ENVIRONMENTAL ENGINEERING

Chapter 4 : Waste Water Treatment (Part 1)

Primary Treatment

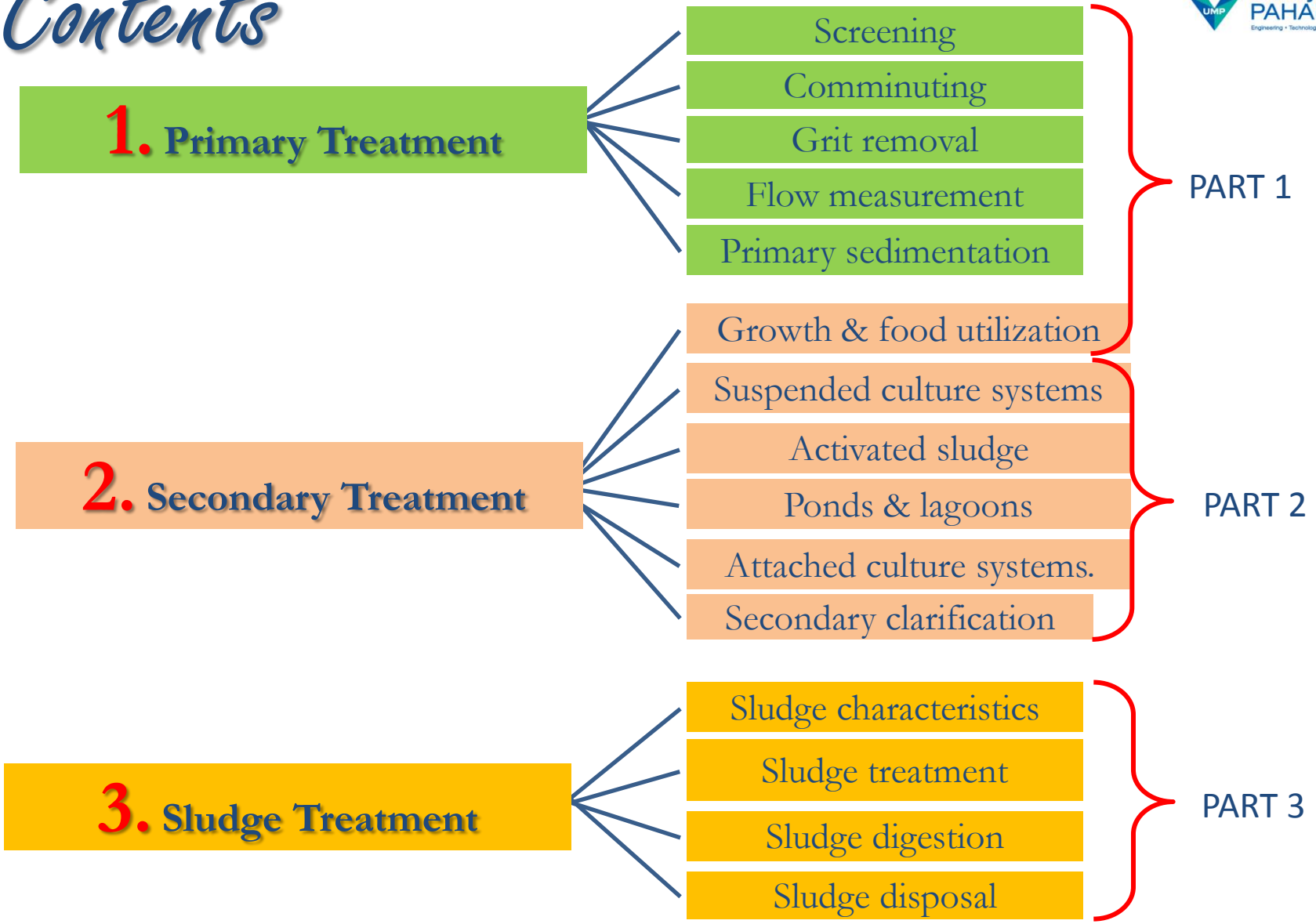
by
Siti Hajar Noor
Faculty of Chemical & Natural Resources Engineering
hajarnoor@ump.edu.my

Chapter Description

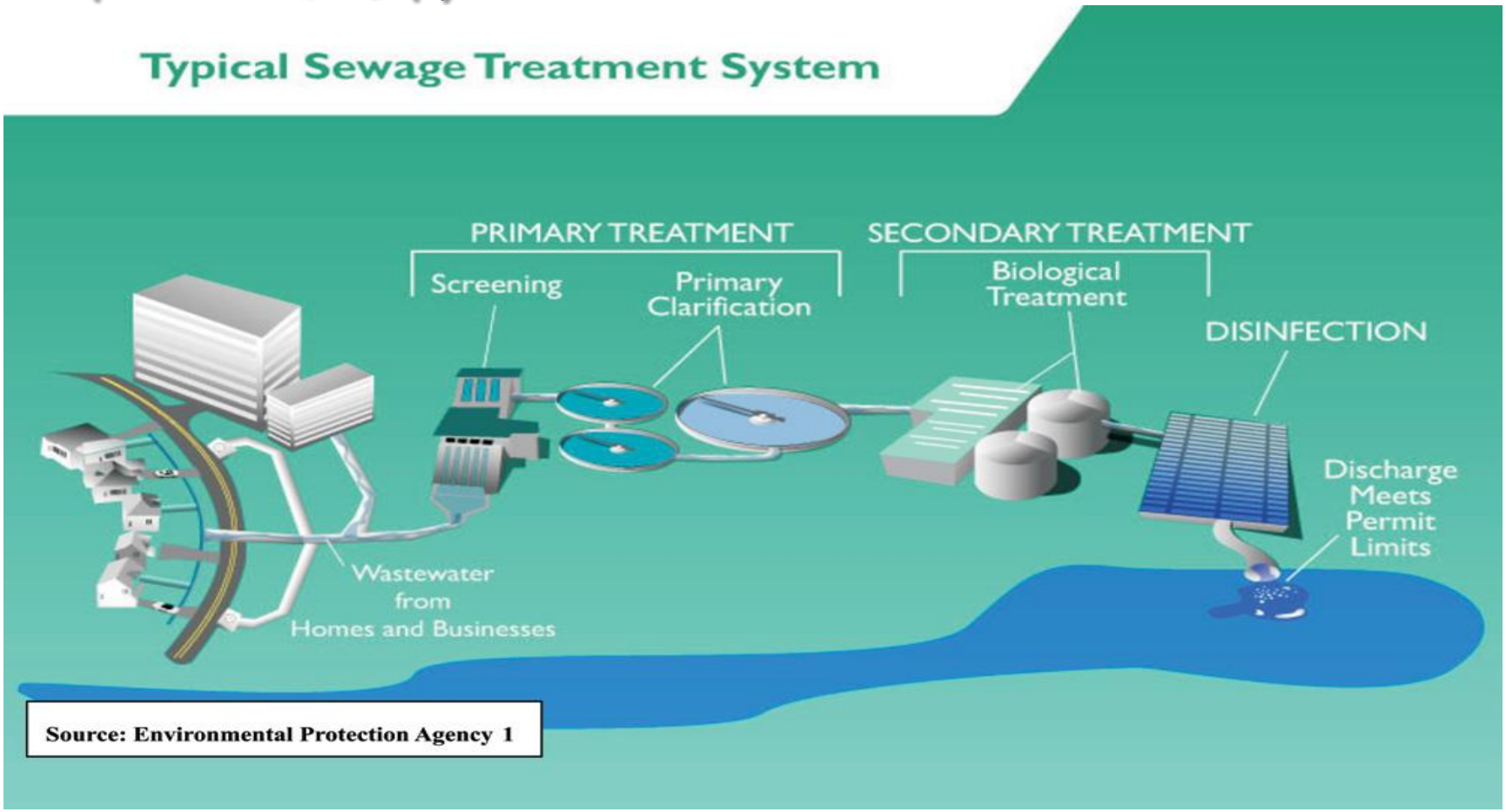
- Topic
  - Primary treatment
- Expected Outcomes
  - Classify the treatment processes involved in wastewater treatment
  - Interpret the concept in wastewater treatment which consists of primary, secondary, sludge and advance treatment
- References

  - Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1985.
  - Mackenze, I.D., Introduction to Environmental Engineering, 4th Edition, Davis A. Cornell, Mc Graw Hill, 2008.
  - Sawyer, C.N. Chemistry for Environmental Engineerin. 4th Edition, McGraw Hill, 1994.
  - Martin, T.A. and David, W.H. Fundamental of Environmental Engineering. 2003.
  - Environmental Quality Act 1974 (Subsidiary Legislation), International Law Book, Service June 2002.

Contents



Where does the water go when it goes down the drain?



Source:http://www.waternews.ir/wp-content/uploads/2015/07/treatment_process1_lg.jpg

Engineered Systems For Wastewater Treatment and Disposal

Primary Treatment	• to remove solid materials from incoming wastewater.
Secondary Treatment	• consists of biological conversion of dissolved and colloidal organics into biomass that can subsequently be remove by sedimentation.
Sludge Treatment	• Concentrate impurities into solid form and separate it from bulk liquid.

Wastewater Characteristics

- To design a treatment process properly, characterization of wastewater is perhaps the most critical step.
- Usually classified as industrial wastewater or municipal wastewater
- Wastewater treatment system – composed of a combination of unit operation (contaminant removal by physical forces) and unit processes (involve biological and/or chemical reaction) designed to reduce certain constituents of wastewater to an acceptable level

Table 5-1: Important wastewater contaminants

Contaminant	Source	Environmental significance
1. Suspended solid	Domestic use, industrial wastes, erosion by infiltration/inflow.	Cause sludge deposits & anaerobic conditions in aquatic environment.
2. Biodegradable organics	Domestic & industrial wastes.	Cause biological degradation, which may use up O_2 in receiving water & result in undesirable conditions.
3. Pathogens	Domestic waste	Transmit communicable diseases.
4. Nutrients	Domestic & industrial waste	May cause eutrophication
5. Refractory organics	Industrial waste	May cause taste & odor problems may be toxic or carcinogenic
6. Heavy metals	Industrial waste, mining, etc.	Are toxic, may interfere with effluent reuse
7. Dissolved inorganic solids	Increases above level in water supply by domestic and/or industrial use.	May interfere with effluent reuse.

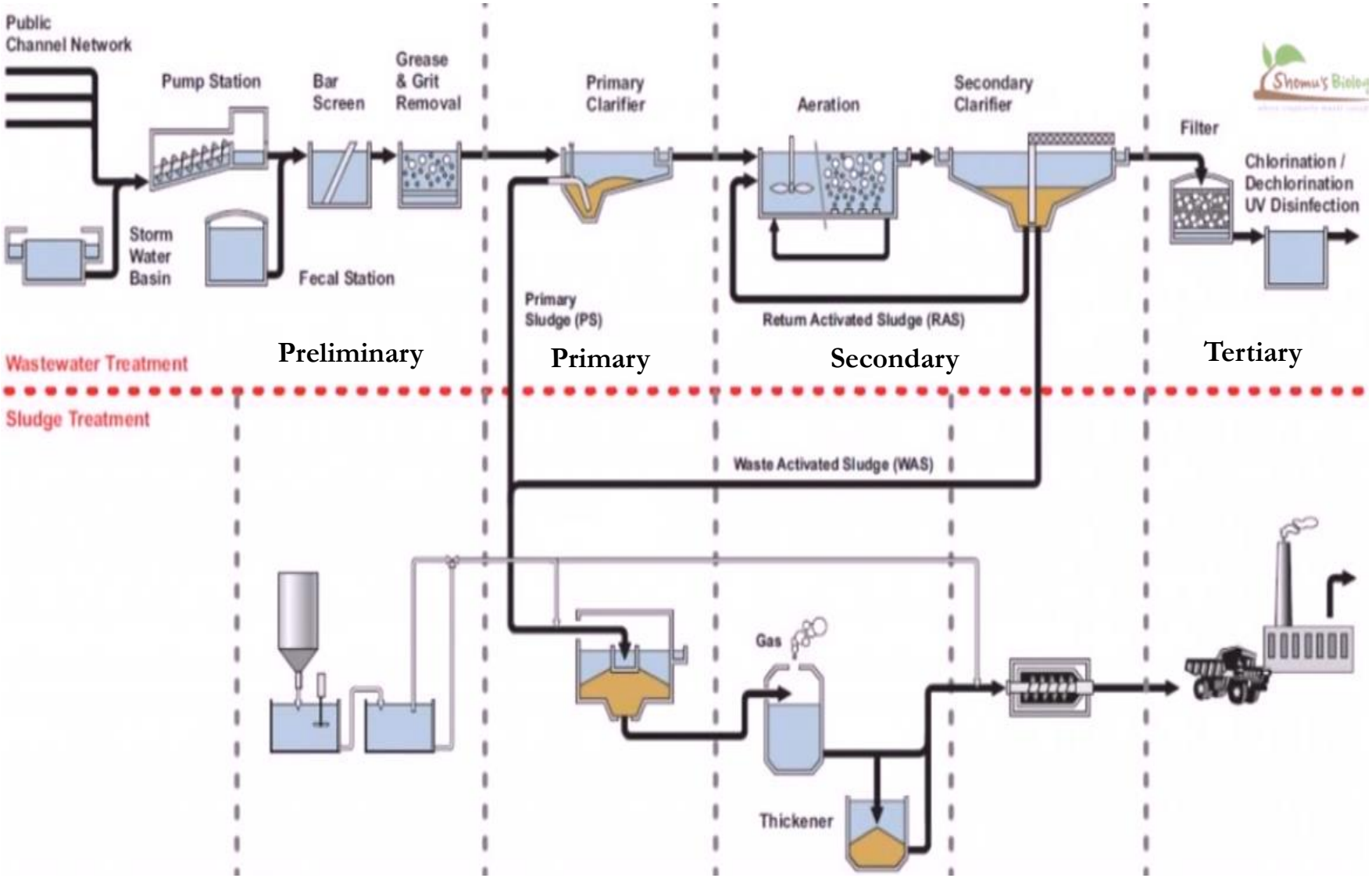
Terminology in Wastewater Treatment

Unit Operations	• Contaminants removal by physical forces.
Unit Processes	• Biological/chemical reaction.
Reactor	• Vessel, where unit operation/processes took place.
Wastewater Treatment System	• Combination of unit processes and operations.
Primary Treatment	• Remove solid materials from incoming wastewater.
Secondary Treatment	• Consist of biological conversion of dissolved & colloidal organics into biomass.
Tertiary Treatment	• Further removal of suspended solids & nutrients.

Table 5-3: Unit operations, unit processes, & systems for wastewater treatment.

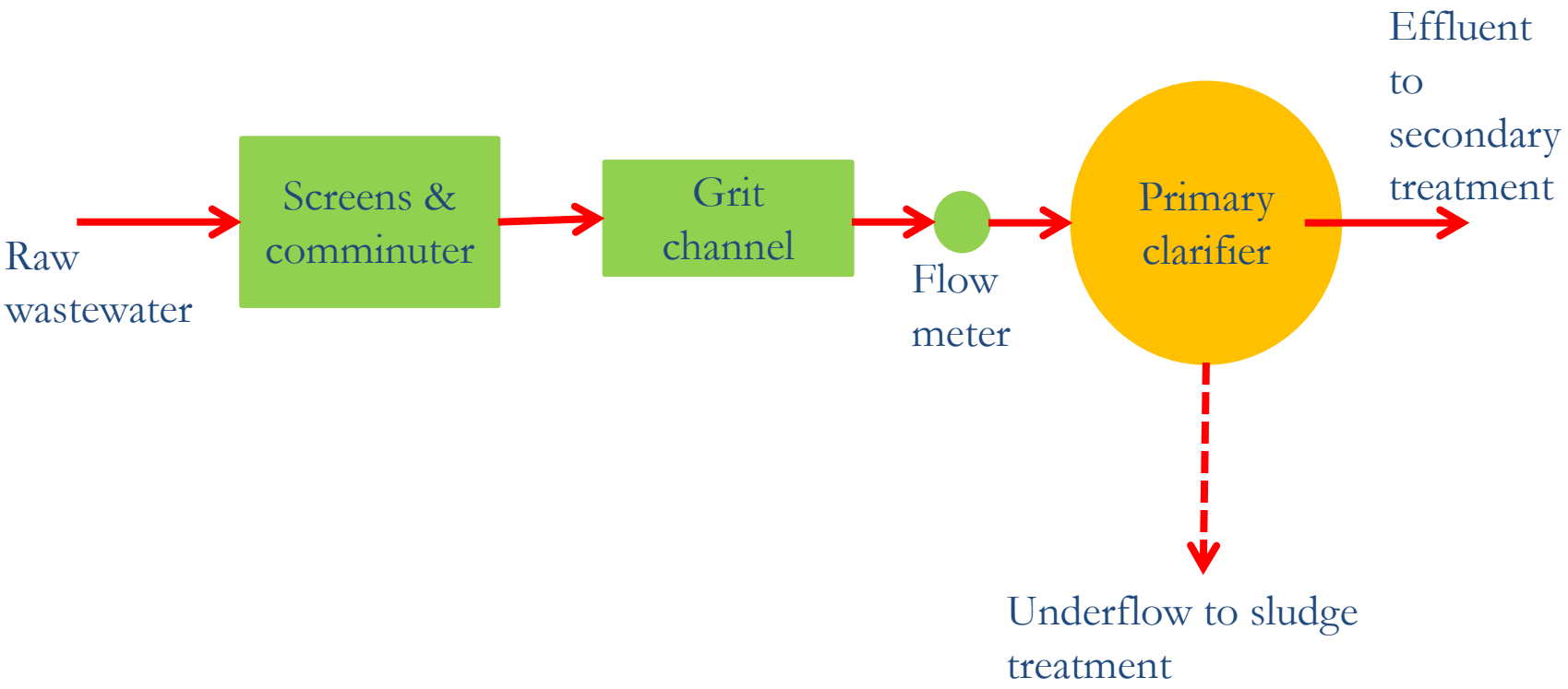
Contaminant	Unit operation, unit process, or treatment system
1. Suspended solids	Sedimentation, Screening & comminution, filtration variations, flotation, chemical-polymer addition, coagulation/ sedimentation, land treatment systems
2. Biodegradable organics	Activated-sludge variations, fixed film: trickling filters, rotating biological contactors, lagoon & oxidation pond variations, intermittent sand filtration, land treatment systems, physical-chemical system.
3. Pathogens	Chlorination. Hypochlorination,. Ozonation, land treatment systems.
4. Nutrients: (a) Nitrogen. (b) Phosphorus	 Suspended growth nitrification & denitrification variations, Fixed film nitrification & denitrification variations, ammonia stripping, ion exchange, break point chlorination, land treatment systems. Metal-salt addition, lime coagulation/ sedimentation, biological-chemical phosphorus removal, land treatment systems.
5. Refractory organics	Carbon adsorption , tertiary ozonation, land treatment systems.
6. Heavy metals	Chemical precipitation, ion exchange, land treatment systems
7. Dissolved inorganic solids	Ion exchange, reverse osmosis, electrodialysis.

Wastewater Treatment Overview



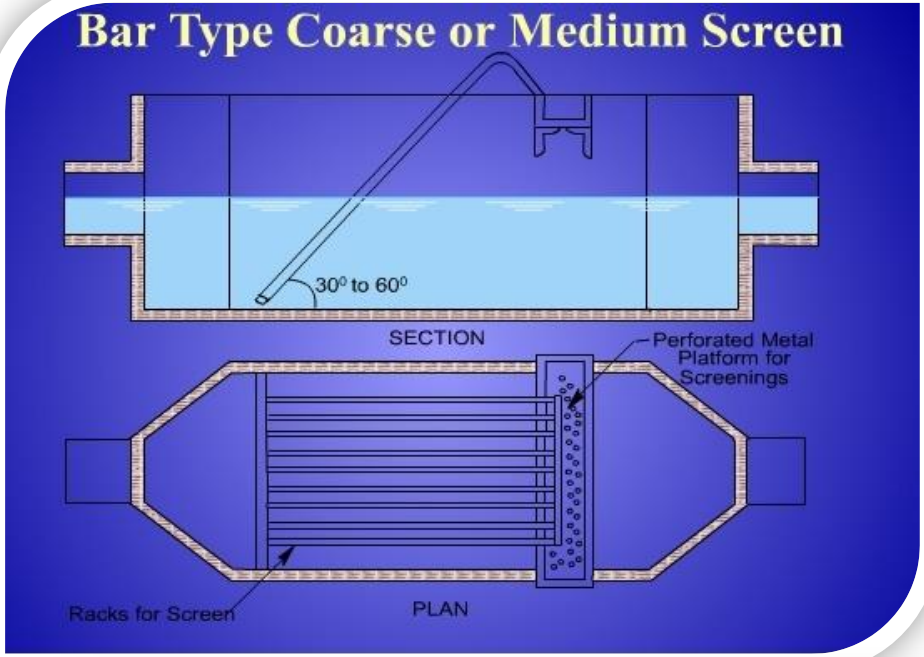
PRIMARY TREATMENT

Typical Primary Treatment



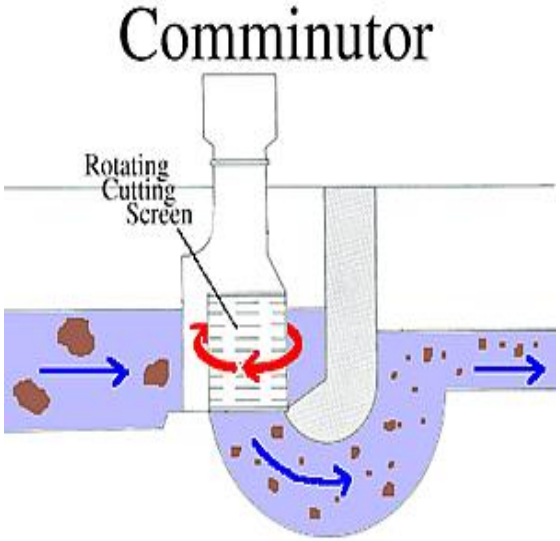
1- Screening

- Purpose – remove coarse solids from wastewater, first operation (prevent blockage).
- Device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.
- Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows



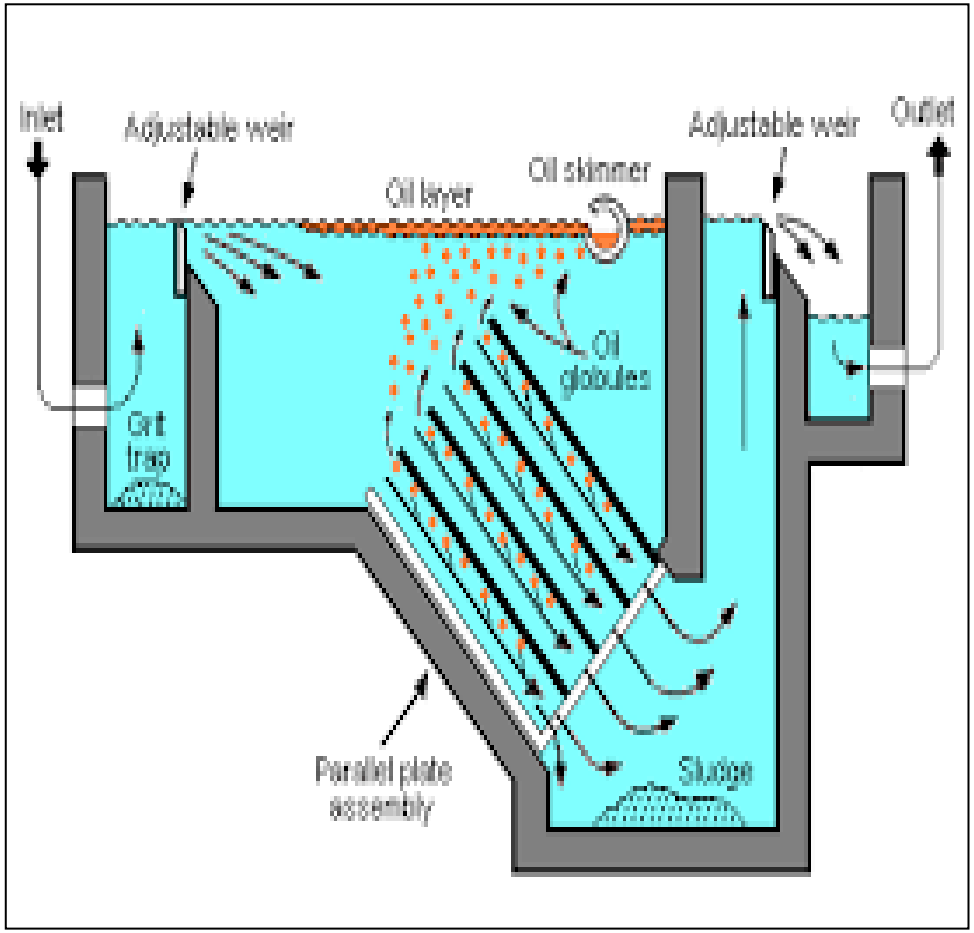
2- Comminuting

- Shredding device, intercept the coarse solid and shred.
- Basic part – screen & cutting teeth
- High cost



3- Grit removal

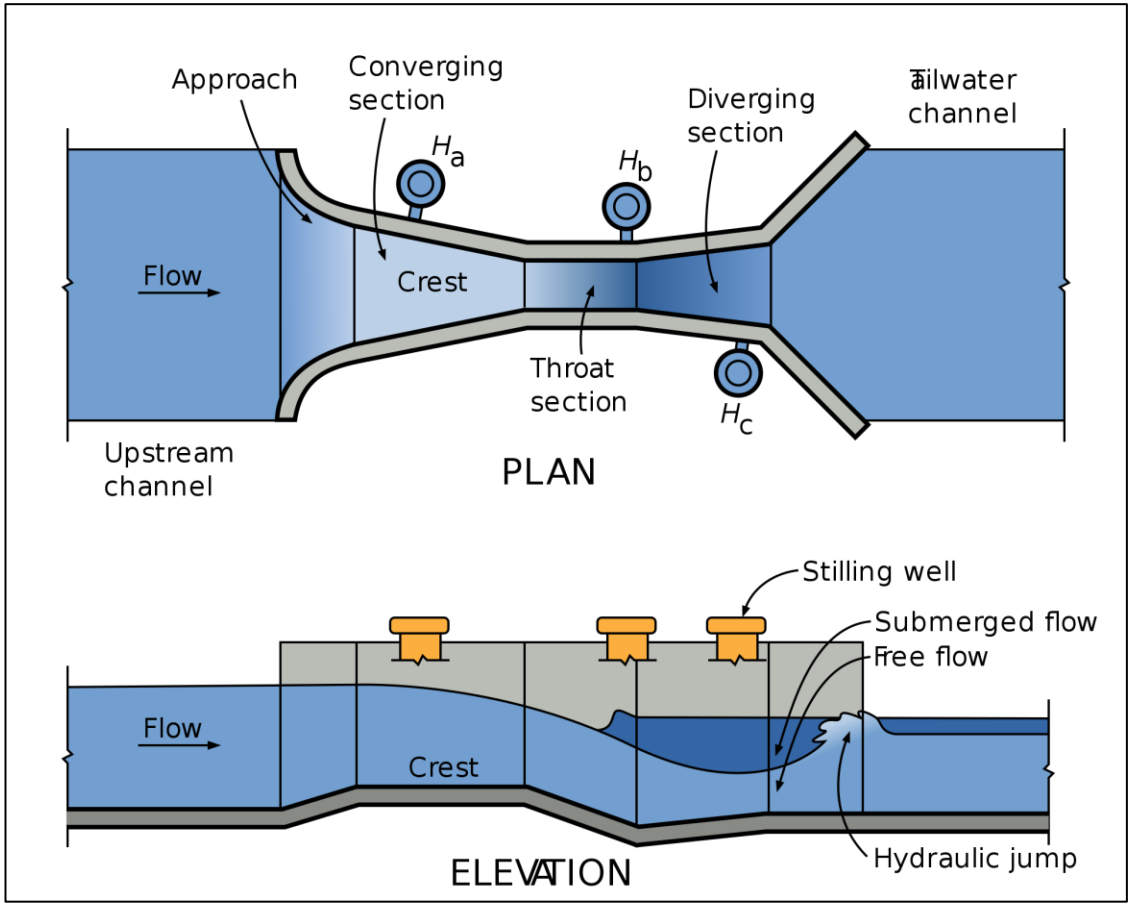
- Compose of inorganic solids and heavy organic
- Consists of enlarged channel area to reduced flow velocities so grit will settle.
- Deposited grit removal by mechanical scrapper.
- Remove type 1 settling (discrete particles).
- Grit chambers: basin to remove the inorganic particles to prevent damage to the pumps, and to prevent their accumulation in sludge digestors.



Souce:https://www.google.com.my/imgres?imgurl=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F2%2F20%2FParallel_Plate_Separator.png&imgrefurl=https%3A%2F%2Fcommons.

4- Flow Measurement

- Hydraulic loading rates.
- Measuring flow-Parshal flumes & Palmer-Bowlus flumes.
- Application – chemical additives, air volume, recirculation rates depends on hydraulic flow rate.
- Record of flows should be kept to establish trends in flow quantities to estimate future capacity needs



Source:https://upload.wikimedia.org/wikipedia/commons/thumb/d/d8/Parshall_Flume.svg/2000px-Parshall_Flume.svg.png

5- Primary sedimentation

- Designed to concentrate and remove suspended organic solids from the waste water.
- Suspended solids in wastewater are sticky & flocculate naturally, settling operations as type-2 settling (flocculating particles).
- Primary sedimentation in a municipal wastewater treatment plant is generally plain sedimentation without the use of chemicals
- It constitutes ***flocculent settling***, and the particles do not remain discrete as in the case of grit, but tend to agglomerate or coagulate during settling.
- Effect secondary wastewater-treatment unit.
- Accomplish by long-rectangular tanks or circular tanks.

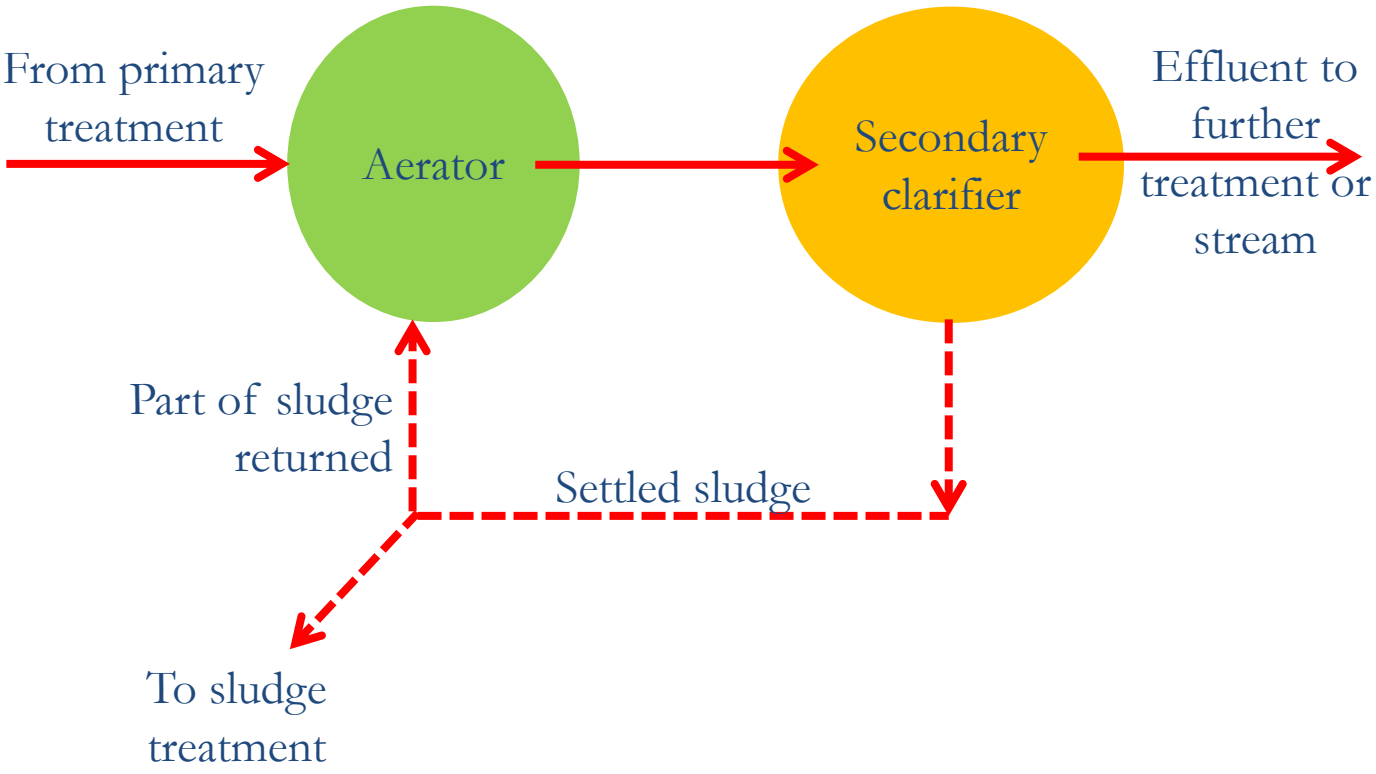
Source:http://s0.geograph.org.uk/geophotos/01/48/19/1481916_deed4570.jpg

SECONDARY TREATMENT

SECONDARY TREATMENT

- The effluent from primary treatment still contains 40-50 % of the original suspended solids.
- **Combinations of chemical-physical processes:**
  - coagulation, microscreening, filtration, chemical oxidation, carbon adsorption, etc. can be used to remove solids & reduce BOD to an acceptable level.
  - High cost – not commonly used.
- **Biological processes:**
  - Microorganisms use the organics in wastewater as food supply and convert them into biological cells, or biomass.
  - Because wastewater contains a wide variety of organics, a wide variety of organisms is required for complete treatment.
  - Practically used.

Typical Secondary Treatment



SECONDARY TREATMENT

1. Growth and food utilization
2. Suspended culture systems
3. Activated sludge
4. Ponds and lagoons
5. Attached culture systems
6. Secondary clarification

1- Growth & Food Utilization

- Biomass – microorganism use organic in wastewater & convert to biological cells.
- Lag phase – acclimation period*.
- Log growth phase – maximum growth.
- Stationary phase – production of new cellular material offset.
- Endogenous phase – biomass slowly decrease.

*Acclimatization is the process in which an individual organism adjusts to a gradual change in its environment, allowing it to maintain performance across a range of environmental conditions.

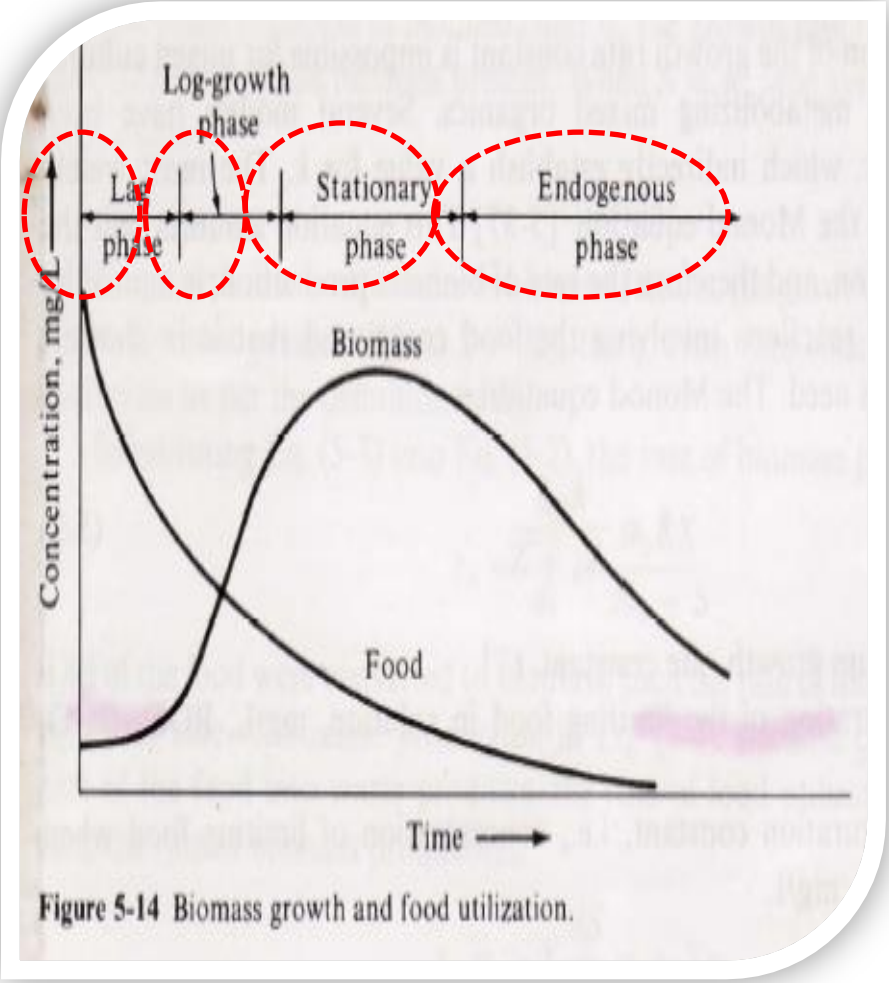


Figure 5-14 Biomass growth and food utilization.

In the log-growth phase, the biomass increases according to:

$$\frac{dX}{dt} = kX$$

dX/dt = the growth rate of the biomass (mg/L.t)

X = the concentration of biomass (mg/L)

k = the growth rate constant, t^{-1}

Monod equation:

$$k = \frac{k_0 S}{K_s + S}$$

k_0 = maximum growth rate constant, t^{-1}

S= concentration of the limiting food in solution, mg/L, BOD, COD or total organic carbon (TOC).

K_s = half saturation constant

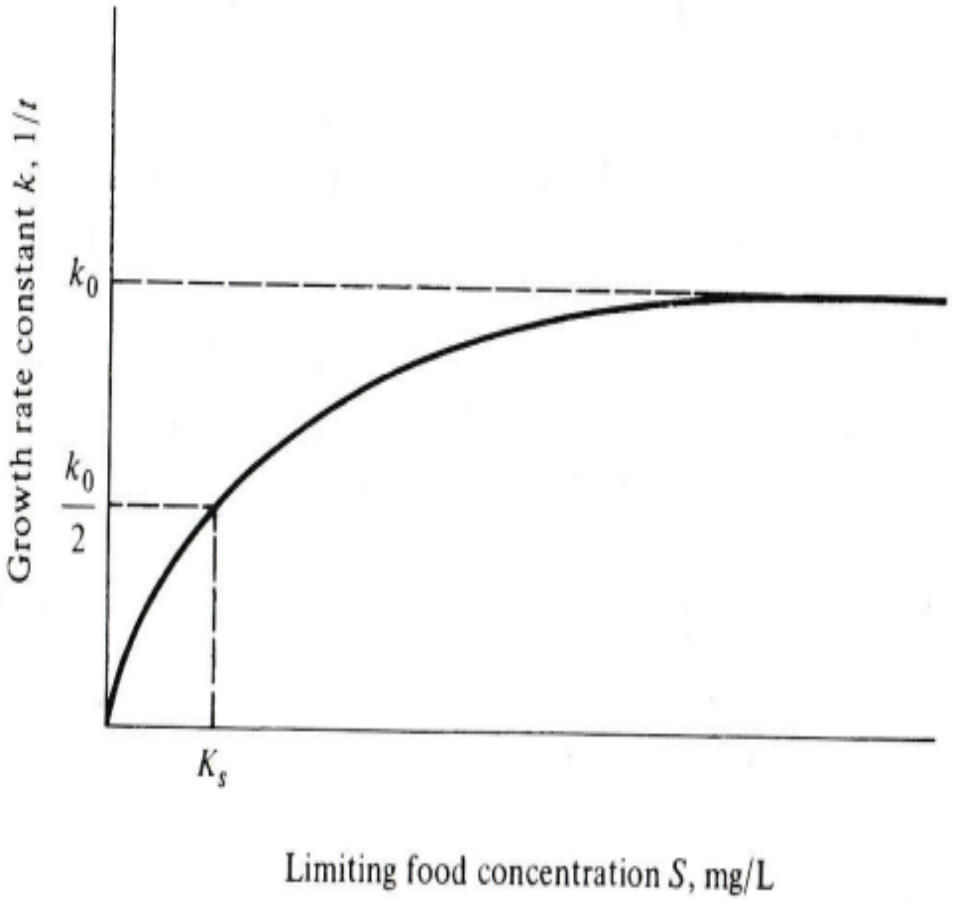


Figure 5-15 Monod growth rate constant as a function of limiting food concentration.

- When $S<K_s$ – system is food-lin $r_x = constant$
- When $S = K_s$, the growth rate constant, $k = \frac{1}{2}k_0$
- Y = decim $r_s = -\frac{r_x}{Y} = -\frac{k_0 SX}{Y(K_s + S)}$ biomass:

  =

  $\frac{mg/L\ biomass}{mg/L\ food\ utilized}$

r_s = dS/dt = rate of food utilization
Y (aerobic) = 0.4- 0.8 kg biomass/kg BOD_5
Y (anaerobic) = 0.08 to 0.2 kg biomass/kg BOD_5

- **External factor affect the rate of biomass production & food utilization:**
  a) Temperature.
  b) pH.
  c) Toxin.

- **Factors affecting biomass growth:**
  a) Toxicants (poison the microorganism).
  b) Salt concentration (interfere with internal-external pressure).
  c) Oxidants (destroy enzyme & cell materials).

- **Reactors may contain:**
  a) Suspended culture – microorganism suspended in the wastewater either single or cluster cells called flocs.
  b) Surrounded by wastewater which contains their food.
  c) Attached cultures – masses of organism adhered to inert surface.
  d) Wastewater passing over the microbial film.

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

To be continued….

Author Information

Credit to the author: Dr Norhanimah Hamidi