CE 370

Biological Processes

1

Outline

- Objectives of Biological Treatment
- Role of Microorganisms in Treatment
- Types of Biological Processes
  - Suspended Growth Processes
    - Activated sludge
    - Stabilization ponds
- Attached Growth Processes
    - Trickling filters
    - Rotating biological contactors
- Biological Kinetics

2

Objectives of Biological Treatment

- For domestic wastewater, the main objectives are:
  - Transform (oxidize) dissolved and particulate biodegradable constituents into acceptable by-products
  - Capture and incorporate suspended and nonsettleable colloidal solids into a biological floc or biofilm
  - Transform or remove nutrients, such as nitrogen and phosphorous
  - Remove specific trace organic constituents and compounds

3

Objectives of Biological Treatment

- For industrial wastewater, the main objectives is:
  - Remove or reduce the concentration of organic and inorganic compounds
- Pre-treatment of industrial wastewater may be required due to presence of toxicants before being discharged to sewer line.
- For agricultural wastewater, the main objective is:
  - Remove nutrients, such as N and P, that stimulate the growth of aquatic life

4

Role of Microorganisms

- Microorganisms (principally bacteria) oxidize dissolved and particulate carbonaceous organic matter into simple end-products

$$Organic + O_2 + NH_3 + PO_4^{3-} \xrightarrow{microorganisms} CO_2 + H_2O + new\,cells$$

- O_2, NH_3, and PO_4^{3-} are required as nutrients for the conversion of organic matter to simple products
- Microorganisms are required to carryout the conversion

5

Role of Microorganisms

- Ammonia can be oxidized by specific microorganisms (nitrification) to nitrite (NO_2^-) and nitrate (NO_3^-)
- Other bacteria can reduce oxidized nitrogen to gaseous nitrogen

$$2NH_3 + 3O_2 \xrightarrow[(Nitrosomonas)]{Nitrite\ bacteria} 2NO_2^- + 2H^+ + H_2O + cells + energy + end\ products$$

$$2NO_2^- + O_2 + 2H^+ \xrightarrow[(Nitrobacter)]{Nitrate\ bacteria} 2NO_3^- + 2H^+ + cells + energy + end\ products$$

- Bacteria with the ability to take up and store large amounts of inorganic phosphorous
- Since biomass (Bacteria flocs) has a specific gravity that is larger than that of water, It can be removed from liquid by gravity settling

6

Types of Biological Processes

- The principle categories of biological processes are:
  - Suspended growth processes
  - Attached growth (bio-film) processes
- Successful design and operation of any process require the knowledge of the following:
  - Types of microorganisms involved
  - Specific reactions they perform
  - Environmental factor that affect their performance
  - Nutritional needs of the microorganisms
  - Reaction kinetics of microorganisms

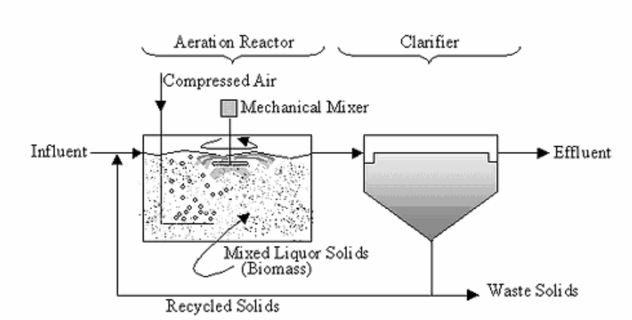
7

Suspended Growth Processes

- Microorganism are maintained in suspension by appropriate mixing methods
- Many of the processes are operated aerobically
- Anaerobic processes are also used for treatment of industrial wastewater having high organic content and organic sludge
- The most common process used in domestic wastewater is the activated sludge process

8

Suspended growth



9

Suspended growth

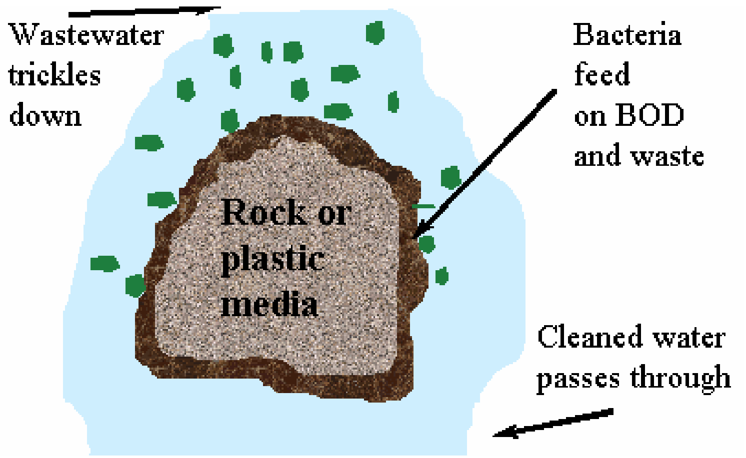
10

Attached Growth Processes

- Microorganism are attached to an inert packing material
- Packing materials include:
  - Rock, Gravel, Sand
  - Slag
  - Redwood
  - Wide range of Plastic and other synthetic materials
- Operate as aerobic and anaerobic processes
- The packing can be submerged completely in liquid or not submerged
- The most common process is the trickling filter
- The process is followed by settling tank

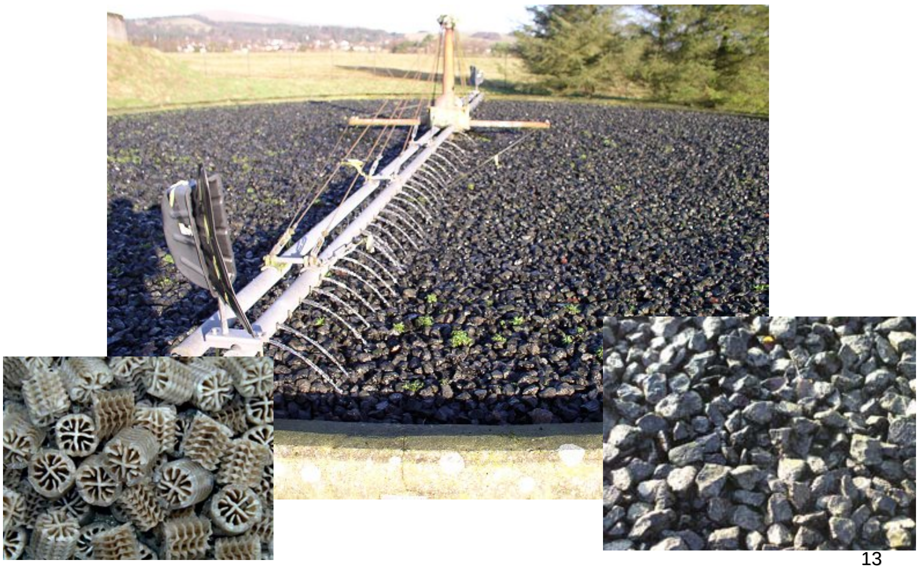
11

Attached Growth Processes



12

Attached Growth Processes



13

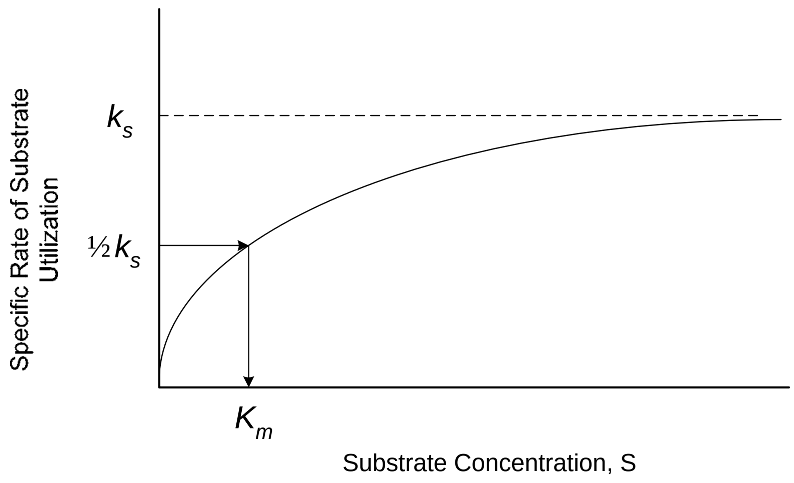
Biological Kinetics

- 1. Michaelis – Menten Concept

$$\frac{1}{X}\frac{dS}{dt} = k_s\left(\frac{S}{K_m + S}\right)$$

- (1/X)(ds/dt) = specific rate of substrate utilization
- (ds/dt) = rate of substrate utilization
- k_s = maximum rate of substrate utilization
- K_m = substrate concentration when the rate of utilization is half maximum rate
- S = substrate concentration

14



15

$$\frac{1}{X}\frac{dS}{dt} = k_s\left(\frac{S}{K_m + S}\right)$$

- If S is very large, Km can be neglected, therefore S cancels out and the reaction is zero order in substrate. K is the rate constant for zero-order reaction.

$$\frac{1}{X}\frac{dS}{dt} = k_s = K$$

- If S is relatively small, it can be neglected in the denominator and the reaction is first-order in substrate. K is the rate constant for the first-order reaction

$$\frac{1}{X}\frac{dS}{dt} = \frac{k_s}{K_m}(S) = KS$$

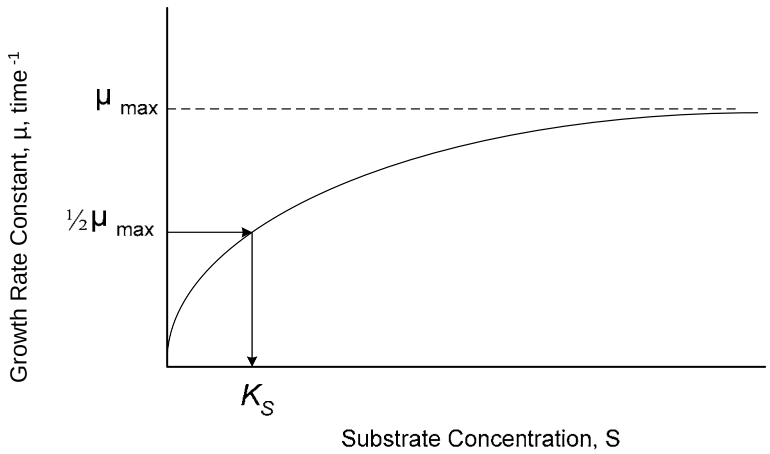
16

Biological Kinetics

➢ 2. The Monod Equation

$$\mu = \mu_{\max}\left(\frac{S}{K_s + S}\right)$$

- μ = growth rate constant, time-1
- μ_{max} = maximum growth rate constant, time-1
- S = substrate concentration in solution
- K_s = substrate concentration when the growth rate constant is half the maximum rate constant.

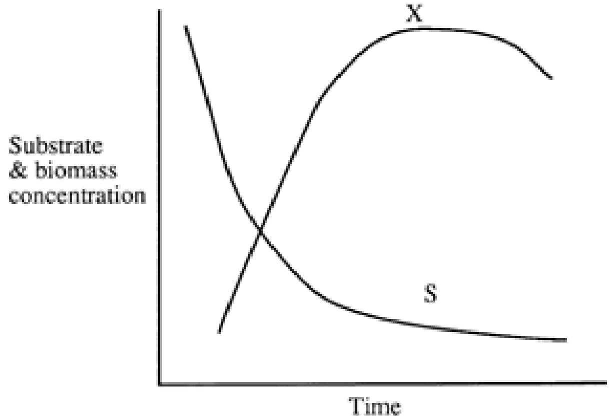


- Monod observed that the microbial growth is represented by:

$$\frac{dX}{dt} = \mu X$$

- dX/dt = rate of cell production
- X = number or mass of microbes present
- μ = growth rate constant

19



20

Effect of Temperature on Growth Rate

➢Arrhenius relationship

$$\frac{k_{T_2}}{k_{T_1}} = \theta^{T_2 - T_1}$$

- k_{T1} = reaction rate constant at temperature T_1
- k_{T2} = reaction rate constant at temperature T_2
- θ = temperature correction coefficient
- T_1 = temperature
- T_2 = temperature

21