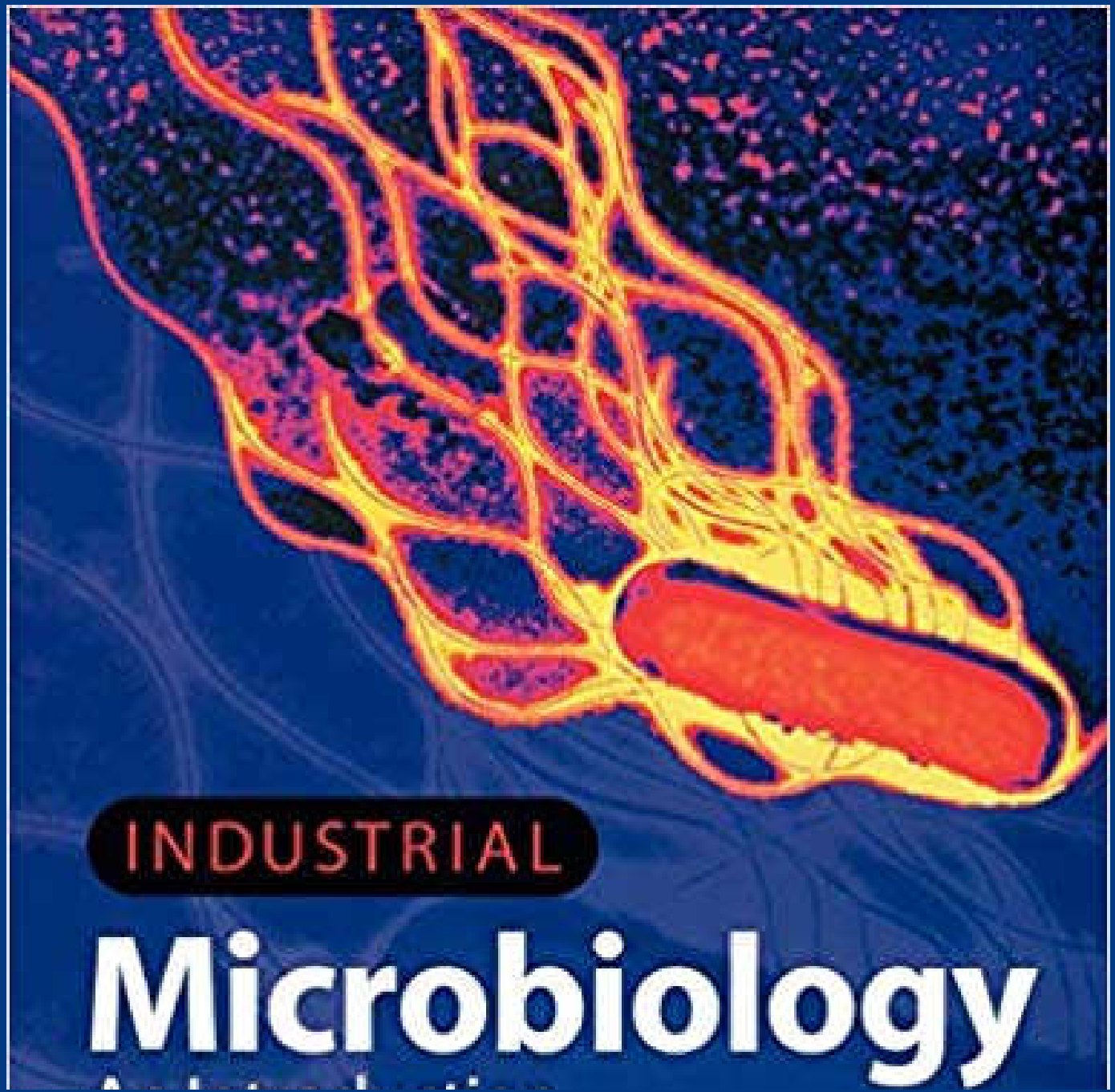
INDUSTRIAL
Microbiology

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.

TYPES OF FERMENTER:

Following are the types of fermenter

- Airlift Fermenter:
- Continuous Stirred Tank Bioreactors:
- Photo-Bioreactors:
- Bubble Column Fermenter:
- Fluidized Bed Bioreactors:
- Packed Bed Bioreactors:

Airlift Fermenter:

- In airlift fermenter the liquid culture volume of the vessel is divided into two interconnected zones by means of a baffle or draft tube.
- Only one of the two zones is sparged with air or other gas and this sparged zone is known as the riser.
- The other zone that receives no gas is called down-comer.
- The bulk density of the gas-liquid dispersion in the gas-sparged riser tends to be lower than the bulk density in the down-comer.
- consequently the dispersion flows up in the riser zone and down-flow occurs in the down-comer.

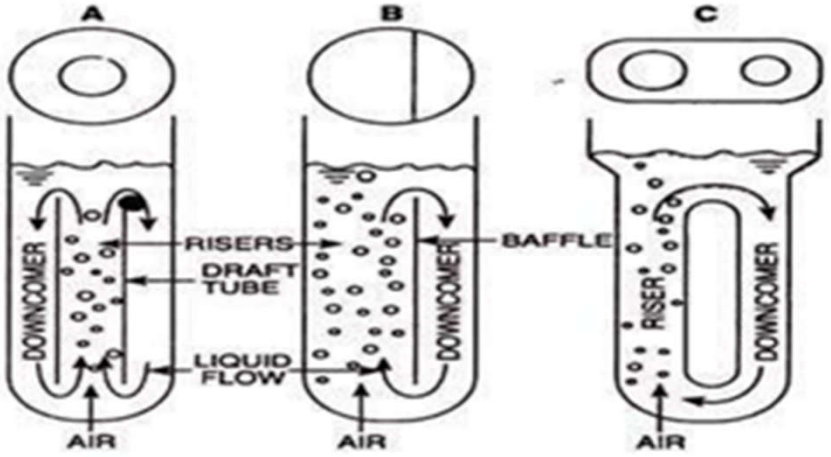

FIG. 39.2. Airlift fermentor. (A) Draft-tube internal loop configuration, (B) a split cylinder device, and (C) an external loop device.

- Airlift fermenters are highly energy-efficient.
- They are often used in large-scale manufacture of biopharmaceutical proteins obtained from fragile animal cells.
- Heat and mass transfer capabilities of airlift reactors are at least as good as those of other systems.
- Airlift reactors are more effective in suspending solids than are bubble column fermenters.
- All performance characteristics of airlift -fermenter are related ultimately to the gas injection rate and the resulting rate of liquid circulation.

- The rate of liquid circulation increases with the square root of the height of the airlift device.
- Because the liquid circulation is driven by the gas hold-up difference between the riser and the down-comer.
- circulation is enhanced if there is little or no gas in the down-comer.
- All the gas in the down-comer comes from being entrained in with the liquid as it flows into the down-comer from the riser near the top of the reactor.

AIRLIFT BIOREACTORS APPLICATION

- Airlift bioreactors are commonly employed for aerobic bioprocessing technology.
- They ensure a controlled liquid flow in a recycle system by pumping.
- Due to high efficiency, airlift bioreactors are sometimes preferred e.g., methanol production, waste water treatment, single-cell protein production.
- In general, the performance of the airlift bioreactors is dependent on the pumping (injection) of air and the liquid circulation.

CONTINUOUS STIRRED TANK BIOREACTORS

- A continuous stirred tank bioreactor consists of a cylindrical vessel with motor driven central shaft that supports one or more agitators (impellers).
- The shaft is fitted at the bottom of the bioreactor.
- The number of impellers is variable and depends on the size of the bioreactor i.e., height to diameter ratio, referred to as aspect ratio.
- The aspect ratio of a stirred tank bioreactor is usually between 3-5. However, for animal cell culture applications, the aspect ratio is less than 2.
- The diameter of the impeller is usually 1/3 rd of the vessel diameter.
- The distance between two impellers is approximately 1.2 impeller diameter. Different types of impellers (Rustom disc, concave bladed, marine propeller etc.) are in use.
- In stirred tank bioreactors or in short stirred tank reactors (STRs), the air is added to the culture medium under pressure through a device called sparger.
- The sparger may be a ring with many holes or a tube with a single orifice.
- The sparger along with impellers (agitators) enables better gas distribution system throughout the vessel.
- The bubbles generated by sparger are broken down to smaller ones by impellers and dispersed throughout the medium.
- This enables the creation of a uniform and homogeneous environment throughout the bioreactor.

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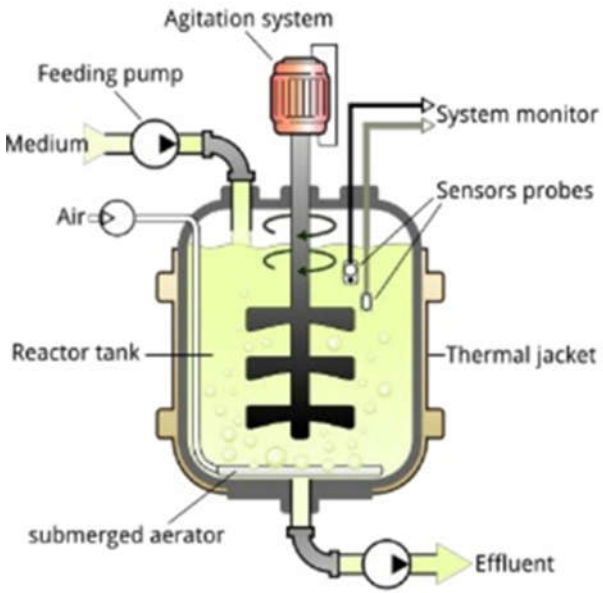
Advantages of STRs:

There are many advantages of STRs.

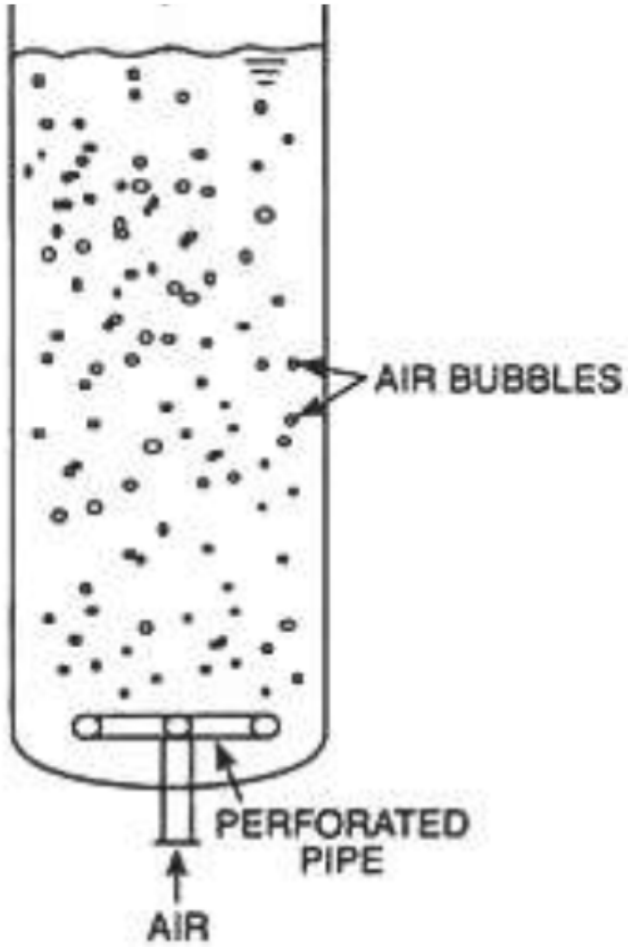
- The efficient gas transfer to growing cells.
- Good mixing of the contents and flexible operating conditions, besides the commercial availability of the bioreactors.



General structure of a continuous stirred-tank type bioreactor

Bubble Column Fermenter

- Bubble column fermenter is usually cylindrical with an aspect (height to diameter) ratio of 4-6.
- Gas is sparged at the base of the column through perforated pipes,perforated plates,or sintered glass or metal micro-porous spargers.
- O2 transfer,mixing and other performance factors are influenced mainly by the gas flow rate and the properties of the fluid.
- Internal devices such as horizontal perforated plates,vertical baffles and corrugated sheet packing,s may be placed in the vessel to improve mass transfer and modify the basic design.
- One exception is the axial mixing performance.
- For a given gas flow rate,the mixing improves with increasing vessel diameter.



- In the bubble column bioreactor, the air or gas is introduced at the base of the column through perforated pipes or plates, or metal micro porous spargers.
- The flow rate of the air/gas influences the performance factors —O2 transfer, mixing.
- The bubble column bioreactors may be fitted with perforated plates to improve performance.
- The vessel used for bubble column bioreactors is usually cylindrical with an aspect ratio of 4-6 (i.e., height to diameter ratio).

Fluidized Bed Bioreactors:

- Fluidized bed bioreactor is comparable to bubble column bioreactor except the top position is expanded to reduce the velocity of the fluid.
- The design of the fluidized bioreactors (expanded top and narrow reaction column) is such that the solids are retained in the reactor while the liquid flows out.
- These bioreactors are suitable for use to carry out reactions involving fluid suspended biocatalysts such as immobilized enzymes, immobilized cells, and microbial flocs.

- For an efficient operation of fluidized beds, gas is spared to create a suitable gas-liquid-solid fluid bed.
- It is also necessary to ensure that the suspended solid particles are not too light or too dense (too light ones may float whereas to dense ones may settle at the bottom), and they are in a good suspended state.
- Recycling of the liquid is important to maintain continuous contact between the reaction contents and biocatalysts.
- This enable good efficiency of bioprocessing.

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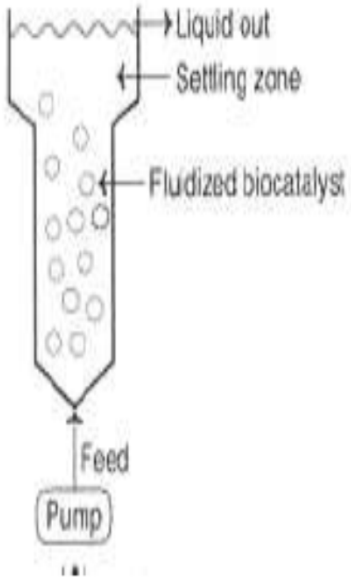
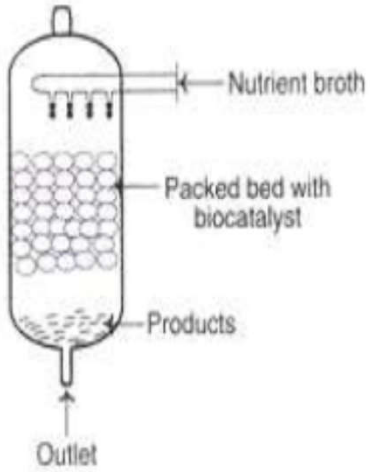


Packed Bed Bioreactors:

- A bed of solid particles, with biocatalysts on or within the matrix of solids, packed in a column constitutes a packed bed bioreactor
- The solids used may be porous or non-porous gels, and they may be compressible or rigid in nature.
- A nutrient broth flows continuously over the immobilized biocatalyst.
- The products obtained in the packed bed bioreactor are released into the fluid and removed.
- While the flow of the fluid can be upward or downward, down flow under gravity is preferred.



- The concentration of the nutrients (and therefore the products formed) can be increased by increasing the flow rate of the nutrient broth.
- Because of poor mixing, it is rather difficult to control the pH of packed bed bioreactors by the addition of acid or alkali.
- However, these bioreactors are preferred for bioprocessing technology involving product-inhibited reactions.
- The packed bed bioreactors do not allow accumulation of the products to any significant extent.

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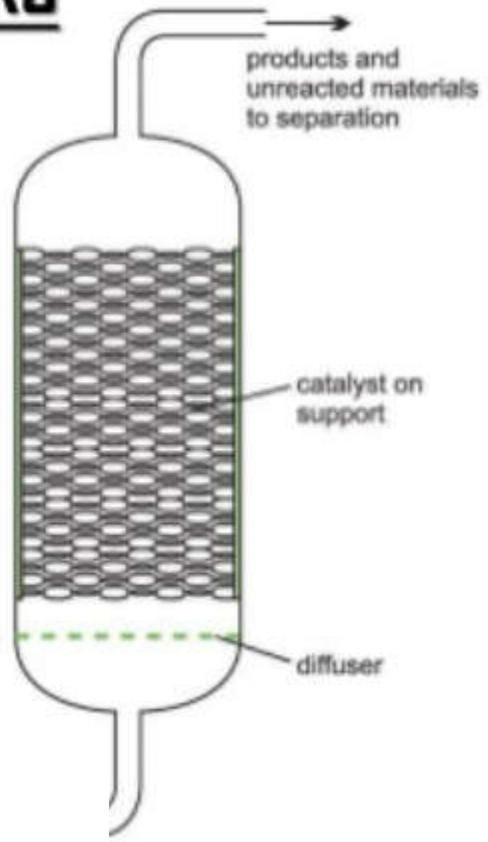

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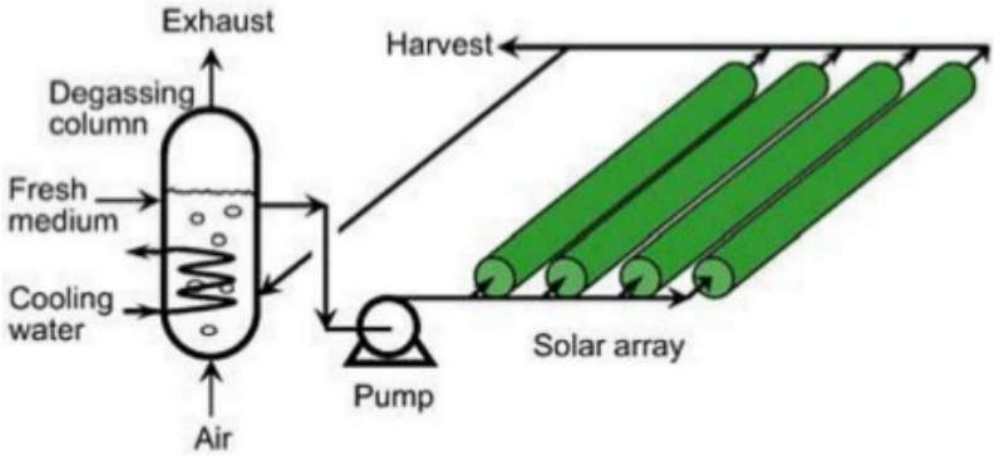
PHOTO-BIOREACTORS

- These are the bioreactors specialised for fermentation that can be carried out either by exposing to sunlight or artificial illumination.
- Since artificial illumination is expensive, only the outdoor photo-bioreactors are preferred.
- Certain important compounds are produced by employing photo-bioreactors e.g., p-carotene, asthaxanthin.
- They are made up of glass or more commonly transparent plastic.
- The array of tubes or flat panels constitute light receiving systems (solar receivers).
- The culture can be circulated through the solar receivers by methods such as using centrifugal pumps or airlift pumps.
- It is essential that the cells are in continuous circulation without forming sediments.
- Further adequate penetration of sunlight should be maintained.
- The tubes should also be cooled to prevent rise in temperature.
- Photo-bioreactors are usually operated in a continuous mode at a temperature in the range of 25-40°C. Microalgae and cyanobacteria are normally used.
- The organisms grow during day light while the products are produced during night.



A tubular photobioreactors with parallel run horizontal tubes.