Wastewater treatment I

Today's lecture

- Wastewater characteristics
- Overview of wastewater treatment processes
- Wastewater treatment processes
  - Pretreatment: bar racks, grit removal, flow equalization
  - Primary treatment
  - Secondary treatment

Significance of wastewater contaminants

- **Suspended solids**: can cause sludge deposits and anaerobic conditions in the environment
- **Biodegradable organics**: can cause anaerobic conditions in the environment
- **Pathogens**: transmit disease
- **Nutrients**: can cause eutrophication
- **Heavy metals**: toxicity to biota and humans
- **Refractory organics**: toxicity to biota and humans
- **Dissolved solids**: interfere with reuse, damage the aquatic ecosystem

Characteristics of domestic wastewater

Typical Composition of Untreated Domestic Wastewater

Constituent	Weak	Medium	Strong
	(all $mg \cdot L^{-1}$ except settleable solids)		
Alkalinity (as $CaCO_3$)[a]	50	100	200
BOD_5 (as O_2)	100	200	300
Chloride	30	50	100
COD (as O_2)	250	500	1000
Suspended solids (SS)	100	200	350
Settleable solids (in $mL \cdot L^{-1}$)	5	10	20
Total dissolved solids (TDS)	200	500	1000
Total Kjeldahl nitrogen (TKN) (as N)	20	40	80
Total organic carbon (TOC) (as C)	75	50	300
Total phosphorus (as P)	5	10	20

[a]This amount of alkalinity is the contribution from the waste. It is to be added to the naturally occuring alkalinity in the water supply. Chloride is exclusive of contribution from water-softener backwash.

Industrial wastewater

- Significant variation in wastewater characteristics
- Some industry may generate certain toxic pollutants

Industry	Pollutant	Concentration (mg/L)
Coke byproduct (steel mill)[1]	Organic nitrogen Phenol	100 2000
Metal plating[2]	Chromium (VI)	3-550
Plywood glue waste[3]	COD Phenol	2000 200-2000

[1]코크스 제조 부산물(제강 공정), [2]금속 도금, [3]합판 접착제 폐액

- May need pretreatment to prevent high loading to the wastewater treatment plant

Municipal wastewater treatment

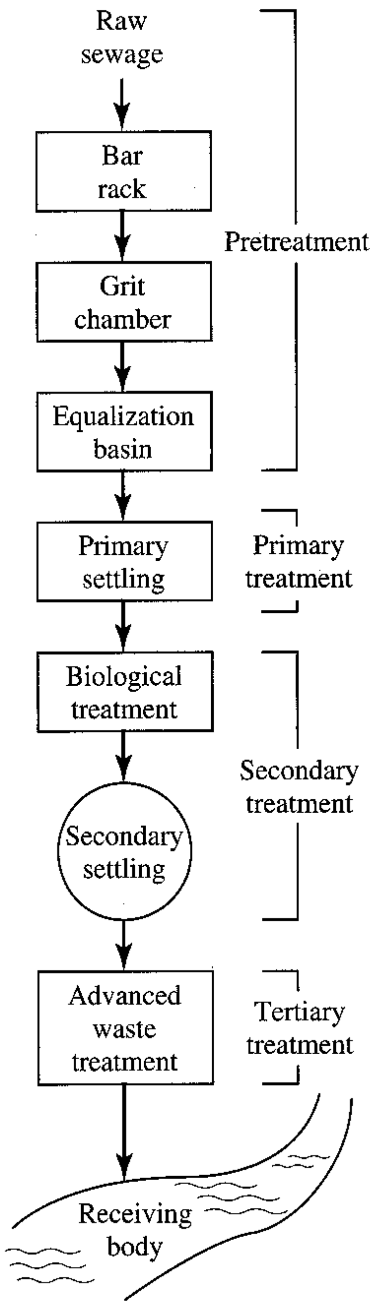
- Major goal: remove BOD and suspended solids (SS)
  - US (1970's): "fishable and swimmable water", 30/30 rule
  - Currently we are also concerned with protecting aquatic ecosystem
  - Current Korean standard: BOD ≤ 10 mg/L, SS ≤ 10 mg/L

- Additional goal: remove N, P, pathogens, total dissolved solids (TDS), trace pollutants (heavy metals, EDCs, PPCPs, …)

Municipal wastewater treatment

Treatment

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 – additional removal of BOD & SS, N & P, and others

Bar racks (screens)

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

http://www.infobarscreens.com

Provided by McGraw-Hill

Grit chamber

- Goal: remove "grit"
- Grit
  - Inert dense material such as sand, broken glass, silt, and pebbles
  - Abrades pumps and other mechanical devices in the following treatment processes
  - Relatively high density → settles down easily

"Vortex type" grit chamber

http://www.hatchmott.com

Flow equalization

- The flow rate and strength of wastewater varies from hour to hour
- High flow rate and strength in the morning, low at night; high flow rate and low strength during storm events
- Flow equalization is to achieve nearly constant wastewater flow rate and strength → better performance of wastewater treatment and reduce the size and cost

Primary sedimentation basins

- Removal of suspended solids by settling
- This removes some BOD as well!
- Removes ~60% of SS and ~35% of BOD
- Sludge (= mass of settled solids) is produced
- Floating materials such as oil and grease are also removed
- Design parameters (recall water treatment!): retention time (~2 hr), overflow rate

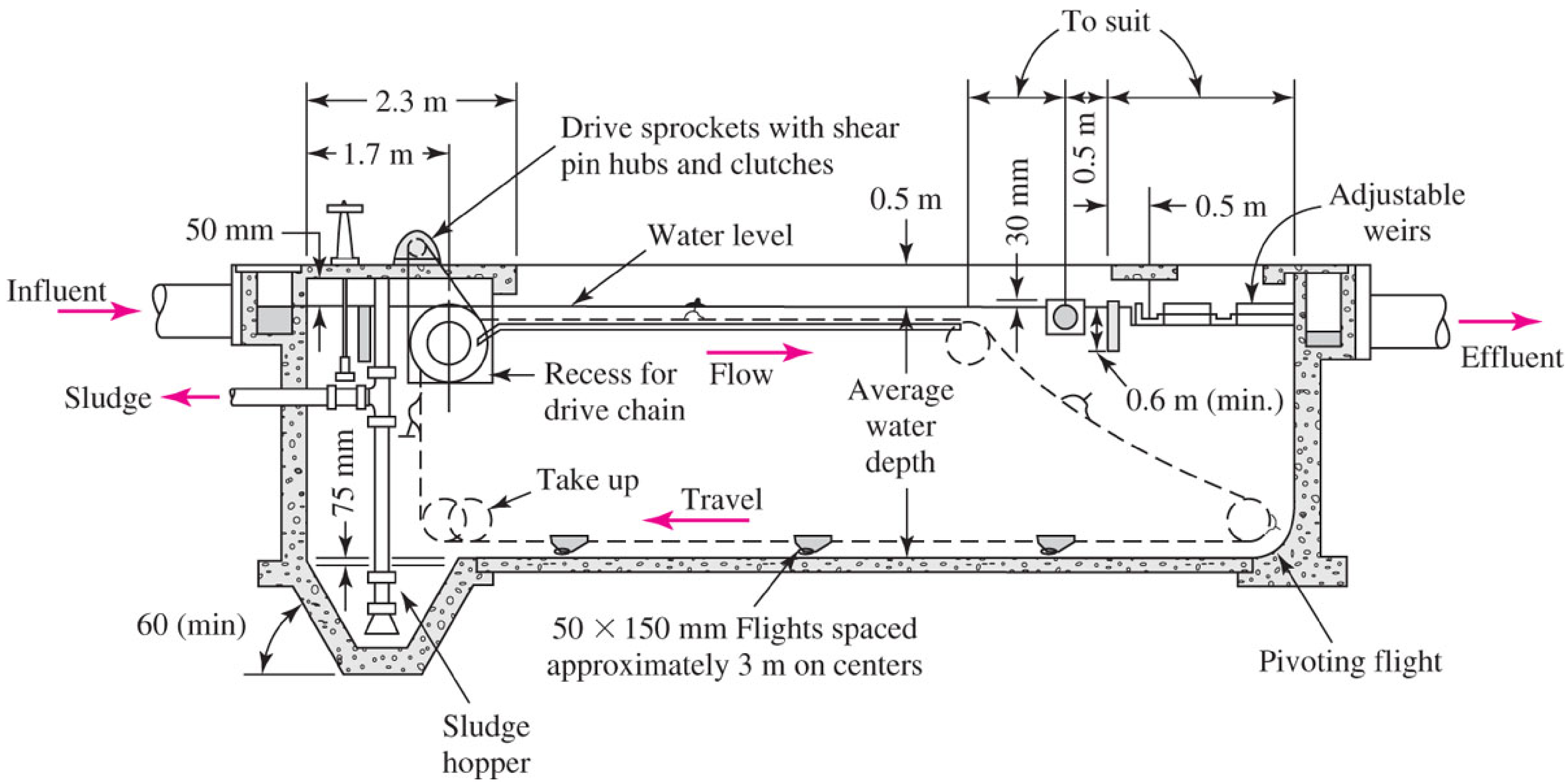
Primary sedimentation basins

- Rectangular or circular

http://www.mlive.com

http://www.lgam.info

Primary sedimentation basins



Secondary treatment

- Goal: provide BOD removal beyond what is achieved in primary treatment
  - Removal of soluble BOD
  - Additional removal of SS
- How??
  - Use microorganisms to convert organic wastes into stabilized compounds

  → Bring the naturally-occurring process (recall self-purification in streams) into an engineering setting, but creating more favorable condition such that things can occur much faster!

Favorable conditions for biodegradation

- 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

Dispersed vs. fixed growth

- Dispersed (suspended) growth
  - Activated sludge
  - Oxidation ponds

- Fixed (attached) growth
  - Trickling filters
  - Rotating biological contactors (RBCs)

Dispersed growth systems

- Activated sludge
  - Most common
  - Large plants

http://www.phlush.org

- Oxidation pond
  - For small communities
  - Low energy & maintenance cost

http://www.niwa.co.nz

Fixed growth systems

- Trickling filter
  - Water trickles through the porous media
- Rotating biological contactor
  - The water gets oxygen when exposed to the air

http://www.purewatergazette.net

http://www.sswm.info

Kinetics of microorganism growth

- Monod equation

$$\mu = \frac{1}{X}\frac{dX}{dt}\bigg|_{growth} = \frac{\mu_m S}{K_s + S} = \mu_m\left(\frac{S}{K_s + S}\right)$$

"saturation type" kinetics

μ = specific growth rate (d^{-1})

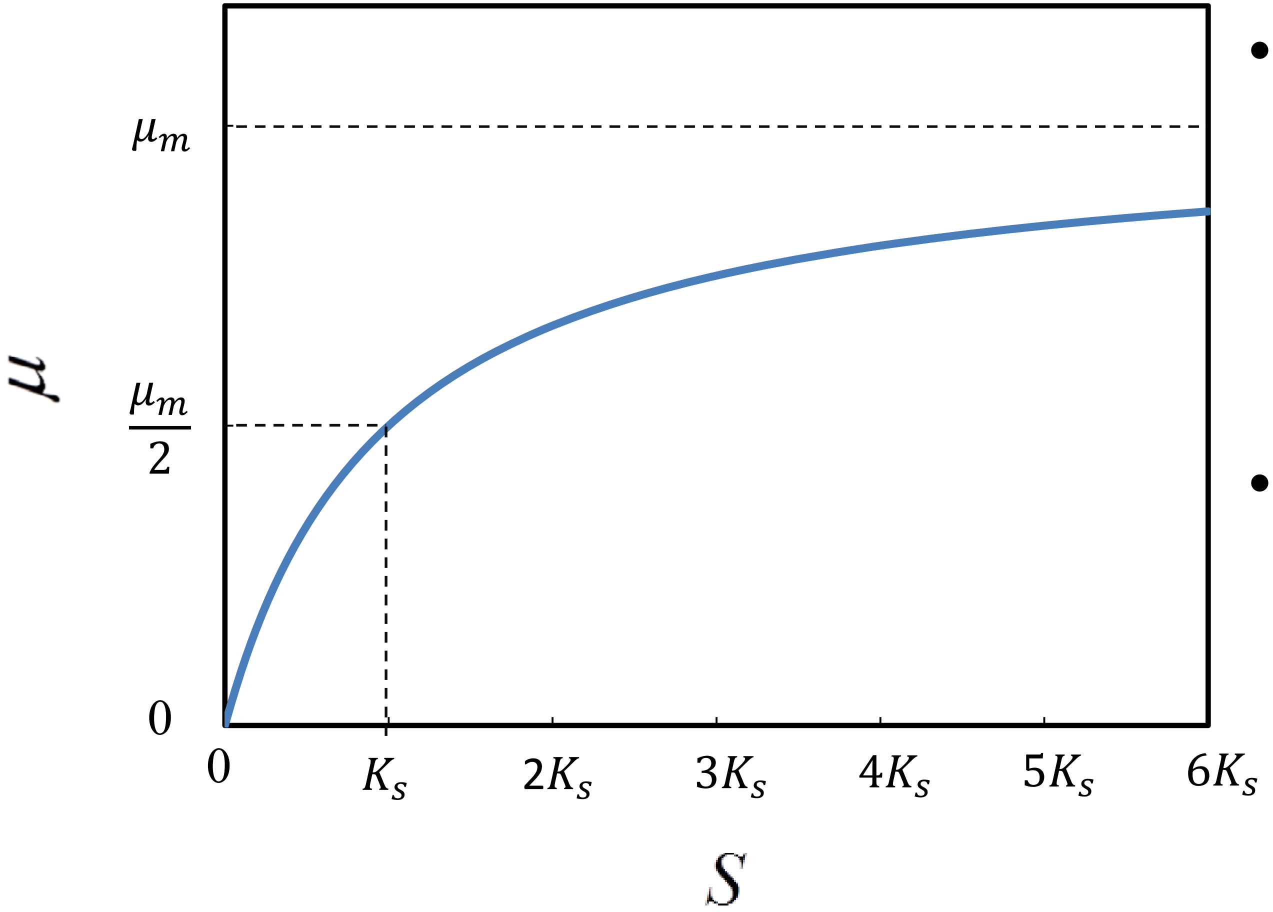
X = biomass concentration (mg/L)

μ_m = maximum specific growth rate (d^{-1})

S = food (substrate) concentration (mg/L)

K_s = half saturation constant (mg/L)

Kinetics of microorganism growth



- $S \gg K_s$: $\mu = \mu_m$ (maximum growth rate); the growth rate is independent of S
- $S \ll K_s$: limited food supply; the growth rate is proportional to S

Kinetics of microorganism growth

- Overall change in biomass concentration
  - Microorganisms not only grow, but also die or get eaten! (this is called "decay")

$$r_g = \frac{dX}{dt} = \frac{\mu_m S}{K_s + S} X - k_d X$$

growth *decay*

r_g = biomass growth rate (mg/L/d)
k_d = decay rate constant (d^{-1})

Kinetics of substrate degradation

- Substrate degradation rate
  - Microorganisms consume food (substrate) to grow
  - A fraction of the consumed food is converted to biomass (microorganisms are not 100% efficient!)

$$r_{su} = -\frac{dS}{dt} = \frac{1}{Y}\frac{\mu_m S}{K_s + S}X$$

r_{su} = substrate consumption rate (mg/L/d)

Y = yield coefficient (mg biomass/mg substrate)

Reading assignment

Textbook Ch 11 p. 519-537