A STEADY-STATE MODULE FOR MODELING ANAEROBIC BIOFILM REACTORS

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***Abstract*— A steady state model of an anaerobic methanogenic biofilm reactor-module that accounts for the biological interactions of four microbial groups, ionic equilibrium in solution, gas-liquid transfer phenomena and biofilm processes is presented. The model consists of a continuous stirred tank reactor type that allocates an inert support material, whose specific surface is taken into account. The biofilm model assumes an homogeneous biofilm of uniform thickness and constant density with no mass transfer resistance. The biofilm detachment process rate is modeled as a second-order function on the biofilm thickness and a first-order function on the mass fraction of the fixed biomass concentration of each microbial group. The balance equations for non-active biomass in liquid and biofilm are included. The model predictions have been satisfactorily compared with steady state experimental data reported in literature from a one-phase methanogenic biofilm system treating an acetic acid-based synthetic effluent, and a two-phase system with combined suspended (acidogenic) and attached (methanogenic) microbial growth treating a food industry wastewater composed by two residual process streams.**

***Keywords*— Anaerobic digestion, biofilm reactor, steady state model, wastewater treatment.**

I. INTRODUCTION

Water contamination is one of the most serious environmental problems that the world is presently facing with. The former biological methods developed to clean wastewaters were the aerobic processes. However, these systems demand high-energy consumption for aeration and pumping, and generate a large amount of waste sludge for disposal. The increasing energy prices and decreasing available land for sludge disposal have motivated the use of the anaerobic process as an alternative. The anaerobic systems produce methane by recovering energy from waste. In addition, anaerobic microorganisms are quite resistant to toxics. However, they exhibit some drawbacks. The main disadvantage is the slow growth rate of the anaerobic microorganisms, which makes necessary to operate the conventional systems at long hydraulic retention times. This drawback has been overcome by accumulating large amount of active biomass within the bioreactor as attached or flocculated biomass. This generation of high-rate anaerobic processes is being successfully applied for treating industrial and municipal wastewaters. Nevertheless, there is a wide room for process optimization and for investigating aerobic-anaerobic hybrid processes. In this context, computer aided modeling, simulation and optimization are important tools to gain both insight into the anaerobic degradation process itself and skills to design, control and operate efficiently high-rate anaerobic processes and hybrid processes.

The aim of this paper is to present a model of a steady state reactor module of anaerobic attached biomass for application on wastewater treatment. Further usage of the model for design, optimization and system analysis is intended.

II. BACKGROUND

A. Kinetics of the anaerobic process

The substrate degradation scheme has generally been described through microorganism groups characteristic of each degradation stage that are present in major concentration in the biological community. The first unified kinetic model for substrate removal and microbial growth in anaerobic conditions was presented by Lawrence and McCarty (l969). This model is based on Monod-type kinetics for describing the removal of acetic, propionic and butyric acids, which are the main intermediates in anaerobic degradation. This model is one of the most widespread in anaerobic digestion and its biokinetic parameters have been used in many published models (Dalla Torre and Stephanopoulos, 1986; Droste and Kennedy, 1988). Andrews (1969), Graef and Andrews (1974) and Buhr and Andrews (1977) have only considered the acetic acid degradation stage by suspended acetoclastic bacteria, which was assumed as the limiting stage. Hill and Barth (1977) have included the hydrolysis and acidogenesis stages to compute the organic overload effect in the methane production rate. Kaspar and Wuhrmann (1978) have shown that the uptake rates and product distribution of some bacterial species are regulated by hydrogen gas. Mosey (1983) has developed a model to account for hydrogen gas and propionic and butyric acids produced in an anaerobic reactor degrading glucose. On growth inhibition, a feature of early models was to combine the inhibitory effects of volatile fatty acids and pH by using the inhibition model proposed by Andrews (1969). Kaspar and Wuhrmann (1978) and Denac (1986) have shown that acetogens rather than acetoclastic methanogens are inhibited by acetic acid. Angelidaki *et al*. (1993) included ammonia inhibition of the acetoclastic methanogenic