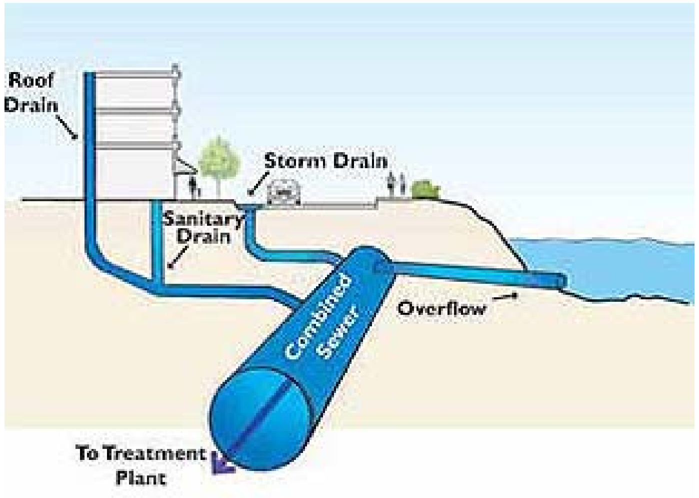
Wastewater treatment processes overview I

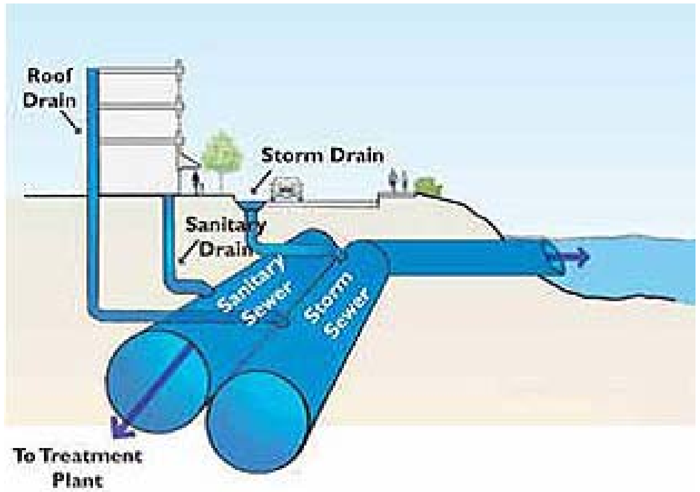
Today's lecture

- Sewer networks
- Municipal wastewater treatment systems
  - Overview
  - Pretreatment: Screens, Grit chamber, flow equalization
  - Primary treatment
  - Secondary treatment: conventional process for BOD removal

Sewer networks

- Combined sewer
  - Sewage and stormwater are collected by a single pipeline
  - For old cities
- Separate sewer
  - Dual pipeline system to collect sewage and stormwater separately
  - New constructions adopt separate sewer



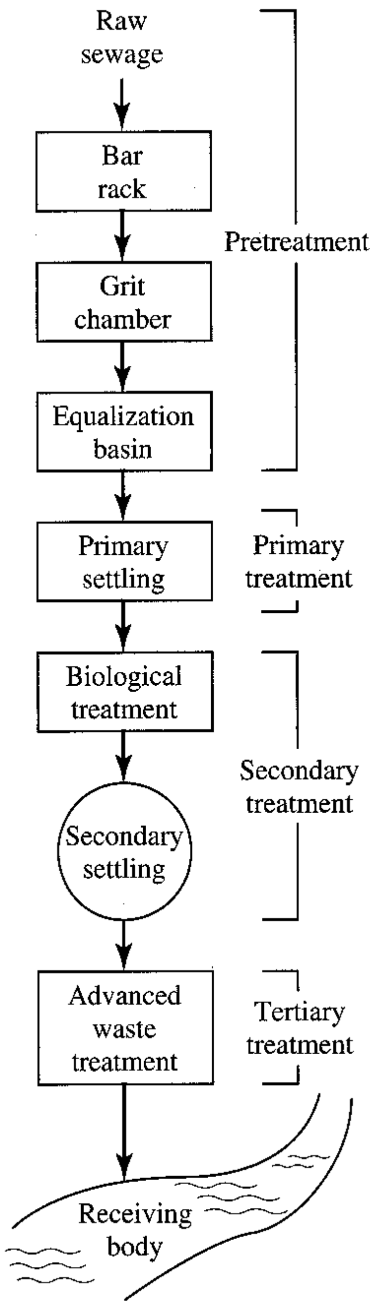


http://www.sfbetterstreets.org

Combined sewer overflow (CSO)

- A non-point source pollution problem
- Some diluted wastewater flows directly to the water body during storm events
- Constant CSO (not diluted!) in some cases due to exceedance of design sewage flowrate

Municipal wastewater treatment systems



- Pretreatment: removes materials that can cause operational problems, equalization optional
- Primary treatment: remove ~60% of SS and ~35% of BOD
- Secondary treatment – remove ~85% of BOD and SS
- Advanced (tertiary) treatment – more BOD and/or SS removal, nutrient removal, refractory organics, or others

Bar racks (screens)

- Purpose: to remove large objects that would damage or foul pumps, valves, and other mechanical equipment

Top: Manually-cleaned bar screen

http://techalive.mtu.edu

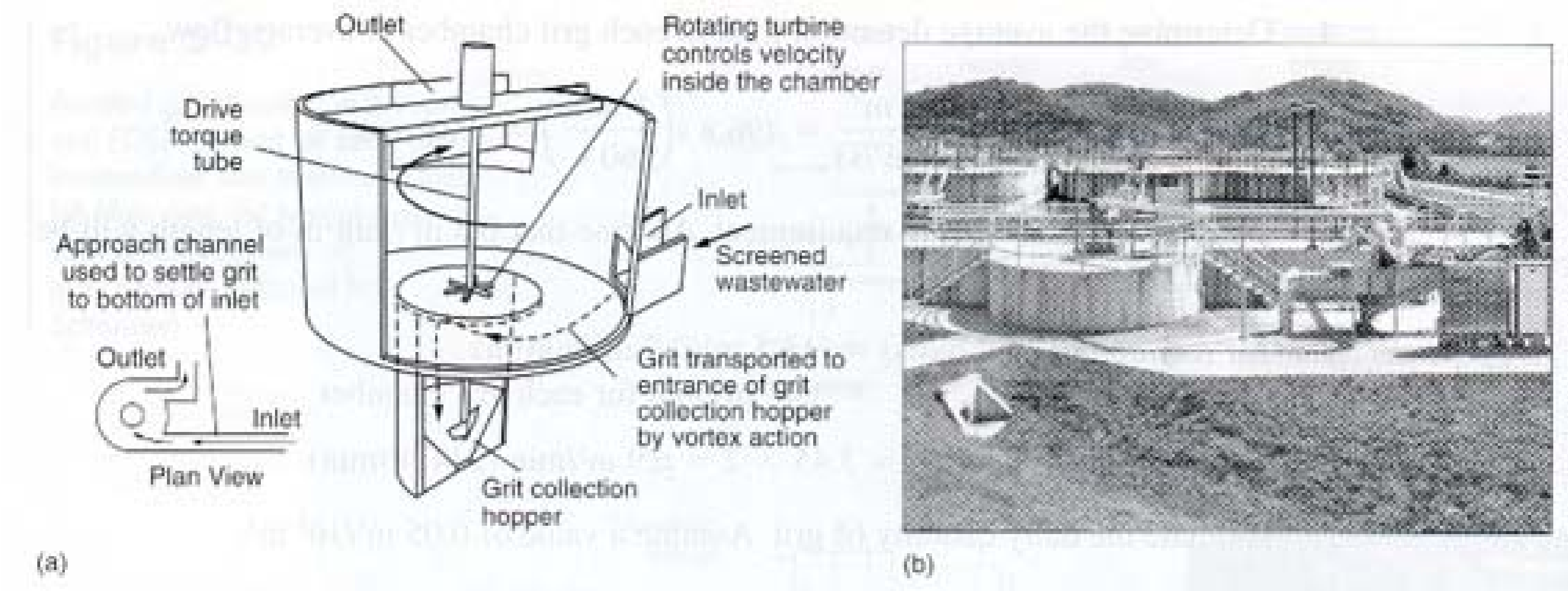
Bottom: Mechanically-cleaned bar screen

http://www.degremont-technologies.com

Grit chamber

- Grits: inert dense materials such as sand, broken glass, silt, and pebbles
- Purpose: to remove grits that can abrade pumps and other mechanical devices

Rectangular horizontal flow grit chamber



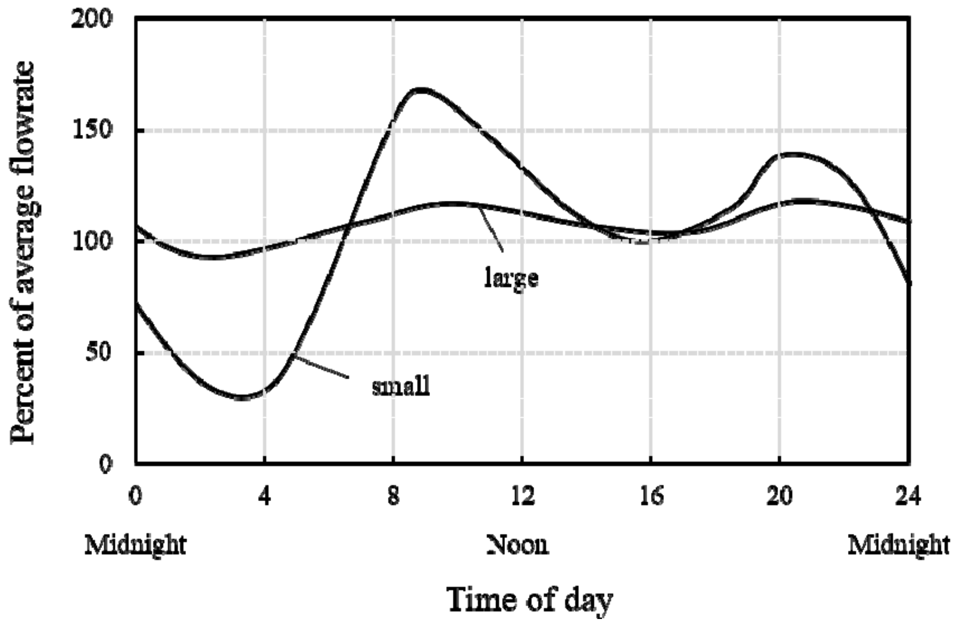
Vortex-type grit chamber

Flow equalization

- **Daily variations**
  – Significant daily variations of flowrate especially for small collections systems

  ** note the lag time for wastewater to reach the treatment plant*

  – Constituent concentration also varies over time



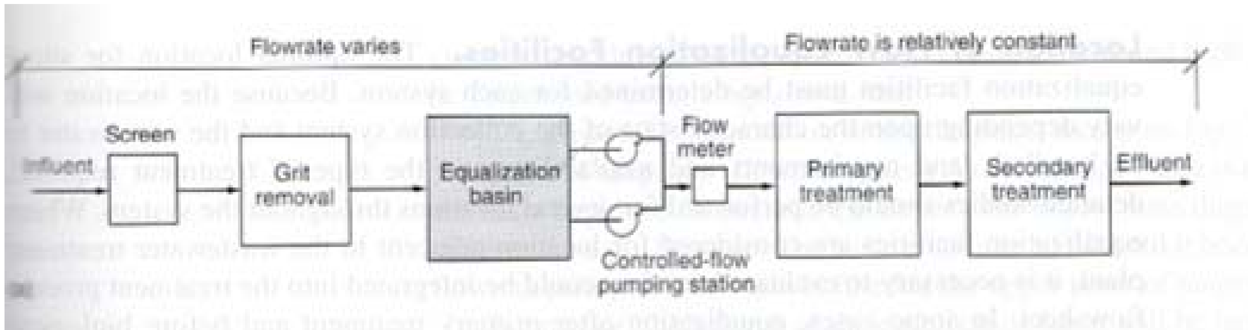
Flow equalization

- Purpose: dampen flowrate variations (and concentration variations) to
  - i) overcome the operational problems caused by flowrate variations
  - ii) improve the performance of the downstream processes
  - iii) reduce the size and cost of downstream treatment facilities

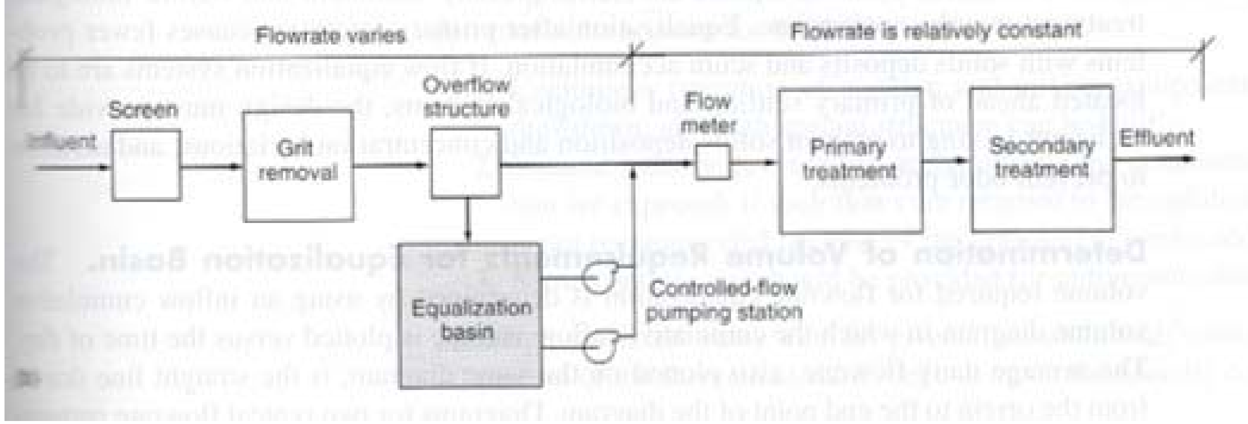
Flow equalization

- **Method of application: in-line or off-line**
  - In-line: can achieve dampening of constituent concentration in addition to the dampening of flowrate
  - Off-line: pumping requirements are minimized

[In-line]



[Off-line]



Primary sedimentation basins

- Removal of suspended solids by settling
- This removes some BOD as well!
- Removes ~60% of SS and ~35% of BOD
- Sludge settled at the bottom and collected by mechanical devices
- Floating materials such as oil and grease are also removed

Primary sedimentation basins

- Design parameters
  - Retention time: ~2 hr
  - Overflow rate, v_0: determines particle removal efficiency

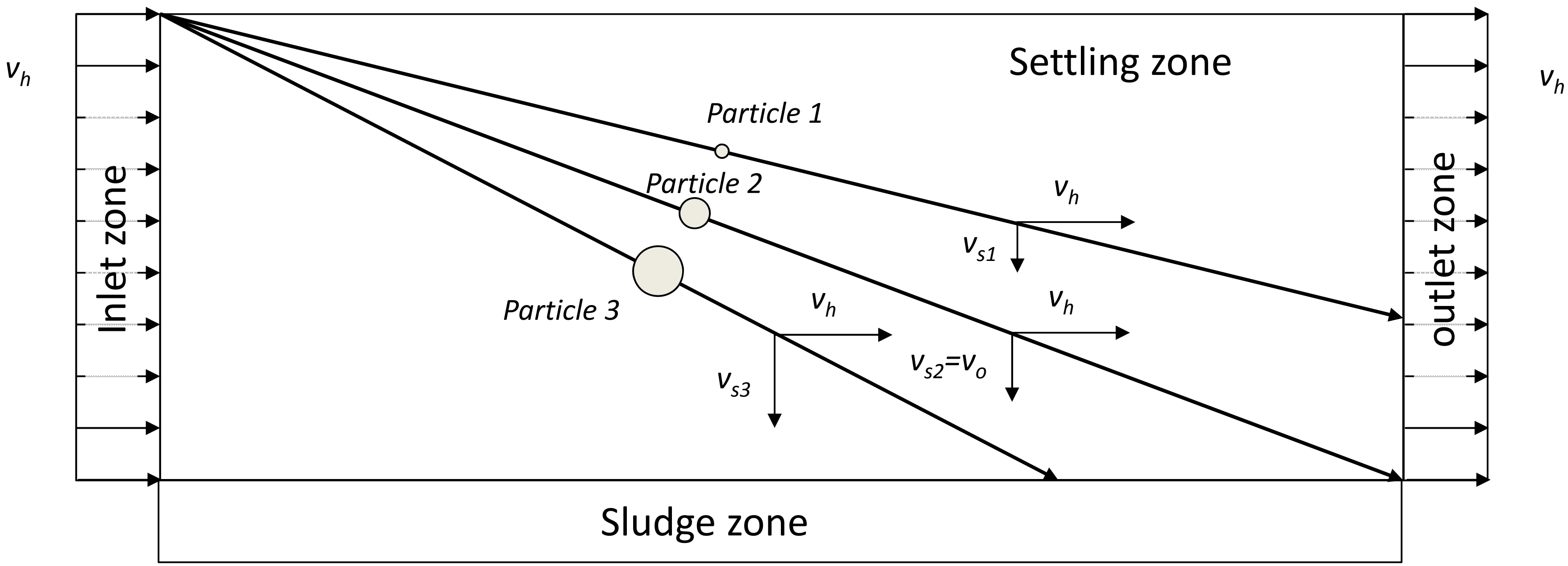
$$v_o = \frac{Q}{A_c}$$

Q = water flow rate (m^3/s)

A_c = surface area of the sedimentation basin (m^2)

Removal of particles in sedimentation basins

Assume a rectangular sedimentation basin:



particle 1: $v_{s1} < v_o$ → partial removal

particle 2: $v_{s2} = v_o$ → 100% removal

particle 3: $v_{s3} > v_o$ → 100% removal

Removal of particles in sedimentation basins

From the diagram in the previous slide,

(time for water to flow through the settling zone) [1]

= (settling zone length, L) / (horizontal velocity, v_h)

(time for particle with settling vel. of v_o entering at the top to settle) [2]

= (settling zone height, H) / (settling velocity, v_o)

Equating [1] and [2], $$\frac{L}{v_h} = \frac{H}{v_o}$$

$$\Rightarrow \quad v_o = \frac{Q}{A}$$

v_o = ***overflow rate*** *(m/s)*

A = surface area of settling zone (m^2)

For particles with settling velocity (v_s) greater than v_o, 100% removed;

For particle with v_s smaller than v_o, removal efficiency is v_s/v_o x 100 (%)

Primary sedimentation basins

- Rectangular or circular

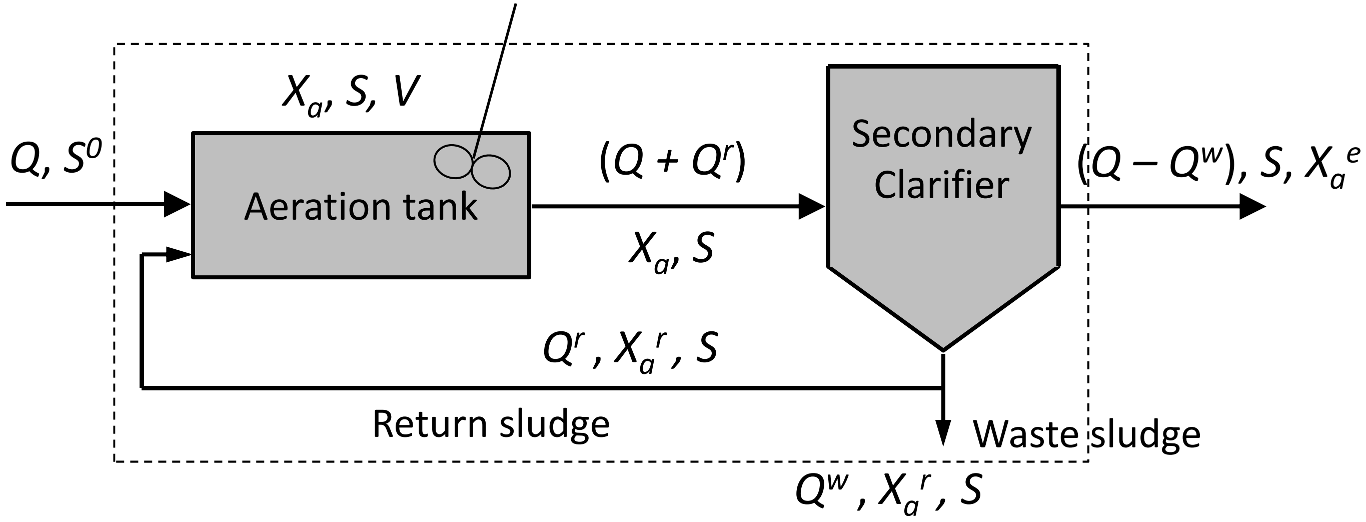
http://www.mlive.com

http://www.lgam.info

Secondary treatment

- Goal: provide BOD removal beyond what is achieved in primary treatment
  - Removal of soluble BOD
  - Additional removal of SS
- How: by providing favorable conditions for microbial activities
  - Availability of high density of microorganisms
  - Good contact between organisms and wastes
  - Favorable temperature, pH, nutrients, carbon source (food)
  - Oxygen (or other electron acceptors)
  - No or little toxic chemicals present

Analyzing activated sludge process



Remember:

$$S = K\frac{1 + b\theta_x}{\theta_x(Y\hat{q} - b) - 1}$$

$$X_a = \frac{\theta_x}{\theta}\frac{Y(S^0 - S)}{1 + b\theta_x}$$

➡ SRT a key parameter

Other important parameters

- Food-to-microorganism ratio (F/M)

$$F/M = \frac{Q^0 S^0}{VX}$$

X = total suspended solids (MLSS) in aeration tank (mg/L)

- Volumetric organic loading rate (Volumetric OLR): the amount of BOD or COD applied to the aeration tank volume per day

$$Volumetric\ \ OLR = \frac{Q^0 S^0}{V}$$

Sludge production

- Sludge production, $P_{X,VSS}$

$$P_{X,VSS} = Y_{obs}(Q)(S^0 - S) + QX_i{}^0$$
$$= QY(S^0 - S)\frac{1 + (1 - f_d)b\theta_x}{1 + b\theta_x} + QX_i{}^0$$

$P_{X,VSS}$ = daily net sludge production (g VSS/d)

Y_{obs} = observed yield (g VSS/g substrate)

Settling problems: **bulking sludge**

- Sludge blanket not stable; large quantities of MLSS carried along with the clarifier effluent
- Exceeding the effluent standard for SS & BOD/COD
- Two principal types of sludge bulking
  - Filamentous bulking: growth of filamentous organisms
  - Viscous bulking: production of excessive amount of extracellular biopolymer

Filamentous vs. viscous bulking

- **Filamentous bulking**
  - Bacteria form filaments of single-cell organisms that attach end-to-end, and the filaments protrude out of the sludge floc
  - Filamentous bacteria are competitive at low DO, low organic conc., low nutrient conc. → need control of these variables!

- **Viscous bulking**
  - Results in a sludge with a slimy, jellylike consistency
  - Biopolymers are hydrophilic → contains significant amount of water in the floc → low density, poor compaction
  - Found at nutrient-limited systems and at a very high F/M ratio

Settling problems: **Nocardioform foam**

- "Nocardioform" bacteria have hydrophobic cell surfaces and attach to air bubbles, causing foaming
- Thick foam (0.5~1 m) of brown color forms
- Can occur in diffused aeration systems and also in anaerobic treatment systems
- Major solutions
  - Avoid trapping foam in the aeration tank effluent
  - Surface wasting of activated sludge
  - Avoid the recycle of skimmings

Settling problem: **rising sludge**

- Rising of sludge having relatively good settling properties due to gas formation
- Gas commonly produced: N_2
- Gas bubble attaches to the sludge and increases buoyant force
- Solutions
  - Increasing the return activated sludge withdrawal rate from the clarifier (less residence time of sludge in the clarifier)
  - Temporally decreasing the rate of flow of aeration liquor into the clarifier
  - Increasing the speed of the sludge collecting mechanism
  - Decreasing the SRT (prevent nitrification) or add an anoxic reactor (complete nitrification-denitrification)