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Oxygen profiles in biofilms undergoing endogenous respiration

Zhou Xiao-Hong [a], Zhang Ming-Kai [a], Yu Tong [b], Liu Yan-chen [a], Shi Han-Chang [a,*]

[a] State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Tsinghua University, Beijing 100084, China
[b] Department of Civil & Environmental Engineering, University of Alberta Edmonton, Canada T6G 2W2

HIGHLIGHTS

- Oxygen profiles in the biofilm undergoing endogenous respiration were measured and modeled.
- Two distinct trends in oxygen profiles in the biofilm were found using microelectrode.
- The simulated endogenous respiration rates were inconsistent with the traditional theory.
- A new model concerning cell-internal substrate generation was proposed, which explained the phenomena well.

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ABSTRACT

Knowledge of oxygen consumption related to oxygen distribution in biofilms is crucial to understand what is really happening in the biofilm endogenous metabolism. In this article, mature biofilms were taken from a municipal wastewater treatment plant for lab-scale experiments. A pH 7 buffer solution was used as influent instead of wastewater, indicating the absence of an external input of substrate. Oxygen distribution was measured in the next approximately 130 h at different locations in the biofilm. Two distinct trends in oxygen profiles in the biofilm were observed during endogenous respiration. In the first period under starved condition, oxygen penetrated more and more deeply in the biofilm with time, which is related to the smaller endogenous oxygen uptake rate. This phenomenon agrees with the traditional endogenous respiration theory developed in activated sludge systems. However, opposite trends were observed as the time passed by, where oxygen penetration became shallower again. A diffusion–reaction model concerning the generation and utilization of electron-donor substrate during endogenous respiration was proposed and agreed well with the changes in the measured oxygen profiles.

1. Introduction

Understanding endogenous respiration is particularly important in the evaluation of respirograms for the determination of biochemical oxygen demands and activated sludge growth kinetics [1]. The energy needed for the growth and maintenance of micro-organisms in activated sludge is obtained from the biochemical oxidation of substrate [1]. In view of the well-accepted microbiological description, the concept of endogenous respiration involves the consumption of the cell-internal substrate (secondary substrates) through the processes of decay and hydrolysis for maintenance purposes due to the absence of an external input of substrate, leading to activity loss and slightly reduced biomass [2]. Some researchers argue that the secondary substrates generated in the decay process result from the release and hydrolysis of bound extracellular polymeric substances (EPS) [3]. The reduction of active biomass for maintenance purposes is directly coupled to a consumption of electron acceptor [4,5]. In general, endogenous respiration is one of the reasons for the loss of microbial activity in general, and, is therefore very important for the modeling of wastewater treatment. As far as we know, endogenous respiration is a concept incorporated into the decay process in the widely-used activated sludge model, which is a complex process modeled in a relatively simple mathematical manner [2]. In recent years, studies related to the decay process in activated sludge systems have been extensively conducted [1,5–10]. However, despite its importance, the decay process is usually neglected in biofilm study and modeling. One of the important reasons is the lack of powerful tools to reveal the decay process in biofilms so far to our best knowing.

In the past years, O_2, pH, NH_4^+, NO_3^-, S_2^-, and redox potential microelectrodes were applied to study microbial metabolic processes such as aerobic oxidation, nitrification, and sulfate reduction in environmental biofilms [11–13]. The kinetic parameters in biofilms and the mass transfer at the boundary layer of bulk solution/biofilm can be excellently obtained by microelectrode studies [14]. Oxygen microelectrodes have been used since 1969 to determine microbial respiration rate in biofilms based on the well-known

* Corresponding author. Tel.: +86 10 62773095; fax: +86 10 62771472.
E-mail address: hanchang@mail.tsinghua.edu.cn (H.-C. Shi).

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