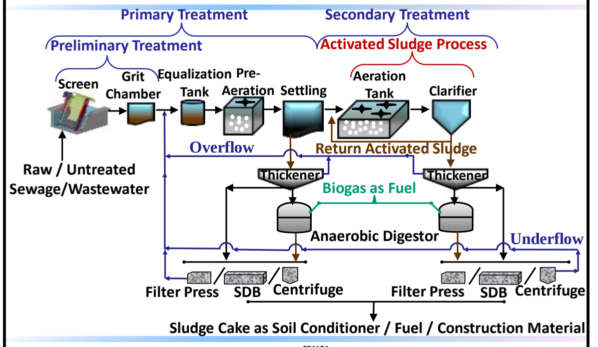
Sewage Treatment Plant (STP) Flow Sheet



Sewage Treatment - Choices

- **Selection of Microorganisms**
  - Heterotrophic or Autotrophic
  - Aerobic or Anaerobic
  - Chemosynthetic or Photosynthetic
- **Growth Rate/Condition of Microbes**
  - High Growth Rate or Auto Oxidation/Endogenous Phase
- **Physical and Chemical Environment**
  - Temperature, pressure
  - pH, nutrition, toxic substances
- **Housing and Mixing**
  - Suspended/immobilized or fixed or attached, homogenous/heterogeneous, stratified/un-stratified, uniform/non-uniform, steady/unsteady, Plug Flow or Completely Mixed
- **Oxygen Supply → Mechanically** (Air/Pure Oxygen; Surface Aerators/Diffused Aeration; Atmospheric Pressure/High Pressure) **or Biologically**
- **Ecology →** Competition, symbiosis, predation, etc.
- **System Performance Criteria**
  - Removal, sludge production, gas production, energy requirement, etc.

How Organisms Grow and Survive

All organisms need the following to survive,

1) Water
2) Carbon
3) Macro Nutrients (N and P)
4) Micronutrients (many other elements)
5) Energy: Obtained by oxidation-reduction reaction involving chemical compounds → This process is known as **Respiration**
6) Electron Donor (Compound which is oxidized is known as an **Electron Donor)**
7) Electron Acceptor (Compound which is reduced is known as an **Electron Acceptor)**

Source of Carbon: Heterotrophic and Autotrophic Microorganisms

Microorganisms are of two types, __Autotrophic__ and __Heterotrophic__

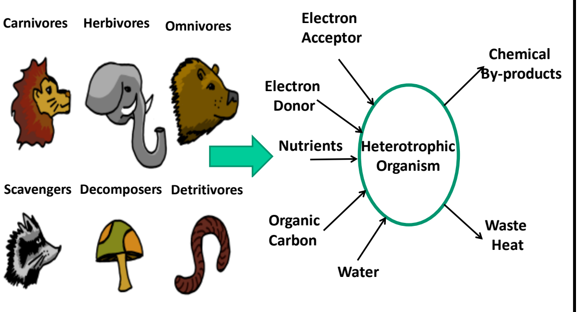
__Autotrophic__ microorganisms use ***Inorganic Carbon*** as carbon (food) source

__Heterotrophic__ microorganisms use ***Organic Carbon*** as carbon (food) source

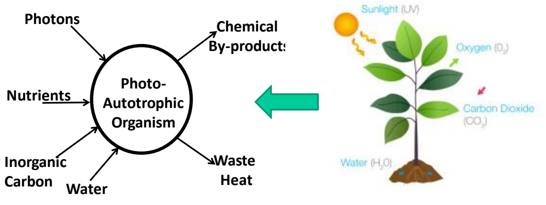
__Heterotrophic__ microorganisms use ***Organic Carbon*** as electron donor. They also use ***Organic Carbon*** as carbon (food) source.

__Photo-Heterotrophic__ microorganisms use light (photons) as energy source. However, they use ***Organic Carbon*** as carbon (food) source.

Heterotrophic Organism



Photosynthetic Autotrophic Organisms



Heterotrophic and Autotrophic Microorganisms

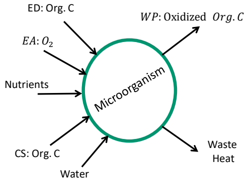
Chemo-Autotrophic microorganisms use ***chemical compounds other than organic carbon*** as electron donor. They use ***Inorganic Carbon*** as carbon (food) source

Photo-Autotrophic microorganisms use light (photons) as energy source. They use ***Inorganic Carbon*** as carbon (food) source

Aerobic microorganisms use ***Oxygen*** as the electron acceptor. They may be either **Heterotrophic** or **Autotrophic**

Anaerobic microorganisms use ***Chemicals*** (other than oxygen*)* as electron acceptor. They may also be either **Heterotrophic** or **Autotrophic**

Examples: Aerobic Heterotrophs



Aerobic Heterotrophic Microorganisms: *Fungi, Protozoa, many bacteria,*

These are aerobic heterotrophic microorganisms

Aerobic: oxygen is the electron acceptor

Heterotrophic: Organic carbon is the carbon source as well as electron donor.

Oxidation State of Carbon in Various Compounds

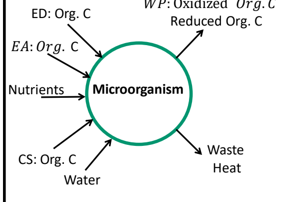
Oxidation state of carbon in inorganic and organic compounds:

- Oxidation state of carbon in most inorganic carbon compounds is +4

i.e., $CO_2, H_2CO_3, HCO_3^-, CO_3^{2-}$

- The average oxidation state of carbon in most organic compounds varies between -4 and +3. Generally oxygenated organic compounds have carbon atoms at higher oxidation states.
- The average oxidation state of carbon in glucose is 0. Since glucose has 6 carbon atoms, it may mean that oxidation states of all C atoms in glucose is not 0, but the average value is indeed 0.
- When an organic compound is oxidized, the average oxidation state of C in that compound increases. Oxidation state of C atoms can increase up to +4.

Examples: Anaerobic Heterotrophs



Anaerobic heterotrophic bacteria, archaea, parasitic protozoa, some fungi

These are anaerobic heterotrophic microorganisms

Anaerobic: Any molecule (except oxygen) is the electron acceptor

Heterotrophic: Organic carbon is the carbon source as well as electron donor.

Different Groups of Bacteria

Denitrifying bacteria

ED: Organic Carbon; $EA: NO_3^-$;
CS: Organic Carbon;
WP: N_2 and Oxidized Organic Carbon

Nitrogen Fixing Bacteria:

ED: Organic Carbon; $EA: N_2$;
CS: Organic Carbon;
WP: NH_3 and Oxidized Organic Carbon

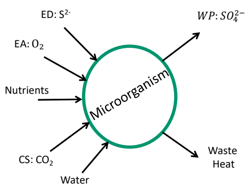
Sulfate reduction bacteria

ED: Organic Carbon; $EA: SO_4^{2-}$;
CS: Organic Carbon;
WP: S^{2-} and Oxidized Organic Carbon

Methanogenasis:

ED: CH_3COO^-; $EA: CH_3COO^-$;
CS: CH_3COO^-
WP: CH_4 and CO_2

Examples: Aerobic Chemo-autotrophs



Mainly bacteria
Sulfur Oxidizing Bacteria: *Thiobacillis*

There are many types of Thiobacillus, which use S^{2-}, S^0, $S_2O_3^{-2}$ as electron donors

Examples: Aerobic Chemo-autotrophs

Nitrosomonas bacteria
$ED: NH_3$; EA: O_2; WP: NO_2^-; CS: CO_2
Nitrobacter
$ED: NO_2^-$; EA: O_2; WP: NO_3^-; CS: CO_2

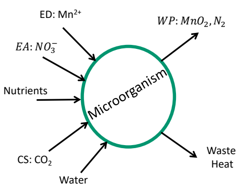
The whole process is known as Nitrification; Nitrosomonas and Nitrobacter together are known as Nitrifying bacteria

Iron oxidizing bacteria:
$ED: Fe^{2+}$; EA: O_2; WP: Fe^{3+}; CS: CO_2

Manganese oxidizing bacteria:
$ED: Mn^{2+}$; EA: O_2; WP: MnO_2; CS: CO_2

These are aerobic chemoautotrophic microorganisms
Aerobic: Oxygen is the electron acceptor
Autotrophic: Inorganic carbon is the carbon source
Chemo-: A chemical molecule (other than organic carbon) is the electron donor

Examples: Anaerobic Chemo-autotrophs



Mainly bacteria
Denitrifying bacteria:

There are many types of denitrifying bacteria which use Fe^{2+}), S^{2-}, etc. as electron donors

Examples: Anaerobic Chemo-autotrophs

Anamox bacteria
$ED: NH_3$; EA: NO_2^-; WP: N_2; CS: CO_2

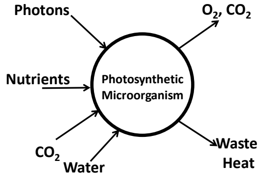
Sulfate reduction bacteria
$ED: Fe^{2+}$; EA: SO_4^{2-}; WP: Fe^{3+}, S^{2-}; CS: CO_2

Methanogenasis:
$ED: H_2$; EA: CO_2; WP: CH_4; CS: CO_2

Iron reduction bacteria:
$ED: S^{2-}$; EA: Fe^{3+}; WP: SO_4^{2-}, Fe^{2+}; CS: CO_2

These are anaerobic chemoautotrophic microorganisms
Anaerobic: Any molecule (except oxygen) is the electron acceptor
Autotrophic: Inorganic carbon is the carbon source
Chemo-: A chemical molecule (other than organic carbon) is the electron donor

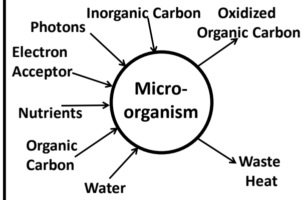
Examples: Photo-autotrophs



Algae, Cyanobacteria, some protozoa

These microorganisms produce organic compounds through photosynthesis. Oxygen is produced as a by-product. The organic compounds produced are partly used for cell synthesis and partly oxidized to CO_2 (using oxygen as electron donor) to energy production. Algae may be net oxygen consumers when photosynthesis is not possible. Some algal species can grow heterotrophically in the absence of light when organic substrate is present.

Examples: Photo-heterotrophs



Purple non-sulfur bacteria, green non-sulfur bacteria, heliobacteria

Photoheterotrophs mostly use light as their source of energy and derive its carbon (food) from organic compounds. Some photoheterotrophs can also partially derive energy from the oxidation of organic compounds.

Housing and Mixing

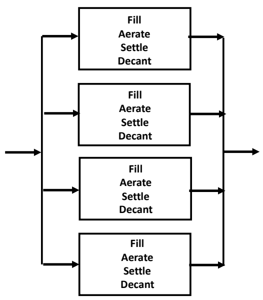
- Suspended Growth Systems - Activated Sludge Process and its Modifications
- Immobilized/Attached Growth or Fixed Film Systems - Trickling Filter/Rotating Biological Contactors

Other Aerobic Reactors

Commonly used variations of ASP are:

1. ASP → Aerated Lagoons (High Growth System) to Extended Aeration Process (Oxidation Ditch)
2. Pure Oxygen to High Pressure Systems (Deep Shaft Process)
3. Sequential Batch Reactor (SBR): suspended growth, does not require separate SST
4. Membrane Bio-Reactor (MBR) : suspended growth, Membrane Filtration instead of SST
5. Oxidation Ponds → Not to be confused with Oxidation Ditch; In Oxidation Ponds additional oxygen supply through photosynthesis by algae utilizing algal-bacterial symbiosis.

Sequential Batch Reactor (SBR)

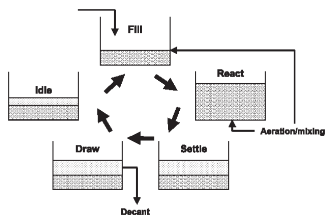


Main Characteristics

1. Suspended growth sequential batch process
2. Fine bubble aeration
3. High quality effluent
4. Moving system of weirs/decanters required
5. Complex operation requiring electronic controls

Sequential Batch Reactor (SBR)

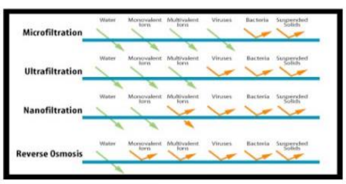
Operating Cycle of SBR



Membrane Bioreactors

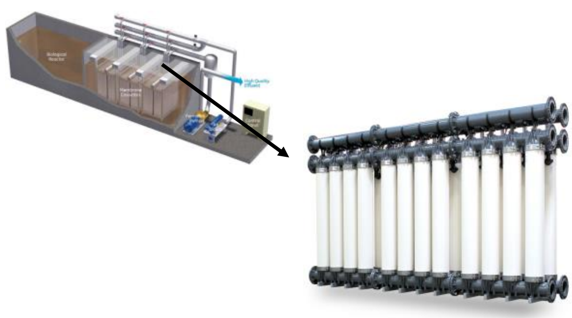
Similar to the conventional activated sludge system, except that the SST has been replaced by a membrane (micro-filtration) module.

This ensures better solid-liquid separation and hence higher quality effluent fit for recycling is guaranteed on a regular basis.



Membrane Process Characteristics

Membrane Bioreactor (Continued)



Membrane Bioreactor (Continued)

Other Aerobic Reactors

Commonly used aerobic bio-reactors (other than ASP) are,

1. Trickling Filter (TF): attached growth, does not require mechanical aeration
2. Rotating Biological contactor (RBC): attached growth, does not require mechanical aeration
2. Mixed Bed Biofilm Reactor (MBBR): Hybrid suspended-attached growth

Essential Requirements for Efficient BOD and TKN Removal in an Aerobic Reactor

1. Availability of large concentration of Biomass
2. Availability of sufficient amount of oxygen

Any reactor where the above two conditions are satisfied is likely to show efficient removal of BOD and TKN

Suspended growth reactors: Biomass suspended in a tank, e.g., ASP

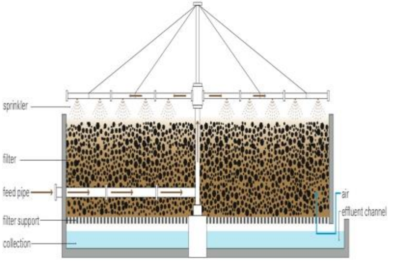
Attached growth reactors: Biomass attached to media kept in a tank

Trickling Filter

Concept of Attached Growth

1. One of the essential requirements for efficient BOD/TKN removal in a bio-reactor is the maintenance of high biomass concentration in the reactor
2. In the suspended growth system, the biomass is allowed to escape from the reactor along with the treated effluent. However, the escaped biomass is captured in the SST and recycled back into the reactor. High biomass concentration is maintained in this way.
3. The attached growth concept is based on the observation that biomass prefers to attach itself to inert surfaces (if available).
4. Hence if inert media is provided inside the reactor, biomass will grow attached to this media. Such biomass will not be able to escape from the reactor easily (since it is attached). Thus, high biomass concentration can be maintained inside the reactor.

Trickling Filter

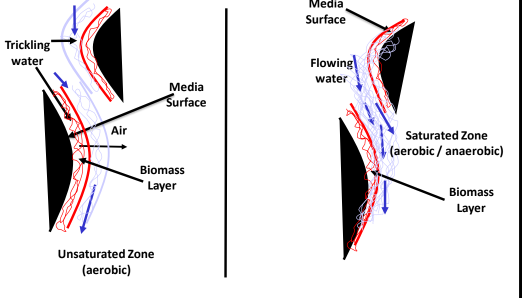


Media: 25 – 100 mm size, rock, gravel, plastic

The sewage must "trickle", i.e., air must be present inside the filter at all times.

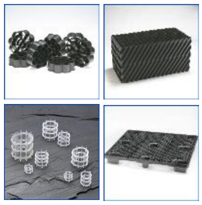
Air supply through convective currents in the TF

Concept of Bio-film



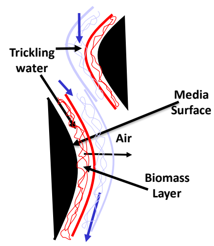
Trickling Filter

Plastic Media used in TF



Trickling Filter

Mode of Operation



Media: 25 – 100 mm size, rock, gravel, plastic

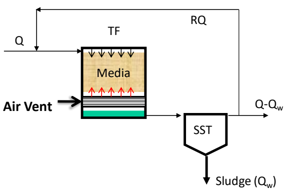
The sewage must "trickle", i.e., air must be present inside the filter at all times.

Sludge Wastage by Sloughing:

Air supply through convective currents in the TF

Trickling Filter

Recirculation in TF



Design Parameters:

Organic Loading Rate (OLR): $Q.S_o/V$
Units:
Kg BOD_5 applied / m^3 reactor volume/d

Hydraulic Loading Rate (HLR): $(Q + R.Q)/A_s$
Units:
m^3 sewage applied/ m^2 reactor surface area/d

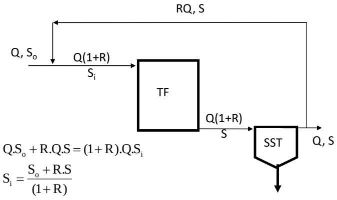
Trickling Filter

Recirculation is from SST. Treated effluent (**not sludge**) is re-circulated.

Recirculation enables the variation of HLR independent of OLR. This is important for high strength waste and also for maintaining most of the media in wetted condition.

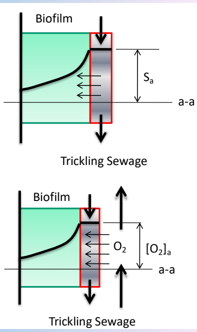
Depending on applied OLR, HLR and other factors, trickling filters can be divided into the following types,

Trickling Filter



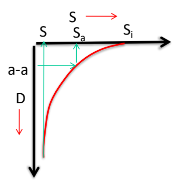
$$Q.S_o + R.Q.S = (1+R).Q.S_i$$

$$S_i = \frac{S_o + R.S}{(1+R)}$$



Trickling Filter

BOD_5 Profile in a Trickling Factor



A trickling filter is **NOT** a completely mixed reactor

$$q = \left[\frac{q_m S}{K_s + S}\right] \cdot \left[\frac{(q_m)_o \cdot [O_2]}{(K_s)_o + [O_2]}\right]$$

When $[O_2]$ is large compared to $(K_s)_o$,

$$q = \left[\frac{q_m S}{K_s + S}\right] \cdot (q_m)_o = \frac{q_{max} S}{K_s + S}$$

Trickling Filter

$$\frac{S}{S_i} = \text{Exp}\left[-K.D.\left(\frac{Q.(1+R)}{A}\right)^{-n}\right]$$

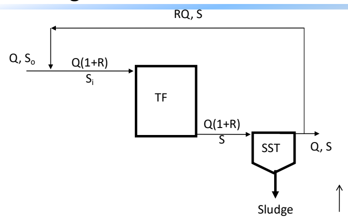
K, n: Treatability Constants
D: Depth of Filter
A: Filter Cross-Sectional Area

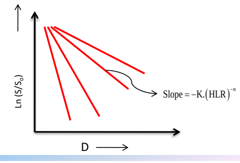
To determine K and n:
Get data on percent BOD_5 Remaining $[(S/S_o).(100)]$ through pilot tests (without recycle) conducted at various HLR values

Depth (m)	HLR (L/min/m²) 20	40	60	80
0.50	50	70	75	82
1.00	40	50	60	60
1.50	25	30	40	50
2.00	15	20	30	40

$$\text{Ln}\left[\frac{S}{S_o}\right] = \left[-K.(\text{HLR})^{-n}\right].D$$

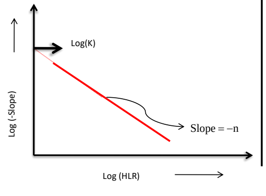
Trickling Filter





Trickling Filter

$$\text{Slope} = -K.(\text{HLR})^{-n}$$
$$\text{Log}(-\text{Slope}) = \text{Log}(K) - n.\text{Log}(\text{HLR})$$



Example Problem
A tricking filter with the following dimensions is available. Depth: 2 m, Surface area: 150 m². The media consists of stones of 7-10 cm diameter. This filter will be used to treat 0.6 MLD wastewater with BOD_5 = 300 mg/L. Based on this information, calculate the expected BOD_5 removal efficiency. K = 1.36; n = 0.5

Solution:
Volume of trickling filter = D.A = (2).150 = 300m³
Organic Loading Rate (OLR) =

$$\frac{Q.S_o}{V} = \frac{(0.6.10^6).(300)}{300.10^6} = 0.6\ \text{Kg/m}^3/\text{d}$$

(okay for intermediate rate)

Trickling Filter

Filter Type	Filter Medium	OLR, kg/m³/d	HLR, m³/m²/d	% Removal	Depth (m)	R
Low Rate	Rock, Slag	0.1 - 0.3	1 - 4	80 - 85	1.8 - 3	0
Intermediate Rate	Rock, Slag	0.3 - 1.2	10 - 30	65 - 85	1 - 3	0.5 - 3
High Rate	Rock	1.2 - 3	40 - 90	65 - 85	2 - 5	1 - 4
Super High Rate	Plastic	3 - 4	60 - 120	65 - 80	4 - 12	1 - 4
Roughing	Plastic	4 - 6	60 - 180	40 - 65	4 - 12	1 - 4

Generally, higher values of OLR and HLR results in diminished filter performance. Increasing the reactor height improves filter performance.

Plastic media is generally used if the filter height in more than 5 m.

Trickling Filter

Without recycle, Hydraulic Loading Rate (HLR) = $\frac{Q}{A} = \frac{(0.6).10^3}{150} = 4\ \text{m}^3/\text{m}^2/\text{d}$ (not okay)

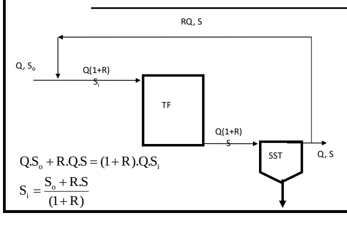
So, let R = 3; Hence, HLR = $\frac{(Q+RQ)}{A} = \frac{(0.6+1.8).10^3}{150} = 16\ \text{m}^3/\text{m}^2/\text{d}$ (okay)

$$\frac{S}{S_i} = \exp[-k..D.(\text{HLR})^{-n}] \qquad S_i = \frac{S_o + R.S}{(1+R)} \qquad \frac{S}{S_i} = \exp[(-1.36).(2).(16)^{-0.5}] = 0.507 = \frac{S.(1+R)}{S_o + R.S}$$

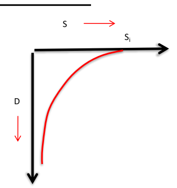
$$0.507.S_o + 1.520.S = 4.S \qquad \frac{S}{S_o} = 0.204 \qquad \left(1 - \frac{S}{S_o}\right) = 1 - 0.204 = 0.796$$

S_o = 300 mg/L; S = 61.2 mg/L; S_i = 120.9 mg/L

BOD Removal Efficiency: 79.6% Removal

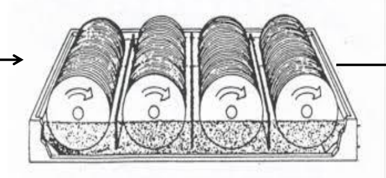


$$Q.S_o + R.Q.S = (1+R).Q.S_i$$
$$S_i = \frac{S_o + R.S}{(1+R)}$$



Rotating Biological Contactor

Inflow



Outflow

Rotating Biological Contactor

Rotating Discs

Actual Installation

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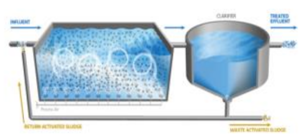
Mixed Bed Biofilm Reactor (MBBR) — Aeration Tank



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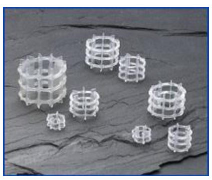
Mixed Bed Biofilm Reactor (MBBR)

Plastic Media



Plastic Media with Biofilm

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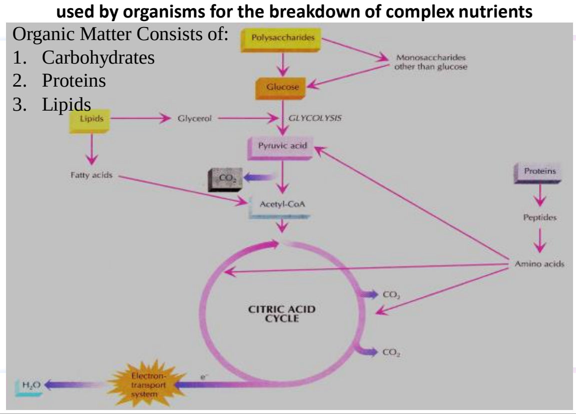
Overall general scheme showing some of the dissimilatory pathways used by organisms for the breakdown of complex nutrients

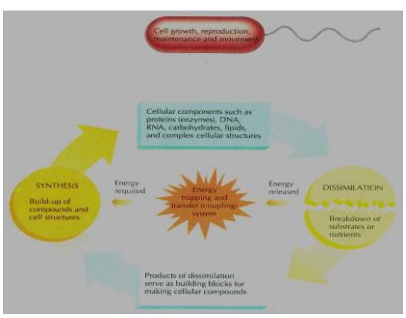
Organic Matter Consists of:

1. Carbohydrates
2. Proteins
3. Lipids



Relationships between the processes of dissimilation and synthesis in microbial cells

Relationships between the processes of dissimilation and synthesis in microbial cells. An energy trapping and transfer (coupling) system carries usable energy between the two processes.



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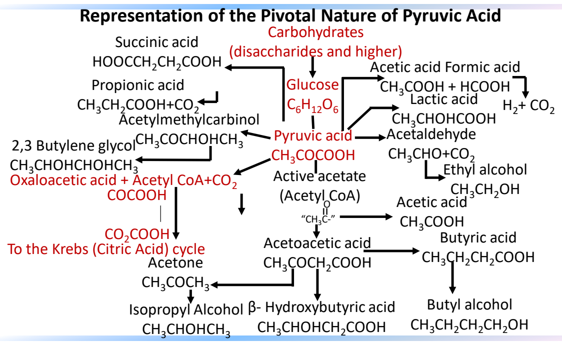
Biodegradation Pathways

Representation of the Pivotal Nature of Pyruvic Acid



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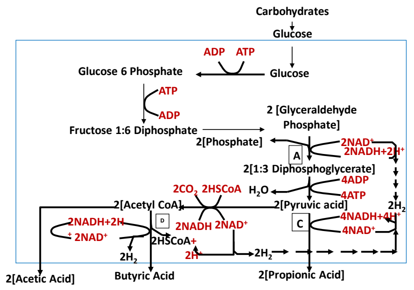
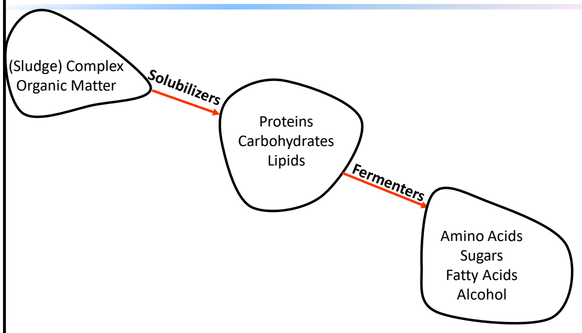
Biodegradation Pathways

Anaerobic Degradation



Anaerobic Biodegradation Biochemistry



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Biochemistry of Anaerobic Biodegradation....Fermentation

Solibilizers: Anaerobic, Heterotrophic

Energy Source: Complex Organic Carbon
Food Source: Organic Carbon
Electron Acceptor: Organic Carbon
By products: Proteins, Carbohydrates, Lipids

Fermenters: Anaerobic Heterotrophic

Energy Source: Organic Carbon (Proteins, Carbohydrates, Lipids)
Food Source: Organic Carbon
Electron Acceptor: Organic Carbon
By-products: Amino Acids, Sugars, Fatty Acids, Alcohol

$$AB \rightarrow A^*(\text{oxidized}) + B^*(\text{Reduced})$$
$$A + B \rightarrow A^*(\text{oxidized}) + B^*(\text{Reduced})$$

AB, A and B are organic Compounds

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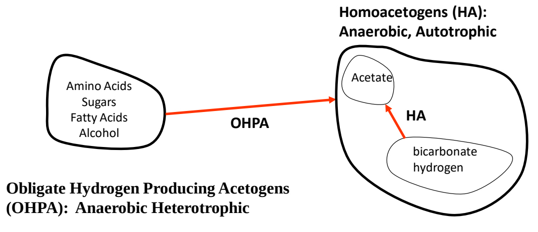
Biochemistry of Anaerobic Biodegradation....Acid Formation



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Biochemistry of Anaerobic Biodegradation....Fermentation

Obligate Hydrogen Producing Acetogens (OHPA): Anaerobic Heterotrophic

Energy Source: Organic Carbon
Food Source: Organic Carbon
Electron Acceptor: H_2O
By-products: Acetate, inorganic carbon, hydrogen

Homoacetogens (HA): Anaerobic, Autotrophic

Energy Source: H_2
Food Source: Inorganic Carbon
Electron Acceptor: Inorganic Carbon
By-product: Acetate

Equation: $$2HCO_3^- + 4H_2 + H^+ \rightarrow CH_3COO^- + 4H_2O$$

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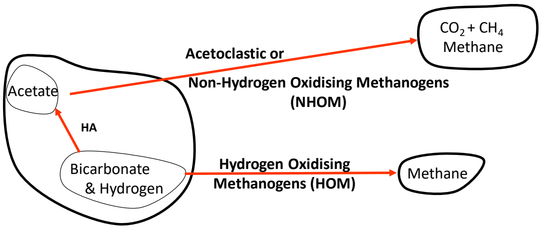
Biochemistry of Anaerobic Biodegradation....Methane Formation



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Biochemistry of Anaerobic Biodegradation….Fermentation

Acetoclastic or Non-Hydrogen Oxidizing Methanogens (NHOM): Anaerobic, Heterotrophic

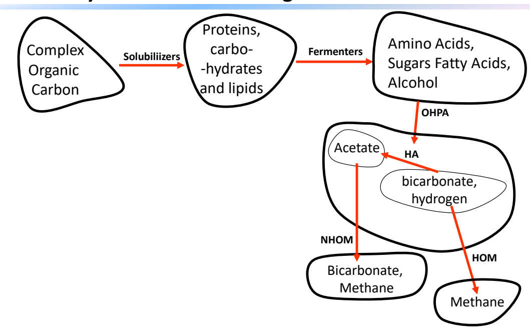
Energy Source: Acetate
Food Source: Acetate
Electron Acceptor: Acetate
By-products: Methane and Bicarbonate
Equation: $CH_3COO^- + H_2O \rightarrow HCO_3^- + CH_4$

Hydrogen Oxidizing Methanogens (HOM): Autotrophic Anaerobic

Energy Source: H_2
Food Source: Inorganic Carbon
Electron Acceptor: Inorganic Carbon
By-product: Methane
Equation: $HCO_3^- + 4H_2 + H^+ \rightarrow CH_4 + 3H_2O$

Complex Organic Matter is Converted to Methane and Inorganic Carbon

Biochemistry of Anaerobic Biodegradation….Fermentation



Biochemistry of Anaerobic Biodegradation….Fermentation

Importance of Reactor pH

Methanogens are active in the pH range of 7.5 – 8.5

Lowering of pH due to accumulation of acids disrupts methane production

What Happens to the Oxygen Demand of Wastewater ??

Oxygen demand is removed from the wastewater and transferred primarily to the methane gas.

Oxygen demand is not satisfied, merely transferred to the gaseous phase (methane).

Thus, COD of methane gas produced ~ COD reduction of wastewater

COD of Methane

Stoichiometry: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
Methane is a flammable gas.
COD of methane = 4 kg/kg
Heat is generated when methane is burnt.

Importance of Hydrogen

Increase in H_2 partial pressure has a negative impact on OHPA activity

This leads to the accumulation of higher aliphatic acids and reduces the production of acetate. Lower acetate means lower methanogenic activity.

Propionate to acetate → below 10^{-4} atm. pp
Butryate to acetate → below 10^{-4} atm. H_2 pp
Ethanol to acetate → below 1 atm. H_2 pp
Lactate to acetate → below 1 atm. H_2 pp

Bio-kinetic Constant Comparison: Aerobic vs Anaerobic Growth

Aerobic (BOD basis)	Anaerobic (COD basis)
Y_T = 0.50	Y_T = 0.04
K_d = 0.05 / d	K_d = 0.015 / d
K_s = 40 mg/L	$K_s = 2224.[10^{0.046(35-T)}]$
	$(K_s)_{20}$ = 10892 mg/L
	$(K_s)_{35}$ = 2224 mg/L
	$(K_s)_{45}$ = 771 mg/L
q_m = 4 /d	$q_m = 6.67.[10^{-0.015(35-T)}]$
	$(q_m)_{20}$ = 3.97 /d
	$(q_m)_{35}$ = 6.67 /d
	$(q_m)_{45}$ = 9.42 /d

Maximum Removal
Assuming μ = 0; $q = k_d/Y_T$
$S = q.K_s/(q_m - q)$

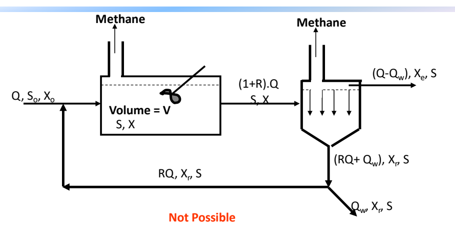
q(aerobic) = 0.05/0.5 = 0.1 / d
S = (0.1).(40)/(4 – 0.1) = 1.02 mg/L
q(anaerobic) = 0.015/0.04 = 0.375 / d

S (at 45°C) =
0.375.(771)/(9.42 - 0.375) = 32 mg/L

S (at 35°C) =
0.375.(2224)/(6.67 – 0.375) = 132 mg/L

S (at 20°C) =
0.375.(10892)/(3.97 – 0.375) = 1136 mg/L

Suspended Growth Anaerobic Reactor: Similar to ASP



Unfavorable biodegradation and poor settling characteristics of anaerobic sludge means that suspended growth anaerobic reactors are not feasible for domestic wastewater treatment due to poor effluent quality.

However, such reactors are used extensively for biological sludge digestion and industrial wastewater treatment.

Hydraulic Considerations during Water / Wastewater Plant Design

Vertical leveling of the various treatment plant units are of extreme importance during water / wastewater plant design.

The line showing the water levels through various units of a treatment plant is known as the hydraulic grade line.

A treatment plant is generally designed to keep pumping to a minimum. Pumping is generally done at the beginning of the treatment train, i.e., from equalization tank. Water is then expected to flow through various treatment units by gravity.

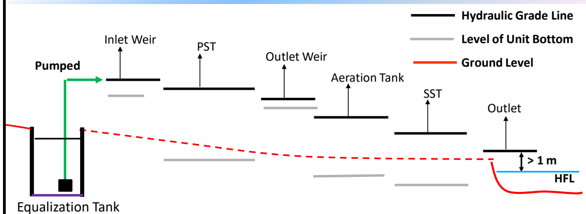
Hence the hydraulic grade line in a treatment plants goes down as the water passes through the treatment plant.

Hydraulic Considerations during Water / Wastewater Plant Design

The hydraulic grade line of a treatment unit, along with the designed depth of water in that unit determine the bottom level of the unit.

Providing the required hydraulic grade line in a treatment plant will require that the upstream treatment units in a treatment plant be at a higher level. This is easy to achieve if the site of the treatment plant is naturally sloping. Otherwise, earthwork is required to re-contour the ground at the treatment plant site or the upstream units of the treatment plants may have to be built on stilts.

Hydraulic Grade Line, Level of the Unit Bottom and Ground Level



The hydraulic grade line of the last unit of a water treatment must be approximately at the ground level, such that the treated water is conveyed to the underground storage tank by gravity.

The hydraulic grade line of the last unit of a wastewater treatment plant should be at least 1m above the HFL of the receiving water body.

Consequences of Pollutant Loading to Natural Water Bodies

Consequences of Oxygen Depletion In Rivers/Lakes

High BOD demand in rivers/lakes causes dissolved oxygen depletion and suffocation / death of fish.

River Classification:
Class A: Drinking Water Quality
Class B: Bathing Quality
Class C: Drinking Water after Treatment
Class D: Wildlife and Fisheries
Class E: Irrigation, Industrial Uses

Below Class E: Basically a drain

Consequences of Nutrient Addition in Lakes

High nutrient loading in lakes and slow flowing rivers causes eutrophication, i.e., excessive growth of aquatic algae/plants.

Algae:
Present as a suspension in water;
Increases dissolved oxygen concentration of water
Important fish food
Dead Algae may cause DO depletion

Dead algae causes Oxygen depletion

Aquatic Plants:
The leaves are outside the water
Causes DO depletion
Dead aquatic plants in increase DO depletion