A MATHEMATICAL MODEL FOR A HYBRID ANAEROBIC REACTOR

by

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1. Hybrid anaerobic reactor
2. Anaerobic reactor

Certificate

This is to certify that the thesis entitled "**A Mathematical Model for a Hybrid Anaerobic Reactor**" being submitted by Mr. V. Saravanan is worthy of consideration for the award of the degree of Doctor of Philosophy. The thesis has been prepared under my supervision and guidance in conformity with the rules and regulations of Indian Institute of Technology Delhi and is a record of the original bonafide research work. The results presented in this thesis have not been submitted in part or full to any other universities or institutes for the award of any other degree or diploma.

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ABSTRACT

A Hybrid Anaerobic Reactor (HAR) has been developed in the laboratory of Dept of Biochemical Engineering and Biotechnology, IIT Delhi. The HAR employs self-immobilized anaerobic bacterial granules under completely fluidized condition as biocatalyst. A mathematical model has been developed for this reactor. Such a model can be used to study the sensitivity of the process to various operating parameters as well as to optimize the reactor design. This model includes a number of steps describing the biochemical and physico-chemical processes. The biochemical process includes: hydrolysis of particulate matter into soluble monomers like sugars, amino acids and fatty acids; acidogenesis of sugar into volatile fatty acids like acetate, propionate and butyrate; acetogenesis of propionate and butyrate into acetate and hydrogen; and methanogenesis. i.e. conversion of acetate to methane and CO_2 and conversion of hydrogen and CO_2 into methane. The physico-chemical processes describe ion association/dissociation and gas-liquid transfer.

In brief the model consists of the following three components:

1. A biofilm model, which describes the substrate conversion kinetics within the individual granule. Glucose was used as the model substrate. The stoichiometric equations considered were taken from literature. The substrate utilization rates were defined by using Monod kinetics with substrate/product inhibition and pH inhibition. Mass balance was written for different components within a granule. By solving these equations components fluxes at the surface of a granule were obtained.
2. A bed fluidization model, which describes the distribution of biogranules inside the fluidized bed volume. Experiments were conducted to study the settling and bed

expansion characteristics of biogranules obtained from the HAR. Based on this study a new correlation relating the up flow liquid superficial velocity and bed void fraction was developed.

3. A reactor flow model, which links the biofilm and the bed fluidization models to predict the substrate and products concentrations as a function of axial position (height) within the reactor. The reactor was divided into a number of compartments. The number of granules in each compartment was calculated using bed fluidization model. The component flux at the surface of a granule was obtained from the biofilm model. Using this, component balance equations for the entire compartment were written. By solving these equations for all the compartments, component profiles were predicted. All the simulations were done using Visual C++ software.

Product inhibition and pH inhibition of each group of bacteria has been considered in the kinetic model. The spatial distribution of each group of anaerobic bacteria within the anaerobic granules has been found to play a vital role in bringing about the conversion. Experiments were conducted in the HAR using synthetic effluent containing glucose as the carbon source to study the treatment efficiency. The model was simulated for the different sets of experimental operating conditions, first assuming a layered distribution of anaerobic bacteria within granules and then homogeneous distribution of anaerobic bacteria. The predictions of model simulation with the assumption of layered structure closely represented the experimental data. This indicated that the granule structure is mainly determined by the substrate kinetics.

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