UNIVERSITAT DE BARCELONA
DEPARTAMENT D'ENGINYERIA QUÍMICA I METAL·LÚRGIA
GRUP DE RECERCA EN BIOTECNOLOGIA AMBIENTAL

MODELLING AND SIMULATION, USING A MODIFIED ASM2d MODEL, OF A NITRIFICATION/ DENITRIFICATION PROCESS IN AN SBR TREATING THE LIQUID FRACTION OF ANAEROBICALLY DIGESTED PIGGERY WASTEWATER

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1. INTRODUCTION

The piggery anaerobic supernatant treatment in a Sequencing Batch Reactor (SBR) by means of a nitrification/denitrification process via nitrite is a very satisfactory and competitive alternative to other treatment strategies [1].

Modelling the biological nitrogen removal (BNR) for the aforementioned activated sludge system based on the Activated Sludge Model ASM2d [2] is feasible. Nonetheless, some modifications need to be introduced in the model in order to simulate the via nitrite [3, 4] .

The main modification consists of describing both nitrification and denitrification as two-step reactions inhibited by unionized ammonia and nitrous acid concentrations. Thus, both the stoichiometry of the involved reactions and the subsequent parameters change.

ASM2d	MODIFIED ASM2d		
Nitrification in one step	Nitrification in two steps	$NH_4^+ \rightarrow NO_2^-$	$Y_{A,I}$; $\mu_{mA,I}$ $X_{BA,I}$; K_{NH}; K_{OA}
		$NO_2^- \rightarrow NO_3^-$	$Y_{A,II}$; $\mu_{mA,II}$ $X_{BA,II}$; K_{NO}; K_{ON}
Denitrification in one step	Denitrification in two teps	$NO_3^- \rightarrow NO_2^-$	K_{NO3}; $\eta_{G,I}$
		$NO_2^- \rightarrow N_2$	K_{NO2}; $\eta_{G,II}$

2. OBJECTIVES

✓ To introduce the necessary changes in the ASM2d model in order to better describe the BNR via nitrite.

✓ To calibrate the system under steady state conditions by determining the relevant kinetic parameters and stoichiometric coefficients involved in both carbon and nitrogen removal.

✓ To validate the adjusted model based on the accuracy of the simulated data to the real values.

3. CALIBRATION OF THE MODIFIED ASM2d BY RESPIROMETRY.

3.1- RESPIROMETRY SET-UP

✓To calibrate the modified ASM2d, a closed intermittent flow respirometer (Figure 1) is used [5].

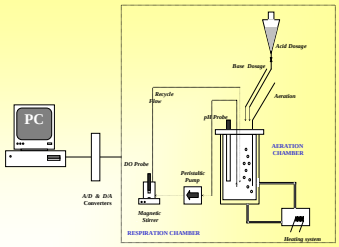

FIGURE 1 – Closed Intermittent Flow Respirometer.

3.2- RESPIROMETRIC BATCH EXPERIMENTS

✓ Each model parameter is evaluated through a respirometric batch experiment where the evolution of the Oxygen Uptake Rate (OUR) is intermittently measured under controlled pH and temperature.

3.3- MODEL PARAMETERS OBTAINED THROUGH RESPIROMETRIC BATCH EXPERIMENTS

✓The assessment of the main model parameters were based on the following correlations with the OUR.

Heterotrophic yield cefficient, Y_H

$$\int OUR\,dt = -(1-Y_H)\int dS_S$$

Correction factor for denitrification

$$\eta_{G,II} = \frac{1.71\,NUR_{NO_2 \rightarrow N_2}}{OUR}$$

Autotrophic yield cefficient during nitritation, $Y_{A,I}$

$$\int OURdt = -(3.43 - Y_{A,I})\int dS_{NH}$$

Affinity constants for the subtrate and for the oxygen

$$\mu_{mA,I}\frac{S_{NH}}{K_{NH}+S_{NH}}X_{BA,I} \qquad \mu_{mH}\frac{S_S}{K_S+S_S}X_{BH}$$

$$\mu_{mA,I}\frac{S_O}{K_{OA}+S_O}X_{BA,I} \qquad \mu_{mH}\frac{S_O}{K_{OH}+S_O}X_{BH}$$

Maximum specific growth ($\mu_{mA,I}$ $X_{BA,I}$ $\mu_{mA,I}$ $X_{BA,I}$, μ_{mH} X_{BH})

$$OUR = -\frac{dS_O}{dt} = \frac{1-Y_H}{Y_H}\mu_{mH}X_{BH} + b_H X_{BH}$$

$$OUR = -\frac{dS_O}{dt} = \frac{3.43-Y_{A,I}}{Y_{A,I}}\mu_{mA,I}X_{BA,I} + b_A X_{BA,I}$$

Oxygen supply

$$\frac{dS_O}{dt} = k_L a\left(S_{O,END} - S_O\right) - OUR_{ENDÒGEN}$$

4. CALIBRATION OF THE MODIFIED ASM2d MODEL AND SIMULATION OF THE CYCLE VIA NITRITE TO TREAT DIGESTED PIGGERY WASTEWATER

4.1- HETEROTROPHIC AND AUTOTROPHIC YIELD COEFFICIENTS

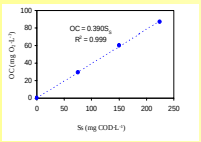

FIGURE 2 – Determination of Y_H.

✓ The **61 %** of the COD (methanol) fed in the SBR is used for the growing of heterotrophic bacteria.

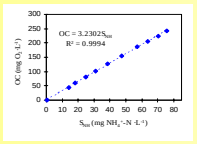

FIGURE 3 – Determination of $Y_{A,I}$.

✓ The **6 %** of the NH_4^+-N fed in the SBR is used for the growing of ammonium oxidizers and the other 94% is converted to nitrite.

4.3- CORRECTION FACTOR FOR DENITRIFICATION

✓Two experiments in parallel to compare the COD removal under aerobic and anoxic conditions.

✓For digested piggery wastewater treated in an SBR, the growth of heterotrophic bacteria under anoxic conditions is **84%** of the same growth in an aerobic environment.

4.5. EXPERIMENTAL AND SIMULATED RESULTS

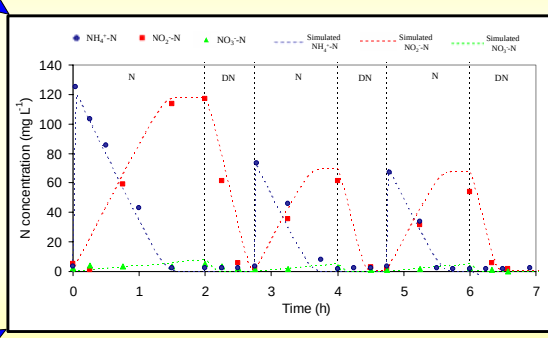

FIGURE 7 – Experimental concentrations and simulated data inside the SBR.
(For specific information on experimental data of the simulated cycle, see reference [1]).

4.2- AFFINITY CONSTANTS FOR THE SUBSTRATE AND THE OXYGEN

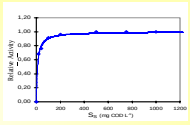

FIGURE 4 – Determination of K_S.

K_{NH}=4.0±0.6 mg NH4$^+$-N L^{-1}
Ks= 10.2±0.4 mg COD L^{-1}

✓ Monod kinetics for both affinity constants for the substrate.

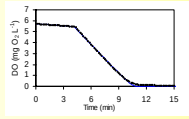

FIGURE 5 – Determination of K_{OA}.

K_{OA}=0.10±0.01 mg O_2 L^{-1}
K_{OH}=0.19±0.05 mg O_2 L^{-1}

✓ The low K_{OA} value allows working under reduced O_2 concentrations without suffering inhibition.

4.4- OXYGEN TRANSFER COEFFICIENT

✓It is determined in the SBR where the BNR takes place, since it largely depends on the geometry, the aeration and the stirring conditions of the SBR.

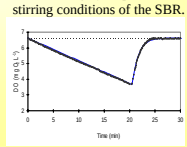

FIGURE 6 – Determination of K_La.

DO profile

K_La =0.9±0.1 min^{-1}

5. CONCLUSIONS

✓ The extended ASM2d is a good basis for the simulation of the activated sludge system in which piggery reject water is treated in a SBR with the aim of carrying out a BNR.

✓ The model parameters linked to ASM2d modifications can be accurately assessed by respirometric batch tests in a closed intermittent-flow respirometer. These model parameters are the input of the mathematical model to simulate and optimize the SBR performance.

✓ The proposed model showed very good agreement between experimental and simulated data for the biological nitrogen removal over nitrite of reject water from mesophilic anaerobic digestion of piggery wastewater in a SBR.

✓ The calibrated model can be used to improve the operational treatment conditions and to choose among many different treatment strategies, for this specific wastewater, based on simulation results.

6. REFERENCES

[1] Minoves, M., Galí, A., Dosta, J., Mata Álvarez, J. (2006). Optimization of a nitrification-denitrification process via nitrite in an SBR for the treatment of the liquid fraction of mesophilic digested piggery wastewater. Comunication submitted at the 7th International Symposium on Waste Management Problems in Agroindustries. The Netherlands, 27-29 September 2006.

[2] Henze, M., Gujer, W., Mino, T., Van Loosdrecht M.C.M. (2000). Activated Sludge Models ASM1, ASM2, ASM2d and ASM3. IWA Publishing, London.

[3] Serralta, J.; Ferrer, J.; Borrás, L., Seco, A. (2004) An extension of ASM2d including pH calculation. Wat. Res. **38**. 4029-4038.

[4] Dosta, J., Galí, A., Benabdallah El-Hadj, T., Macé, S., Mata-Álvarez, J. (2006). Operation and model description of a sequencing batch reactor for the treatment of the supernatant of anaerobic digestion of sewage sludge. Bioresource Technology (manuscript accepted).

[5] Spanjers, H., Vanrolleghem, P.A., Olsson, G., Dold, P.L. (1998). Respirometry in Control of the Activated Sludge Process: Principles. IAWQ Scientific and Technical Report N. **7**. London. UK. (1-12).