Chemical Papers 67 (3) 326–335 (2013)
DOI: 10.2478/s11696-012-0274-8

ORIGINAL PAPER

Cadmium concentration stabilization in a continuous sulfate reducing bioreactor via sulfide concentration control

[a]Pablo Antonio López Pérez, [b]M. Isabel Neria González, [a]Ricardo Aguilar López*

[a]*Department of Biotechnology & Bioengineering CINVESTAV-IPN, Instituto Politécnico Nacional 2508, San Pedro Zacatenco, DF, 07360 México*

[b]*Chemical and Biochemical Engineering Division, Tecnológico de Estudios Superiores de Ecatepec, Tecnológico, Valle de Anáhuac, Ecatepec de Morelos, 55210 México*

Received 29 April 2012; Revised 30 August 2012; Accepted 31 August 2012

Cadmium concentration stabilization in a single input–single output continuous bioreactor via sulfide concentration, as the controlled and measured output state variable, was assumed. For the above process, a novel kinetic model of the sulfate-reducing process for cadmium removal was proposed and experimentally confirmed. This model has been extended to continuous operation, which is employed as a virtual plant to enable the implementation of the proposed controller. The considered nonlinear control law contains a sigmoid feedback of the given control error in order to regulate the sulfide concentration at the maximum value indirectly leading to cadmium concentrations meeting the environmental regulations. A theoretical frame of the closed-loop stability of the bioreactor is provided under the assumption that bounded trajectories occur in the bioreactor. Finally, numerical experiments proved satisfactory performance of the proposed methodology in comparison with the standard sliding-mode and linear PI controllers.

Keywords: cadmium stabilization, sulfide control, continuous bioreactor, sigmoid controller

Introduction

The indiscriminate use of natural resources has caused serious pollution of aquatic ecosystems principally due to chemical pollution of organic and inorganic origin, especially by organochlorinated compounds and heavy metals. Metal-related industries, such as metal finishing and electroplating, generate large quantities of metal polluted wastewaters, while acid mine drainage (AMD) is one of the most widespread forms of pollution in the world (Dochain & Vanrolleghem, 2001; Sampaio et al., 2009). Depending on the process, the waste-streams vary greatly in composition and volume, discharges of heavy metals can have devastating effects on aquatic and terrestrial ecosystems, differing from acute toxic to chronic effects depending on the contaminants' effect on the microorganisms (Cabrera et al., 2006). Metals like Hg and Cd exhibit toxicity at extremely low concentrations while others, like Cu or Zn, are also micronutrients which become toxic at concentrations of higher orders of magnitude (Bassirani et al., 2011). Conventional treatment methods for effluents contaminated with heavy metals involve physicochemical processes such as flocculation, precipitation, electrolysis, and crystallization. However, these processes are very expensive and generate new products, merely resulting in the transfer of the metal from one medium to another, not providing a definitive solution of the problem (Fu & Wang, 2011). The search for cheaper and definitive solutions led to the development of new technologies based on the utilization of biological systems of organic substrates for the removal of heavy metals by sorption processes (Głuszcz et al., 2008; Lesmana et al., 2009; Dąbrowska, 2012).

As it is well known, the operation of bioreactors

*Corresponding author, e-mail: raguilar@cinvestav.mx