BIOREACTORS

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WHAT ARE BIOREACTORS?

A bioreactor may refer to any manufactured or engineered device or system that supports a biologically active environment.

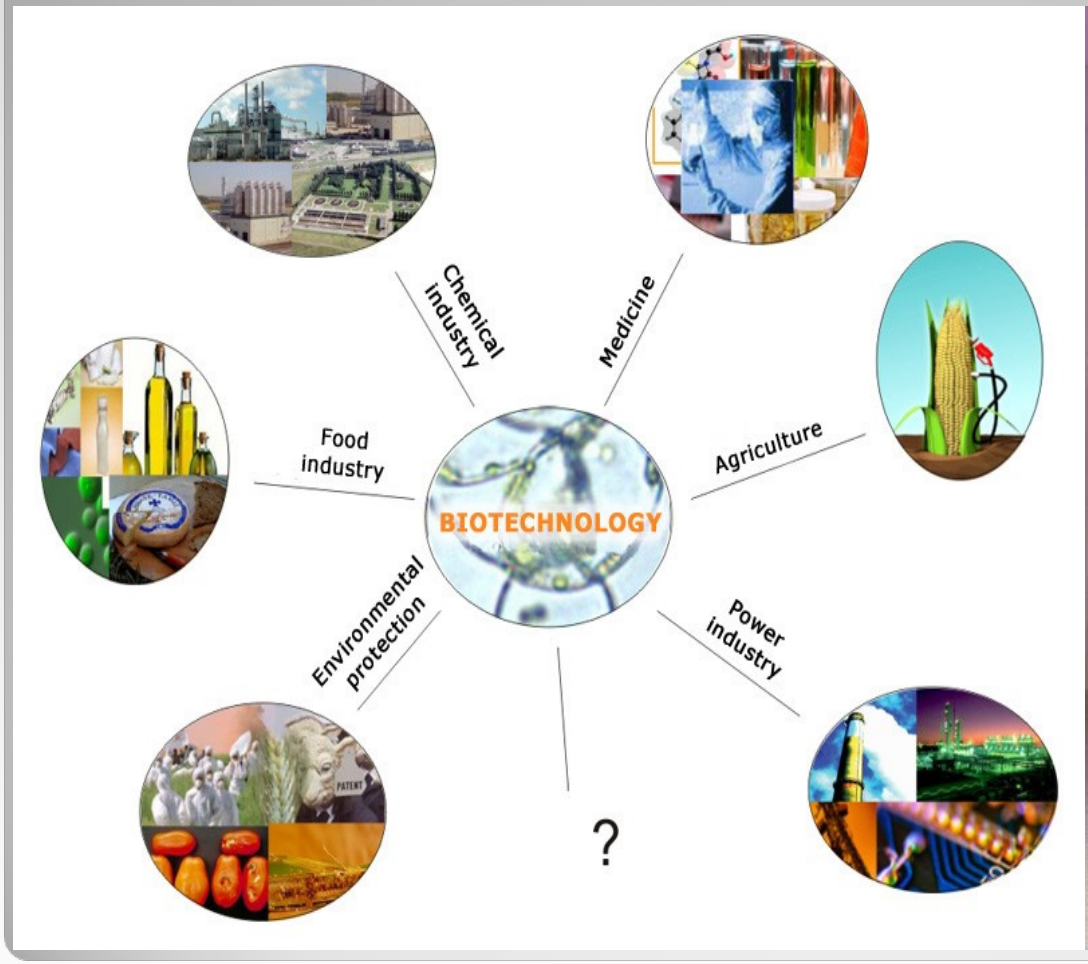
A bioreactor is a vessel in which a chemical process is carried out which involves organisms or biochemically active substances derived from such organisms. This process can either be aerobic or anaerobic

The Role of bioreactors in biotechnology:
To reach its' necessary goals, the biotechnological process has usually 3 major stages:
1. Preparation of nutrient media for the cultivated microorganism and the cultivation process;

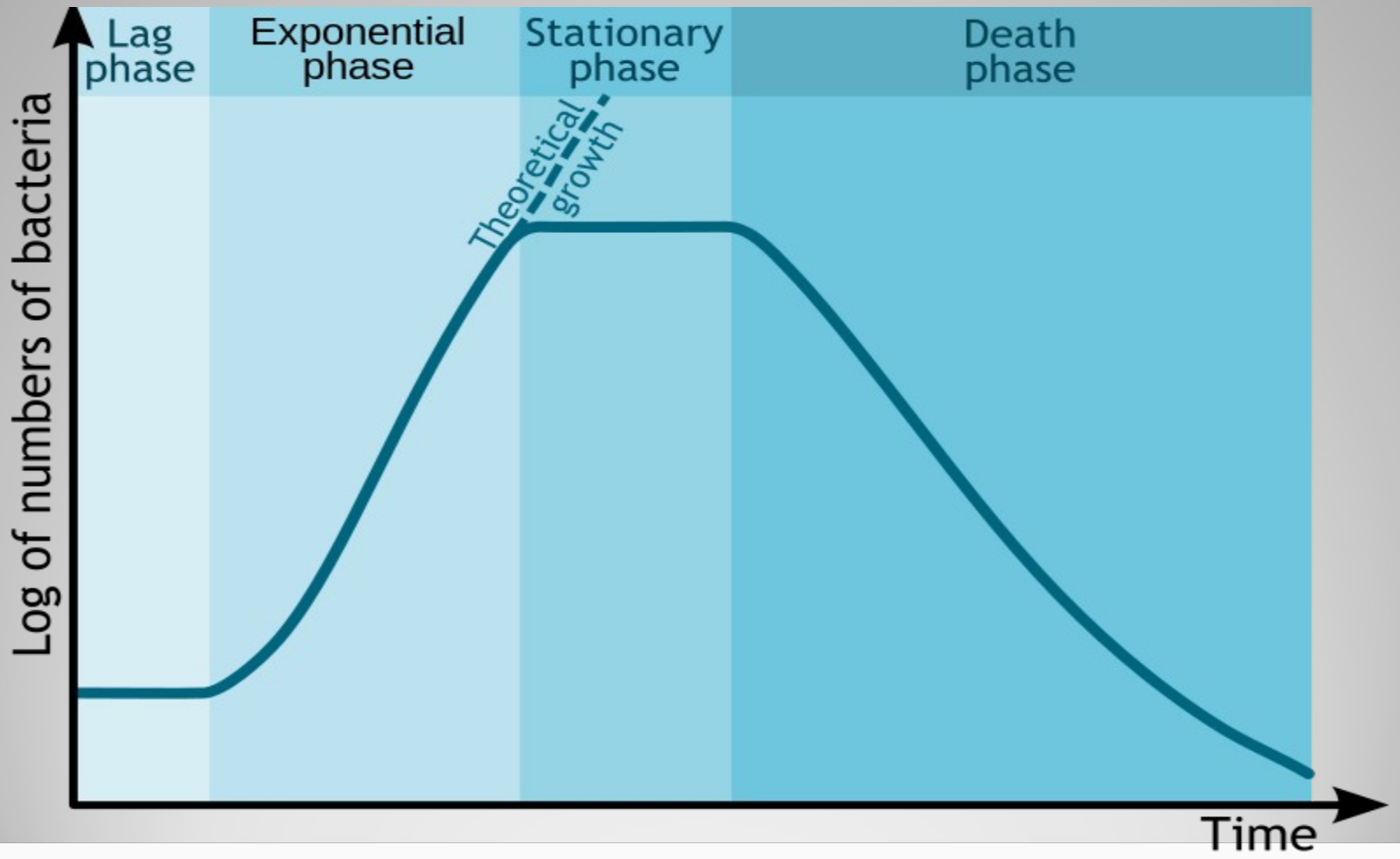
2.The course of the microorganism reproduction process in bioreactors (called also fermenters) or in other equipment;

3. Obtaining of the final product or substance from the cultivated medium. This stage includes operations such as separation, purification and other technologies, which are connected with obtaining the commodity form.

THE APPLICATIONS OF BIOTECHNOLOGY



THE GROWTH OF MICROORGANISMS



TYPES AND CLASSIFICATIONS OF BIOREACTORS

Bioreactors are generally classified into two broad groups;

1. SUSPENDED GROWTH BIOREACTORS;
The reactors use microbial metabolism under aerobic, anaerobic, or sequential anaerobic/aerobic conditions to biosorb organic compounds and biodegrade them to innocuous residuals. The microbial activity in the systems produces biomass that is removed by gravity sedimentation, with a portion of the settled biomass recycled to maintain a desired mixed liquor suspended solids concentration in the bioreactor. E.g Batch reactors, CSTR'S, Plug-flow reactors etc

2. BIOFILM BIOREACTORS:
In biofilm reactors most of the microorganisms are attached to a surface, and in this manner kept within the reactor. Biofilm is also used regularly for wastewater treatment, and the bacteria can either absorb or break down toxic substances in the water. The different kinds of biofilm reactors include membrane, fluidized bed, packed bed, airlift, and upflow anaerobic sludge blanket reactors.

SUSPENDED GROWTH REACTORS

1. **THE BATCH BIOREACTOR:**

A typical batch reactor consists of a tank with an agitator and integral heating/cooling system. These vessels may vary in size from less than 1 litre to more than 15,000 litres. They are usually fabricated in steel, stainless steel, glass lined steel, glass or exotic alloy

Liquids and solids are usually charged via connections in the top cover of the reactor. Vapors and gases also discharge through connections in the top. Liquids are usually discharged out of the bottom.

ADVANTAGES OF THE BATCH BIOREACTOR

1. EASY OPERATION AND ABSENS EOF MECHANICAL PUMPS

2. VERSATILITY; A SINGLE VESSEL CAN CARRY OUT A SEQUENCE OF DIFFERENT OPERATIONS

DISADVANTAGES

1. WHERE MIXING IS A CRITICAL PARAMETER , THEY ARE NOT THE IDEAL SOLUTION

THE CONTINUOUS STIRRED TANK REACTOR:

The continuous stirred-tank reactor (CSTR), also known as vat- or backmix reactor. The liquid or slurry stream is continuously introduced and liquid contents are continuously removed from the reactor.

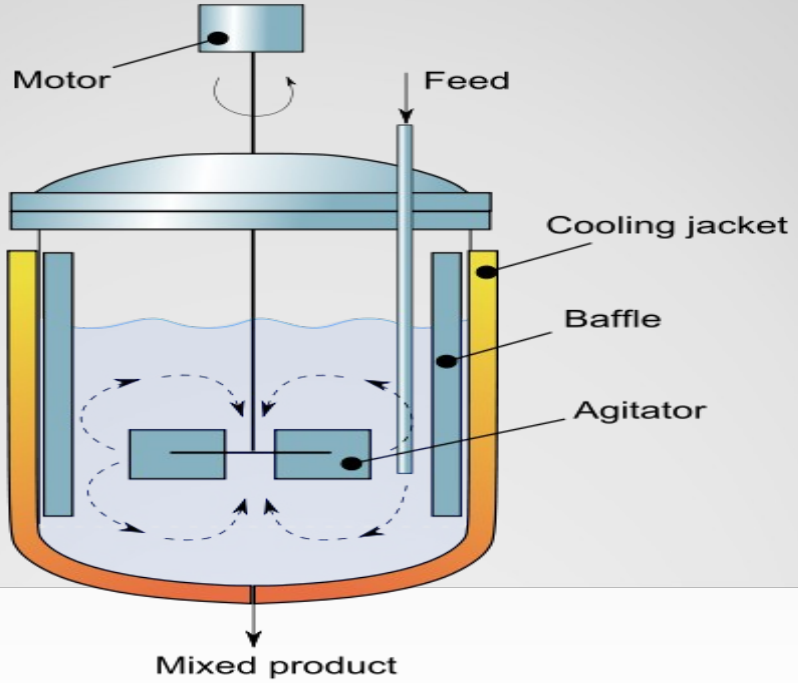
Microbial culture may or may not be introduced to the reactor under normal operation. If operated properly micro- organisms that grow within the reactor continuously replace the micro organisms removed from the reaction in the effluent. The basic characteristic of the ideal CSTR is that the concentration of the substrate and microorganisms are the same everywhere through out the reactor.

ADVANTAGES :

The rate of many chemical reactions is dependent on concentration, continuous reactors are generally able to cope with high concentrations due to their superior heat transfer capabilities

Disadvantages:

consumption of more power due the presense of mechanical pumps



THE PLUG FLOW REACTOR

This is also referred to as a tubular reactor or a piston- flow reactor. The liquid or slurry stream continuously enters one end of the reactor and leaves at the other end. In the ideal plug flow reactor (PFR) we envision that flow moves through the reactor with no mixing with earlier or later entering flows.

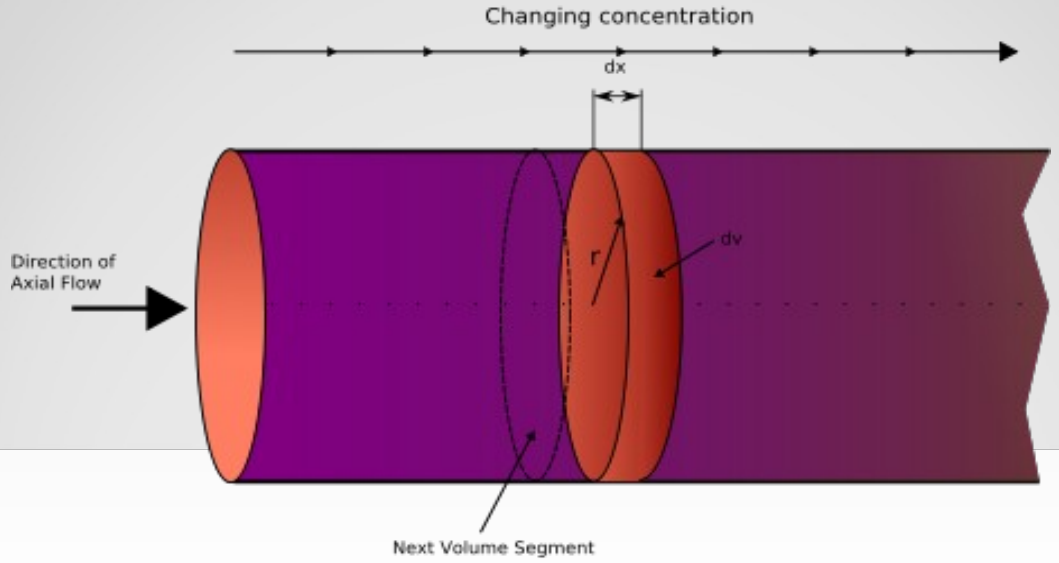
The concentration of substrates and microorganisms vary throughout the reactor. Concentrations of substrates are highest at the entrance of the reactor, which tends to make rates there quite high

ADVANTAGES:

1. **Can run for long periods of time without maintenance.**
2. **The heat transfer rate can be optimized by using more, thinner tubes or fewer, thicker tubes in parallel.**

DISADVANTAGES:

1. **Temperatures are hard to control and can result in undesirable temperature gradients**
2. **Expensive to maintain.**



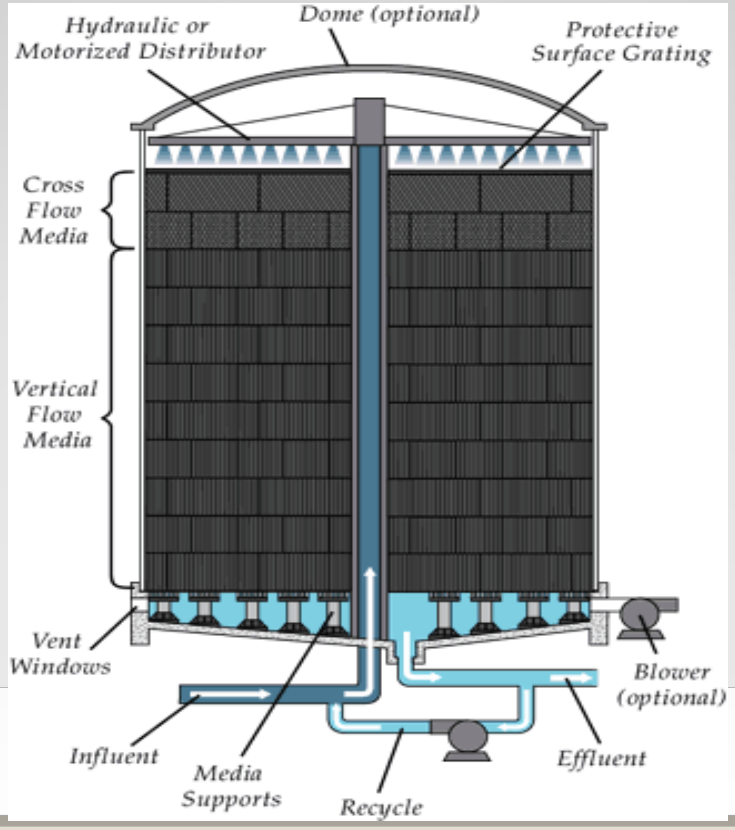
BIOFILM REACTORS

1. PACKED BED BIOREACTORS

The medium to which the microorganisms are attached is stationary (e.g plastic media or pea sized stones). Commonly packed bed reactors are used for aerobic treatment of waste waters and are known as tricking filters and or biological towers.

ADVANTAGES:

1. There is improved contact between the waste stream and the micro organisms .

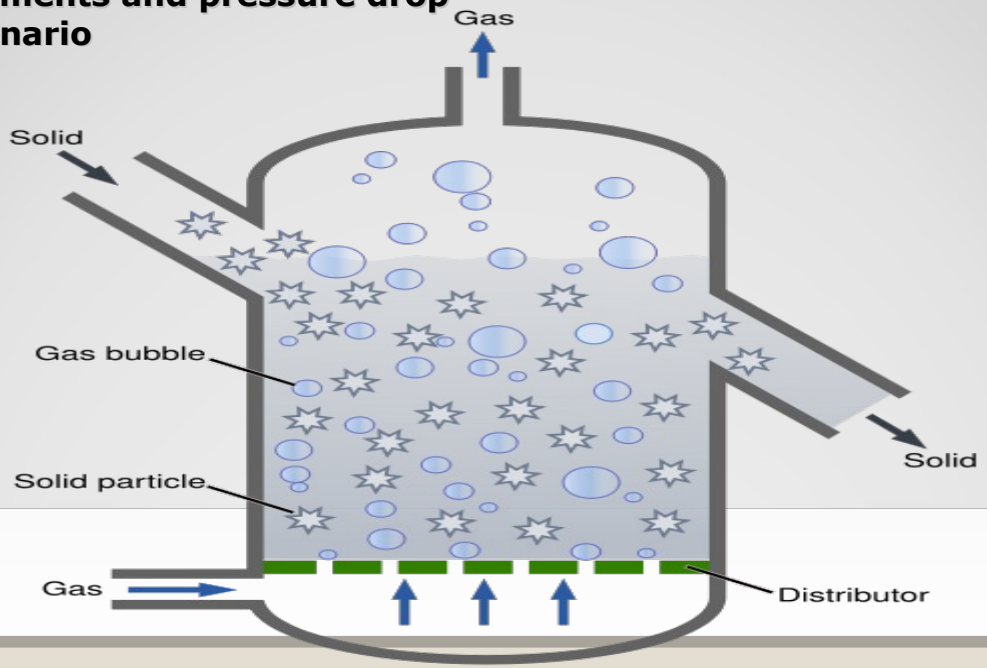


FlUIDIZED BED REACTOR;

The fluidized bed reactor depends upon the attachment of particles that are maintained in suspension by a high upward flow rate of the fluid to be treated. The particles are often called biofilm carriers. The carriers may be sand grains, granular activated carbon, diatomaceous earth.

ADVANTAGES:
1. Uniform particle mixing
2.Uniform temperature gradients
3. The ability to operate reactor in conitnuos state.

DISADVANTAGE:
1. Increased reactor vessel size
2. pumping requirements and pressure drop
3. Pressure loss scenario



THE ROTATING BIOLOGICAL CONTACTOR

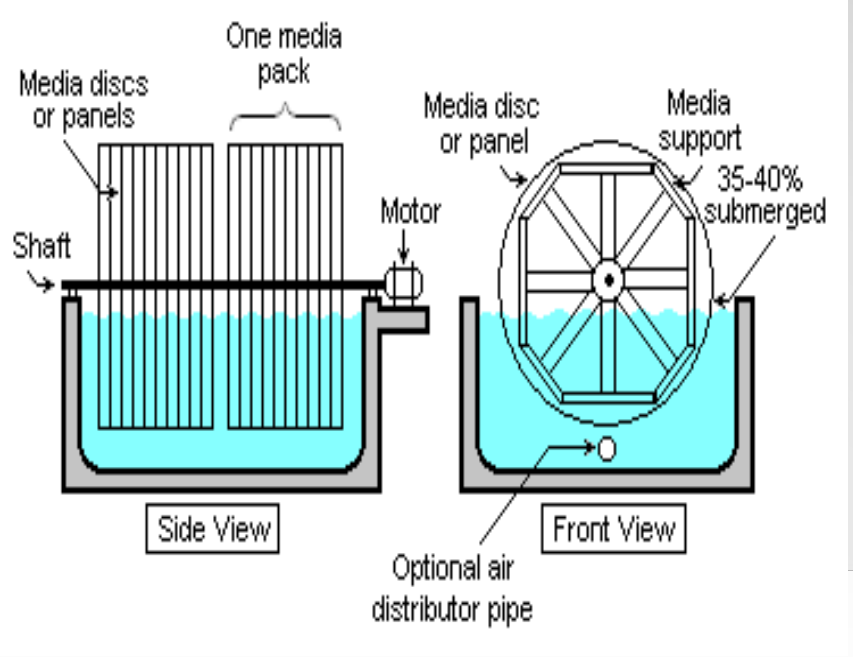
The RBC process involves allowing the wastewater to come in contact with a biological medium in order to remove pollutants in the wastewater before discharge of the treated wastewater to the environment.

It consists of a series of closely spaced, parallel discs mounted on a rotating shaft which is supported just above the surface of the waste water. Microorganisms grow on the surface of the discs where biological degradation of the wastewater pollutants takes place.

The discs are submerged in waste water to about 40% of there diameter and are rotated by power supplied to the shaft.

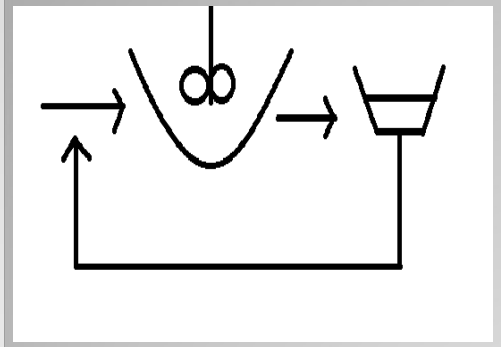
ADVANTAGES:

1.Due to high amount of aeration, waste water is degraded faster and more efficiently.

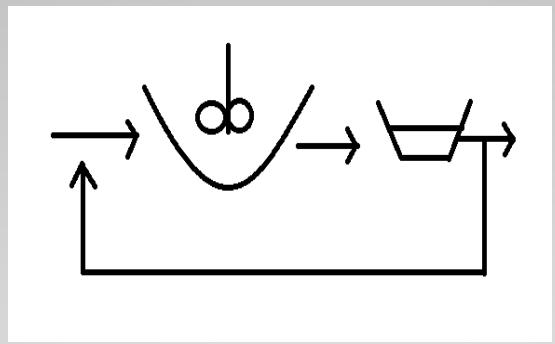


REACTOR ARRANGEMENTS

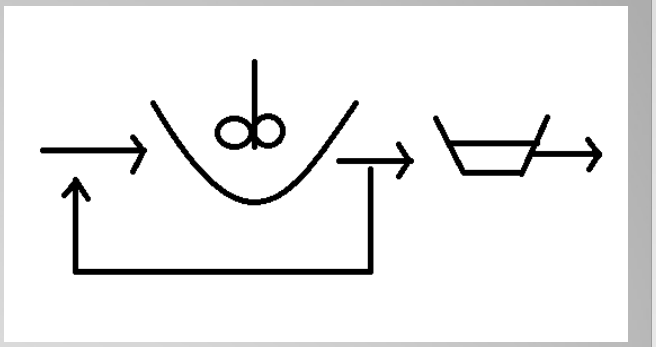
RECYCLE OF SETTLED SOLIDS



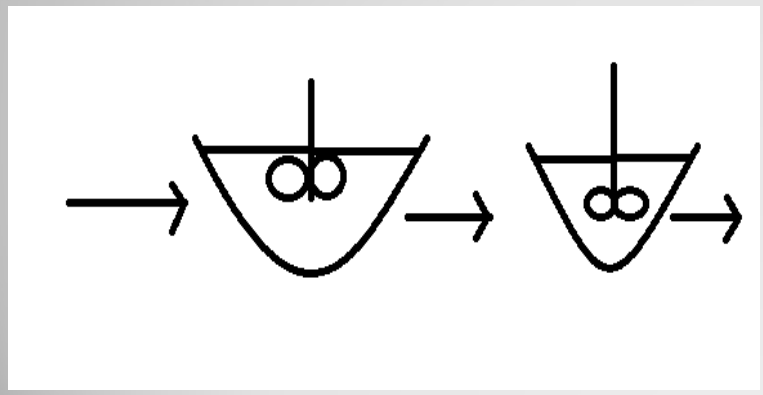
RECYCLE AFTER SETTLING



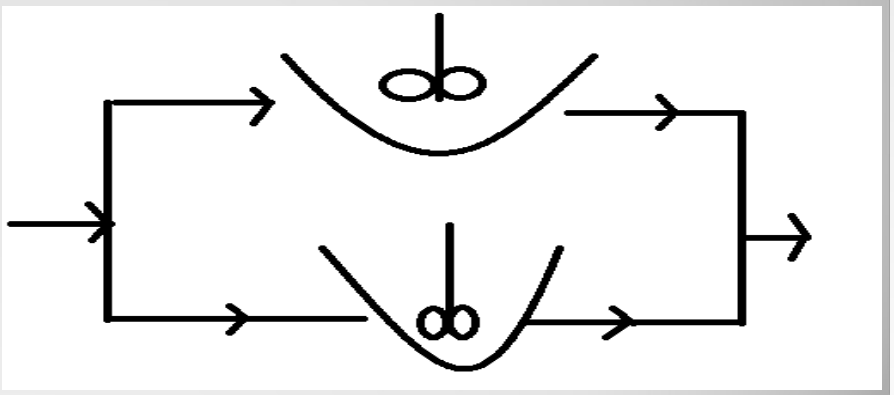
RECYCLE BEFORE SETTLING



REACTORS IN SERIES



REACTORS IN PARALLEL



MASS BALANCES

A mass balance (also called a material balance) is an application of conservation of mass to the analysis of physical systems.
By accounting for material entering and leaving a system, mass flows can be identified which might have been unknown, or difficult to measure without this technique.

The mass balance is the key to design and analysis of microbial processes. A mass balance is provided by a balanced stoichiometric chemical equation.

EXAMPLE:
$0.0333C_6H_5COO^- + 0.12NO_3^- + 0.002NH_4^+ + 0.12H^+$ ------
$0.02\ C_5H_7O_2N + 0.06N_2 + 0.12CO_2 + 0.0133HCO_3 + 0.1067H_2O$

$0.033C_6H_5COO^-$ = BENZOATE TO BE CONSUMED BY MICROBES
$0.12NO_3^-$ = ELECTRON ACCEPTOR
$0.02NH_4^+$ = AMMONIUM TO BE CONSUMED BY MICROBES AS NUTRIENT

$0.O2C_5H_7O_2N$ = BIOMASS PRODUCED AFTER DEGRADATION BY MICROBES
$0.06N_2$, $0.12C0_2$, $0.0133HCO_3$, $0.1067H_2O$ =(NIRTROGEN,CARBON DIOXIDE , CARBONATE AND WATER PRODUCED DUE TO THE DEGRADATION

A very important aspect of mass balances is that each component must have their own mass balance.
Components may include, oxygen, electron acceptor, TOC, COD,biomass, ammonium and nitrate and macro nutrients.

RATE OF MASS ACCUMULATION = RATE(S) IN CONTROL VOLUME - RATE(S) OF MASS IN + MASS OUT + RATE OF MASS GENERATION

MASS BALANCE FOR BATCH REACTORS

The batch reactor is assumed well stirred, and also let the entire reactor contents be the reactor volume element.
Hence,

$$d(VC)/dt = Q_{in} \cdot C_{in} - Q_{out} \cdot C_{out} + R.V$$

Where d(VC)/dt = Rate of mass accumulation in control volume
Q in = flow rate into the system
Q out = flow rate out of the system
C = Concentration of stream/substrate
R = Rate of reaction
V = Volume of the stream/ substrate

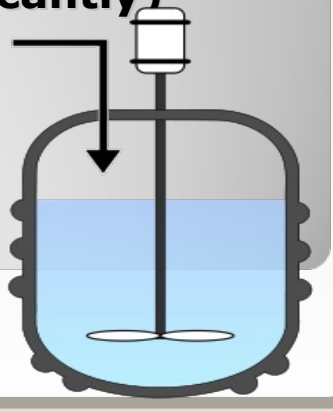
The inflow and outflow stream rates are zero, Q in – Q out = 0
Hence , we have

$$d(VC)/dt = R.V$$ **(if reactant volume changes significantly)**

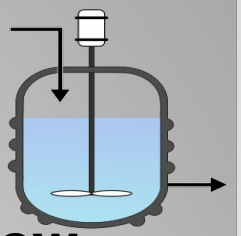
or

$$d(C)/dt = R$$ **(if reactant volume remains constant)**

R= k. C, where k = rate constant, c = concentration



MASS BALANCE FOR THE CONTINUOUS STIRED TANK BIOREACTOR



Writing the material balance for this reactor gives,

$d(VC)/dt = Q_{in}.C_{in} - Q_{out}.C_{out} + R.V$

If the reactor volume is constant and the volumetric flow rates of the inflow and outflow streams are the same, then

$d(C)/dt = 1/\tau\ (C_{in} - C_{out} + R)$

This parameter $\tau = V/Q_{in}$ it is called the mean residence time of the CSTR.

We refer to this balance as the constant-density case. It is often a good approximation for liquid-phase reactions.

for steady state:

The steady state of the CSTR is described by setting the time derivative in the expression $d(VC)/dt = 0$

$0 = Q_{in} . C_{in} - Q_{out} . C_{out} + R.V$

Conversion of reactant x is defined for a steady-state CSTR as follows:

$$X = (Q_{in}. C_{in} - Q_{out}. C_{out}) / Q_{in} .C_{in}$$

MASS BALANCE FOR THE PLUGFLOW BIOREACTOR

Plug flow in a tube is an ideal-flow assumption in which the fluid is well mixed in the radial and angular directions.
The fluid velocity is assumed to be a function of only the axial position in the tube

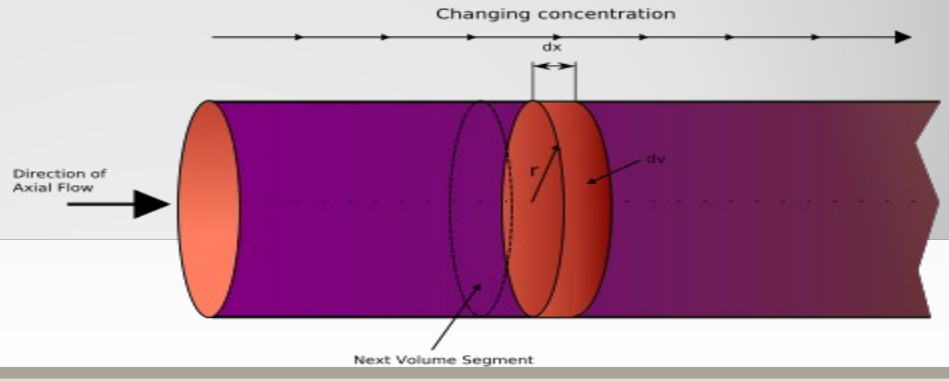
Given the plug flow assumption, it is natural to take a thin disk for the reactor volume element.

Expressing the material balance for the volume element
d(VC)/dt = Q IN z. C in - Q OUT z+ /_\z. C out + R. /_\V
Dividing the above equation by / _*V* and taking the limit as /_*V* goes to zero yields,

d (C)/dt = - dC.Q/dV + R
If the tube has constant cross section, *Ac*, then velocity, *v*, is related to volumetric flow rate by *v* = *Q/Ac*, and axial length is related to tube volume by *z* = *V/Ac*,

The equation can be rearranged to the familiar form
dC/dt = -d(C *v*)/ d z + (R)

Setting the time derivative in the equation above we have;
Dcq/dV = R



BIOREACTOR APPLICATIONS IN WASTE TREATMENT

Many waste streams are amenable to biological treatment, either degradation option of harmful materials to ones with reduced environmental consequences, or, upgrading to useful products by means of natural, selected or engineered microorganisms and microbial enzymes

GASEOUS EFFLENTS

Bioreactors provide better containment and superior environmental controls that allow faster, more complete and cost-effective treatment
We will briefly look some newer bioreactor based technologies for treatment of gaseous, liquid and solid wastes

1. BIOFILTERS:
Biofilters are beds of soil or compost, about 1 m deep, with an underlying distribution system for the contaminated gas. As the contaminant laden gas moves up through the moist bed, the pollutants are removed by sorption and oxidized by the microbial population immobilized in the bed.

2. BIOSCRUBBERS: Conceptually similar to conventional gas scrubbers, bioscrubbers are employed when heavier contaminant loadings, less soluble contaminants or contaminant toxicity make biofilters unsatisfactory. Activated sludge mixed in water is contacted with the gaseous effluent in a packed bed absorption tower. Contaminants transfer to the sludge-water slurry which is taken to holding or sedimentation tanks where most of the degradation takes place.
Clarified liquor from the sedimentation tanks is recycled to the absorption column.

LIQUIDS AND SLURRYS

LOW VOLUME-HIGH-RATE AIRLIFT AND DEEP SHAFT BIOREACTOR TECHNOLOGIES :A recent trend in biological treatment of liquid effluents by the activated sludge method is toward *process intensification by greater application of lowvolume*- high-rate airlift and deep shaft bioreactor technologies

These reactors are being employed as stand alone treatment units, as well as being used to extend the performance of the older, conventional, plants. Airlift reactors are pneumatically agitated by air injection into the riser . Upflow of air and wastewater occurs in the riser, most of the gas leaves the liquid in the head region of the reactor and gas-free wastewater recirculates through the downcomer. Highly turbulent flows, combined with good oxygen absorption characteristics of these reactors, create conditions which allow rapid biological oxidation of pollutants.

ARTIFICIAL WETLAND, OR 'REED BED'

Bioreactor systems for reduction of biochemical oxygen demand (BOD 5) and total suspended solids (TSS) in municipal and industrial wastewaters. Aquatic plants such as bulrush, cattails, common reed, water hyacinth, swamp potato and duck potato rooted in rock and gravel media beds flooded with wastewater flowing though the bed and root zone, make-up the wetland filters.

THE MYCOPROTEIN PROCESS

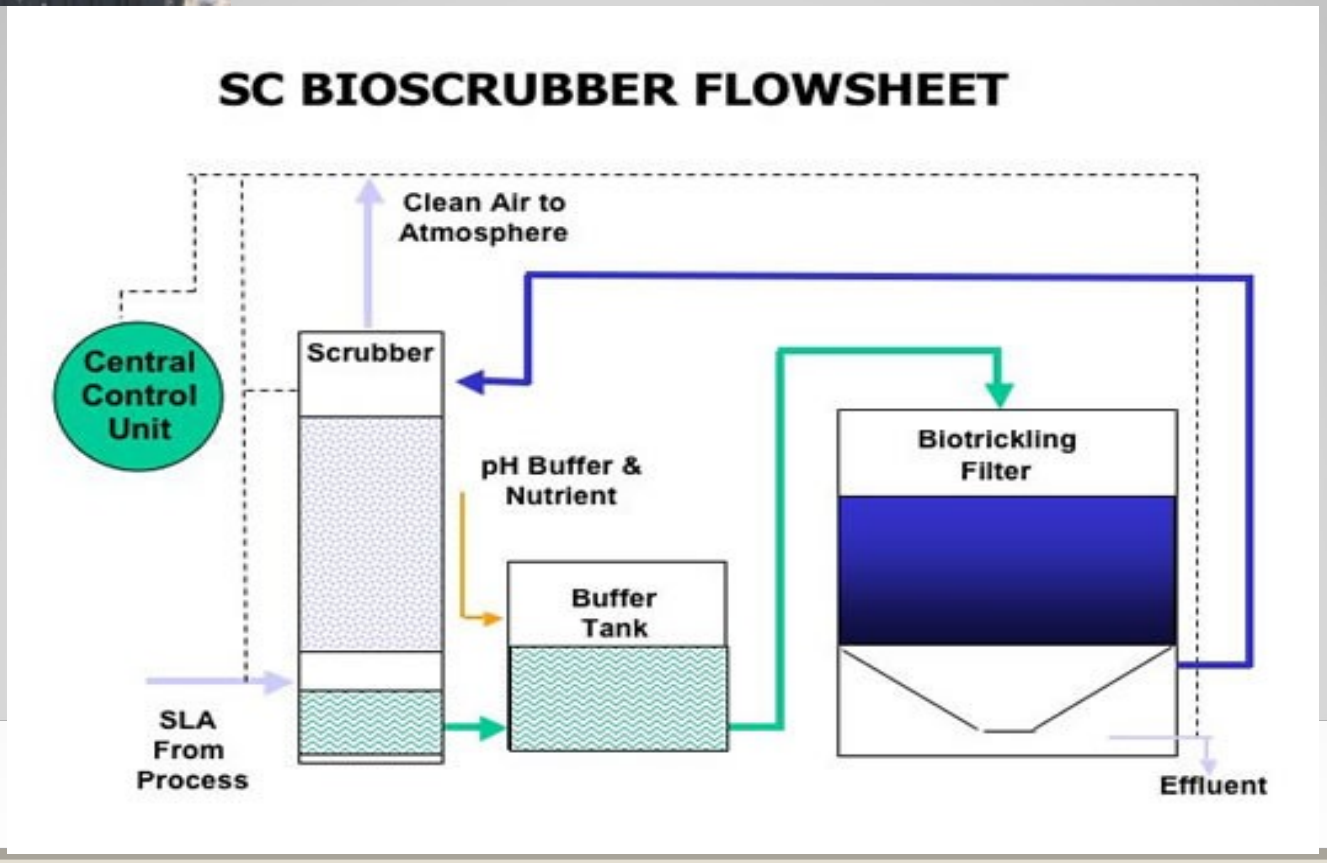
Lignocellulosic residues *(e.g., straw,* corn stover, sugarcane bagasse) from agriculture and silviculture represent a solid waste disposal problem which can be abated by reuse of this resource.

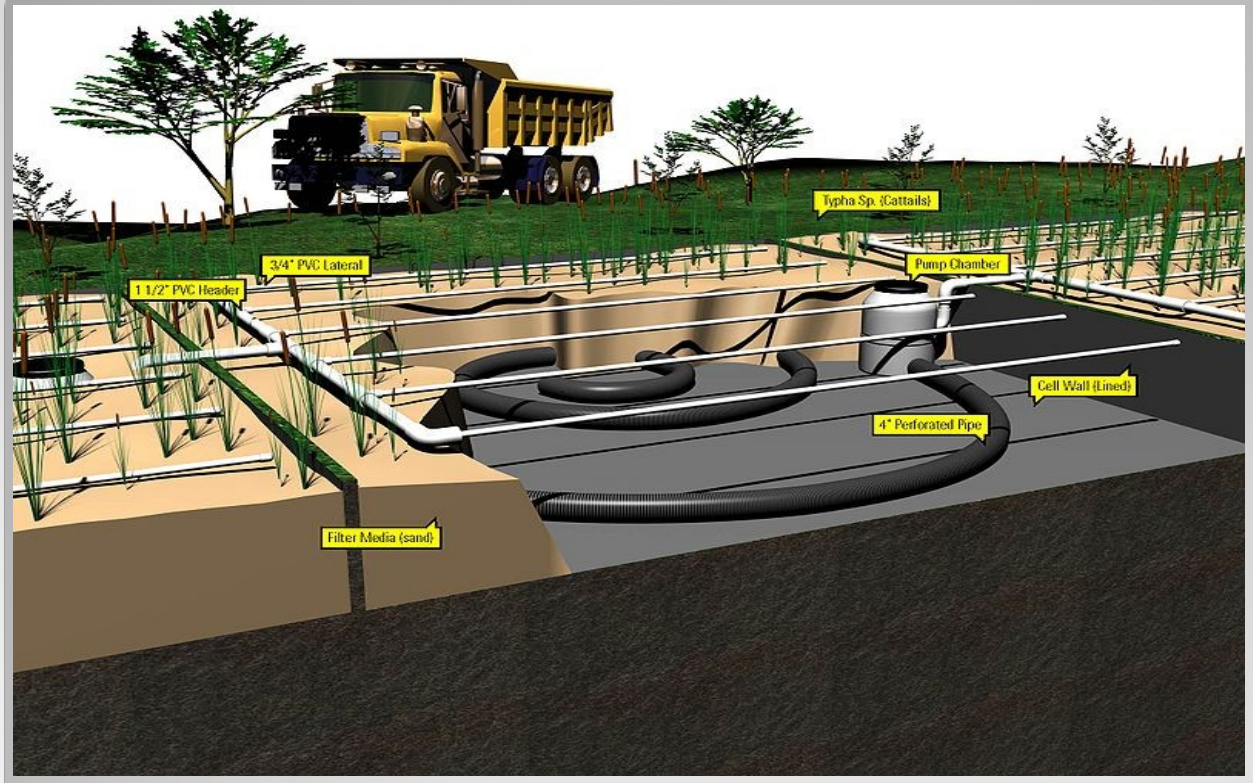
The process is an extension of a recent invention for converting cereal-grain bran residues into proteinaceous products

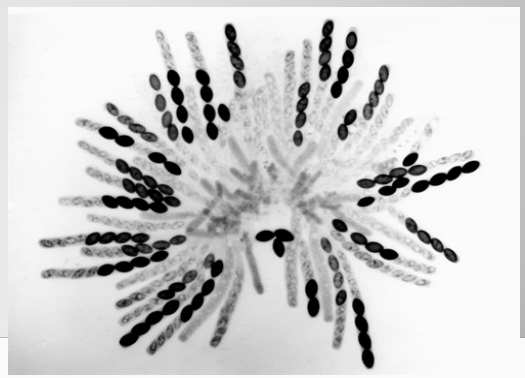
Conceptually, the *N. sitophila mycoprotein production process consists of* the following steps:

- size reduction of the cellulosic residue by milling or grinding;
- treatment of the residue with alkali, acid and/or steam to increase the accessibility of the cellulose in the particles;
- fermentation of the residue with *N. sitophila either in submerged or surface* culture;
- solid-liquid separation and dehydration of the product for direct use as fodder; and
- blending, possible nucleic acid reduction, texturizing and flavouring operations for human food applications

PICTORALS


SC BIOSCRUBBER FLOWSHEET
Clean Air to Atmosphere
Central Control Unit
Scrubber
pH Buffer & Nutrient
Buffer Tank
Biotrickling Filter
SLA From Process
Effluent


Typha Sp. (Cattails)
3/4" PVC Lateral
1 1/2" PVC Header
Pump Chamber
Cell Wall (Lined)
4" Perforated Pipe
Filter Media (sand)



CONCLUSIONS

Bioconversion of wastes to harmless substances or higher value products already has a significant role in environmental pollution control and improved resource utilization. Both in-situ and bioreactor based treatment processes are experiencing rapid development and increasing deployment in practical applications.

THANK YOU FOR LISTENING AND GOD BLESS YOU.