A Comparative Study on Bio Reactors

Kathir.Viswalingam[1], F. Emerson Solomon[2] and Sharmila[3]

[1]*Dean, Research,* [2]*Professor of Bio Medical Engineering,* [3]*Asst. professor of Bio Technology,*
BIST, Bharath University, Chennai- 600 073.
[1]drkathir2011@yahoo.com, [2]emerson_solomon@yahoo.com, [3]tsharmilabio@yahoo.com

Abstract

Bioreactors are the heart of fermentation processes and effluent treatment plants. This paper deals with different types of Industrial bioreactors, Applications and merits and demerits of each Bioreactor. This is a first effort on Engineering point of view on Bioreactors.

Keywords: Bioreactor, Fermentation, Bio mass, Cell culture, CSTR, COD, Photo Bioreactor, Fluidized Bed Bioreactor.

1. Introduction

"Bioreactor" is the generic term for a system or a reactor that degrades the contaminants with the help of microorganisms [1]. The reactor can be an open system, such as a constructed wetland (described as a separate technology), or an enclosed chamber. Biological Reactors cum Bio reactors are previously known as Fermentors. Fermentation is any chemical process that breakdowns complex molecules into simpler ones and releases gas. There are several types of bio-reactors.

Bioreactors can also be installed in-situ (i.e., in place). Vertically placed bio-reactors are called bio-plugs [2]. Horizontally placed bio-reactors are called bio-conduits. These techniques enhance degradation as contaminated groundwater passes through the reactor. This technology has been successfully implemented in the remediation of organic compounds at several leaking underground storage tank and industrial sites.

Knowledge of biological reaction kinetics and mass transfer are essential for understanding how biological reactors work [3]. In order to assemble complete portrait biological reactor operations, it is necessary to integrate these two fundamental phenomena with the gas and liquid mixing and contacting patters in the unit. Different design and scale procedures are required for reactors with different flow and mixing characteristics.

Biological reactor design and analysis requires different types of approximations, which would be introduced in order to simplify the kinetic description of the cell population [4]. Design includes complicated fluid flow, mixing and heat transfer. We must also consider the effect of scale or size of the reactor on the mixing, flow, heat and mass transfer patterns inside the reactor and how different flow and transport fields will influence and interact with bio catalyst kinetics.

2. Types of Bio Reactor

- Ideal Bio Reactor
- Fed Batch reactor
- Continuous Stirred Tank Reactor
- Plug Flow Tubular Reactor
- Membrane Bio reactor
- Photo Bio – Reactor

2.1 Ideal Bio Reactor

In these systems, mixing is presumed to be sufficiently intense and uniform such that conditions is presumed to be sufficiently intense and uniform such that reaction conditions and biocatalyst levels are effectively homogeneous throughout the reactor. This approximation will be valid if any gradients which do exist are sufficiently small so that the reaction rate locally for a given cell or bio catalyst particle in is not changed significantly as that catalyst particle moves from one domain of the reactor to another. Alternatively, if the catalyst particles circulate through different regions of the reactor very rapidly with respect to characteristic response time of the catalyzed reaction to changing conditions, then calculating reactor performance based on the assumption of the average, uniform conditions throughout will usually be satisfactory. Conditions like the ones described may be met in laboratory reactors and even pilot

scale reactors, depending upon the process involved. In growth of dense cultures of filamentous organisms or organisms producing extra cellular polymer, however, highly non-Newtonian conditions are encountered in which, even in small bench top reactors, ideal mixing is not approximated [5].

Examination of the theory of ideal completely mixed bioreactors is important for several reasons. First, such reactors provide well – defined conditions for kinetic studies in the laboratory. Second, such models may frequently used with reasonable success even at conditions required for validity of these models are not well satisfied. Finally such ideal mixing configurations provide a starting point for examination and characterization of non ideal mixing and reactors with significant spatial non uniformities in reaction conditions. As we shall see, we can sometimes calculate and simulate in the laboratory non-idealities in large scale reactors using model systems comprises of interconnected ideal reactors. Small scale stirred vessels which are used for low viscosity cell culture or fermentation systems and tubular enzyme bioreactor when operated at high flow rate are the examples of this category.

2.2 Fed-Batch Reactor

It is often desirable to add liquid streams to a batch bioreactor as the reaction process occurs. This can be done to add precursors for desired products, to add regulating compounds such as inducers at a desired point in the batch operation, to maintain low nutrient levels to minimize catabolite repression or to extend the stationary phase by nutrient addition to obtain additional product. When a liquid feed stream enters the reactor, the culture volume is also altered, and this must be taken into account in the equations used to describe the reactor [6].

Space must be allowed in fed-batch bioreactors for addition of fresh medium; in such cases a portion of the froth is removed before injection of additional material. The flow rate and timing of the feed are often determined by monitoring parameters such as dissolved-oxygen level or exhaust gas composition. It is used extensively in the production of baker's yeast; It is also used routinely for penicillin production, cell cultures or fermentation [7].

2.3 Continuous Stirred Tank Reactor (CSTR)

From the view of Engineering application, continuous operation of bioreactors shows great advantage over batch and fed batch reactors. CSTR used of enzyme- catalyzed reactions assume a variety of configurations depending on the method employed to provide the necessary enzyme activity. In the simplest design, enzymes are continuously added to and removed from the reactor via feed and effluent lines. Obviously this approach is practical only.

Use of more costly enzymes are retained or recycled in the reactor. CSTR employs an ultra filtration membrane in the effluent stream with pores sufficiently small to prevent escape of the relatively large enzyme molecules in solution. A screen in the effluent line suffices if the enzyme is immobilized is insoluble particles which are suspended in the reaction mixture as a slurry. A more conveniently implemented arrangement for achieving the same objective is circulation or reaction mixture from a well-mixed reservoir through a packed column of immobilized enzyme. So long as the re-circulation rate is large. This type of design is convenient for laboratory kinetic studies.

Addition of a cell separator and a recycle stream containing concentrated cells to a CSTR can be used to increase biomass and product yield per unit reactor volume per unit time. That is productivity of biomass or aimed product is high. It is used for animal and plant cell cultures, fermentation processes including Penicillin production.

2.4 Plug Flow Tubular Reactor (PFTR)

When the fluid moves through a large pipe or channel with sufficiently large Reynold's Number (e. g >2100 in a pipe), it approximates plug flow, which means that there is no variation of axial velocity over the cross section. In plug flow with constant velocity, each thin slice of fluid moves through the vessel with absolutely no interaction with neighboring slices. PFTR implies zero biomass concentration in the effluent. Plug flow prevents slice of fluid moving through the vessel from ever being inoculated. PFTR provides greater substrate conversion and higher product concentration than the CSTR of equal volume. CSTR provides satisfactory results and presents a feasible technology for the treatment of hydrocarbon-rich wastewater from petrochemical industries and petroleum refineries.

2.5 Membrane Bio Reactors

A membrane is defined as a material that forms a thin wall capable of selectively resisting the transfer of different constituents of a fluid and thus effecting a separation, of the constituents. This concept is extended to include the separation of dissolved solutes in liquid streams and the separation of gas mixtures for membrane filtration. Membrane Bioreactor (MBR) systems essentially consists of combination of membrane and biological reactor systems.

Membrane Bio Reactors (MBRs) bring a new age of biological waste water treatment. With pure oxygen the benefits of MBRs are enhanced resulting in even higher rate biological treatment systems which provide compact control of COD, microorganisms and

VOCs in waste water. Oxy-Dep MBR can use high biomass concentrations, which for air-based stems cause oxygen transfer limitations. High purity oxygen resolves this, as well as the foaming and VOC issues associated with air-based systems [8].

- High Treatment Rates (up to 35kgCOD-m^3/day)
- Treatment of High Strength COD (>20,000mg/1)
- Minimal Sludge Production
- Low VOC Emissions
- Disinfected treated water

In general, MBR applications for wastewater treatment can be classified into four groups, namely:

- Extractive Membrane Reactors
- Bubble-less Aeration Membrane Bioreactors
- Recycle Membrane Reactors
- Membrane Separation Reactors

2.6 Photo – bio Reactor

A photo bioreactor (PBR) incorporates some type of light source to provide photonic energy input into the reactor. A photo bioreactor can be described as an enclosed, illuminated culture vessel designed for controlled biomass production of phototrophic liquid cell suspension cultures [9].

PBR provides an artificial environment for photosynthetic organisms (Algae) to perform a chemical conversion. Scientists and engineers have been developing several types of PBRs over the past fifty years to grow microorganisms that are used in a wide variety of applications. Mass-scale Algal cultures can be used to produce human food, animal feed, health food, therapeutics, chemicals, fuel, hormones, and fertilizer. A prototype PBR was built at SDSU in 1998 that had a reactor capacity of 1 gallon. The prototype was inoculated with algae obtained from Argonne National Laboratory and produced an algae biomass in excess of 25g. The success of the prototype led to the decision to scale up the prototype PBR to capacity of 500 gallons. The 500 gallon PBR is large enough to study the feasibility of commercial production of algae from sea weeds[10,11].

3. Comparison of Bioreactors

A comparative study on bioreactors will be very useful to the Scientists, Industrialists and new Entrepreneurs. Bio-reactors are used primarily to treat volatile organic compounds (VOCs) and fuel hydrocarbons. The process is less effective for pesticides. In one application, the concept was used to treat soil containing TNT and RDX. In the laboratory, it operated under aerobic and anaerobic conditions, and there was a large decrease in contaminant concentration. Intermediate byproducts were also degraded.

In Situ bioreactors can also be used to provide a co-metabolite for degradation of hazardous by-products produced during the degradation process of some of the chlorinated solvents. This type of bioreactor contains adapted microbes that mineralize the organic compounds of interest. The microbes are trapped onto a biological support medium [12]. An *in-situ* immobilized bioreactor system can be used in conjunction with a vapor extraction system.

Bubble Column Bioreactors and Fluidized Bed Bioreactors are not dealt in this paper. Comparison of flow rates, merits and applications are give in Table 1.

Table 1. *Comparison of Bioreactors*

Sl.No.	Type	Flow Rate	Merits	Applications
1	Ideal Bioreactor	Medium	Suitable for Large Capacity waste water treatment plants	Waste water treatment plants.
2	Fed Batch Reactor	Medium	Suitable for Batch process operations	Baker's yeast production, fermentation processes, culture of Microbial cells.
3	CSTR	High	Suitable for Catalyzed Reactions	Treatment of Tannery effluents, Biochemical reactions, Penicillin production.
4	PFTR	Medium	Suitable for Constant velocity operations	Petrochemical industries and petroleum refineries

5	Membrane Bio Reactor	Medium	Suitable for High concentrated effluents	Sewage sludge treatment plants, Reverse osmosis water purification plants, waste water treatment plants.
6	Photo Bioreactor	Low	Suitable for Algae extractions	Algae extraction from sea weeds and growth of micro organisms.

4. Conclusion

Whatever the type of the bioreactor, the conditions in it have to be favorable so that living microorganism can exhibit their activity (specific biochemical and microbial reactions) under defined conditions. This results in a series of special features in the reaction engineering of biocatalytic processes. There are several unique aspects of biotechnological processes, which require special consideration in design of bioreactors. The selection of specific type of bioreactor depends on the type of feed, Biocatalyst or Microorganism involved, flow rate, reaction rate, temperature and location of the plant.

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