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MODÉLISATION DE COMPORTEMENTS TRANSITOIRES DE LA BIOMASSE DANS LES PROCÉDÉS DE BOUES ACTIVÉES À L'AIDE D'UN MODÈLE MÉTABOLIQUE

MODELLING OF TRANSIENT BEHAVIOR OF ACTIVE BIOMASS IN ACTIVATED SLUDGE PROCESSES USING A METABOLIC MODEL

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Abstract

For wastewater treatment, the activated sludge models (ASMs) 1, 2, and 3 of the International Water Association (IWA) are accepted as industrial standard. However, many authors have observed that the kinetic parameters of these models depend on the type of substrate, process configuration, and sludge age. Some publications showed that the kinetic parameters of ASMs could be influenced by regulation of enzyme production. In the models currently used to describe the activated sludge process, the distribution of the substrate flux between growth and storage is an empirical function.

Therefore, an engineer aiming to make some modifications to a specific treatment system is not able to predict the response of the real system after the modifications and choose the right configuration or modifications with the same set of parameters.

Sixty years ago, Monod (1949) proposed the application of the Michaelis Menten relation describing enzyme kinetics to a culture of micro-organisms. For the purpose of simplification, the mathematical relation proposed by Monod (1949) reduced the entire cell to a single enzyme genetically expressed at a single level. However, cell metabolism is based on a large number of biochemical reactions.

Chapter 2 of this thesis reviews the literature to identify the controlling factors of cell metabolism and the regulation of the specific activity of the cell. The literature review was designed to highlight which regulation mechanisms induce a growth rate variation so that they can be expressed mathematically ($d\mu/dt$). The study of these processes will focus on modeling the specific activity variation. The review is limited to heterotrophic prokaryote organisms growing under aerobic conditions.

Cybernetic models are proposed for modeling cell growth and focus, among other things, on regulation of enzyme production, that is to say on induction. The objective of this work is to present an activated sludge model that mimics the enzymatic induction of active biomass within the framework of ASMs. In the proposed model presented in chapter 3, process rates are modulated according to the environmental conditions and cell history. In a first step, the model was fitted on the basis of data found in the literature. All data collected

from short and long transient experiments were fitted with the same set of parameters, which was not possible with various models. The proposed model gave a more realistic picture of active biomass and of its specific activity under highly varying process conditions.

In a second step, an experimental protocol is presented to perform the evaluation of the structured biomass model. The protocol was designed to induce transient behaviour and characterize the evolution of several internal biomass components. In chapter 5, the theoretical model proposed in chapter 3 is adapted to an experimental protocol and fitted to the collected data. In these experiments it was observed that filling the storage capacity of cells leads to special transient behaviour and a temporarily reduced metabolic activity. The model-based interpretation of the results showed that the observed transient behaviour can be explained by cross-regulation of carbon and nitrogen metabolism. Hence, according to an extensive literature review, the cross-regulation of carbon and nitrogen can be used to model some observed transient behavior and regulation of the storage process in activated sludge.

In chapter 6, rRNA-structured biomass models are proposed to describe the metabolic status of cells using new molecular techniques in view of predicting the growth response ($d\mu/dt$) of cells in the activated sludge process. The autocatalytic reaction rate of the synthesis of the PSS component (rRNA) can provide a mechanistic explanation for the growth response and the growth lag phase. The proposed models were able to properly describe and predict the growth response of the biomass in various types of reactor. Such models could be more widely applicable by using intrinsic model parameters, and this could be a key improvement as it could lead to improved models for design.