Processes of aerobic/anaerobic biofilm development
by Steven Owen Schaftel

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Civil Engineering
Montana State University

Abstract:
The constitutive response of an aerobic/anaerobic composite annular biofilm reactor was modeled with fundamental kinetic parameters obtained independently from a completely aerobic, reactor utilizing glucose, a completely anaerobic reactor utilizing glucose, and a completely aerobic reactor utilizing products formed in the anaerobic reactor. The model satisfactorily predicted the biofilm areal carbon density dependence of the specific glucose removal rate, the specific suspended biomass production rate, and the specific oxygen removal rate. Specific product formation rate and specific biofilm accumulation rate were not predicted satisfactorily as a function of biofilm areal carbon density.

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Signature Steven O. Schaftel

Date August 25, 1982

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DEVELOPMENT

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ABSTRACT

The constitutive response of an aerobic/anaerobic composite annular biofilm reactor was modeled with fundamental kinetic parameters obtained independently from a completely aerobic reactor utilizing glucose, a completely anaerobic reactor utilizing glucose, and a completely aerobic reactor utilizing products formed in the anaerobic reactor. The model satisfactorily predicted the biofilm areal carbon density dependence of the specific glucose removal rate, the specific suspended biomass production rate, and the specific oxygen removal rate. Specific product formation rate and specific biofilm accumulation rate were not predicted satisfactorily as a function of biofilm areal carbon density.

INTRODUCTION

Background

A biofilm is an attached microbial mat which is composed of both cells and an adhesive polysaccharide material termed glycocalyx. In natural environments such as rivers and streams, the relative number of attached cells per square centimeter of biofilm is as much as 3 to 4 orders of magnitude greater than the number of suspended cells per cubic centimeter of liquid. In a polluted stream, the attached bacterial areal density is as much as 4 orders of magnitude greater than in an unpolluted stream (Costerton, et al, 1978).

Therefore, due to the relatively enormous cell density, biofilm process rates are much greater than suspended cell process rates. The wastewater treatment industry has taken advantage of these high process rates through the use of fixed film reactors such as trickling filters (Eckenfelder, 1961) and rotating biological contactors (Bunch, 1976). Trickling filters and rotating biological contactors (RBC's) receive oxygen from air. In some cases, the effluent is recycled to reduce the likelihood of oxygen limitations within the biofilm. Recycling, then increases the amount of waste removed.

In previous studies using fixed film reactors (Eckenfelder, 1961; Antonie et al, 1971; Wu et al, 1980; Yeun et al, 1981), measurement of influent and effluent organic carbon was done on the basis of BOD, COD, or TOC. However, these analytical methods provided only a gross measure of the biological processes occurring. Only by accounting for the individual components of the influent (and effluent) can a quantitative evaluation of fixed film processes be made.

Preliminary Studies

A more quantitative evaluation of fixed film processes was completed as a preliminary study to aid in experimental design. (The tabular data is presented in Appendix E). Lactate was used as the sole carbon and energy source. After 100 hours, lactate consumption rate increased to a plateau value approximately 75% of the feed rate (Figure 1.1. In all figures error bars indicate one standard deviation.). However, lactate consumption rate increased again at approximately 120 h until all lactate in the reactor was consumed. Though several explanations are possible, the second phase of growth was probably due to lactate consumption within a developing anaerobic region of the biofilm.

Further evidence of a developing anaerobic region was observed in the progression of biofilm thickness (Figure 1.2). The rate of biofilm accumulation appeared to slow at approximately 120 h. This observation could be accounted for by anaerobic biofilm development because anaerobic processes are typically less efficient than aerobic processes and would result in slower biofilm growth.

Anaerobic biofilm development was also the probable reason for

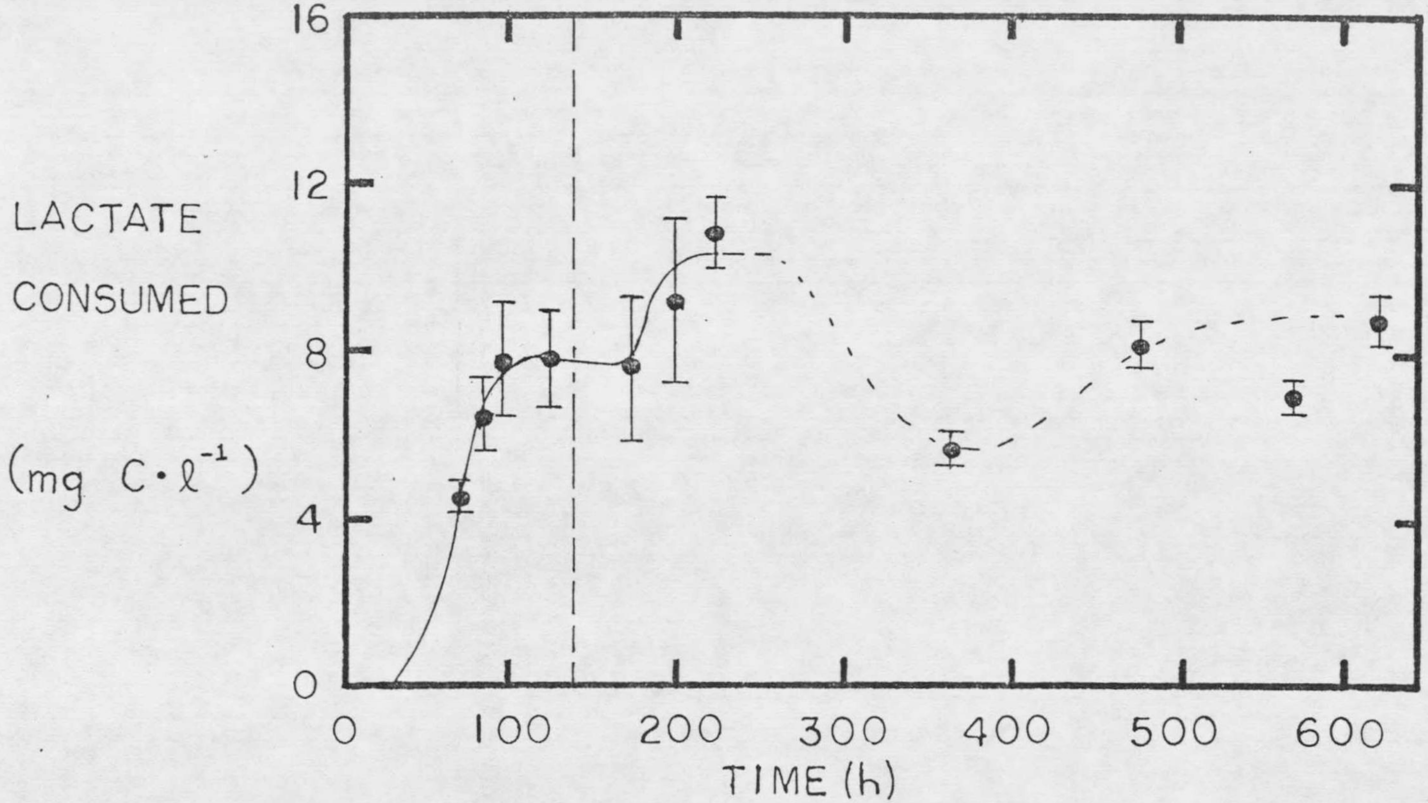

Figure 1.1 Progression of lactate consumed by a fixed film. Lactate was the sole carbon and energy source. Vertical dashed line indicates estimated time for initiation of anaerobic biofilm layer.