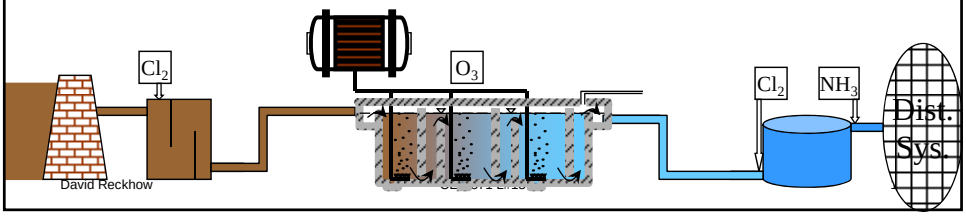
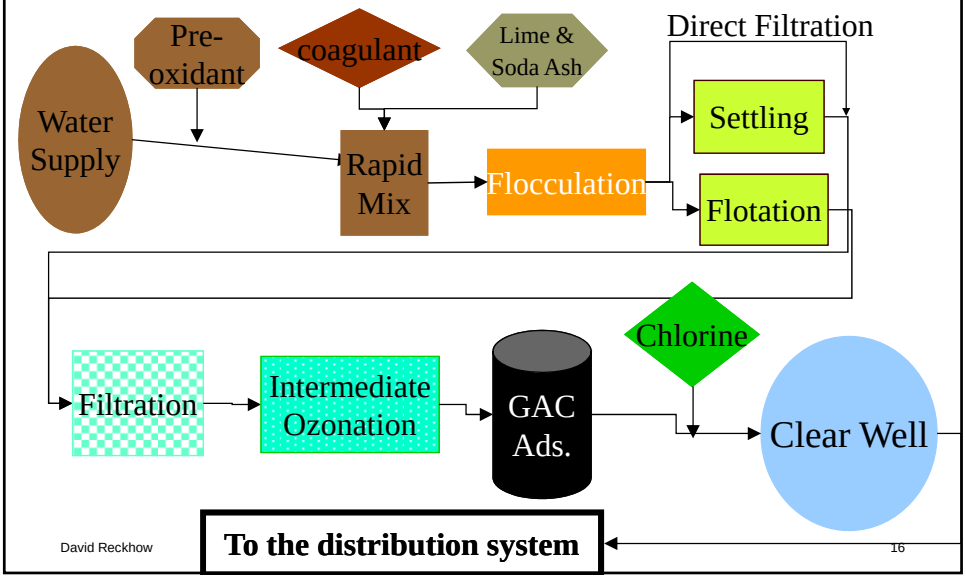
Ozone Plant

- Many types
  - Simplest type: ozone, non-filtration shown below
    - examples: MWRA (Boston), Portland ME

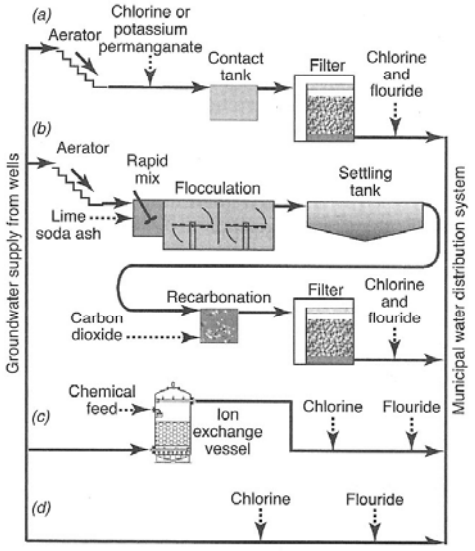


An advanced water treatment process



Groundwater Treatment

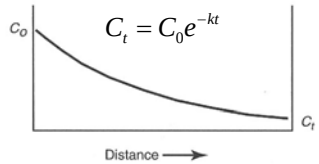
- Tends to be simpler due to higher quality
  a. Fe/Mn removal
  b. Precip. Softening
  c. Ion exchange
  d. Simple disinfection



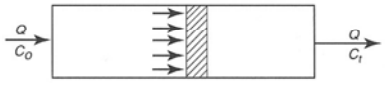
H&H, fig 7-25, pg.250

Reactor Hydraulics

- mean hydraulic detention time (t_R) H&H fig 7-3, pg.211
- "ideal" flow regimes
  - plug flow (PFR)



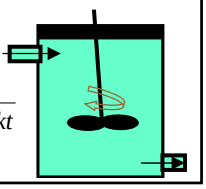
$$t_R = \frac{V}{Q} = \frac{L}{v}$$

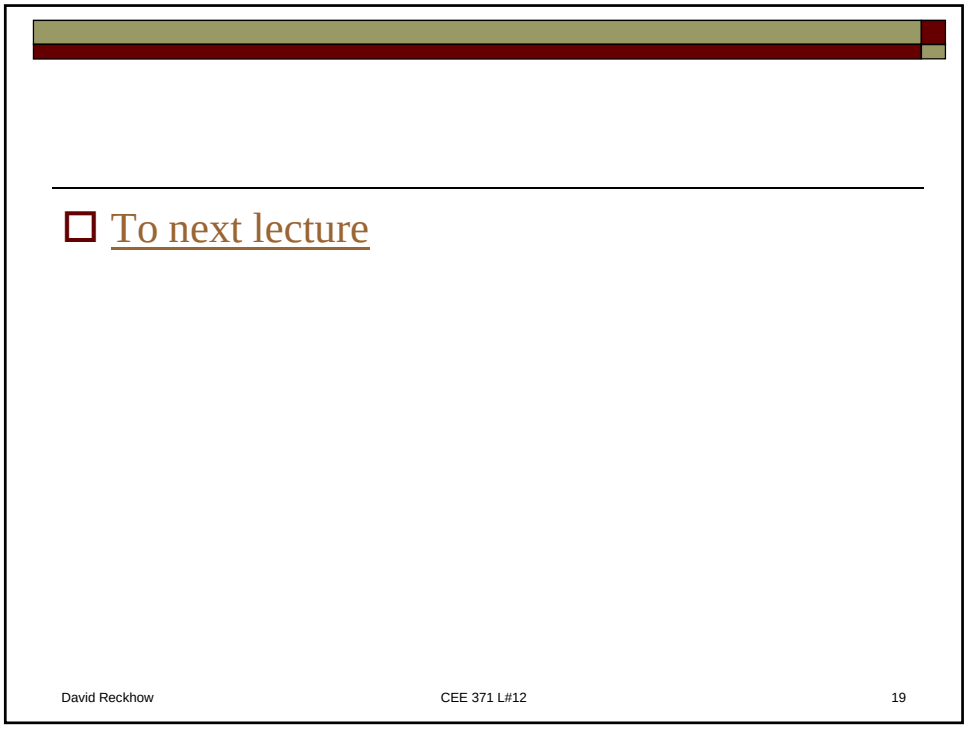


  - completely mixed reactor (CSTR)

$$t_R = \frac{V}{Q}$$

$$C_t = \frac{C_0}{1+kt}$$

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