Wastewater
(Liquid Wastes)

By

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Definition of Wastewater:

Is the water that has been used, as for washing, flushing, or in a manufacturing or agricultural processes, and so contains waste products.

Main Sources of Wastewater:

- **Domestic Wastewater**
- **Industrial Wastewater**
- **Agricultural Wastewater**

Main Sources of Wastewater :

I. Domestic wastewater

(*Municipal wastewater* or *Sewage*):

It includes waste water from homes and commercial establishments. 70% of this wastewater is transmitted by sewers to municipal waste water treatment plant, while the remaining 30% released as a raw sewage into waterways or septic tanks for waste disposal.

Sewage composed mainly of oxidizable organic matters. The organic matters when discharged directly into waterways without treatment gets oxidized by bacterial decomposition to *nitrate, phosphate, carbon dioxide and water.*

As this type of decomposition needs the use of dissolved oxygen, it places an oxygen demand on the water.
Because of this tendency to consume oxygen in the decomposition process, a common indicator used to monitor this type of input organic pollution in receiving waters has been the *BOD (Biological "Biochemical" Oxygen Demand)* test.

** *The higher the organic matter content, the lower the oxygen content in water (oxygen depletion)* → *The higher BOD result.*

II. Industrial wastewater.

The types of industrial wastewaters are widely varied according to the type of the industry (its raw materials and processing). The wastewaters discharged from the different industries might be have organic, inorganic or microbiological content , depending on the type of the industry and in turn lead to different impacts on the receiving water.

III. Agricultural wastewater :

Agricultural wastes which discharged into waterways by the drainage water include;

- Wastes generated by farm animals, which add organic pollution to the water stream.

- Inorganic fertilizers , which cause first inorganic pollution followed by organic pollution.

- Soil erosion, which decreases the transparency of the water that limits the photosynthesis. In addition, the sediments carried into fresh water systems tends to clog the gills of fish, causing suffocation.

- Pesticides that have been used to combat the pests, when sprayed on cropland they remain in the soil for long periods of time. During periods of heavy rain or when the crops are irrigated, they tend to be carried, into surface, marine or ground water systems causing organic pollution to the drinking water supplies.

IV. RADIOACTIVE WATER POLLUTION.

V. THERMAL WATER POLLUTION.

VI. SHIPPING WATER POLLUTION.

Some Classifications of Liquid wastes:

A) According to the liquid waste degradability

1- Degradable liquid wastes:

Degradable sewage, degradable industrial wastewaters and degradable organisms.

2- Non-degradable liquid wastes:

Inorganic substances (salts and salts of Heavy metals) and persistent chemicals (Organic chemicals “for example DDT and Phenols”).

B) According to their being “Point source or Non-point source”:

1- Point source liquid wastes:

Industrial and municipal discharges.

2- Non-point source liquid wastes:

i) Liquid runoff from agricultural lands.

ii) Liquid runoff from urban areas; like rain water from paved areas.

Wastewater Characteristics:

A) Physical and Chemical properties of wastewater:

The chemical composition of a wastewater and its physical characteristics provide essential information for the development of wastewater treatment plants.

1. Solids:

Solids may be classified based on the dimension of the particles. The following types of solids can be distinguished:

Dissolved solids, Colloidal solids

& Coarse suspended solids

** "Bacteria and algae can be classified as coarse suspended solids".*

Table The various waste fractions and a way to separate them (Sayed, 1987

Distinghuised wastewater	fraction	seperation procedure	size limits of fraction removed
Wastewater (total)	= coarse suspended solids + colloidal + soluble fraction	screen	
$Wastewater_{pf}$	= colloidal + soluble fraction	filtration paper filter	coarse suspended solids 1 mm - 7.4 µm
$Wastewater_{mf}$	= soluble fraction	filtration membrane filter	coarse suspended solids + colloidal fraction 7.4 µm - 0.45 µm

Waste-water_{pf} = $\text{waste-water}_{\text{paper filtered}}$

Waste-water_{mf} = $\text{waste-water}_{\text{membrane filtered}}$; this fraction is arbitrarily defined as soluble

2. Organic Matter:

Organic matters are of animal or vegetable origin and are mainly composed of combination of carbon (C), hydrogen (H) and Oxygen (O). In much smaller amounts, nitrogen (N) and phosphorus (P) are present. Organic matters can be divided into the following major groups:

1) Carbohydrates (25-50%);
2) Proteins (40-60%);
3) Fats and oils (10%);
4) Urea and other organics such as pesticides.

The Organic matter content of wastewater can be expressed as:

a) Biochemical Oxygen Demand (BOD):

It is the amount of oxygen required for the oxidation of organic matter by aquatic microorganisms.

By increasing the BOD, there is a decrease in the dissolved oxygen (DO).

$$BOD_5^{20} \text{ mg } O_2/l = DO_0 - DO_5$$

b) Chemical Oxygen Demand (COD):

It is used as a measure of the amount of oxygen equivalent to the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant ($K_2Cr_2O_7$).

$$C_6H_{12}O_6 + 2CrO_7^{2-} + 4H^+ \xrightarrow{Ag_2SO_4} 2Cr^{3+} + 6CO_2 + 8H_2O + 6e^-$$

** *COD is measured as* $mg\ O_2/l$

c) Total Organic Carbon (TOC):

TOC expresses the organic content of a water expressed as g C/l. TOC is determined by measuring the amount of CO_2 gas released during the combustion of organic carbon at a temperature of 900 °C.

Theoretical Chemical Oxygen Demand "ThCOD"

Theoretical Chemical Oxygen Demand (ThCOD)

The term ThCOD refers to the calculated oxygen uptake by oxidation of a model substrate "g O_2/L"

The oxid. of glucose is an example:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Element	Atomic Mass
H	1
C	12
O	16

1 mole glucose demands 6 mole O_2

180 g glucose ~ 192 g O_2

1 g ~ /L ~ 1.067 g O_2/L

∴ 1 mole glucose ≡ 192 g COD

Ex1 Calculate the COD of a 10 mm glucose solution in mg/L.

1 mole glucose ≡ 6 mole O_2

1 mole glucose ≡ 6 × 32 = 192 g O_2/L

1 mmole ~ ≡ 0.192 g O_2/L

10 mmole ~ ≡ 1.92 g O_2/L

10 mmole ~ ≡ 1920 mg O_2/L

Ex 3 Calculate the COD of 10 mmol ethanol solution?

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

1 mole ethanol ≡ 3 mole of O_2

~ ~ ~ = 3 × 32 = 96 g O_2/L

1 m mole ~ ≡ 0.096 g O_2/L

10 mmole ~ ≡ 0.96 g O_2/L

10 ~ ~ ~ ≡ 960 mg O_2/L

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Theoretical Organic Carbon "ThOC"

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Theoretical Organic Carbon (ThOC):

refers to the calculated amount of carbon present in a model substrate (g.C/L)

ex.: glucose $\xrightarrow{COD}$ 192 gO_2/L

$TOC = C_6 = 12 \times 6 = 72\ g/L$

* Characterization of a wastewater on the basis of its organic compounds:

The organic compound of solids in medium strength domestic wastewater can be calculated per solids fraction:

Dissolved solids : 36% organic (⟶ 64% inorganic)

Colloidal solids : 80% organic (⟶ 20% inorganic)

Coarse suspended solids: 54% organic (⟶ 46% inorganic)

Total solids : 55% organic (⟶ 45% inorganic)

3. Nitrogenous compounds

(Total Nitrogen = Organic Nitrogen + Inorganic Nitrogen)

4. Phosphorus compounds.

5. Inorganic salts. (like chloride, sulfides, nitrates, ...etc.).

6. Metals (Pb, Hg, Mn, Co, Cd, ... etc.).

7. Priority pollutants (PCB, DDT, Chloroform, ...etc).

8. Acidity (Hydrogen ion "H^+" conc.) & Alkalinity (CO_3^{2-}, HCO_3^- & OH^-).

9. Colour, taste and odour.

10. Turbidity, density and viscosity.

B) Microbiological properties (Pathogenic bacteria, virus, worms, …etc.).

c) Radiological properties.

Primary Wastewater Treatment

Primary wastewater treatment leads to the removal of 65% of S.S., 30% of BOD and most of the floatable matter.

The effluent discharge standards of wastewater after the treatment requires removal of at least 85% of S.S. And BOD. In turn, the secondary treatment (Biological treatment) is necessary to achieve this objective.

Biological Treatment

1) Activated Sludge
2) Aerated Lagoons
3) Trickling Filters
4) Oxidation Ponds
5) Septic Tanks

(1) Activated Sludge System

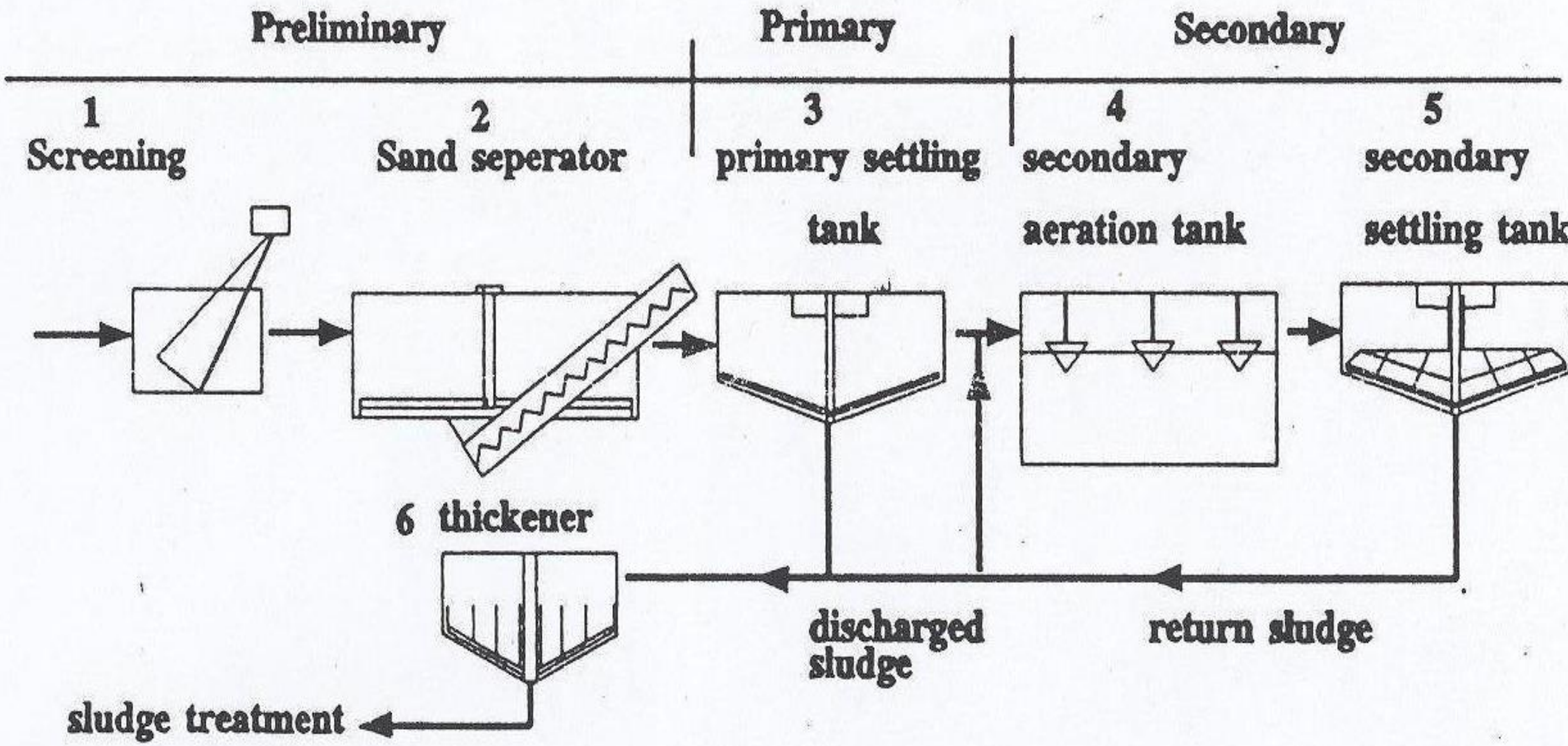
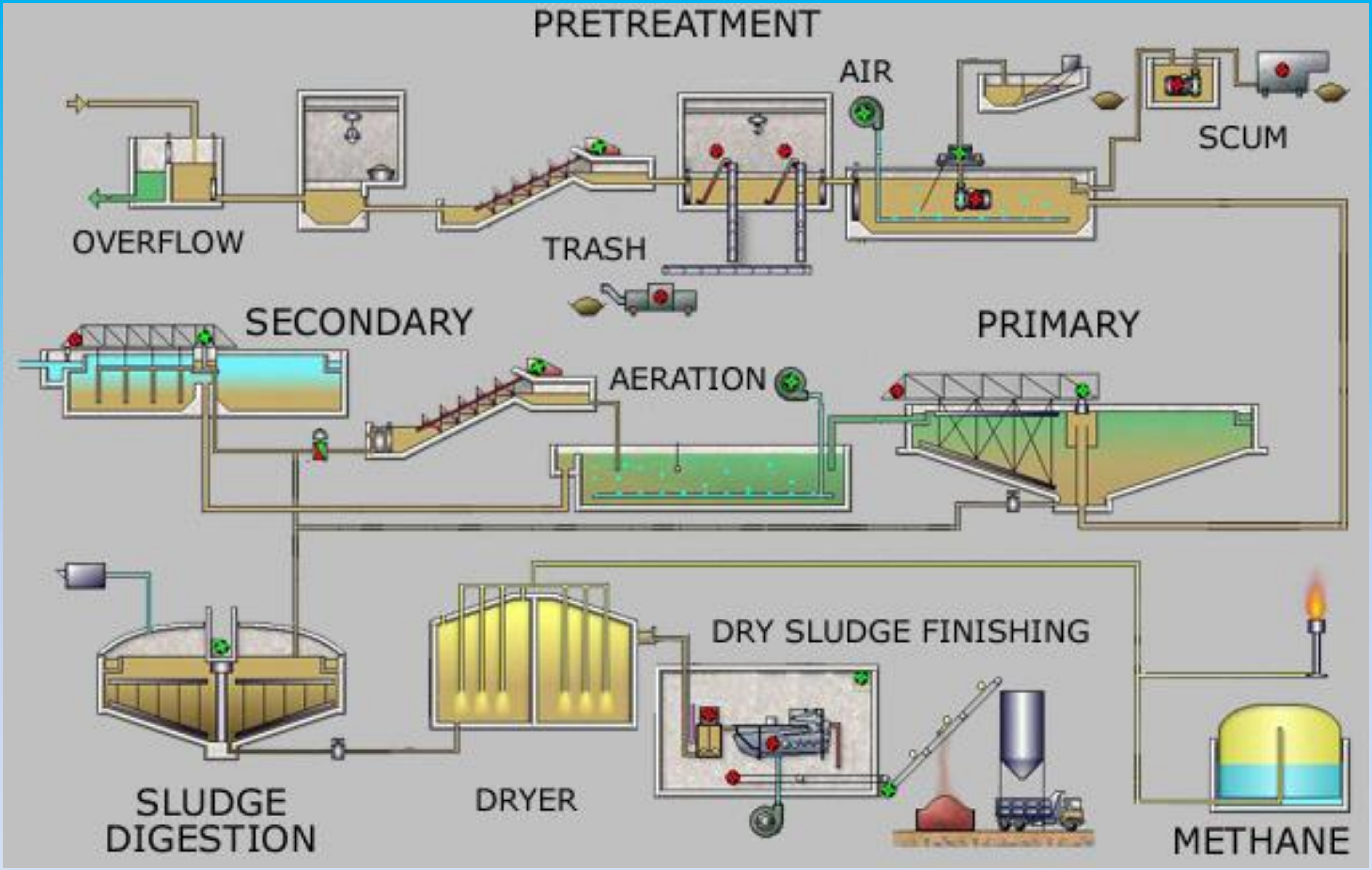
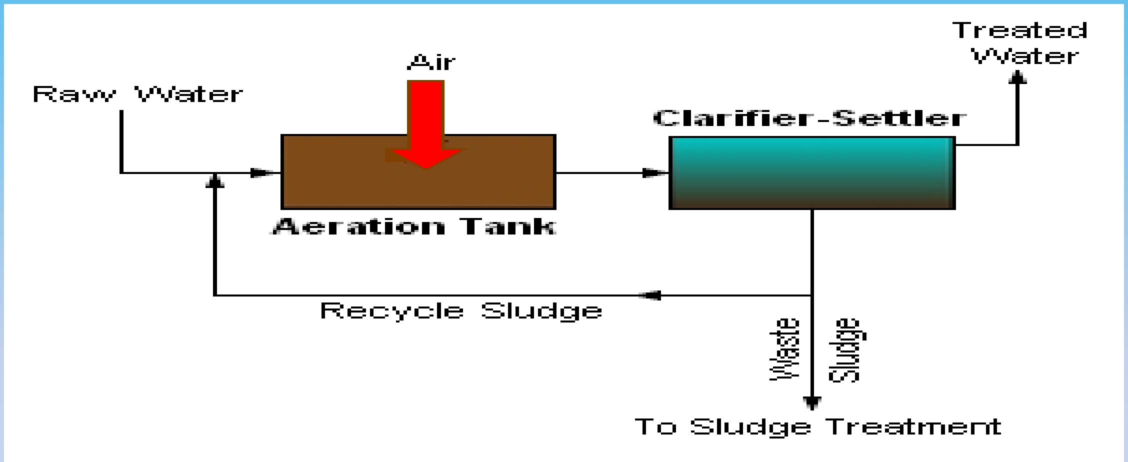


Figure A conventional waste-water treatment plant with a one stage activated sludge process (Ahlstrom, 1987)

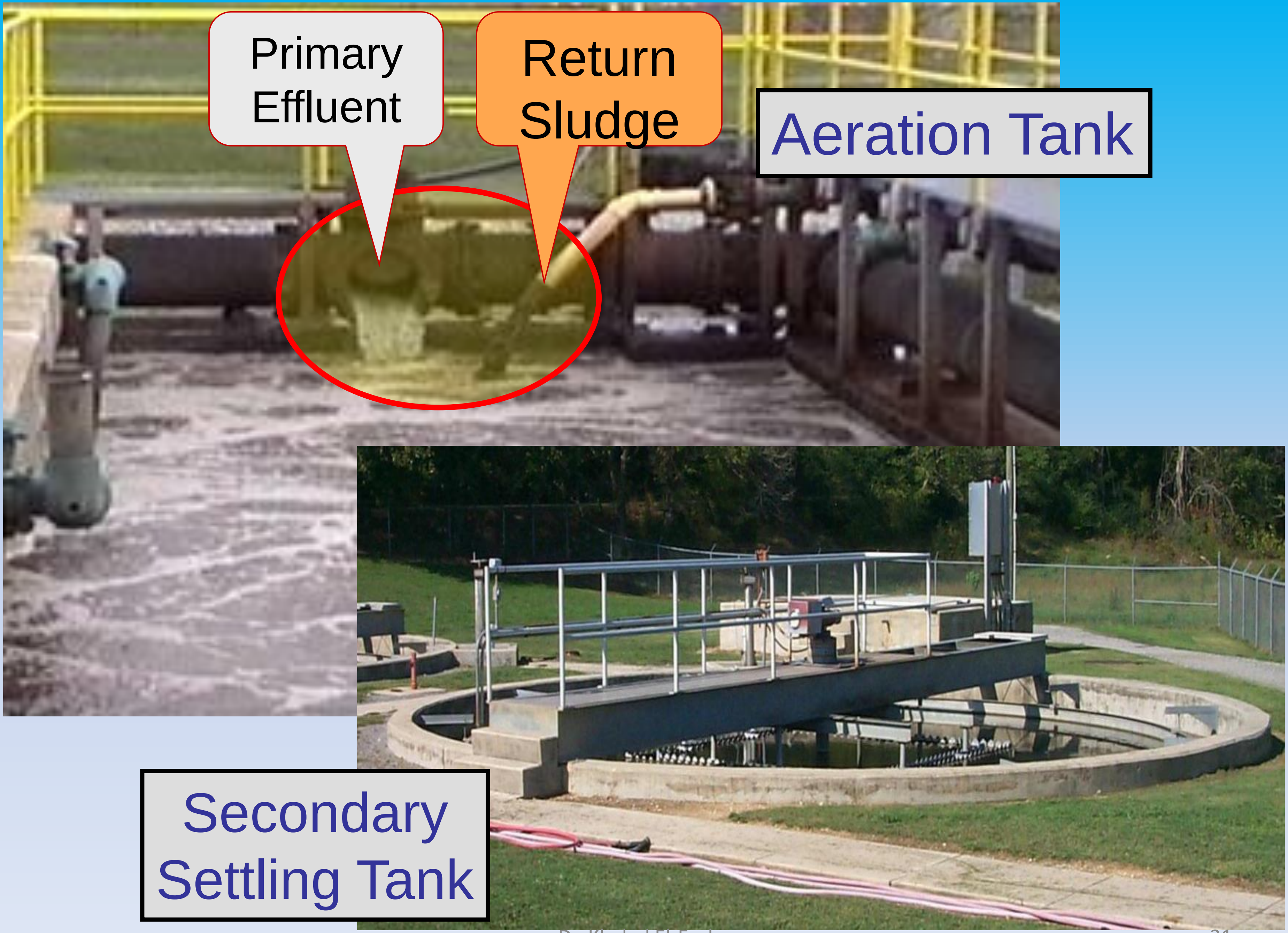


Process Flow Diagram for a typical large-scale municipal sewage treatment plant



A generalized, schematic diagram of an activated sludge process (Secondary Wastewater Treatment Stage)

An empty sedimentation tank at the treatment plant


Primary Effluent
Return Sludge
Aeration Tank
Secondary Settling Tank

- Type of bacterial growth is: *Suspended growth system*.
- Removal Efficiency of *BOD* and S.S. = 85-90%
- Hydraulic Retention Time (HRT) at the Aeration Tank:

  = 3-6 hrs. (for sewage)

  = 6-24 hrs. (for industrial wastewater)
- Hydraulic Retention Time (HRT) at the Secondary Settling Tank = 1-2 hrs.

Sludge Treatment:

After concentrating the sludge in the thickener, the sludge is de-watered in drying beds “via sunlight”, or vacuum filtered. The de-watered sludge, can be sent for ultimate disposal. The various methods used for ultimate disposal include dumping in land-fills, incineration, dumping at selected sited in sea, or utilizing as a low grade fertilizer (soil modifier). It also possible to *digest the sludge anaerobically* in a sludge digester to convert it into a methane gas, which is used as a source of energy.

Some of *Tertiary Treatment* options:

Treated effluents from the secondary treatment

↓

Chemical Coagulation and settling

or

Sand filtration

↓

Disinfection

(Chlorination *and dechlorination or* U.V.)

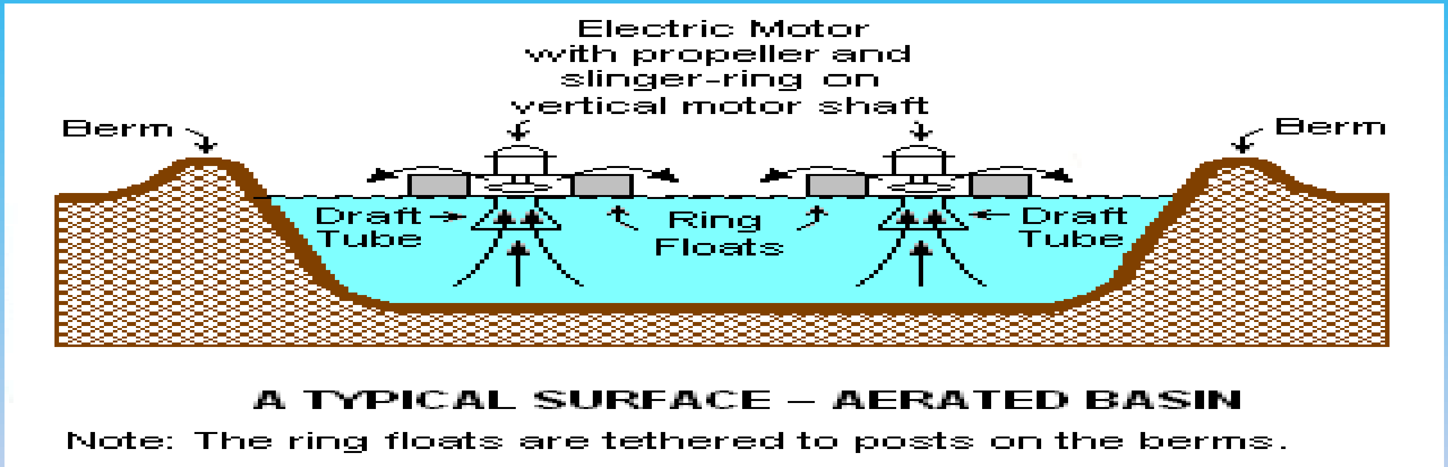
↓

Treated effluents

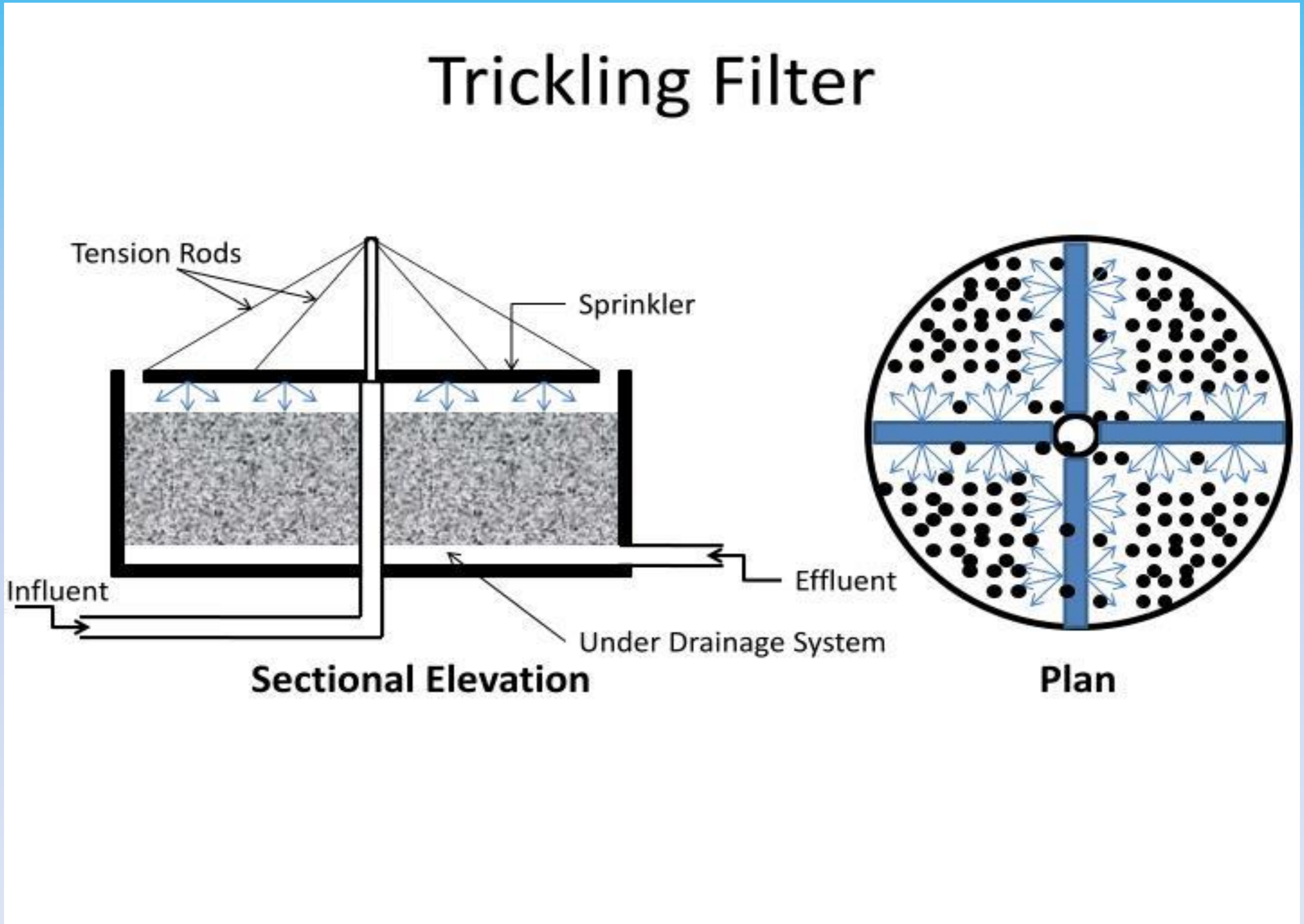
Tour a wastewater treatment plant in seven minutes on Vimeo.mp4

(2) Aerated Lagoons

- Holding tanks or ponds with a depth of about 3.5 meter.
- Lined with cement or rubber.
- Mechanically aerated for about 2-6 days.
- BOD removal efficiency = 75-80%


Electric Motor
with propeller and
slinger-ring on
vertical motor shaft
Berm
Berm
Draft
Tube
Ring
Floats
Draft
Tube
A TYPICAL SURFACE – AERATED BASIN
Note: The ring floats are tethered to posts on the berms.

(3) Trickling Filter



Trickling Filters

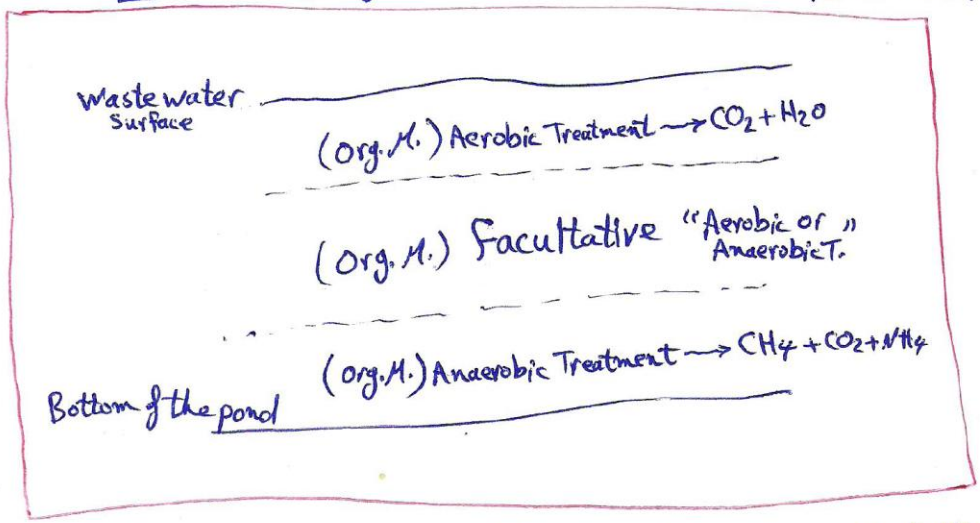
- Trickling filters are artificial beds of crashed stones or other porous media through which the settled sewage is allowed to percolate.
- It is widely used for biological treatment of wastewater in order to remove organic matter
- The liquid waste is applied intermittently over the top surface of the filters by means of a distributor. Filtered liquid is collected at the bottom through filter box and under drain system

- Type of bacterial growth is: ***Attached growth system.***
- Filter diameter is up to 15 m
- Height of the trickling filter = 1-3 m
- Diameter of packing material (for example: Stone) = 5-10 cm
- Artificial aeration
- BOD removal efficiency = 65-85%
- Final sedimentation tank is an integral part of the trickling filter. The function of this tank is to remove the large masses of biological growth which flow with the effluent from the filter media.

(4) Oxidations ponds

- A man made pond (large shallow pond with a depth of 0.5-1.5 meter) that contains untreated wastewater which is then left to allow the growth of algae and bacteria which decompose the wastewater.
- At this pond, the wastewater lasts for about 30 days.

[Theory of treatment in the Oxidation Ponds]



- At the upper layer of the oxidation pond, algae growth takes place → Photosynthesis → $O_2 \uparrow$ → aerobic bacterial growth → Oxidation of organic matter (waste water treatment)

(5) Septic Tank

Even today some 30-35 % of the U.S. population (about 100 million people) are not served by sewers. They depend instead on some form of on-site subsurface sewage-disposal system. The most common of these is the **septic tank**.

Septic Tank

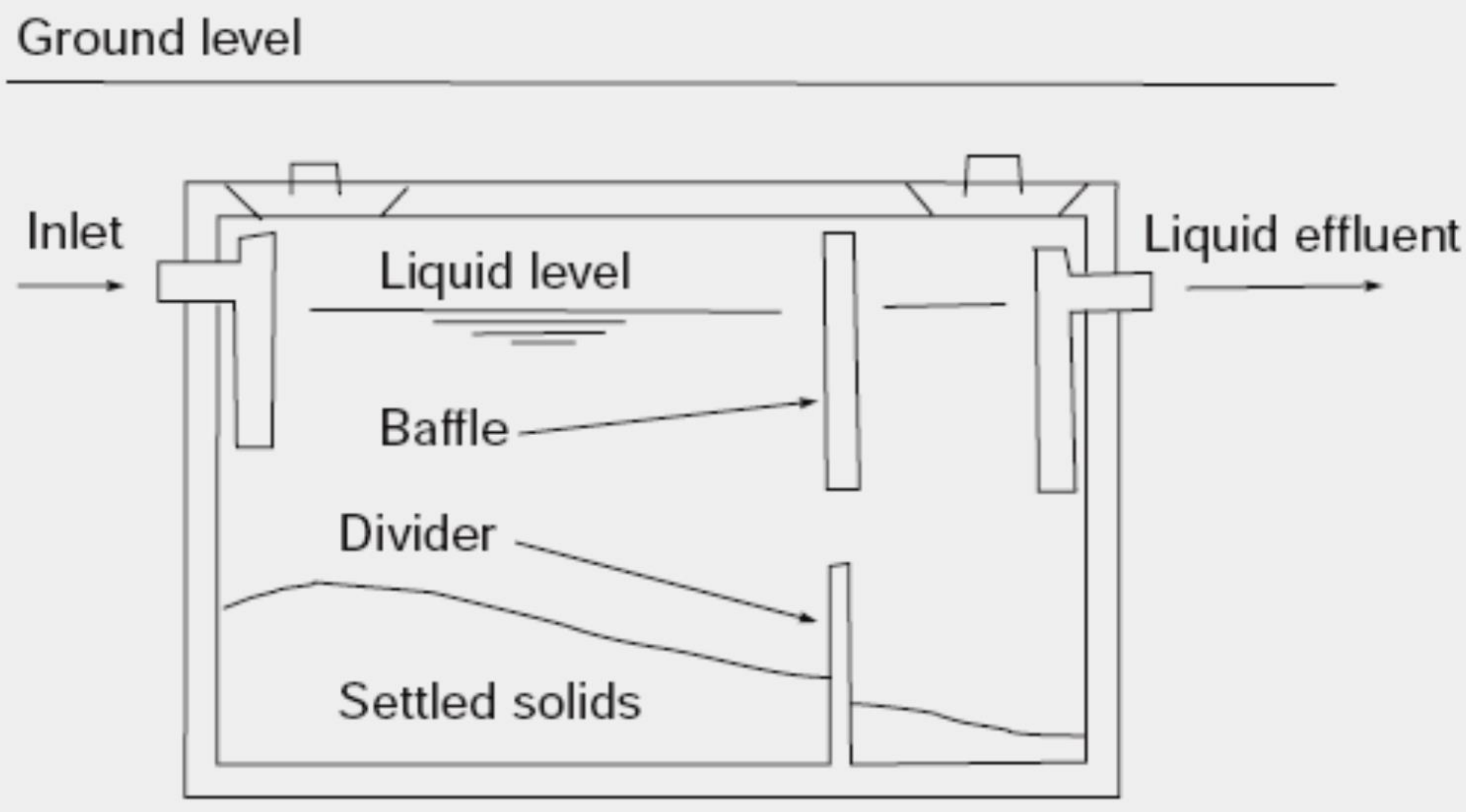


Figure 8.2 Cross section of a typical septic tank

The functions of the septic tanks:

1- Removing of suspended solids from wastewater (sewage), by settling.

2- Removing of some of the organic matter content of wastewater by the action of anaerobic bacteria through the following equation:

$$\text{Organic Matter } (CH_2O) \xrightarrow{\textit{Anaerobic Bacteria}} CH_4 + H_2O$$

- For proper performance of Septic tanks, it is generally recommended that:

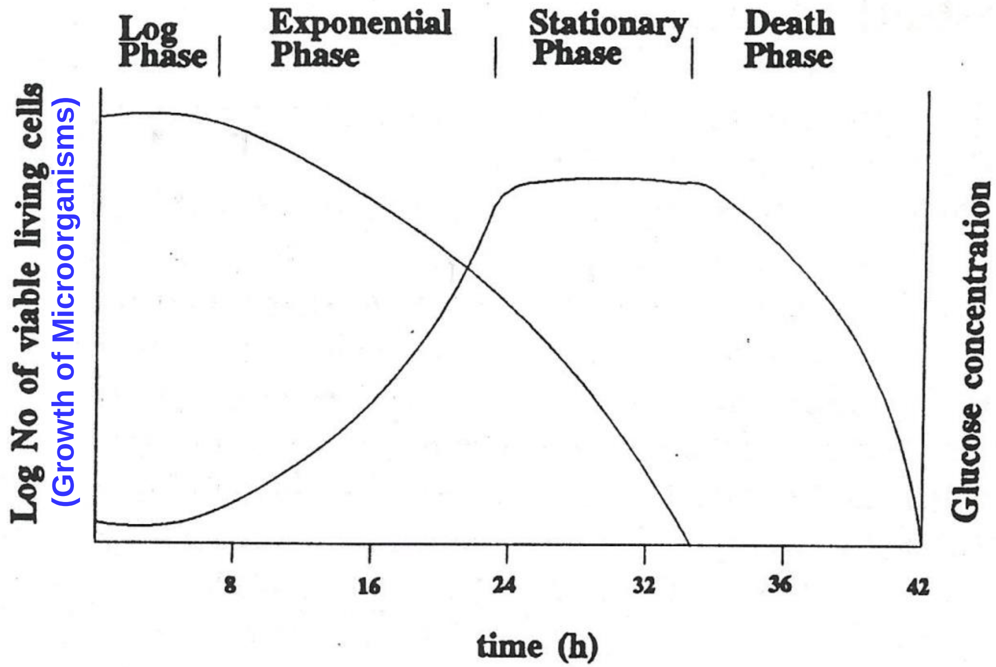
1- the tank hold a volume of at least 2000 liters.

2- the soil in which the drain field is located be sufficiently porous to absorb the effluent.

3- the land area be adequate for absorption of the volume of flow anticipated.

4- the tank be cleaned (solids removed) every three to five years.

Microbial Growth Patterns in Batch Cultures



The growth curve described in variation of cell mass.

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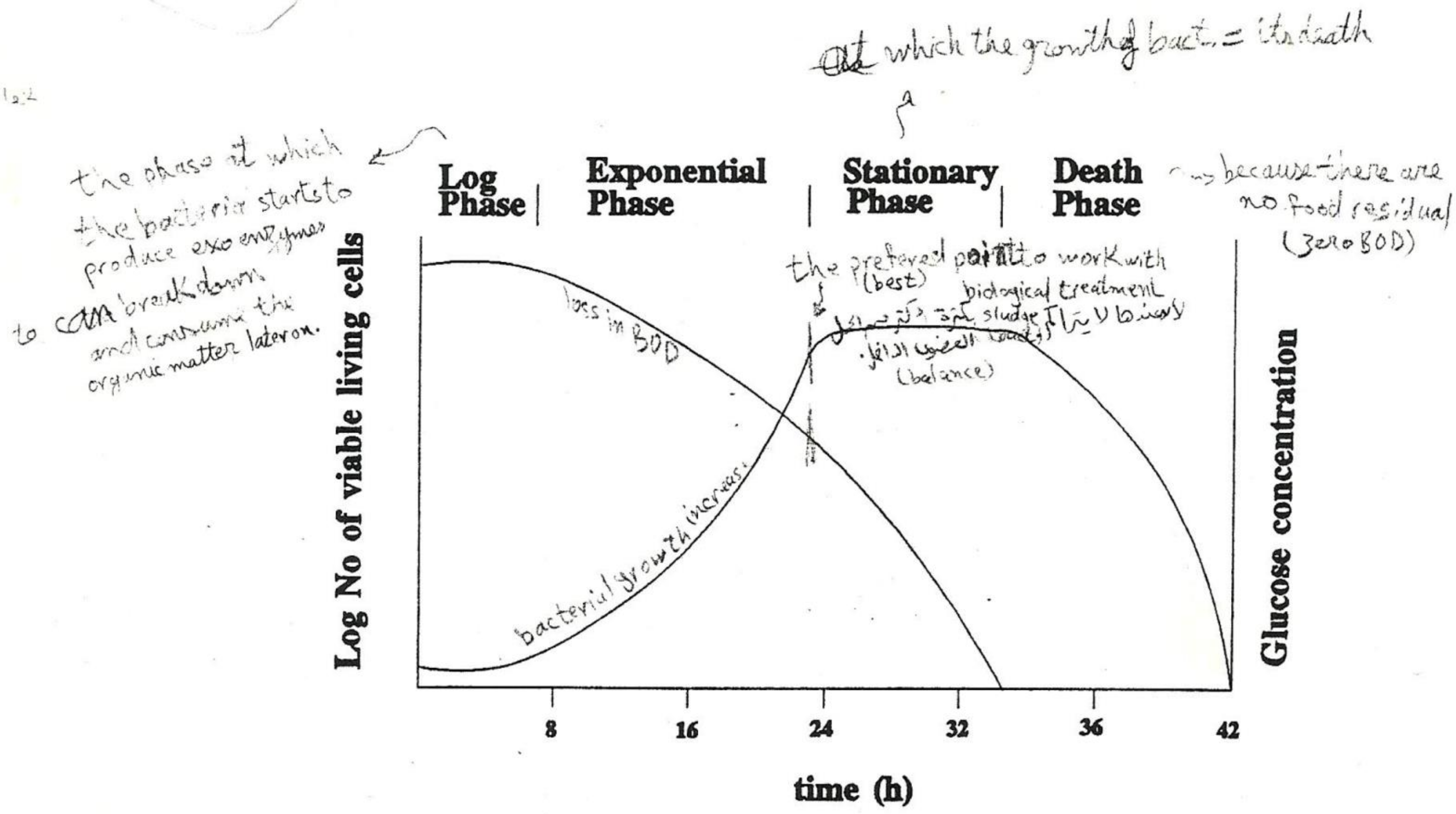
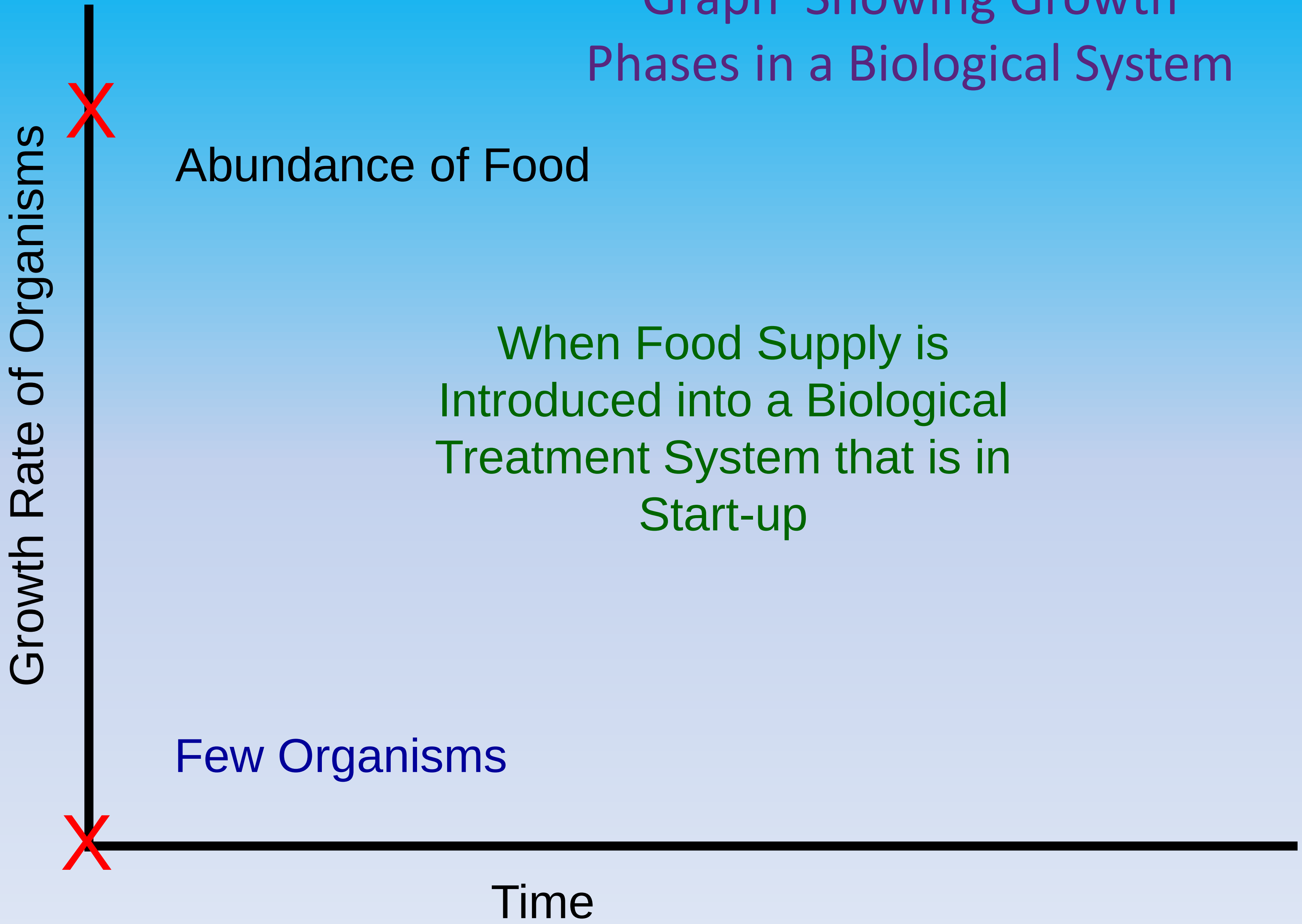
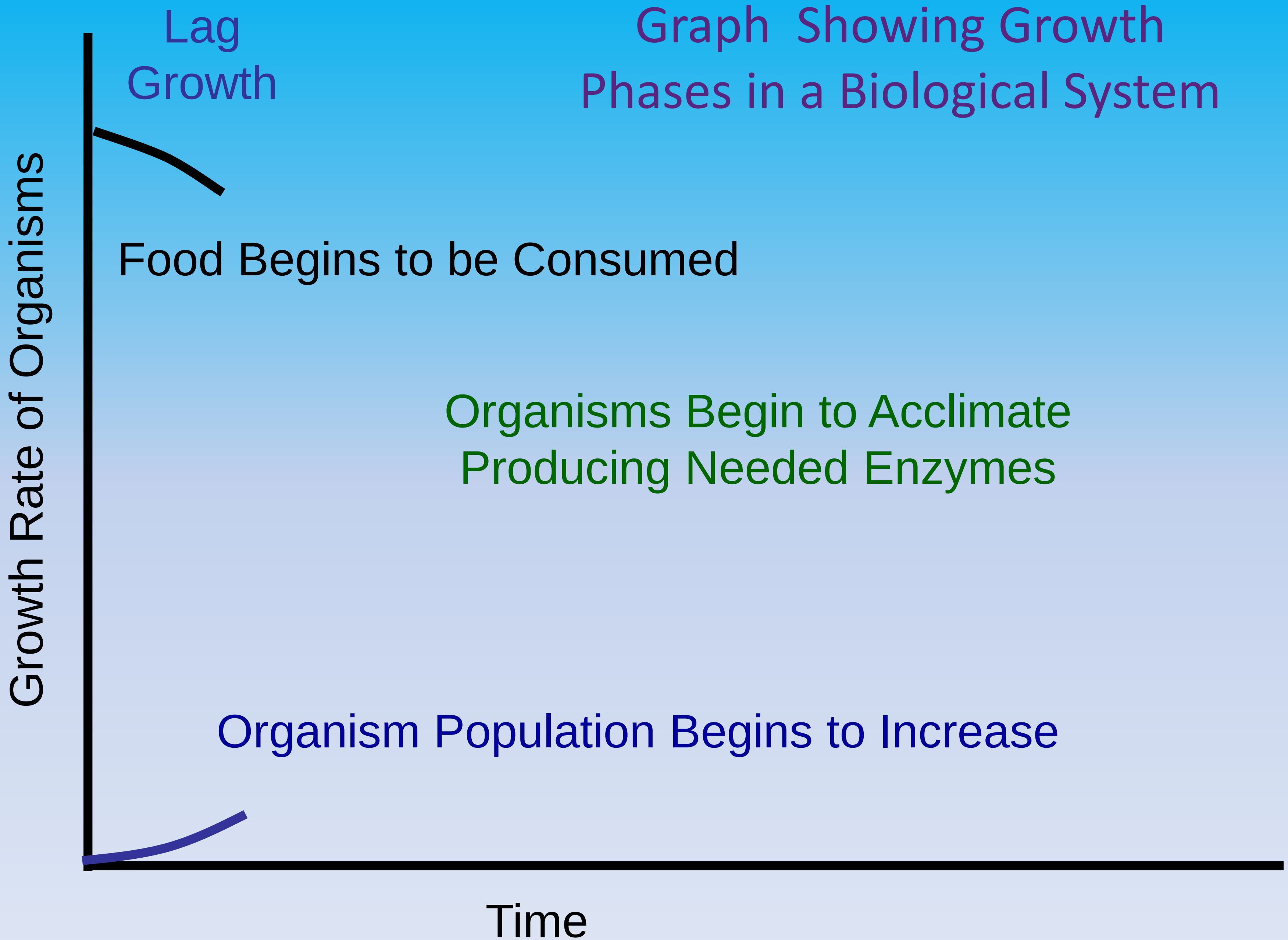


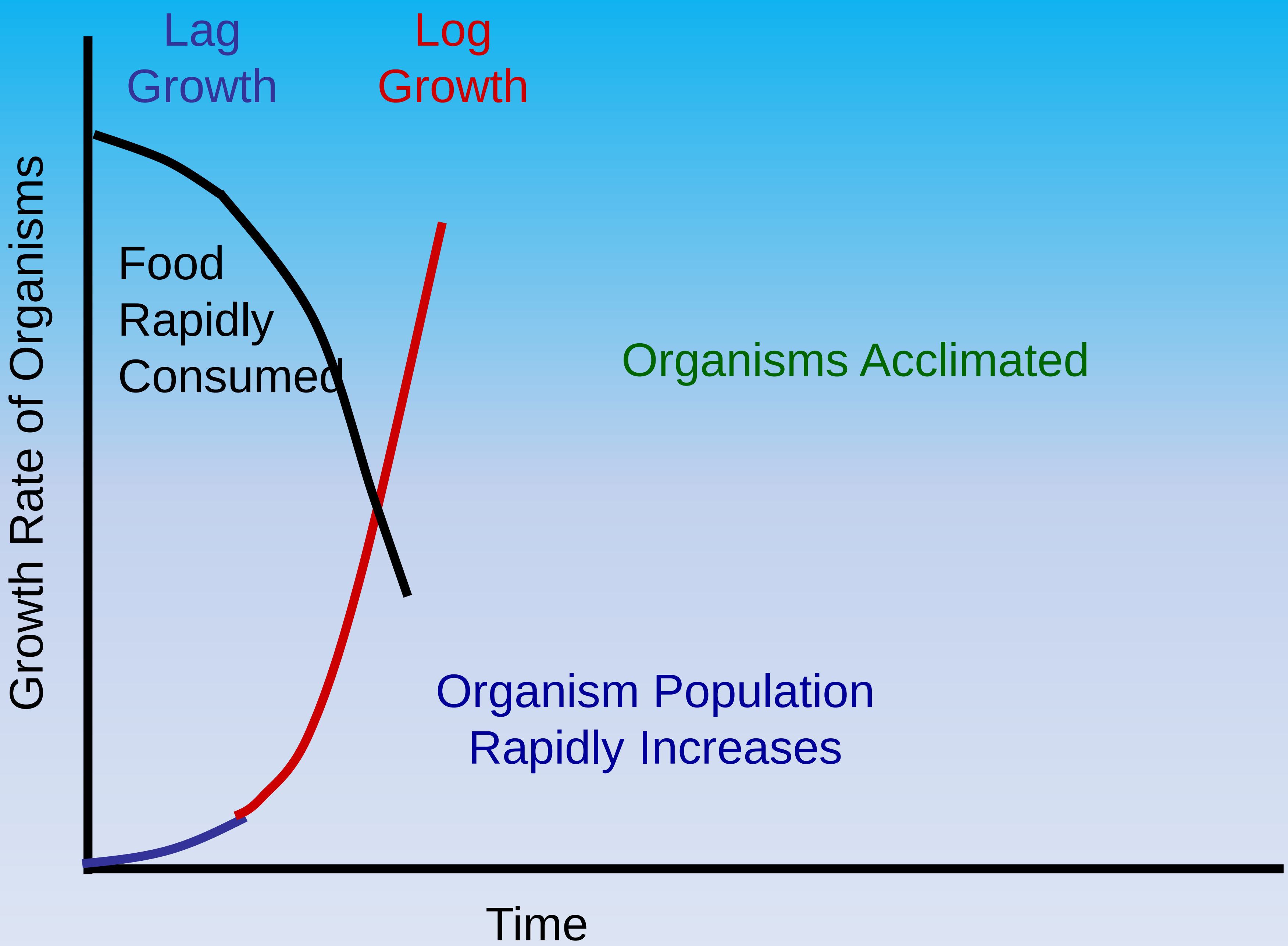
Figure 3.6 The growth curve described in variation of cell mass.

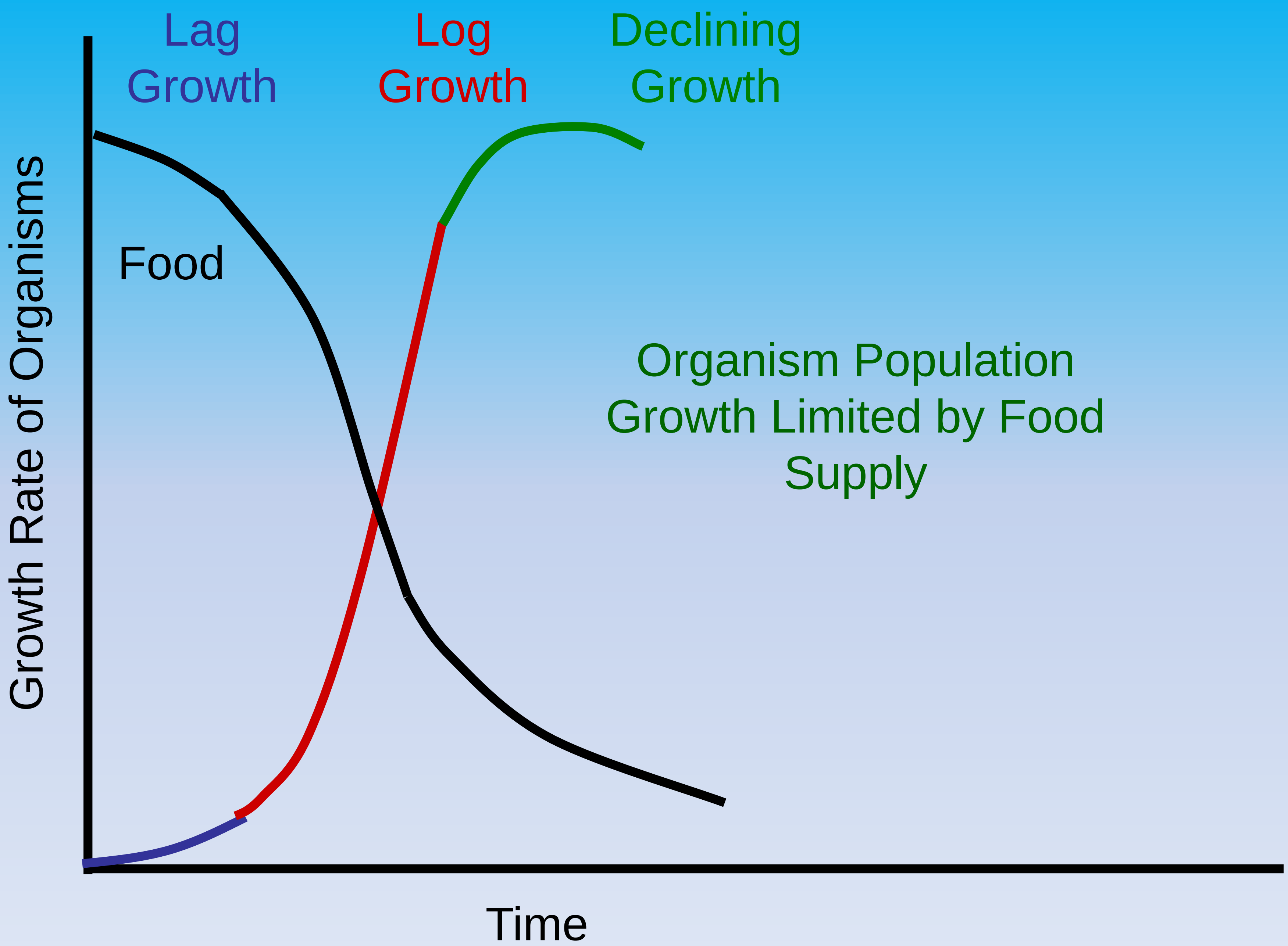
Graph Showing Growth Phases in a Biological System



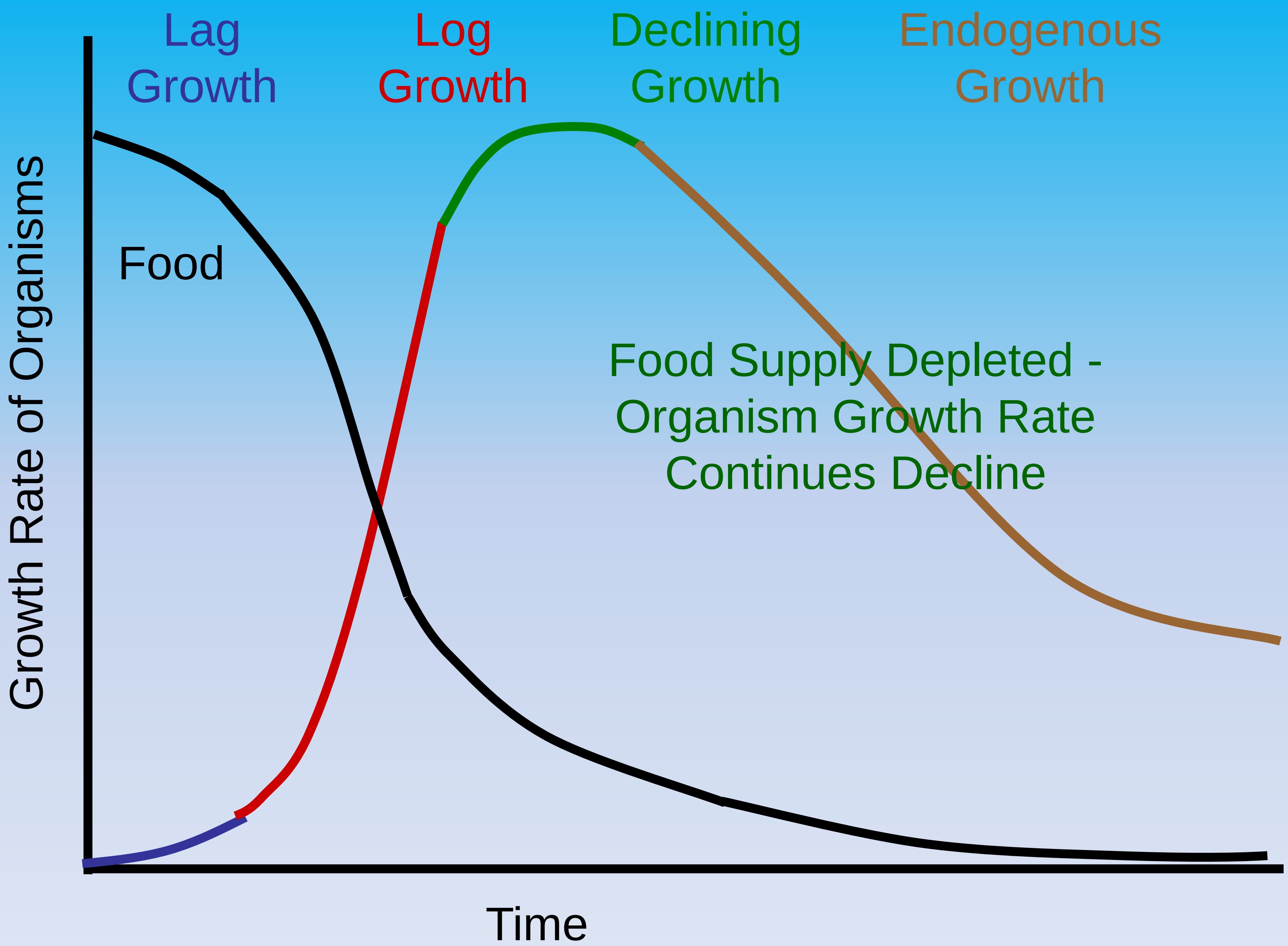
Graph Showing Growth Phases in a Biological System

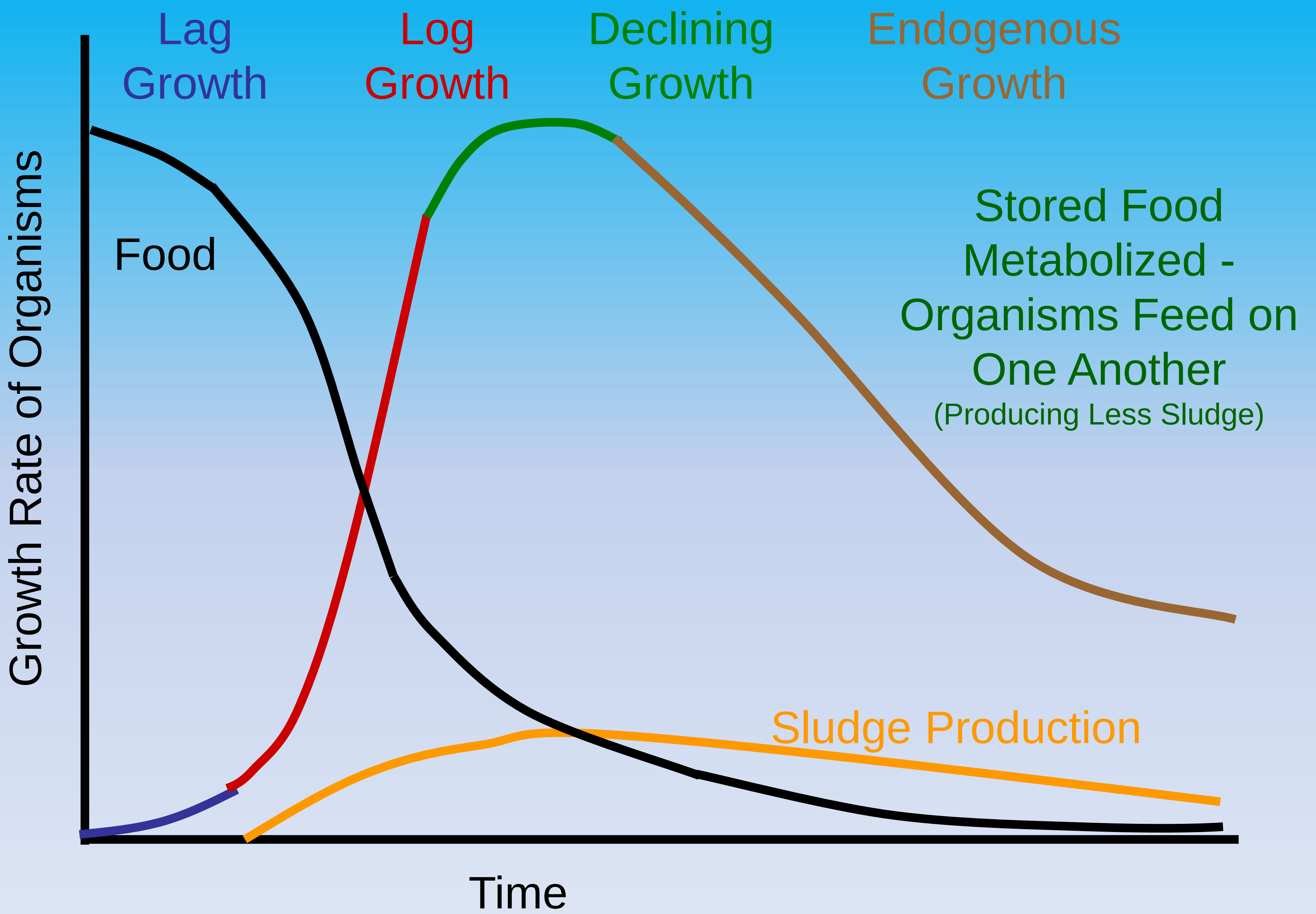



Lag
Growth
Log
Growth
Growth Rate of Organisms
Food
Rapidly
Consumed
Organisms Acclimated
Organism Population
Rapidly Increases
Time



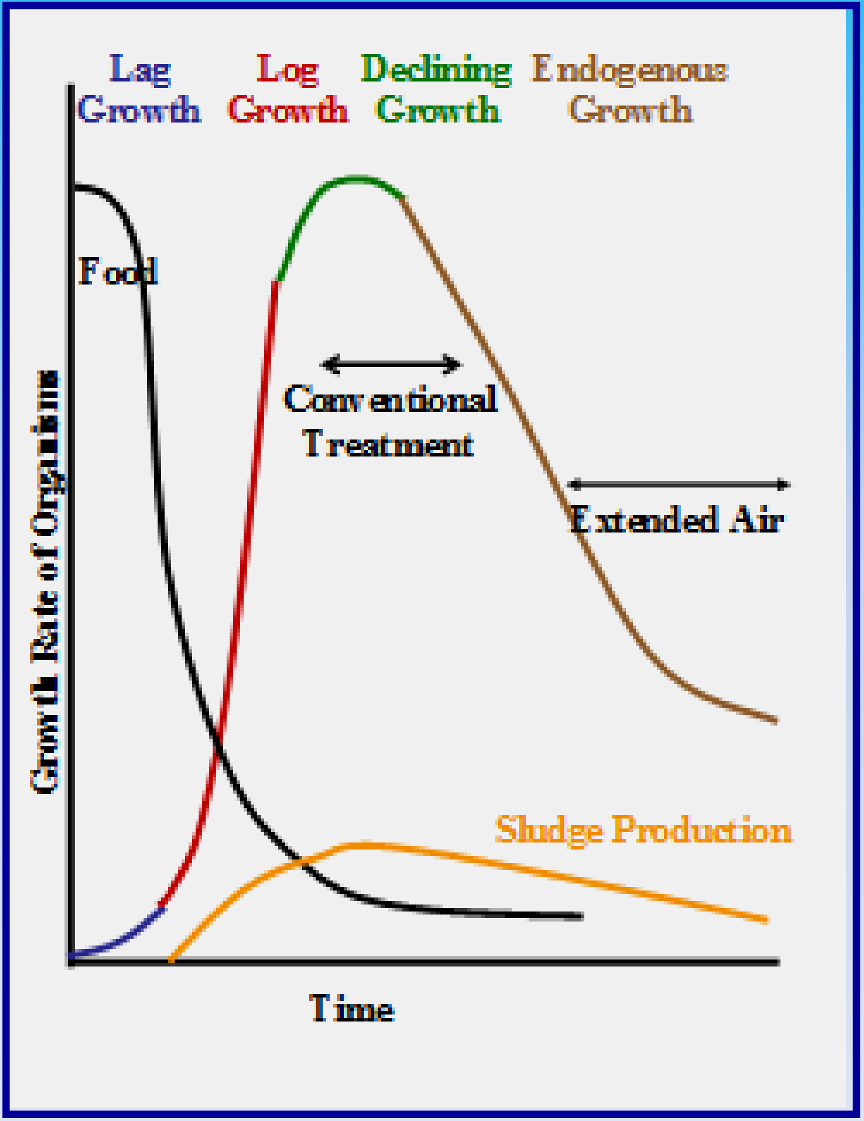
Lag Growth
Log Growth
Declining Growth
Growth Rate of Organisms
Food
Organism Population Growth Limited by Food Supply
Time


Lag Growth
Log Growth
Declining Growth
Endogenous Growth
Growth Rate of Organisms
Food
Food Supply Depleted - Organism Growth Rate Continues Decline
Time


Lag
Growth
Log
Growth
Declining
Growth
Endogenous
Growth
Growth Rate of Organisms
Food
Stored Food
Metabolized -
Organisms Feed on
One Another
(Producing Less Sludge)
Sludge Production
Time

Graph Showing Growth Phases in a Biological System

This graph illustrates that the activities of Microorganisms in a biological treatment system is related to the Average Age of the Organisms in the biological system.



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Operational parameters of Wastewater treatment plant with activated sludge systems:-

- **MLSS (Mixed Liquor Suspended Solids dried at 105 C°).**
- **MLVSS (Mixed Liquor Volatile Suspended Solids dried at 550 C° for 1hr.).**
- **HRT (Hydraulic Retention Time)** $= \dfrac{V_r}{Q_i}$

Where V_r = Volume of the aeration tank (m^3),
Q_i = flow of the influent to the aeration tank (m^3/h).

- **Treatment Plant Loading:**

$$\text{Sludge Loading Rate} = \frac{f}{m} = \frac{\text{Organic Loading Rate}}{\text{Volume of Sludge}} = \frac{Q_i \times BOD_5 \times 24}{V_r \times X_r}$$

Where Q_i = flow of the influent to the aeration tank (m^3/h),
BOD_5 = (Kg/m^3) = g/l = mg/ml,
V_r = Volume of the aeration tank (m^3),
X_r = Biomass concentration in the aeration tank = MLSS in the aeration tank (kg/m^3) ≈ g/L

Moreover, sludge loading rate can be calculated as follows:

$$\text{Sludge Loading Rate} = \frac{BOD_5 \times 24}{X_r \times HRT}$$

Sludge Loading Rate is expressed as: **Kg BOD_5 / Kg MLSS / day** ***(Kg BOD_5 Kg^{-1} MLSS d^{-1}).***

Example:

For a conventional activated sludge plant with a HRT of 4.5h, an influent BOD_5 of 240 mg/l and a MLSS concentration of 2500 mg/l,

the sludge loading is: $\dfrac{240 \times 24}{2500 \times 4.5} = 0.51$ Kg BOD_5 Kg^{-1} MLSS d^{-1}

$$\text{Volumetric Organic Loading Rate} = \frac{Q_i \times BOD_5 \times 24}{V_r}$$

$$= \frac{Q_i \times BOD_5 \times 24}{Q_i \times HRT}$$

$$= \frac{BOD_5 \times 24}{HRT}$$

Volumetric Organic Loading Rate expresses the organic content of wastewater in: **Kg BOD_5 m^{-3} d^{-1}**

Example:

An activated sludge plant with a retention time of 4.5h and an influent BOD_5 of 240 mg/l, will have a volumetric loading of: $\frac{0.240 \times 24}{4.5} = 1.28$ Kg BOD_5 m^{-3} d^{-1}

- **Sludge Age:**

$$\text{Sludge Age (Sludge Retention Time [SRT] in days)} = \frac{V_r \times MLSS_r}{Q_w \times MLSS_w}$$

Where V_r = volume of the reactor (m^3),
$MLSS_r$ = MLSS inside the reactor (Kg/m^3),
$MLSS_w$ = MLSS of the wasted sludge (Kg/m^3),
Q_w = wasted sludge flow rate (m^3/day).

- **Treatment Rate:**

Treatment rate	HRT (hr)	Sludge loading (f/m) Kg BOD_5 kg^{-1} d^{-1}	Sludge Age (d)
Conventional (Conventional treatment → BOD 20-30)	5 -14	0.2 – 0.5	3 - 4
High (Pre- or partial treatment)	1 - 2	> 1	0.2 – 0.5
Low (Full treatment)	24 - 72	< 0.1	> 5 - 6

Anaerobic Treatment

Definition of anaerobic digestion:

Anaerobic digestion is a biological process in which organic materials are converted into methane and carbon dioxide in the absence of oxygen, by the action of anaerobic bacteria.

This process is widely used for the treatment of wastes containing high concentration of biodegradable organics, i.e. domestic sewage, sludge, manure and to some extent also for high strength wastes from various industries.

The ***anaerobic degradation of organic matters*** can be **grouped into *four stages*** which occur simultaneously during the anaerobic degradation of organic material:-

1) Hydrolysis (Liquification)

In this stage, complex non soluble material is converted into less complex soluble compounds “sugars, amino acids, fatty acids” by enzymes excreted by fermentative bacteria.

2) Acidogenesis (Fermentation)

In this stage, soluble compounds are converted into a number of simple compounds by fermentative bacteria. The products that are excreted, for instance: volatile fatty acids, alcohols, lactic acid, CO_2, H_2, NH_3 and H_2S as well as new biomass

3) Acetogenesis

In which the products of the fermentation processes are converted into acetate, H_2 and CO_2 as well as new biomass.

4) Methanogenesis

In this stage, *the end phase of anaerobic decomposition*, acetic acid, H_2 and CO_2, formic acid and methanol are converted into methane and CO_2 as well as new biomass

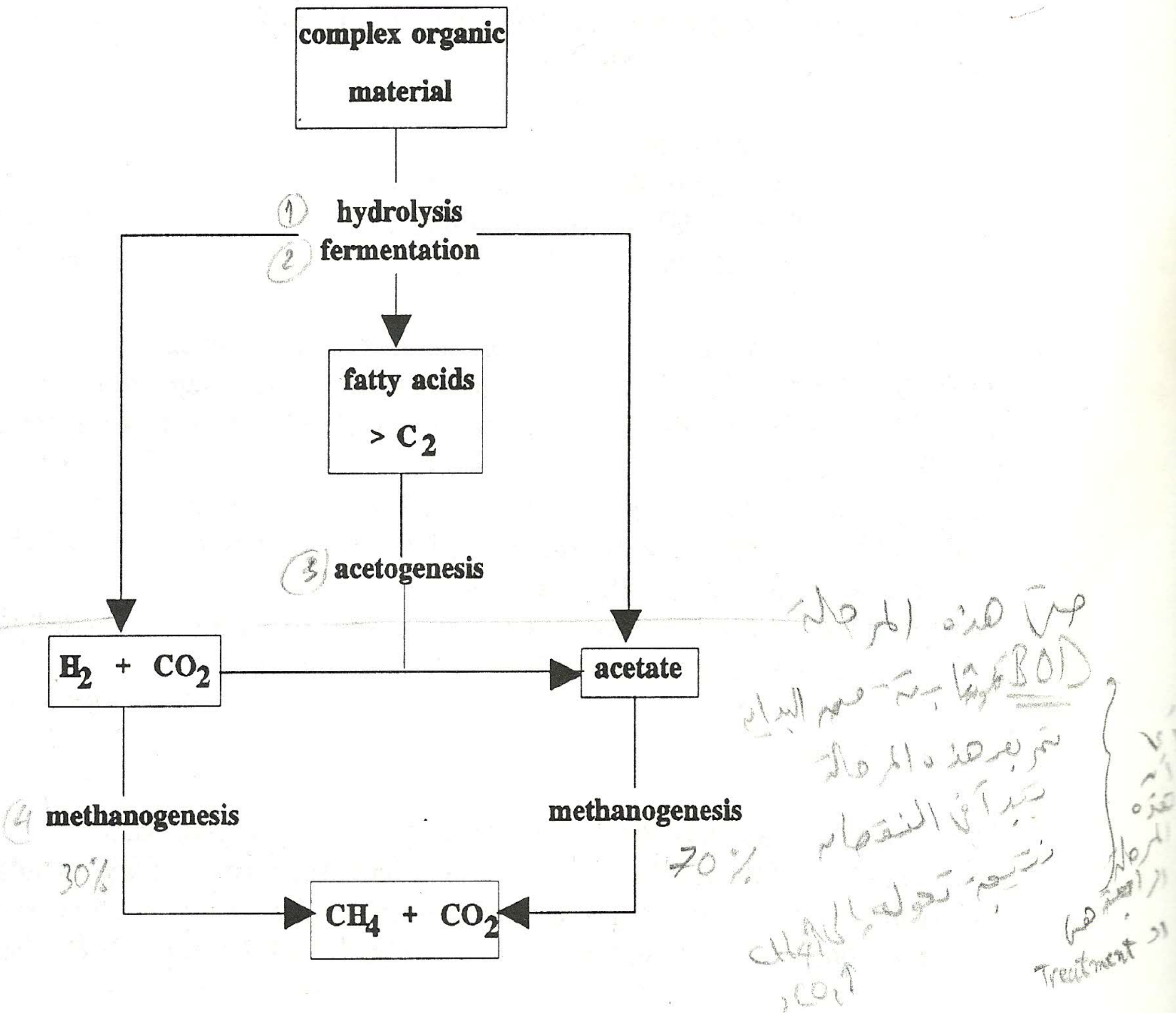


Figure A schematic survey of the four phases of anaerobic degradation.

Sludge Digestion (Anaerobic Digestion "Fermentation):

The thickened sludge coming to the thickener from the primary and secondary sedimentation tanks, will undergo slow fermentation (digestion) by anaerobic bacteria in a sludge digester, wherein the sludge is maintained at a temperature of 35°C at pH 7-8 for about 30 days. The organic matter is aerobically digested, then CH_4, CO_2 and some NH_3 are liberated as the end products.

The schematic representation of the anaerobic sludge digestion process is shown in the following figure:

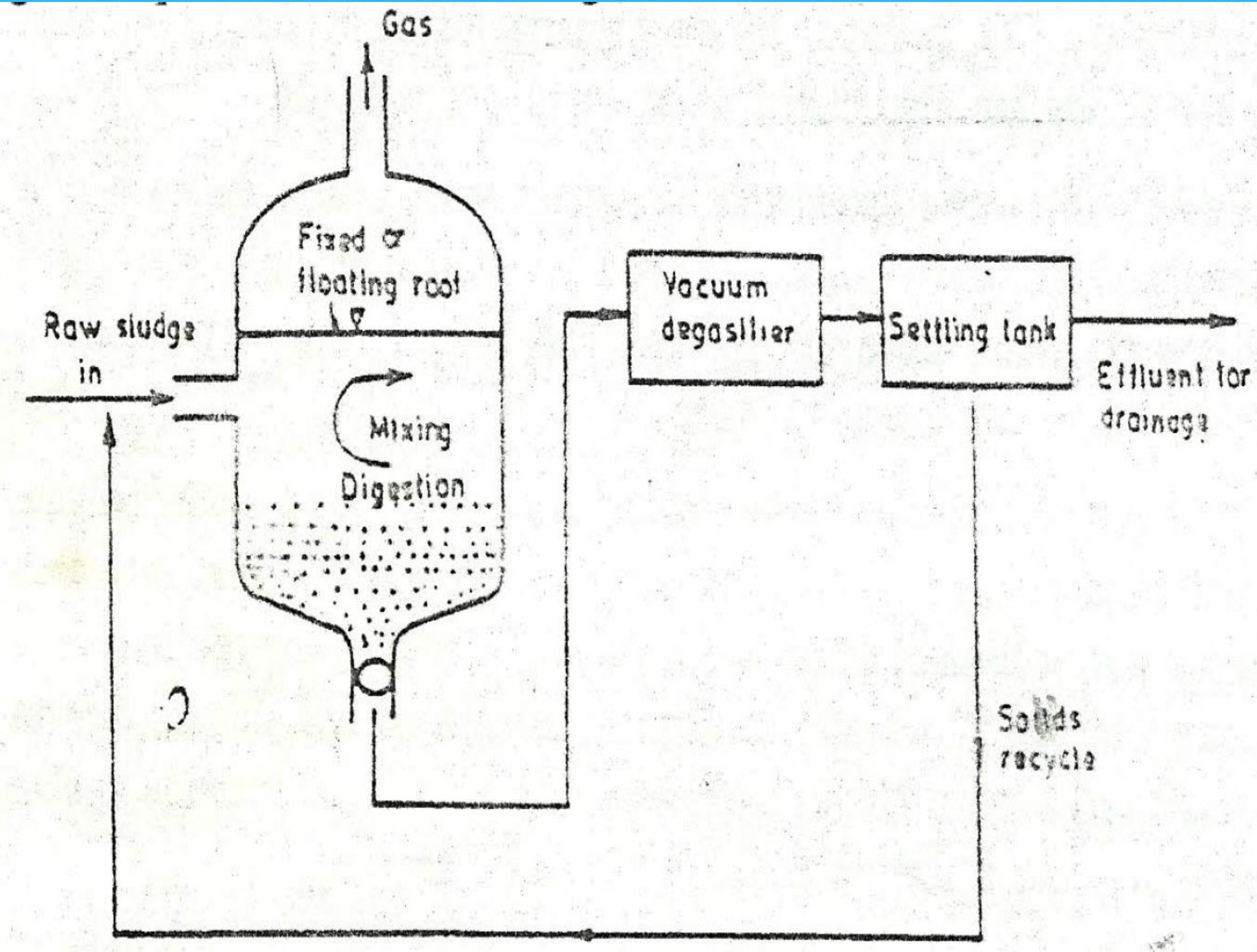


Fig. Anaerobic Sludge Digestion Process.

The advantages of anaerobic digestion process are as follows:

1) Reduction in volume of the waste by about 65%.
2) The digested sludge is safer to be used as manure than the undigested sludge.
3) The digester gas obtained has the following percentage composition by volume:-

   CH_4: 65 to 80%; CO_2: 5 to 30%; N_2, H_2, H_2S and CO together: about 5%.

   The calorific value of the methane gas produced is about 26 MJ/m^3 (*i.e.,* about 700 BTU/ft^3). The methane gas can therefore be used as a fuel to provide the heat required to warm the digestion tanks. In large Installations, it can be used for power generation.

4) Although anaerobic treatment is a slow process, it is useful for treating small quantities of wastes, containing readily oxidizable dissolved organic solids in liquid form or in a finely divided form. The operation and maintenance costs are lesser with this treatment. That is why some liquid wastes containing soluble organics from dairy, slaughter house and paper mill industries have been economically and effectively treated by this process.

Table Comparison of aerobic waste-water treatment systems with anaerobic systems

parameter:	aerobic	+/-	anaerobic	+/-*
sludge production[1]	high	-	low	+
COD removal	good	+	good	+
COD load[2]	low	-	high	+
Reactor volume	large	-	small	+
space[3]	large	-	small	+
energy consumption[4]	high	-	low	+
sludge adaptation[5]	fast	+	slow	-
sensitivity of:				
- temperature	low	+	high	-
- acidity	low	+	high	-
- flow fluctuations	low	+	high	-
methane production	no	-	yes	+
process controllability[6]	good	+	difficult	-
investment	high	-	low	+

\+ = positive (profitable), - = negative (not profitable)

Advanced Wastewater Treatment Technology

"Membrane Bioreactor (MBR)"

I. Membrane Filtration

Membrane filtration is used to remove particles that are too small for ordinary filters to remove. Most membrane filtration systems use cross flow filtration where the feed stream flows across the membrane rather than through it, as in conventional filtration (Dead-end filtration). This helps prevent clogging of the membrane by retained particles.

A cross flow filtration system separates an influent stream into two effluent streams known as the permeate and the concentrate. The permeate is the portion of the fluid that has passed through the membrane. The concentrate stream contains the constituents that have been rejected by the membrane.

There are basically **four types of membrane filters**,

differing from each other primarily by the molecular size and weight of the contaminant they filter from the water or wastewater. They are in descending order of pore size: **microfiltration**, **ultrafiltration**, **nanofiltration** and **reverse osmosis**.

Microfiltration is the membrane process which most closely resembles conventional coarse filtration. The pore sizes of microfiltration membranes range from 10000 to 50 nm, making the process suitable for retaining suspensions and emulsions.

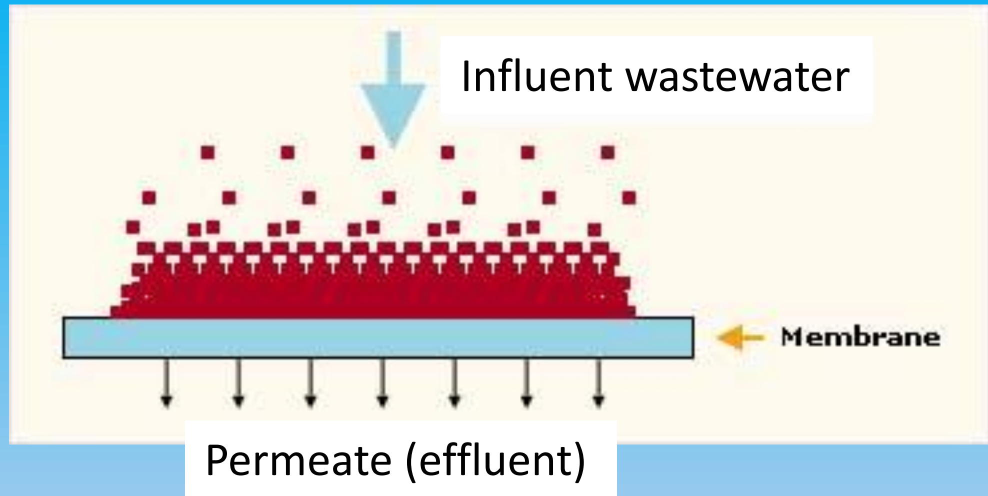
Ultrafiltration is a membrane process whose nature lies between nanofiltration and microfiltration. The pore sizes of the used membranes range from 50 nm (on the microfiltration side) to 1 nm (on the nanofiltration side). Ultrafiltration is typically used to retain macromolecules and colloids from a solution.

Nanofiltration membranes have pore sizes range from 5 to 0.5 nm and can remove some inorganic ions.

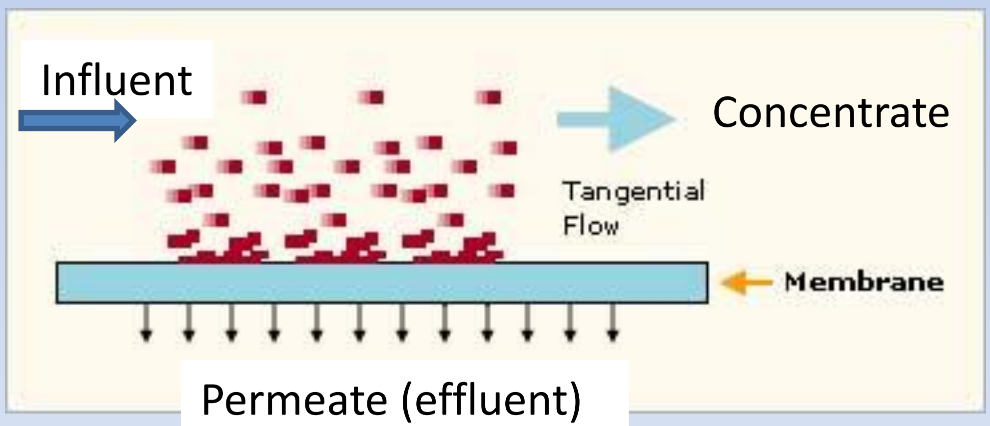
Ultrafiltration and nanofiltration can be used to reduce the biochemical oxygen demand (BOD) of wastewater by removing substances such as sugar and protein molecules.

Reverse Osmosis (RO) removes the smallest particles, retaining substances smaller than 1nm. It also can retain ionic substances such as dissolved salts or metal ions.(9)

Generally, ultrafiltration is used when the only issues are fine filtration and removal of most organic contaminants. Reverse osmosis is used when the reduction in inorganic salts (e.g. sodium, alkalinity) is added to this list; and nanofiltration is used when the interest is only a particle reduction in the inorganic salt levels, along with fine filtration and organic removal.



Dead-end filtration (Ordinary filtration).



Cross flow filtration.

* Dead-end Filtration

When using a dead-end filtration technique, all the fluid passes through the membrane and all particles larger than the pore sizes of the membrane are stopped at its surface. Particle size prevents contaminants from entering and passing through the membrane. This means that the trapped particles start to build up a "filter cake" on the surface of the membrane which reduces the efficiency of the filtration process until the filter cake is washed away in back flushing.

* Cross flow Filtration

In cross flow filtration, the fluid feed stream runs tangential to the membrane, establishing a pressure differential across the membrane. This causes some of the particles to pass through the membrane. Remaining particles continue to flow across the membrane, "cleaning it". In contrast to the dead-end filtration technique, the use of a tangential flow will prevent thicker particles from building up a "filter cake".

II. Biological Processes

Biological processes are primarily designed for the removal of dissolved and suspended organic matter from wastewaters. The correct environmental conditions are provided to encourage the growth of micro-organisms which use the organic compounds, often measured as biochemical oxygen demand (BOD) or chemical oxygen demand (COD), as carbon substrate. The micro-organisms that grow on the substrate are subsequently separated from the water which has BOD removed, leaving a relatively clean effluent. They derive energy and cellular material from the oxidation of this organic matter and can be aerobic or anaerobic. Biological wastewater treatment is also capable of removing other wastewater components, including suspended solids, nitrogen and phosphorus.

Suspended growth processes rely upon the biomass being in free suspension, as in the activated sludge process. Contact with the wastewater constituents will rely upon good mixing in such reactors. One advantage of suspended growth processes is the ability to more closely control the biomass retention time.

III. Membrane Bioreactors (MBR)

Combining membrane technology with biological reactors for the treatment of wastewaters has led to the development of membrane bioreactors (MBRs) for separation and retention of solids Membranes when coupled to biological processes are most often used as a replacement for sedimentation i.e., for separation of biomass. Biomass separation membrane bioreactors, the most type of MBR, are the amalgamation of a suspended growth reactor and membrane filtration device into a single unit process.

The membrane unit can be configured external to, as in side stream operation or immersed in the bioreactor (Figure 1).

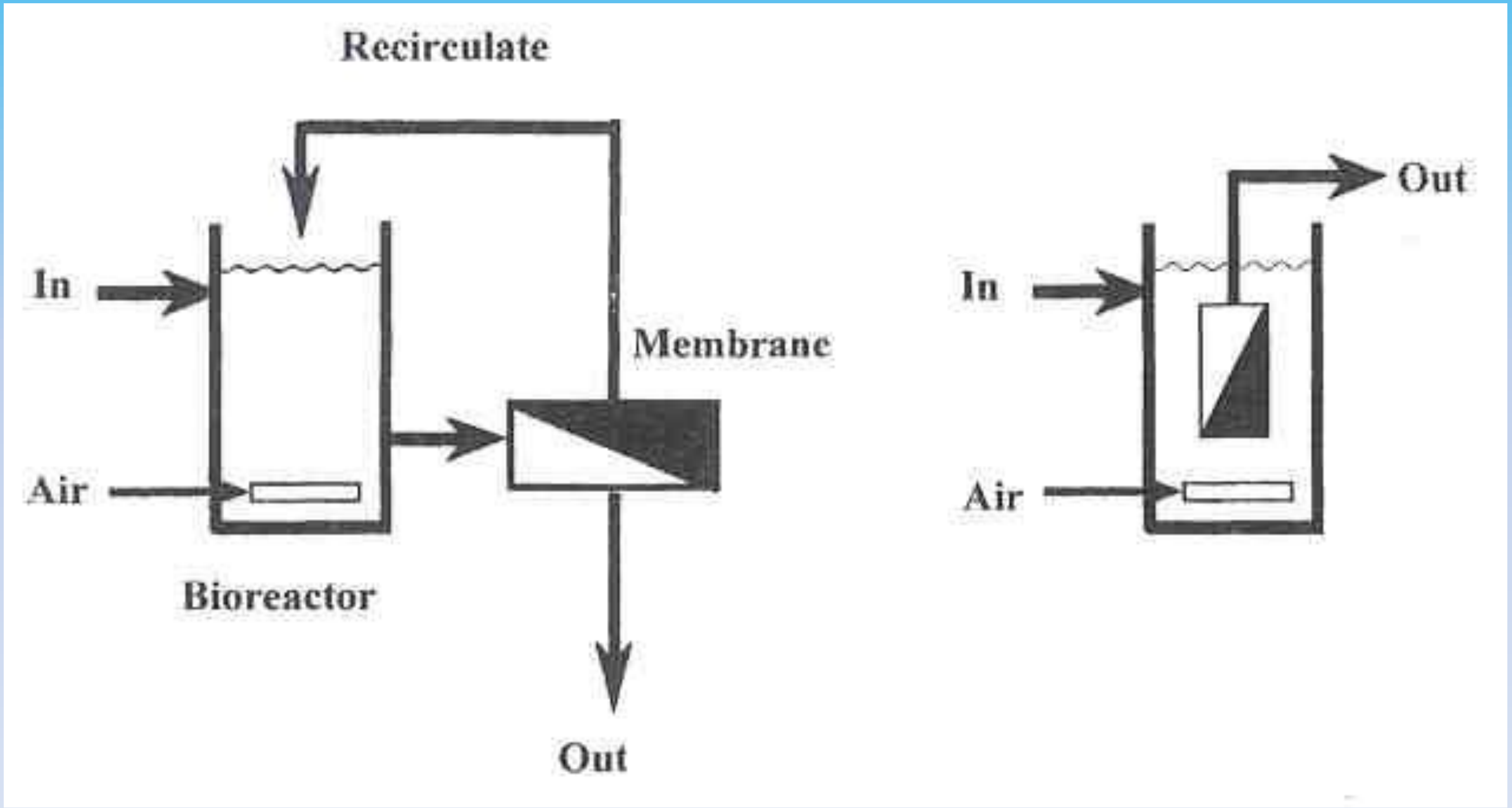
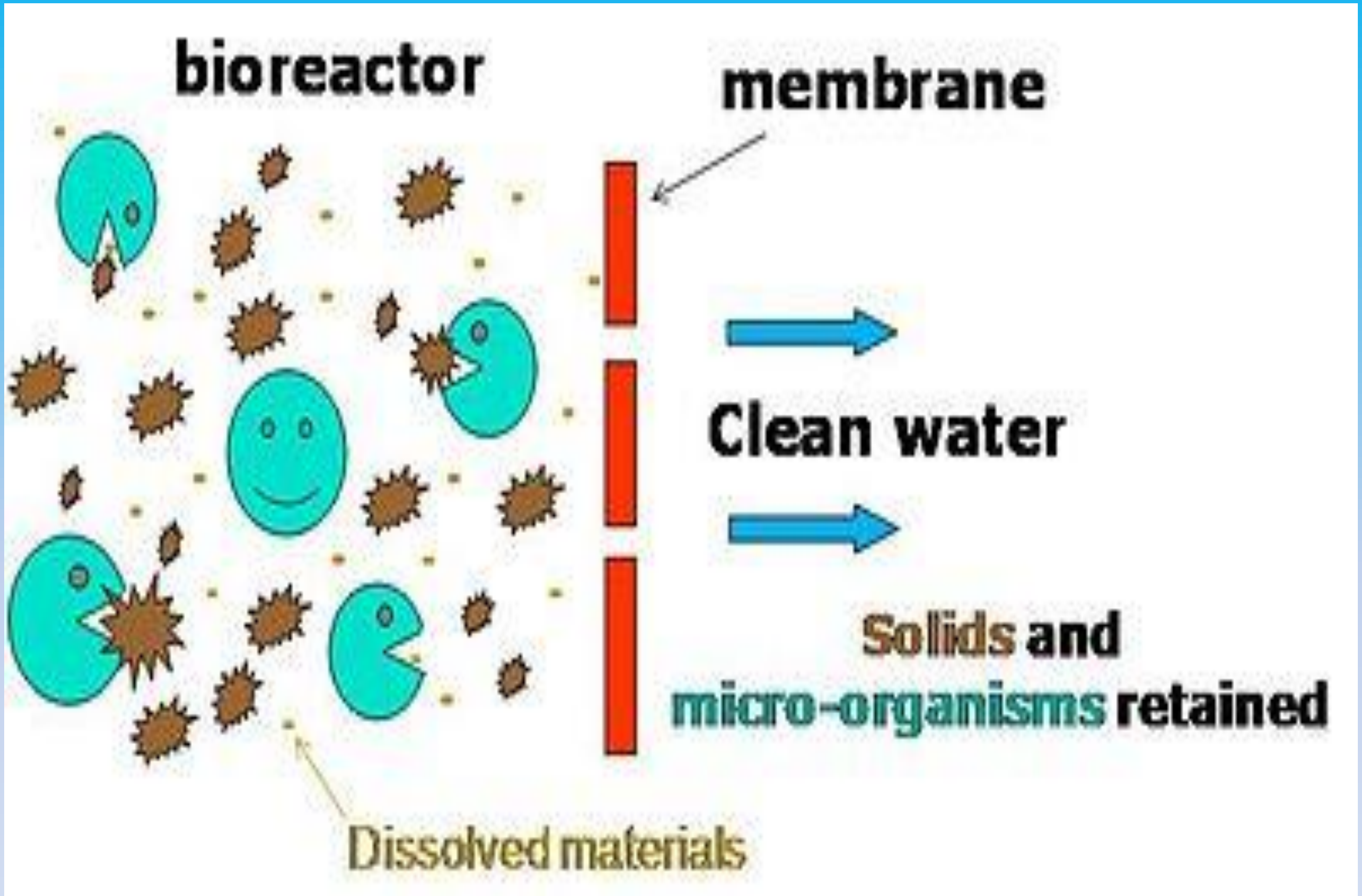


Figure (1): Configuration of MBRs: Sidestream (left) and submerged (right)

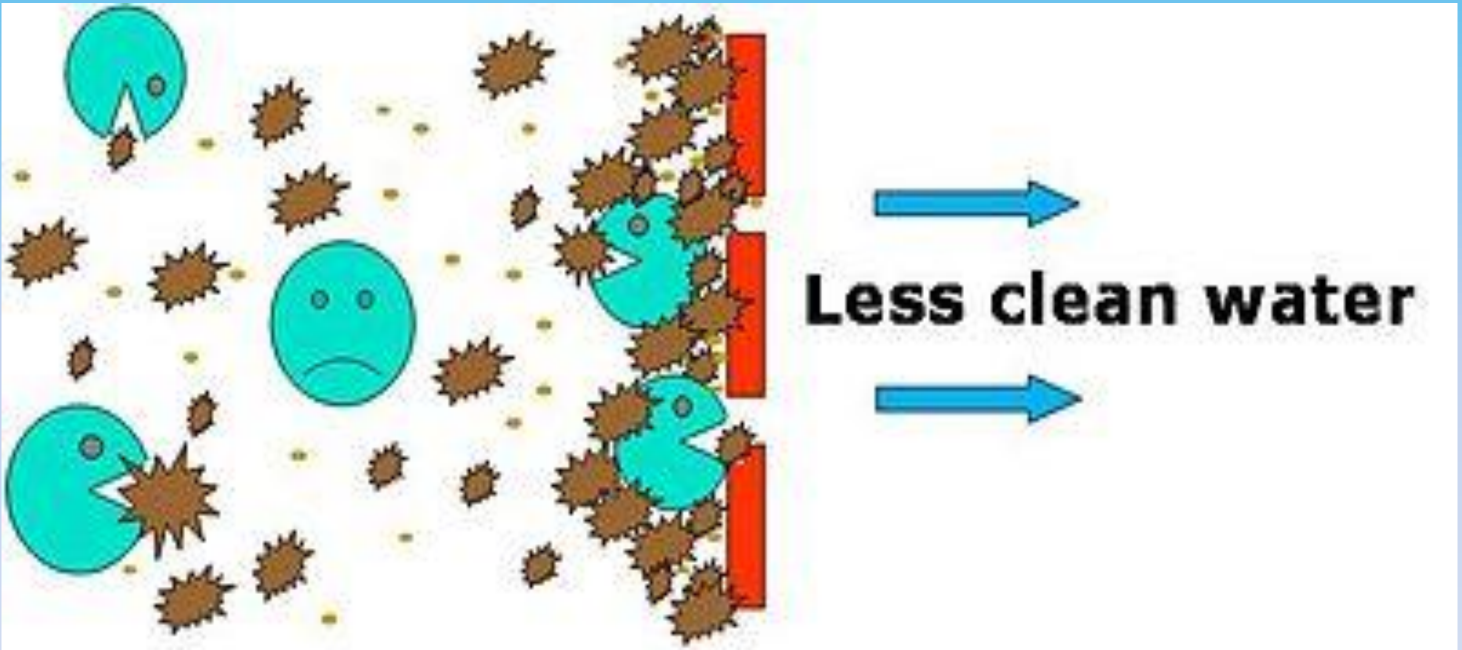
In the case of an external system the membrane is independent of the bioreactor. Feed enters the bioreactor where it contacts biomass. This mixture is then pumped around a recirculation loop containing a membrane unit where the permeate is discharged and the retentate returned to the tank. The transmembrane pressure (TMP) and the crossflow velocity, which define the operation of the membrane, are both generated from a pump. Immersed systems differ in that there is no recirculation loop as the separation occurs within the bioreactor itself. Under these circumstances the TMP is derived from the hydraulic head of the water above the membrane.

The coupling of a membrane to a bioreactor has attracted increasing interest both academically and commercially because of the inherent advantages the process offers over conventional biological wastewater treatment systems. The primary driver for using a membrane bioreactor technology is to achieve a high degree of treatment while reducing treatment complexity and operational requirements. In addition, the process of MBR reduces the excess sludge production down to below half that commonly occur in activated sludge. Moreover, permeate from the membrane is free from solids and macro-colloidal material. Typical water product qualities are <5 mg/l suspended solids and <1 NTU turbidity. Such MBR effluents can be of a quality suitable for discharge to sensitive regions, further purification by dense membrane processes or even recycling.



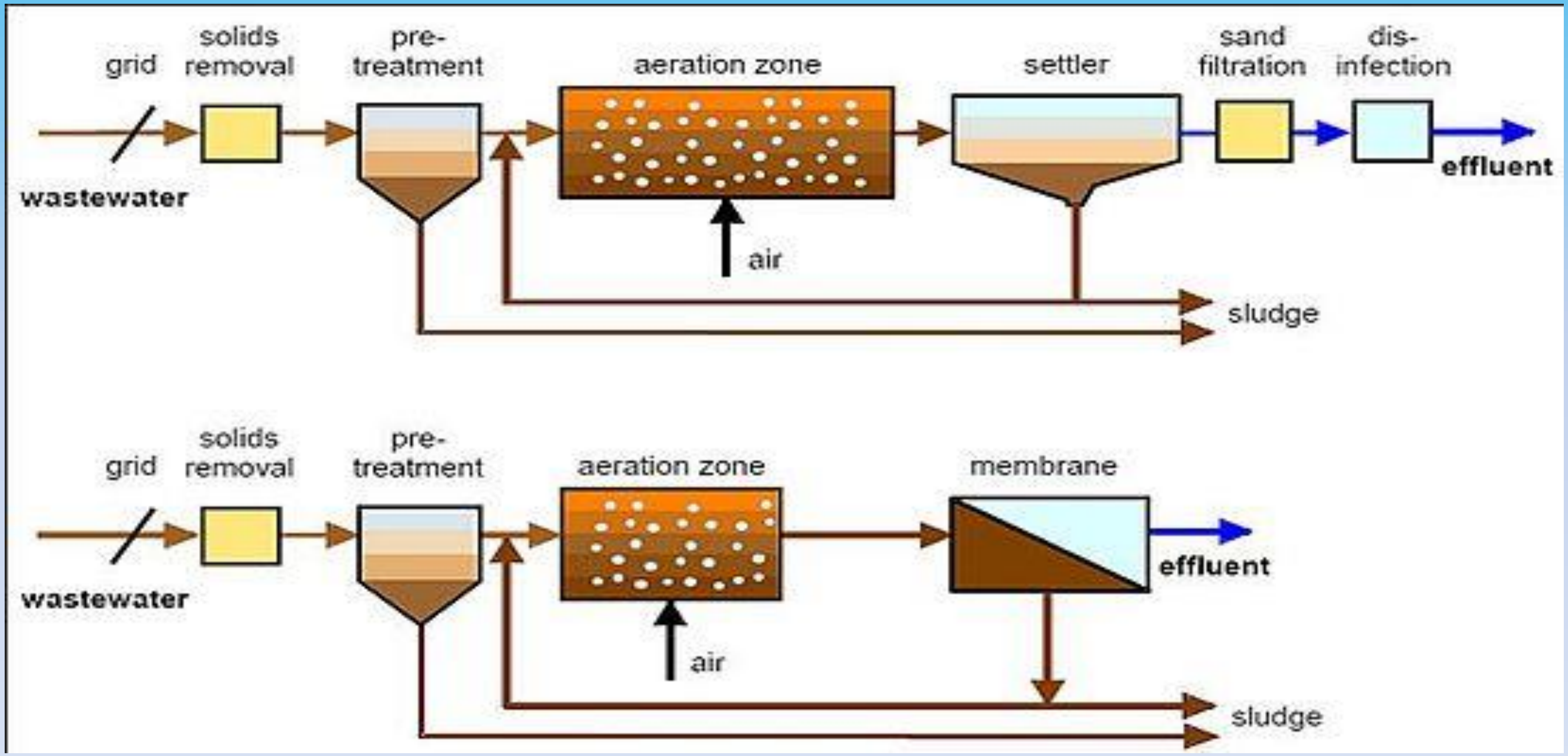
Simple schematic describing the MBR process

Biofouling **occurs for the membrane after the operation of the MBR for a long period, and in turn leads to less clean water production :-**



At present, membranes are cleaned periodically with solutions containing chlorine, acids and/or bases to maintain and restore membrane flux.

** Comparison between conventional activated sludge process and external (side stream) membrane bioreactor for wastewater treatment:



Schematic diagram of conventional activated sludge process (top) and external (side stream) membrane bioreactor (bottom)

Table (1): The principal advantages and disadvantages of the biomass separation MBR

Advantages	Disadvantages
1- Small footprint	1- Aeration limitations.
2- Complete solids removal from effluent.	2- Membrane fouling.
3- Effluent disinfection.	3- Membrane costs.
4- Combined COD, solids and nutrient removal in a single unit.	
5- High loading rate capability.	
6- Low/zero sludge production.	
7- Rapid start up.	
8- Sludge bulking not a problem.	
9- Modular/retrofit.	

Definition of Urban Liquid Wastes Management

- **Urban Water Management is the management of all aspects of liquid wastes in the urban setting.**
- **Includes**
  - ***Industrial water***
  - ***City maintenance water***
  - ***Used water***
  - ***Rainwater***

Drawbacks present in Urban Wastewater Management

- **Water (~ drinking water) used to transport and dilute wastes – wastage of water, chemicals, energy**
- **Ongoing pollution of resource water, even when applying (conventional) treatment (a 50 PE. plant, 90% efficient, discharges 5 PE.)**
- **Dilution/ distribution of resources into the environment and wastage of resources (e.g. water, N, P, heavy metals)**
- **Infrastructural investments unaffordable**
- **Groundwater depletion**
  - ***'Take and dump' attitude***

Needed

- A different way of looking at 'waste',

- An attitude of 'Resource responsibility'

Water Management in the city of tomorrow

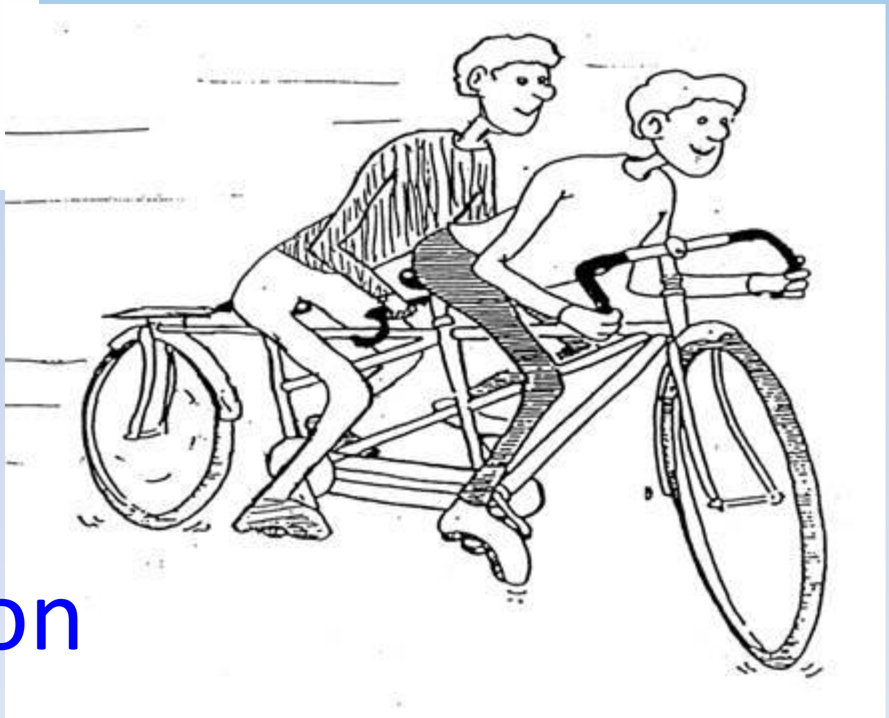
- **How does water management in the city of today, compare with that in the city of tomorrow? What has to be different and why?**

Aspect	City of today	City of tomorrow
	Wastewater	
1. Collection	Collection from domestic and industrial origin to point of discharge or (central) treatment	Collection of 'clean' wastewater within the WMU to point of further processing Specific waste flows kept separate
2. Treatment	Predominantly of the activated sludge type	Further processing determined by the reuse/recovery options and the specific use of the water within the WMU Indirect reuse is objective
3. Discharge	Into nearest surface water	Depending on possibilities within WMU, *e.g.:* irrigation, groundwater recharge, surface water discharge

Aspect	City of today	City of tomorrow
	Rainwater	
1. Approach	Removal as quick as possible so as not to have flooding problems	Make best possible use of this resource
2. Processing	Removal into sewer	Collection, temporary storage, followed by some type of treatment
3. Usage	None	Various options, *e.g.*: street cleaning, green areas, ground water recharge, or drinking/process water

Needed: a vision to safeguard our water needs today but also tomorrow

Without vision



With vision