Mathematical and Computer Modelling 54 (2011) 1930–1942

Contents lists available at ScienceDirect

Mathematical and Computer Modelling

journal homepage: www.elsevier.com/locate/mcm

On the dynamics of biodegradation of wastewater in aerated continuous bioreactors

AbdelHamid Ajbar*, Malik AlAhmad, Emad Ali

Department of Chemical Engineering, King Saud University, P.O. Box 800, Riyadh 11421, Saudi Arabia

ARTICLE INFO

Article history:
Received 17 June 2010
Received in revised form 28 April 2011
Accepted 28 April 2011

Keywords:
Continuous bioreactors
Aerobic biodegradation
Contois model
Oscillations
Performance

ABSTRACT

The paper investigates the static and dynamic behavior of a continuous flow bioreactor for the aerobic biodegradation of municipal and industrial waste. The unstructured kinetic model for the bioreactor accounts for oxygen limitation in the bioreactor model while the growth rate is described by the biomass-dependent Contois model. This kinetic model is known to explain the aerobic biodegradation of solid municipal organic waste well. The yield coefficient is assumed to depend linearly on the substrate. The analysis of the unsteady-state model is carried out both analytically and through numerical simulations. The results show the ability of the model to predict a wide range of behavior, including oscillations for some range of kinetic and operating parameters. The analysis also showed that a variability of the yield coefficient is necessary for the existence of Hopf points in the model. The effects of the model parameters on the performance of the bioreactor are also investigated.

1. Introduction

Bioreactors with different configuration are used for the biodegradation of municipal and industrial waste. These include flow bioreactors with or without recycling, suspended batch reactors (SBRs) and plug flow reactors (PFRs), among others. Of all types of bioreactor, flow reactors have been used extensively in the treatment of industrial wastewater. One advantage they offer over other types of bioreactor is that they produce a greater operational stability in response to shock loads. The stringent environmental regulations governing the treatment and disposal of waste are pushing the process industry to increase the performance of these bioreactive systems. In this regard, continuous investigation of the static and dynamic behavior of these bioreactors is a necessary step for the optimization of their performance. The quantification of the static and dynamic behavior of a bioreactor is, however, complicated, because bioreactors can exhibit a number of nonlinear phenomena. These may include bistability between nontrivial steady states and washout, the occurrence of multiple steady states (the famous hysteresis phenomenon), and the occurrence of oscillations [1–10]. The mechanisms of most of these phenomena are not well understood, but they are known to be strongly dependent on the inherent mechanisms of the biodegradation (kinetics) as well as on external operating parameters of the unit. In this paper, we investigate the performance of a continuous flow tank bioreactor (CFTB) with the following major features. (1) The bioreactor is considered for the case of a gaseous limiting substrate. This situation occurs in aerobic growth subjected to oxygen limitation and requires accounting for the mass transfer of oxygen. (2) The growth rate is assumed to follow the Contois model [11]. This biomass-dependent growth model is qualitatively different from substrate-dependent growth models [12]. The Contois growth model has been used in a number of biodegradation studies of different food and industrial waste [9,13–18]. The methodology of the paper consists in the analysis of an unstructured mathematical model for an aerated bioreactor. Unlike

* Corresponding author. Fax: +966 1467 8770.
E-mail address: aajbar@ksu.edu.sa (A. Ajbar).

0895-7177/$ – see front matter
doi:10.1016/j.mcm.2011.04.035