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A modified Activated Sludge Model to estimate solids production at low and high solids retention time

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ABSTRACT

In this paper, a modified version of the IWA-ASM1 model capable of correctly simulating the production of solids over a wide range of solids retention time (SRT) is presented. The parameters of the modified model have been estimated by integrating the results of respirometric and titrimetric tests with those of studies conducted on pilot scale plants that treat industrial wastewaters of differing characteristics.

On the basis of the experimental results and their subsequent processing, it appears that the production of solids may be satisfactorily estimated using the modified model in which fractions X_P and X_I are supposed to be hydrolysable with a first-order kinetic.

In the cases that were examined, the constant of the aforementioned kinetics was estimated to be $k_i = 0.012\ d^{-1}$ and $k_i = 0.014\ d^{-1}$, for tannery and textile wastewater respectively.

A reliable calibration of the parameter k_i was possible when data relative to the experiment conducted in the pilot plants for no less than 60 d and in conditions of complete solid retention was utilized.

1. Introduction

Estimation of sludge production from activated sludge plants plays a major role for Wastewater Treatment Plants (WWTPs) for the choice between different technological solutions, design and management (such as cost–benefit analysis in choosing process conditions).

In the case of activated sludge processes, the Activated Sludge Models (ASM) of the International Water Association (IWA) are considered to be the reference models for design and sludge production estimation in both the research community and the industry (Gernaey et al., 2004).

In addition, respirometric and titrimetric techniques are normally used for wastewater COD fractionation and in the estimation of kinetic and stoichiometric parameters that are to be used in the ASM (Artiga et al., 2005; Spanjers and Vanrolleghem, 1995).

The IWA-ASM show an application limit regarding simulations of activated sludge processes that operate at elevated SRT, nevertheless, interest in this type of operating condition

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Nomenclature[2]

ASM	Activated Sludge Model
f_p	Fraction of biomass yielding particulate products
$f_{I,p}$	Fraction of S_I produced during X_P hydrolysis
$f_{I,I}$	Fraction of S_I produced during X_I hydrolysis
$f_{N,P}$	Ammonium nitrogen produced during X_P hydrolysis (mgN mgCOD^{-1})
$f_{N,I}$	Ammonium nitrogen produced during X_I hydrolysis (mgN mgCOD^{-1})
IWA	International Water Association
k_i	Hydrolysis rate of X_I and X_P (d^{-1})
S_S	Soluble biodegradable COD
S_I	Soluble inert COD
SRT	Solids retention time
X_I	Inert particulate COD in the influent (mgCOD L^{-1})
$fX_{I,in}$	Inert particulate COD fraction in the influent (%)
X_P	Inert particulate COD generating from the endogenous decay (mgCOD L^{-1})
X_S	Hydrolysable particulate COD (mgCOD L^{-1})

is growing for its ability to minimize sludge production and because many industrial wastewater treatment processes are conducted at elevated SRT.

The application range of ASM is clearly indicated by the authors who stated that ASM are designed to simulate activated sludge processes applied to domestic wastewater treatment at a solids retention time (SRT) of no more than 30 d (Henze et al., 2000).

In fact, in the literature there are several cases where an overestimation of sludge production by ASM, with respect to the experimental evidence has been reported (Hay et al., 2006; Lubello et al., 2007; Pollice et al., 2004). This phenomenon was particularly evident in the case of a number of Membrane Bioreactors (MBRs) (Muller et al., 1995; Yamamoto et al., 1989; Laera et al., 2005; Benìtez et al., 1995; Chiemchaisri et al., 1992; Wagner and Rosenwinkel, 2000; Rosenberger et al., 2002).

One of the primary reasons of such behaviour can be linked to the ASM approach used to model the behaviour of particulates produced by the endogenous decay of both the heterotrophic and autotrophic biomass (X_P). In fact, it ought to be considered that the fraction X_P consists of organic material derived from biomass decay. Consequently, the assumption that a fixed part of the biomass (indicated by f_p) cannot be biodegraded any further can be considered correct only for limited values of sludge age (Henze et al., 2000; Nowak et al., 1999; Van Loosdrecht and Henze, 1999). Another reason which can explain the difficulty ASM have in estimating the sludge production of biological processes that operate at high SRT is linked to the fact that the definitions of experimental procedures that estimate the inert particulate COD fraction of influent wastewater ($fX_{I,in}$) are quite uncertain.

The $fX_{I,in}$ fraction is usually estimated with respirometry; this technique, however, is not entirely adequate for the following reasons:

- respirometric tests are short-term and so, a part of the hydrolysable fraction is identified as inert particulate;
- in the case of very slowly hydrolysable fractions, exogenous and endogenous OUR cannot be adequately distinguished using the techniques of measurement and analysis employed in respirometric testing.

In order to overcome the difficulty of estimating the inert particulate COD fraction of influent wastewater, the fraction $fX_{I,in}$ is often estimated by calibrating the ASM on experimental data (Petersen, 2000; Nowak et al., 1999).

In this paper, a modified version of the ASM1 (ASM-S) is presented, which can be applied to a wide range of SRT and allows the results of respirometric tests and the calibration of the model to be coherently integrated. In combination with the results of respirometric tests, the proposed model is applied to two pilot scale MBRs that treat textile and tannery wastewater. The results obtained with the ASM-S are compared to those obtained with traditional ASM and considerations regarding the calibration of the new model are reported.

The ASM-S may be useful in simulating both the wastewater and sludge treatment trains. As a matter of fact, the hydrolysable fractions of the excess sludge are not, to date, adequately characterized. This has been the primary limit in creating a sound representation of the phenomena that occur in sludge digestion.

2. Materials and methods

2.1. Model structure

2.1.1. *The reference model (ASM1′) and the modified model (ASM-S)*

An IWA-ASM1 based model was used as reference (ASM1′); with respect to the original (ASM1), the endogenous death–regeneration process was substituted with a simple decay process as is used in the IWA-ASM3 model.

For the purpose of this research, the obtained reference model (ASM1′) represents a compromise between the simplicity of an ASM1 (which is characterized by fewer parameters than an ASM3) and a more suitable calibration of the model (Gernaey et al., 2004). In fact the particulate biodegradable fraction of COD (X_S) in the ASM1 model is hydrolysed with a unique process (and kinetics) even if it originates from both biomass decay and COD in the influent while in the reference model the kinetics of the endogenous decay process and of the particulate hydrolysable COD are independent.

In order to improve the representation of the solids production at high sludge age, other changes are proposed to the ASM1′. In particular, the modifications concern:

- the COD characterisation;
- the introduction of the hydrolysis of X_I and X_P.

[2] Note: the nomenclature for ASM1 parameters is not listed here. They can be found in Henze et al. (2000).