

Wastewater Treatment Processes

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

Objective: To learn about processes used in wastewater treatment plant

Courtesy: Dr. Irene Xagorarakis, MSU, USA

Minor 1 copies

- Minor 1 copies next week Monday afternoon in different slots
- Slot timings will be emailed.

Characteristics of Domestic Wastewater

Typical Composition of Untreated Domestic Wastewater

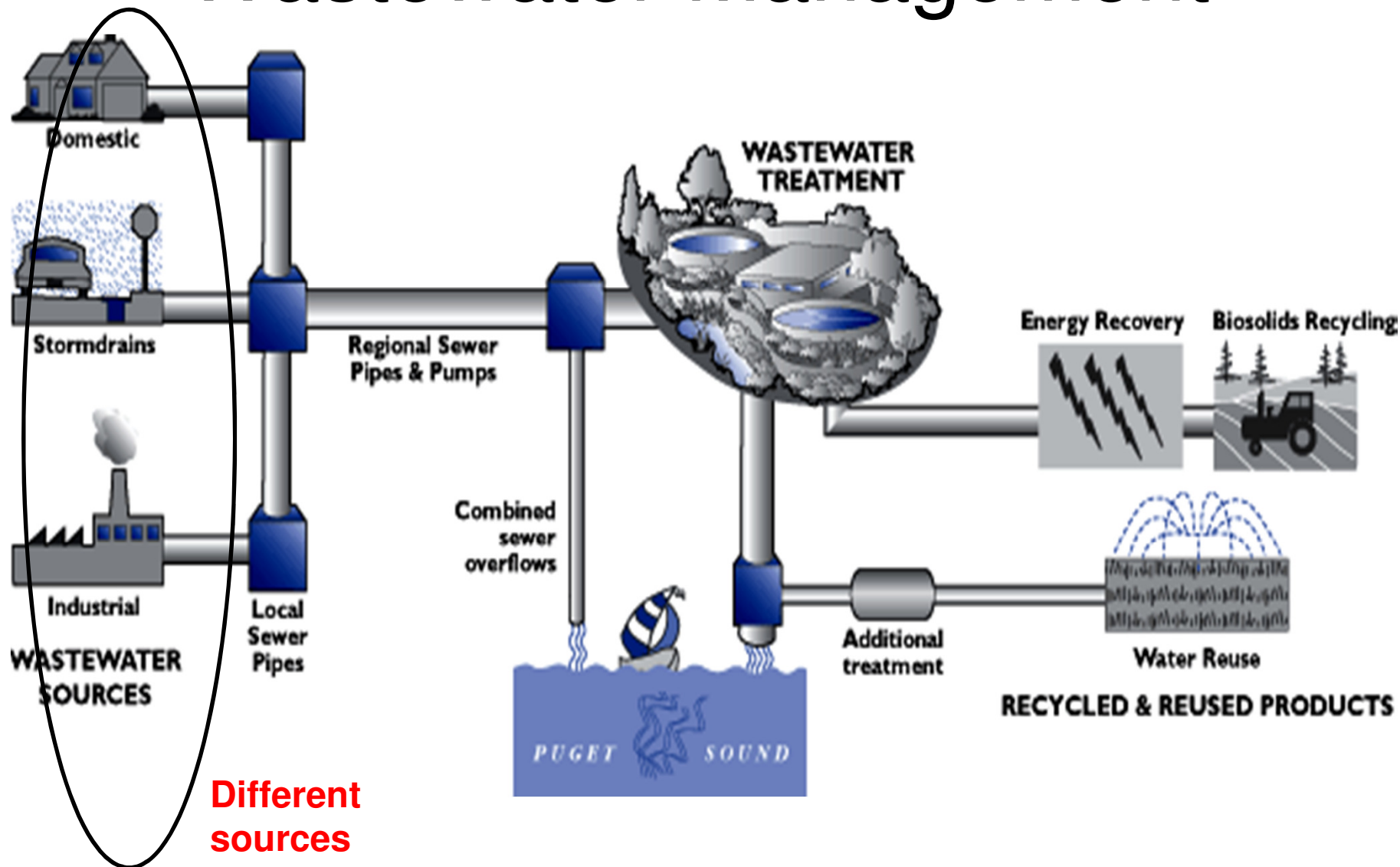
Constituent	Weak (all mg · L ⁻¹	Medium except settleable solids)	Strong
Alkalinity (as CaCO ₂) ^a	50	100	200
BOD ₅ (as O ₂)	100	200	300
Chloride	30	50	100
COD (as O ₂)	250	500	1000
Suspended solids (SS)	100	200	350
Settleable solids (in mL · L ⁻¹)	5	10	20
Total dissolved solids (TDS)	200	500	1000
Total Kjeldahl nitrogen (TKN) (as N)	20	40	80
Total organic carbon (TOC) (as C)	75	50	300
Total phosphorus (as P)	5	10	20

^aThis amount of alkalinity is the contribution from the waste. It is to be added to the naturally occurring alkalinity in the water supply. Chloride is exclusive of contribution from water-softener backwash.

Wastewater characteristics

- Compare wastewater (WW) characteristics of
 - Domestic WW
 - Industrial WW (for ex: tannery industry; distillery industry)

Wastewater Management

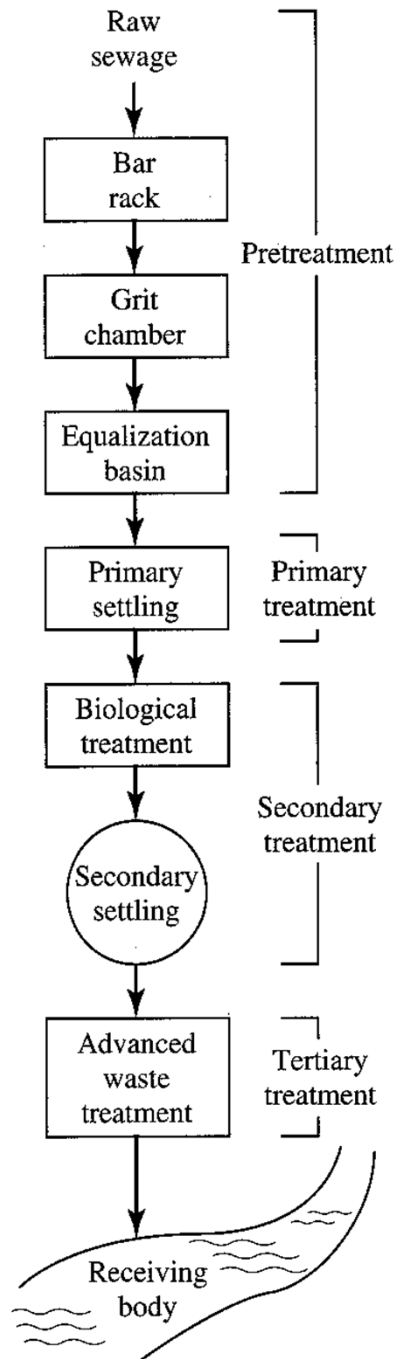


Wastewater Management



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Municipal Wastewater Treatment Systems



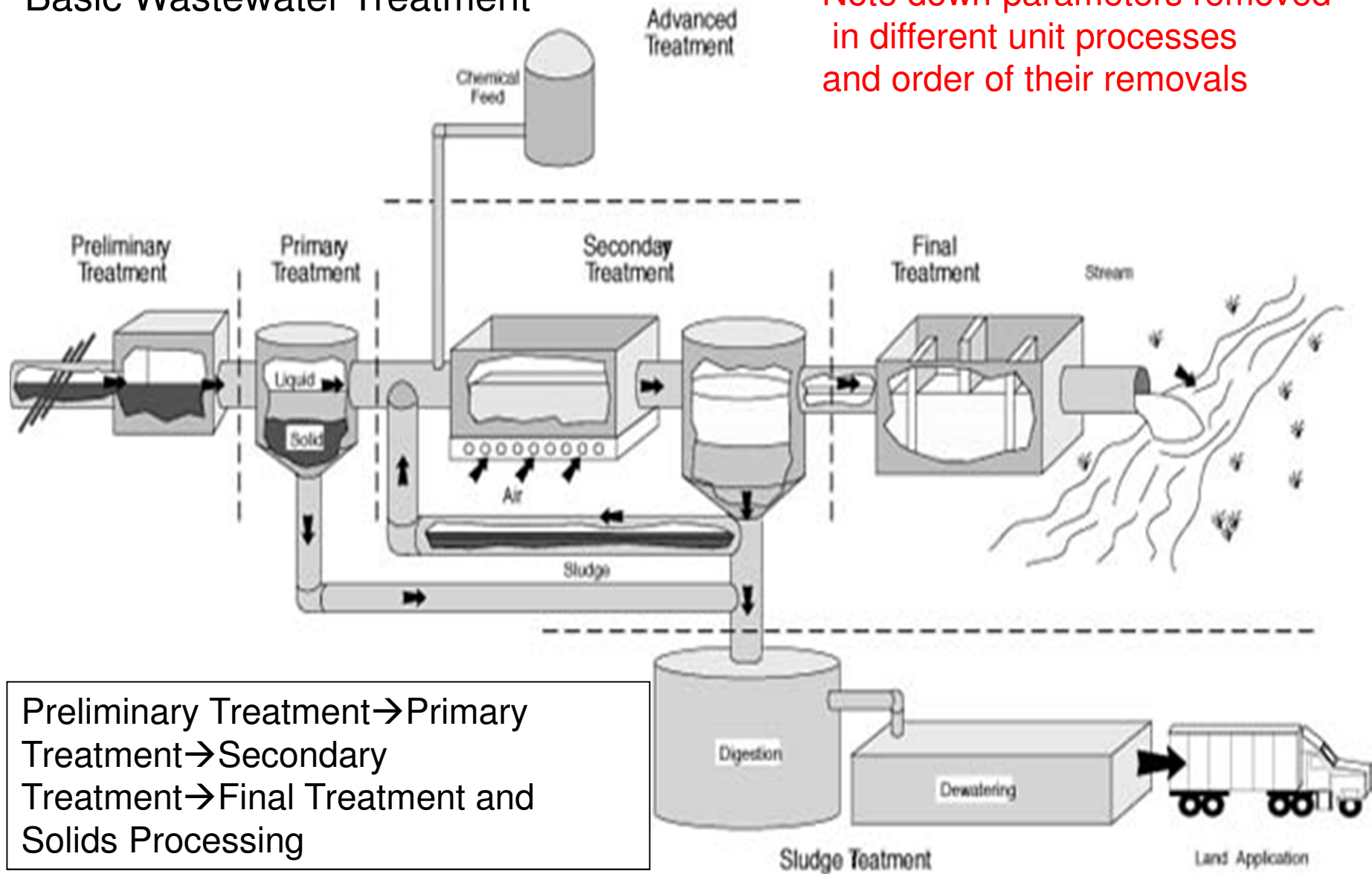
- **Preliminary treatment** (removes materials that can cause operational problems, equalization basins are optional)
- **Primary treatment** (remove ~60% of solids and ~35% of BOD)
- **Secondary treatment** (remove ~85% of BOD and solids)
- **Advanced treatment** (varies: 95+ % of BOD and solids, N, P)
- **Final Treatment** (disinfection)
- **Solids Processing** (sludge management)

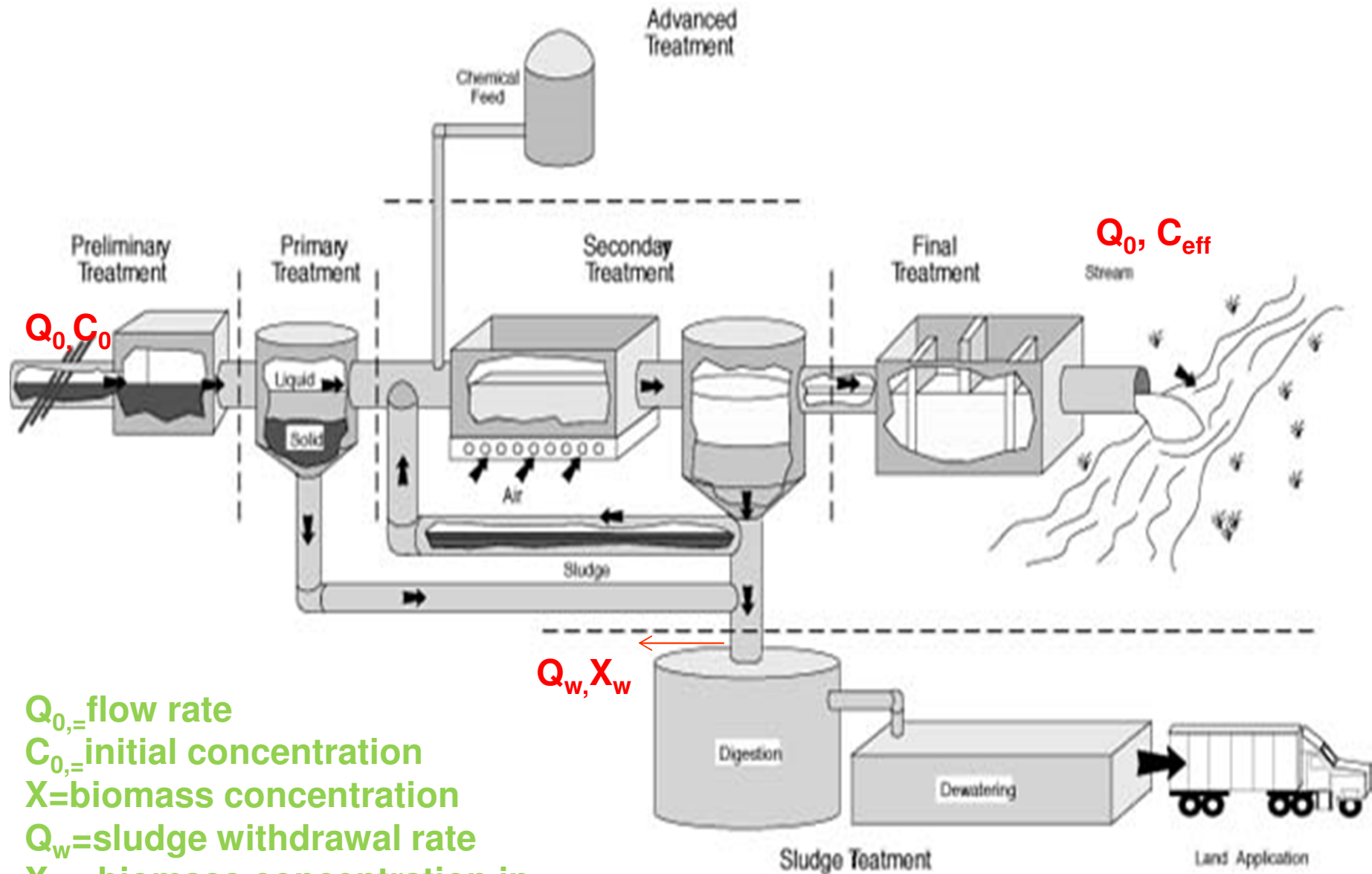
Pre-Treatment of Industrial Wastewaters

- Industrial wastewaters must be pretreated prior to being discharged to municipal sewer system
- Pretreatment requirements set by regulatory agencies
- Why: remove materials that will not be treated by municipal system, remove materials that inhibit the biological processes in secondary treatment
- For example: silver ions are toxic to bacteria which might affect biological process. Thus silver ions are removed at pre-treatment before biological process so that bacterial performance do not get affected.

Basic Wastewater Treatment

Note down parameters removed
in different unit processes
and order of their removals





Q_0 = flow rate

C_0 = initial concentration

X = biomass concentration

Q_w = sludge withdrawal rate

X_w = biomass concentration in secondary settling tank

Preliminary treatment

Upon arrival via the sewer system, the wastewater is sent through a bar screen, which removes large solid objects such as sticks and rags.

Leaving the bar screen, the wastewater flow is slowed down entering the grit tank, to allow sand, gravel and other heavy material that was small enough not to be caught by the bar screen to settle to the bottom. All the collected debris from the grit tank and bar screen is disposed of at a sanitary landfill.

Primary treatment

Primary treatment is the second step in wastewater treatment. It allows for the physical separation of solids and greases from the wastewater. The screened wastewater flows into a primary settling tank where it is held for several hours allowing solid particles to settle to the bottom of the tank and oils and greases to float to the top.

Secondary treatment

-biological treatment process that removes dissolved organic material from wastewater. The partially treated wastewater from the settling tank flows by gravity into an aeration tank.

-mixing of water to solids containing that use oxygen to consume the remaining organic matter in the wastewater as their food supply (use of air bubble for mixing and oxygen supply)

-liquid mixture (i.e., solids with micro-organisms and water) is sent to the final clarifier.

-In clarifier, solids settle out to the bottom where some of the material is sent to the solids handling process and some is recycled back to replenish the population of micro-organisms in the aeration tank to treat incoming wastewater.

Final treatment

Treated water is disinfected and then it is send out for wastewater reuse activities or for discharging in river/streams. mostly chlorination and/or ultra violet irradiation is used for disinfection purposes.


Solids processing

The primary solids from the primary settling tank and the secondary solids from the clarifier are sent to a digester. Micro-organisms use the organic material present in the solids as a food source and convert it to by-products such as methane gas and water.

Digestion results in a 90% reduction in pathogens and the production of a wet soil-like material called “**biosolids**” that contain 95-97% water.

In order to remove some of this water, mechanical equipment such as filter presses or centrifuges are used to squeeze water from the biosolids to reduce the volume prior to being **sent to landfill, incinerated or beneficially used as a fertilizer or soil amendment.**

Wastewater Treatment

- Preliminary Treatment (screening) 
- Primary Treatment (primary settling)
- Secondary Treatment (e.g. activated sludge)
- Advanced Treatment (e.g. P removal)
- Final Treatment (disinfection)
- Solids Processing (sludge treatment)

Bar racks

- Purpose: remove larger objects
- Solid material stored in hopper and sent to landfill
- Mechanically or manually cleaned

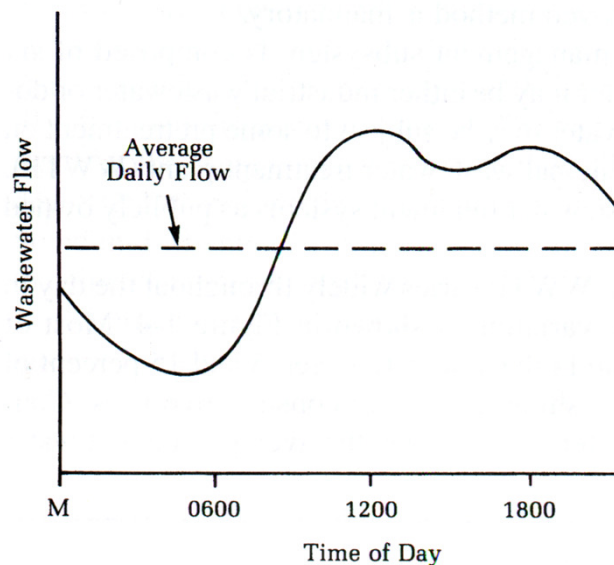


Grit Chambers

- Purpose: remove inert dense material, such as sand, broken glass, silt and pebbles
- Avoid abrasion of pumps and other mechanical devices
- Material is called “grit”




Equalization Basins



- Wastewater flow has daily fluctuations
- Purpose: To dampen the variation in wastewater flow into a WWTP
- Flow equalization is not a treatment process
- Improves effectiveness of primary & secondary treatment
- Usually achieved by large basins to collect wastewater and pumped to treatment plant at a constant rate
- Adequate aeration and mixing need to be provided to prevent odors and deposition of solids

Wastewater Treatment

- Preliminary Treatment (screening)
- Primary Treatment (primary settling) 
- Secondary Treatment (e.g. activated sludge)
- Advanced Treatment (e.g. P removal)
- Tertiary Treatment (disinfection)
- Solids Processing (sludge treatment)

Primary Treatment (settling)

- Primary treatment separates suspended solids and greases from wastewater. Wastewater is held in a tank for several hours allowing the particles to settle to the bottom and the greases to float to the top.
- The solids drawn off the bottom and skimmed off the top receive further treatment as sludge. The clarified wastewater flows on to the next stage of wastewater treatment.

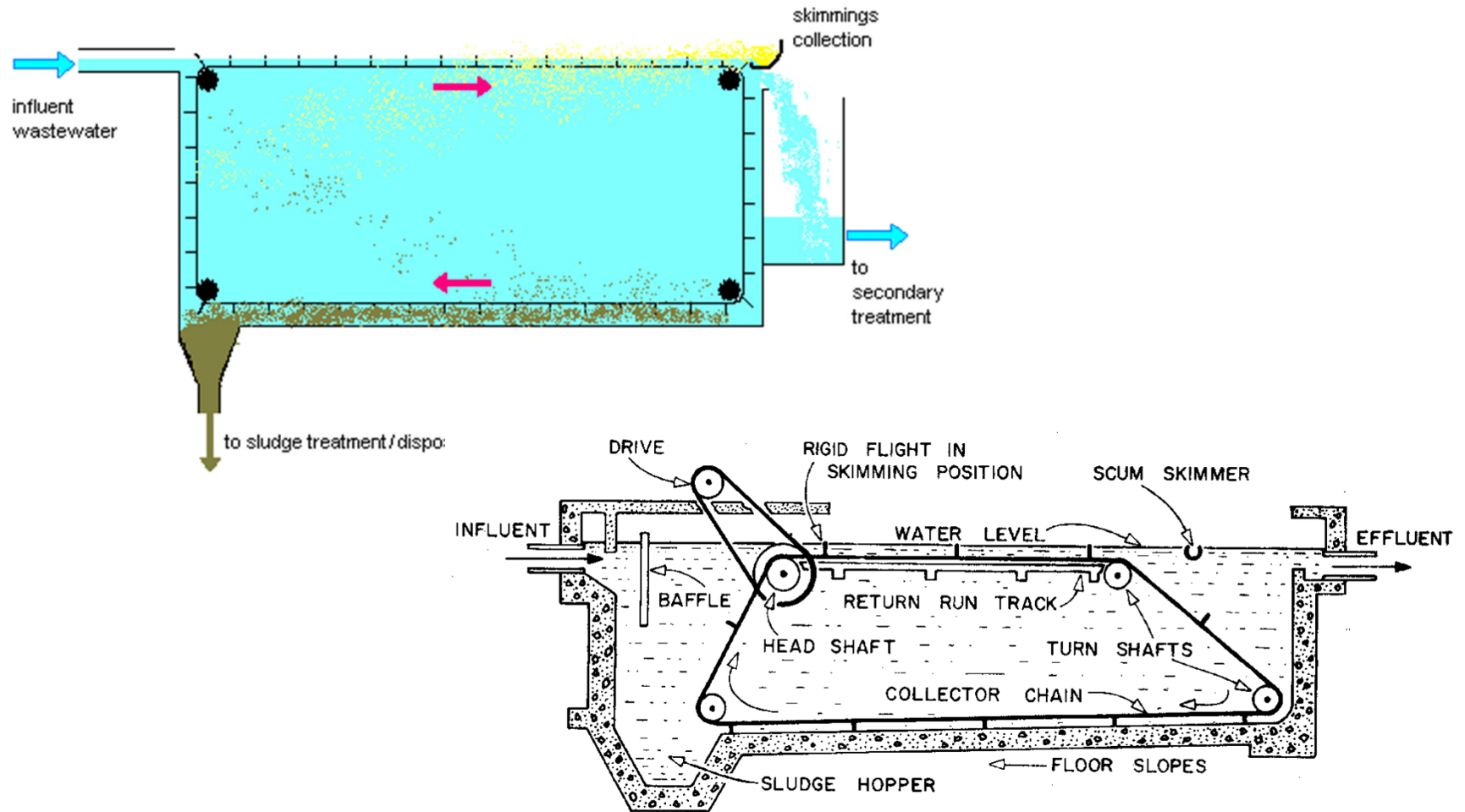
Settling/Sedimentation

- Solid liquid separation process in which a suspension is separated into two phases –
 - Clarified supernatant leaving the top of the sedimentation tank (overflow).
 - Concentrated sludge leaving the bottom of the sedimentation tank (underflow).
- **Purpose of Settling**
 - To remove coarse dispersed phase.
 - To remove coagulated and flocculated impurities.
 - To remove precipitated impurities after chemical treatment.
 - To settle the sludge (biomass) after activated sludge process / tricking filters

Some basic definitions

- ***Sedimentation***, also known as *settling*, may be defined as the removal of solid particles from a suspension by settling under gravity.
- ***Clarification*** is a similar term, which usually refers specifically to the function of a sedimentation tank in removing suspended matter from the water to give a clarified effluent. In a broader sense, clarification could include flotation and filtration.
- ***Thickening*** in sedimentation tanks is the process whereby the settled impurities are concentrated and compacted on the floor of the tank and in the sludge-collecting hoppers.
- Concentrated impurities withdrawn from the bottom of sedimentation tanks are called ***sludge***, while material that floats to the top of the tank is called *scum*.

Primary Settling Basin



Primary Settling Basins



Primary Settling Tank Design Example

- Size:
 - rectangular: 3-24 m wide x 15-100 m long
 - circular: 3-90 m diameter
- Detention time: 1.5-2.5 hours
- Overflow rate: 25-60 m³/m²·day
- Typical removal efficiencies:
 - solids: 50-60%
 - BOD₅: 30-35%

Example 1

Question: A rectangular primary clarifier (2.4 m deep & 4.0 m wide) is designed to settle a flow of 2000 m³/day and have an overflow rate of 32 m³/m².day

- I) How long should it be?
- II) What detention time will it have?

Example 1

I) Length:

$$\text{Overflow rate} = \frac{\text{flow rate}}{\text{area}} = \frac{2000 \frac{\text{m}^3}{\text{day}}}{4 \text{ m} \times \text{Length}} = 32 \frac{\text{m}^3}{\text{m}^2 \cdot \text{day}}$$


Solve for length:

$$\text{Length} = \frac{2000}{4 \times 32} = 15.6 \text{ m}$$

II) Detention time:

$$\text{Detention time} = \frac{\text{volume}}{\text{flow rate}} = \frac{2.4 \text{ m} \times 4 \text{ m} \times 15.6 \text{ m}}{2000 \frac{\text{m}^3}{\text{day}} \times \frac{\text{day}}{24 \text{ hr}}} = 1.8 \text{ hr}$$

Wastewater Treatment

- Preliminary Treatment (screening)
- Primary Treatment (primary settling)
- Secondary Treatment (e.g. activated sludge) 
- Advanced Treatment (e.g. P removal)
- Final Treatment (disinfection)
- Solids Processing (sludge treatment)

Secondary Treatment

- Secondary treatment is a **biological treatment process** that removes dissolved organic matter from wastewater.
- Sewage microorganisms are cultivated and added to the wastewater. The **microorganisms use organic matter from sewage as their food supply**. This process leads to decomposition or biodegradation of organic wastes.

Secondary Treatment

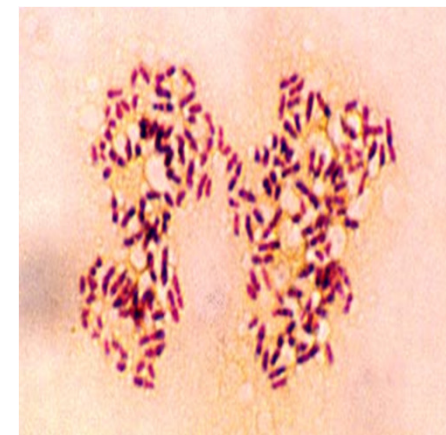
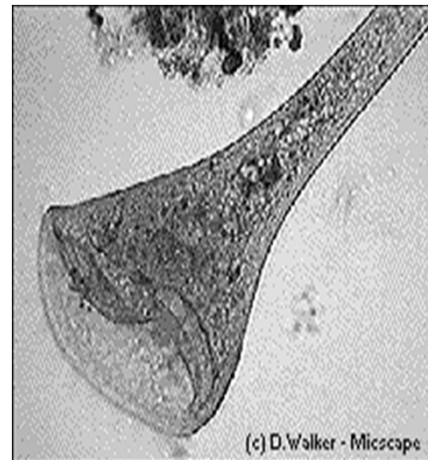
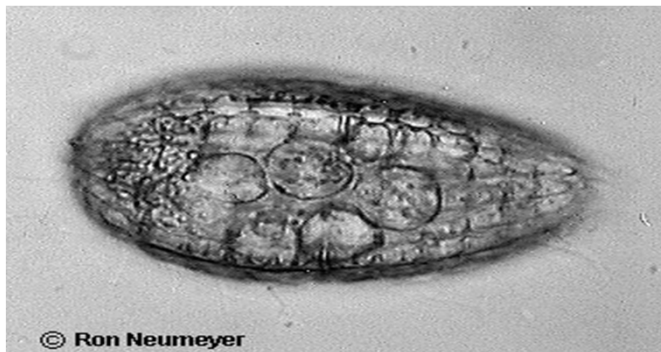
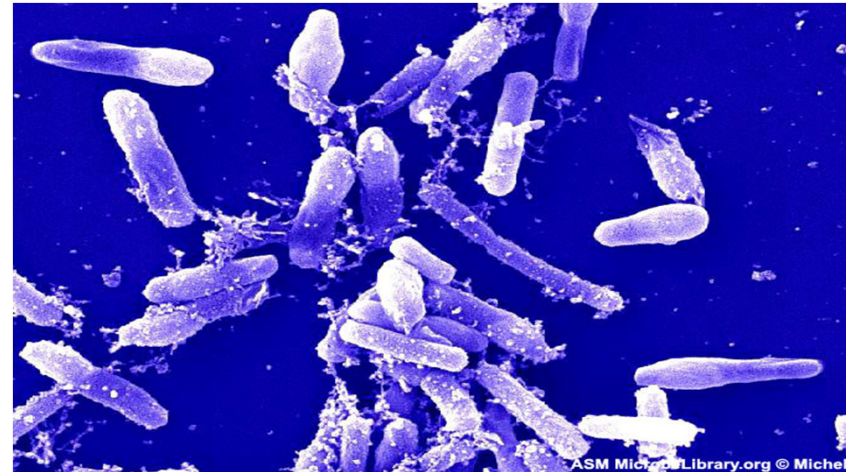
- Basic approach is to use aerobic biological degradation:



- Objective is to allow the BOD to be exerted in the treatment plant rather than in the stream

How is this accomplished?

Create a very rich environment for growth of a diverse microbial community



Basic Ingredients

- High density of microorganisms (keep organisms in system)
- Good contact between organisms and wastes (provide mixing)
- Provide high levels of oxygen (aeration)
- Favorable temperature, pH, nutrients (design and operation)
- No toxic chemicals present (control industrial inputs)

Dispersed (suspended) growth vs Fixed growth

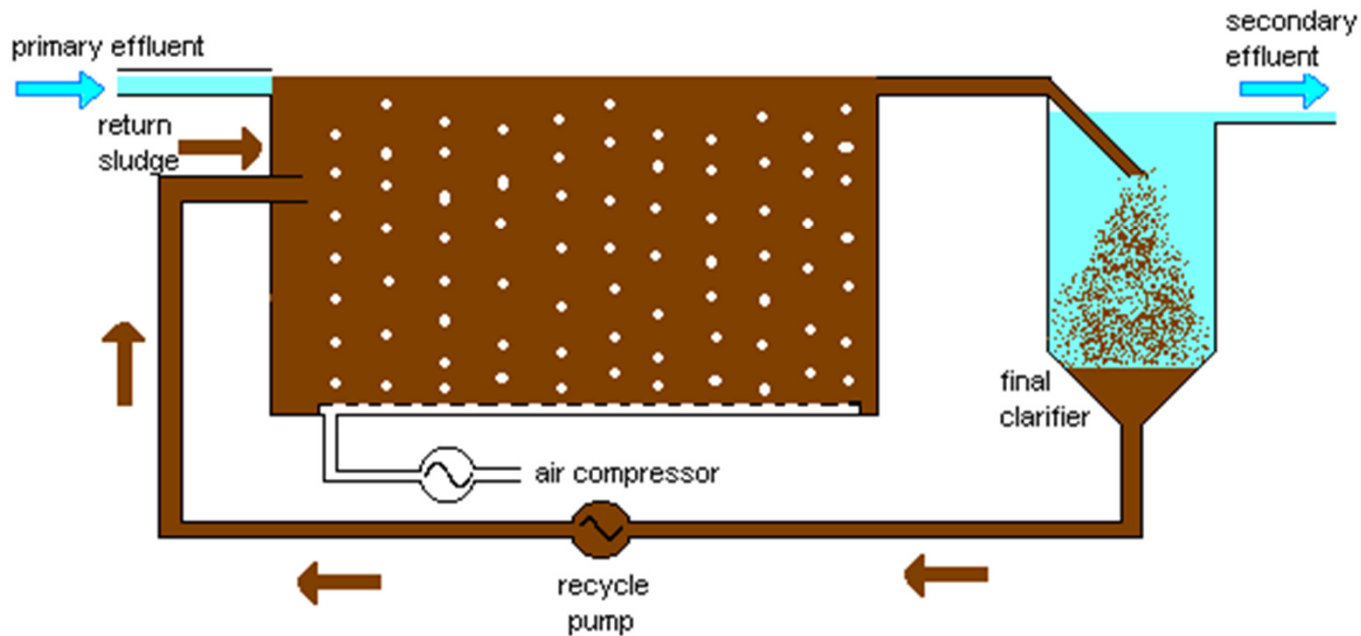
- Two approaches of secondary treatment
 - fixed film, and suspended film systems
- Dispersed Growth (suspended organisms)
 - Activated sludge
 - Oxidation ditches/ponds
 - Aerated lagoons, stabilization ponds
- Fixed Growth (attached organisms)
 - Trickling filters
 - Rotating Biological Contactors

Activated Sludge

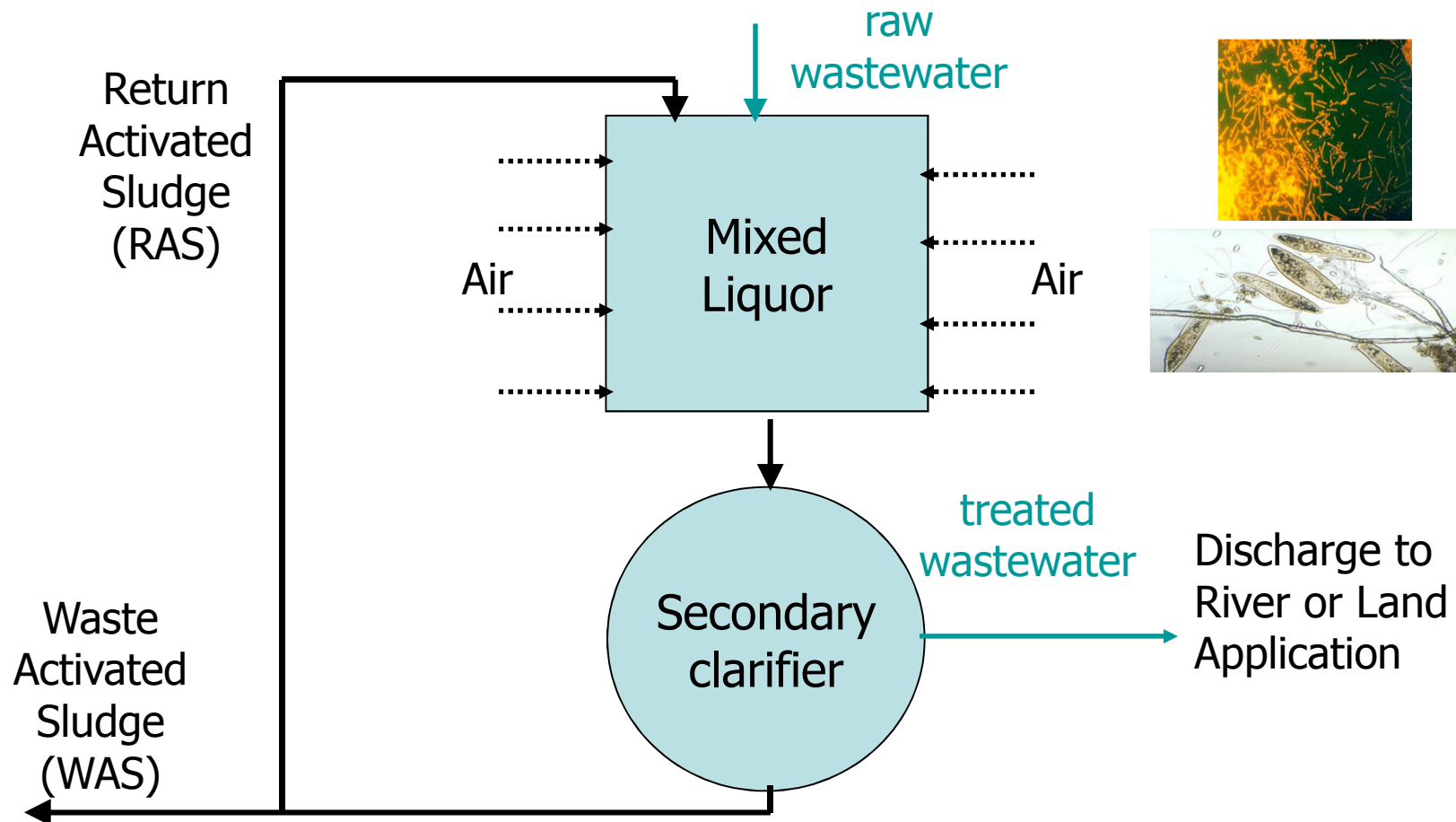
- Process in which a mixture of wastewater and microorganisms is agitated and aerated
- Leads to oxidation of dissolved organics
- After oxidation, separate sludge (mostly microbial cells, water, and other contaminants) from wastewater
- Induce microbial growth
 - Need food, oxygen
 - Want Mixed Liquor Suspended Solids (MLSS) of 3,000 to 6,000 mg/L

Activated Sludge Process

Activated Sludge Process



Activated Sludge Process



Activated Sludge Process with secondary clarifier



East Lansing WWTP



East Lansing WWTP

F/M Parameter

- Low F/M (low rate of wasting)
 - starved organisms
 - more complete degradation
 - larger, more costly aeration tanks
 - more O₂ required
 - higher power costs (to supply O₂)
 - less sludge to handle
- High F/M (high rate of wasting)
 - organisms are saturated with food
 - low treatment efficiency

Activated Sludge Design

- Detention time: t_d = approximately 6 - 8 hr
- Long rectangular aeration basins
- Air is injected near bottom of aeration tanks through system of diffusers
- Aeration system used to provide mixing
- MLVSS and F/M controlled by wasting a portion of microorganisms

Other options

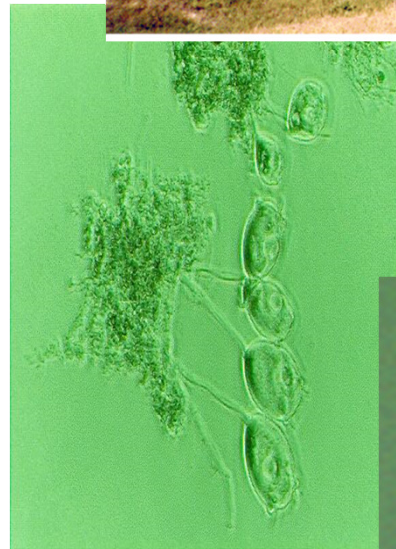
Low-tech solutions

- Aerobic ponds
- Facultative ponds
- Anaerobic ponds



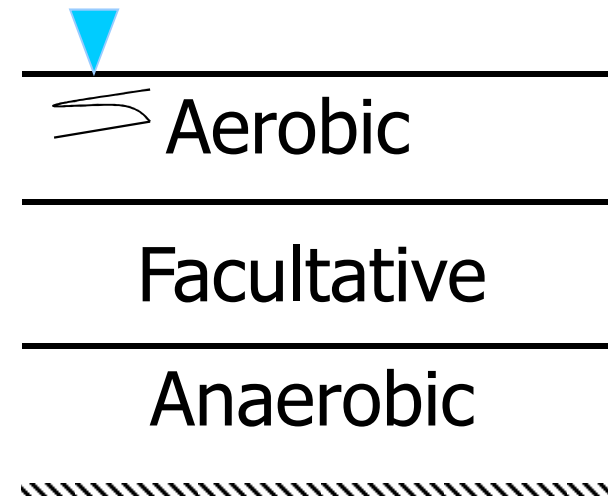
1. Aerobic ponds

- Shallow ponds (<1 m deep)
- Light penetrates to bottom
- Active algal photosynthesis
- Organic matter converted to CO_2 , NO_3^- , HSO_4^- , HPO_4^{2-} , etc.



2. Facultative ponds

- ponds 1 - 2.5 m deep
- $t_d = 30 - 180$ d
- not easily subject to upsets due to fluctuations in Q , loading
- low capital, O&M costs



3. Anaerobic Ponds

- Primarily used as a pretreatment process for high strength, high temperature wastes
- Can handle much high loadings
- 2 stage:
 - Acid fermentation: Organics \rightarrow Org. acids
 - Methane fermentation Org. Acids \rightarrow CH_4 and CO_2

Example 1: Performance of a “AA” WWTP

(Grit chamber → PST → Activated sludge unit → SST → Nitrification unit → Effluent)

Typical Composition of Untreated Domestic Wastewater

Constituent	Weak (all mg · L ⁻¹ except settleable solids)	Medium	Strong
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Performance in a “AA” WWTP

Influent flow rate	1 MLD (million liters per day)
Influent parameters	Take highest value of parameters from previous slide
Remaining Suspended solids after primary sedimentation tank	100 mg/L (inf: 300mg/L)
remaining BOD5 after primary sedimentation tank	250mg/L(inf: 350mg/L)
BOD5 after activated sludge process	100mg/L
TKN after biological nitrification process	50 mg/L as N(inf: 80mg/L)

Question: Find out efficiency of different unit processes;
remaining conc. Of different parameters?

Is it meeting the standards of river?

How much is sludge generation? What information are required?

Performance in a “AA” WWTP

Influent flow rate	1 MLD (million liters per day)
Influent parameters	Take highest value of parameters from previous slide
Removal Suspended solids after primary sedimentation tank	$=((350-100)/350)*100$
Removal BOD5 after primary sedimentation tank	$=(300-250)*100/300$
Removal of BOD5 after activated sludge process	$=(250-100)*100/250$
Removal of TKN after biological nitrification process	??
Conc. Of bacteria in SST	10000mg/L
Sludge withdrawal rate from SST	0.1MLD

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