Combined anaerobic digestion and biological nitrogen removal for piggery wastewater treatment: a modelling approach

P. Rousseau, J.-P. Steyer, E. I. P Volcke, N. Bernet and F. Béline

ABSTRACT

In order to deal with the environmental problems associated with animal production industrialization and at the same time considering energy costs increasing, a piggery wastewater treatment process consisting of combined anaerobic digestion and biological nitrogen removal by activated sludge was developed. This contribution presents a modelling framework in order to optimize this process. Modified versions of the well established ASM1 and ADM1 models have been used. The ADM1 was extended with biological denitrification. pH calculation and liquid gas-transfer were modified to take into account the effect of associated components. Finally, two interfaces (ADMtoASM and ASMtoADM) were built in order to combine both models. These interfaces set up the COD, nitrogen, alkalinity and charge fractionation between both models. However, for the mass balances between both models, some hypotheses were considered and might be evaluated.

Key words | ADM1, anaerobic digestion, ASM1, denitrification, nitrification, piggery wastewater

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INTRODUCTION

Since the seventies, intensification of animal production, particularly pig production, has been observed in Europe. This intensification led to production industrialization and a concentration in specific localised regions. Among these regions, Brittany (France), accounting for only 7% of the French agricultural land, nowadays covers nearly 60% of the national pig production. This concentration leads to an excessive production of livestock wastewaters compared with available area for land spreading.

Different options for piggery wastewater treatment have been developed in order to reduce the nitrogen load and avoid fresh water pollution by nitrates resulting from over-application. Among the treatments available, the biological aerobic/anoxic treatment allowing nitrogen removal by nitrification/denitrification is the most widespread with more than 250 units running actually in Brittany. Such treatments are generally preceded by a mechanical separation of the solid phase and allow a

nitrogen removal close to 70% for an electrical consumption about $25\,kWh/m^3$.

At the same time, due to the increasing energy costs and in order to reduce the greenhouse gas emissions, anaerobic digestion of livestock wastewaters was developed in various European countries, particularly Denmark and Germany. Anaerobic digestion of piggery wastewater can produce about $25\,kWh/m^3$ of electrical energy and the same amount of heat. However, nitrogen is not removed from the effluent during anaerobic digestion, and thus, such treatments are not developed within areas such as Brittany, where nitrogen removal remains the priority.

A process combining both anaerobic digestion and nitrogen removal allows partial conversion of organic matter into a valuable energy, at the same time respecting the environmental constraints as regards nitrogen, reducing the energy costs at the farm scale. In this context, a process for piggery wastewater treatment combining anaerobic

digestion and nitrogen removal by nitrification/denitrification has been developed. Facing (i) system and processes complexity and (ii) highly fluctuating influent characteristics, experimental optimization is rarely efficient and modelling provides a useful alternative. The objective of this work was to develop a model combining both processes, aiming at process optimization.

PROCESS LAY-OUT

Process design

In Western Europe, the concentration of total suspended solids in piggery wastewaters is higher than 15–20 g/L. Consequently, the Upflow Anaerobic Sludge Blanket (UASB) and the Fluidized Bed (FB) reactors are not appropriated for anaerobic digestion of these effluents and the Continuous Stirred Tank Reactor (CSTR) is the most widespread technology used for digestion of piggery wastewaters (Moletta 2006). Moreover, the treatment management at farm level requires a "rustic" process, robust and easy to implement and manage. As a result, farm-scale anaerobic digesters are typically CSTR-configurations without recirculation nor retention of sludge, leading to a Hydraulic Retention Time (HRT) equal to the Sludge Retention Time (SRT). In addition to the process design, the substrate degradation kinetics also influences the HRT. For piggery wastewaters, these kinetics are slow, leading to HRT for CSTR in mesophilic conditions higher than 10–20 days (Burton & Turner 2003). Actually, HRTs applied are about 20 to 35 days (Clemens *et al.* 2006), corresponding to organic loads from 1 to 2 kgCOD/m^3_{react}/day.

Nitrogen removal from piggery wastewaters by activated sludge nitrification/denitrification is also typically carried out in CSTRs, for the same reasons as above. The nitrification and denitrification processes are carried out sequentially in space (2 reactors) or in time (a single reactor with intermittent aeration). In France, typically one reactor configurations with intermittent aeration are used. HRT and SRT are the same and even if a HRT about 10–20 days appears theoretically sufficient, the HRTs applied are higher than 30–35 days (Béline *et al.* 2007), corresponding to a nitrogen loads of about 0.1–0.15 kgN/m^3_{react}/day.
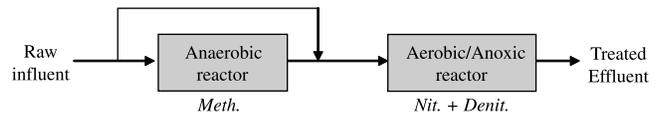

Figure 1 │ Bypass process diagram.

The main difficulty in combining the anaerobic digestion process with an activated sludge nitrification/denitrification process, lies in the competition for organic matter. Indeed, the C/N ratio after anaerobic digestion is generally insufficient for denitrification. An external addition of carbon in the aerobic/anoxic reactor could be performed using a bypass flow of anaerobic digestion (Kim *et al.* 2004; Deng *et al.* 2006). For this, Deng *et al.* (2006) used a bypass flow rate fixed at 30% of the input influent (Figure 1).

During this study, the BOD/NH_4^+-N ratio of piggery wastewater was 6 whereas this ratio is about 3–4 for piggery wastewaters in Brittany. Kim *et al.* (2003) applied a bypass flow rate varying from 20 to 100%. In this case, the biodegradability of the wastewater COD was estimated around 86% whereas only 40 to 45% of the wastewater COD is biodegradable in Brittany (Boursier 2003). With this process design, the organic matter directly used in the aerobic/anoxic reactor is generally higher than the requirements for denitrification in order to ensure a good nitrogen removal in spite of the variation of the influent characteristics.

To avoid the over-use of organic matter in the aerobic/anoxic reactor, Bernet *et al.* (2000) proposed an alternative process with recirculation of the nitrified effluent from the aerobic reactor to the digester carrying out the denitrification inside the anaerobic reactor (Figure 2).

In this case, methane production only takes place after denitrification because of the inhibiting effect of nitrogen oxides on methanogenesis. The recirculation rate used was 2 to 3 times the feed flow rate, and allowed nitrogen removal up to 70%. The main advantage of this design was the optimisation of the organic matter use However, important flow rates were generated by the recirculation reducing the HRT inside the reactors.
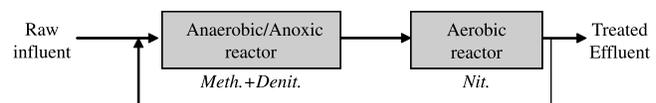

Figure 2 │ Recirculation process diagram.

Process development

Based on the literature results (Bernet *et al.* 2000; Kim *et al.* 2004; Deng *et al.* 2006) and aiming to optimize the organic matter use, a combined anaerobic and aerobic treatment was developed for piggery wastewater treatment (Figure 3).

About 60% of the piggery wastewater influent is first digested while 40% is bypassed to the activated sludge aerobic/anoxic reactor. After the anaerobic digestion, nitrogen is removed in the aerobic/anoxic reactor and the influent bypass allows to provide the organic matter required for denitrification. Finally, a recirculation loop from the aerobic/anoxic reactor to the anaerobic digester allows to partial denitrification inside the anaerobic reactor ensuring a good quality effluent even for important influent characteristics variations.

PROCESS MODELS

Activated sludge nitrification/denitrification – modified ASM1

Two types of biomass are involved in biological nitrogen removal: after oxidation of ammonia by autotrophic biomass, the formed nitrite and nitrate are denitrified by heterotrophic biomass using organic matter. The IWA Activated Sludge Models (ASMs, Henze *et al.* 2000) initially developed for the simulation of urban wastewater treat-ment, are commonly used to describe nitrogen removal. Recently, modifications have been proposed to adapt the model for piggery wastewater treatment (Béline *et al.* 2007). These modifications mainly concerned (i) the consideration of nitrite as intermediate of nitrification and also of denitrification, and (ii) the differentiation between hetero-trophic anoxic and aerobic yields. The modified model is composed of 15 state variables describing the behaviour of 7 soluble compounds and 8 particulate compounds (Table 1).
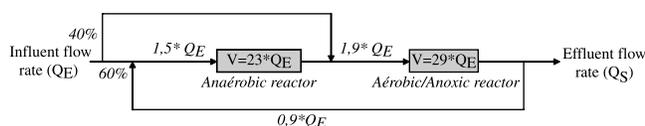

Figure 3 | Process treatment diagram.

Anaerobic digestion – modified ADM1

Anaerobic digestion model no1

During anaerobic digestion, organic matter is removed into methane and carbon dioxide in a series of 4 biological processes: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Oxygen, ammonia and nitrogen oxides are the main inhibitors of these processes, especially the methanogenesis step. The IWA Anaerobic Digestion Model no. 1 (ADM1, Batstone *et al.* 2002) has found widespread application in simulating the anaerobic digestion process. Besides the mentioned biological conversions, the model also takes into account chemical equilibria, influencing pH, as well as liquid/gas transfer of methane, carbon dioxide and di-hydrogen, allowing taken into account in order to simulate the produced gas flow rate. The resulting model comprises 26 state variables: 14 soluble compounds and 12 particulate compounds (Table 1).

Modified ADM1

Firstly, in order to simulate the recirculation of nitrogen oxides from the anoxic/aerobic reactor to the anaerobic reactor, ADM1 was modified to include the denitrification process, the inhibitions and the competitions with other substrates (Tugtas *et al.* 2006). For that, the denitrification step is considered as a succession of processes leading from nitrate (S_{NOA}) to nitrite (S_{NOI}) and then to molecular nitrogen (S_{N2}). All these steps are carried out by a heterotrophic biomass (X_{BH}) consuming valerate (S_{va}), butyrate (S_{bu}), propionate (S_{pro}), acetate (S_{ac}) and hydrogen (S_{h2}). For each substrate, a reaction process was added to the model (Table 2). Face to their low degradation rate, denitrification from sugars (S_{su}), amino acids (S_{aa}) and long chain fatty acids (S_{fa}) were not considered. The nitrogen oxides inhibition was introduced into the acetogenesis and methanogenesis steps. They were considered as a non-competitive inhibition:

$$I_{NOX} = \frac{1}{1 + (S_{NOX}/K_{I,NOX})}$$

The charge balance equation has been extended to include the pH effect of nitrate and the nitrite/nitrous acid equilibrium. N_2 and its transfer into the headspace modify

Table 1 | Description of the ADM and ASM state variables

	ADM			Modified ASM		
	Compounds	Abbr.	Unit	Compound	Abbr.	Unit
Soluble fractions	Soluble Inerts	S_I	kg COD.m^{-3}	Inert soluble substrat	S_I	g COD.m^{-3}
	Valerate	S_{va}	kg COD.m^{-3}	Readily biodegradable substrate	S_s	g COD.m^{-3}
	Butyrate	S_{bu}	kg COD.m^{-3}			
	Propionate	S_{pro}	kg COD.m^{-3}			
	Acetate	S_{ac}	kg COD.m^{-3}			
	Monosaccharides	S_{su}	kg COD.m^{-3}			
	Amino acids	S_{aa}	kg COD.m^{-3}			
	Long Chain Fatty Acids	S_{fa}	kg COD.m^{-3}			
	Inorganic nitrogen	S_{IN}	kmole N.m^{-3}	Ammonium + Ammonia nitrogen	S_{NH}	g N.m^{-3}
	Inorganic carbon	S_{IC}	kmole C.m^{-3}	Nitrite nitrogen	S_{NOI}	g N.m^{-3}
	Cations	S_{cat}	mole	Nitrate nitrogen	S_{NOA}	g N.m^{-3}
	Anions	S_{an}	mole	Soluble organic nitrogen	S_{ND}	g N.m^{-3}
Particulates fractions	Particulates Inerts	X_I	kg COD.m^{-3}	Inert particulate substrate	X_I	g COD.m^{-3}
	Composite	X_c	kg COD.m^{-3}	Slowly biodegradable substrate	X_S	g COD.m^{-3}
	Carbohydrates	X_{ch}	kg COD.m^{-3}			
	Proteins	X_{pr}	kg COD.m^{-3}			
	Lipids	X_{li}	kg COD.m^{-3}			
	Monosaccharides degrading biomass	X_{su}	kg COD.m^{-3}	Ammonium oxidizing biomass	X_{AI}	g COD.m^{-3}
	Amino-acids degrading biomass	X_{aa}	kg COD.m^{-3}	Nitrite oxidizing biomass	X_{AA}	g COD.m^{-3}
	LCFA degrading biomass	X_{fa}	kg COD.m^{-3}	Heterotrophic biomass	X_H	g COD.m^{-3}
	C4 degrading biomass	X_{c4}	kg COD.m^{-3}	Inert particulate substrate from biomass	X_P	g COD.m^{-3}
	Propionate degrading biomass	X_{pro}	kg COD.m^{-3}	Organic particulate nitrogen	X_{ND}	g N.m^{-3}
	Acetate degrading biomass	X_{ac}	kg COD.m^{-3}	Inert particulate nitrogen	X_{NI}	g N.m^{-3}
	Hydrogen degrading biomass	X_{h2}	kg COD.m^{-3}			
Gaseous fractions	Hydrogen	S_{h2}	kg COD.m^{-3}	Dissolved oxygen	S_O	g COD.m^{-3}
	Methane	S_{ch4}	kg COD.m^{-3}			

Table 2 | Denitrification process includes into the modified Anaerobic Digestion Model no1

Compound →	i	4	5	6	7	8	12	13	37	38	39	42	
j	Process ↓	S_{va}	S_{bu}	S_{pro}	S_{ac}	S_{h2}	S_{IN}	X_c	S_{noa}	S_{noi}	S_{no}	X_{bh}	Process rate (ρ_j, kgCOD/m^3/day)
8-1	Uptake of valerate with	NO$_3$	-1					$-Y_{c4}.N_{bac}$		$-(1-Y_{c4})/1.14$	$(1-Y_{c4})/1.14$		Y_{c4}	$k_{m,noa,va} \cdot (S_{va})/(K_{S,noa,va} + S_{va}) \cdot (S_{noa})/(K_{S,noa} + S_{noa}) \cdot X_{bh}$
8-2		NO$_2$	-1					$-Y_{c4}.N_{bac}$			$-(1-Y_{c4})/0.57$	$(1-Y_{c4})/0.57$	Y_{c4}	$k_{m,noi,va} \cdot (S_{va})/(K_{S,noi,va} + S_{va}) \cdot (S_{noi})/(K_{S,noi} + S_{noi}) \cdot X_{bh}$
9-1	Uptake of butyrate with	NO$_3$		-1				$-Y_{c4}.N_{bac}$		$-(1-Y_{c4})/1.14$	$(1-Y_{c4})/1.14$		Y_{c4}	$k_{m,noa,bu} \cdot (S_{bu})/(K_{S,noa,bu} + S_{bu}) \cdot (S_{noa})/(K_{S,noa} + S_{noa}) \cdot X_{bh}$
9-2		NO$_2$		-1				$-Y_{c4}.N_{bac}$			$-(1-Y_{c4})/0.57$	$(1-Y_{c4})/0.57$	Y_{c4}	$k_{m,noi,bu} \cdot (S_{bu})/(K_{S,noi,bu} + S_{bu}) \cdot (S_{noi})/(K_{S,noi} + S_{noi}) \cdot X_{bh}$
10-1	Uptake of propionate with	NO$_3$			-1			$-Y_{pro}.N_{bac}$		$-(1-Y_{pro})/1.14$	$(1-Y_{pro})/1.14$		Y_{pro}	$k_{m,noa,pro} \cdot (S_{pro})/(K_{S,noa,pro} + S_{pro}) \cdot (S_{noa})/(K_{S,noa} + S_{noa}) \cdot X_{bh}$
10-2		NO$_2$			-1			$-Y_{pro}.N_{bac}$			$-(1-Y_{pro})/0.57$	$(1-Y_{pro})/0.57$	Y_{pro}	$k_{m,noi,pro} \cdot (S_{pro})/(K_{S,noi,pro} + S_{pro}) \cdot (S_{noi})/(K_{S,noi} + S_{noi}) \cdot X_{bh}$
11-1	Uptake of acetate with	NO$_3$				-1		$-Y_{ac}.N_{bac}$		$-(1-Y_{ac})/1.14$	$(1-Y_{ac})/1.14$		Y_{ac}	$k_{m,noa,ac} \cdot (S_{ac})/(K_{S,noa,ac} + S_{ac}) \cdot (S_{noa})/(K_{S,noa} + S_{noa}) \cdot X_{bh}$
11-2		NO$_2$				-1		$-Y_{ac}.N_{bac}$			$-(1-Y_{ac})/0.57$	$(1-Y_{ac})/0.57$	Y_{ac}	$k_{m,noi,ac} \cdot (S_{ac})/(K_{S,noi,ac} + S_{ac}) \cdot (S_{noi})/(K_{S,noi} + S_{noi}) \cdot X_{bh}$
12-1	Uptake of hydrogen with	NO$_3$					-1	$-Y_{h2}.N_{bac}$		$-(1-Y_{h2})/1.14$	$(1-Y_{h2})/1.14$		Y_{h2}	$k_{m,noa,h2} \cdot (S_{h2})/(K_{S,noa,h2} + S_{h2}) \cdot (S_{noa})/(K_{S,noa} + S_{noa}) \cdot X_{bh}$
12-2		NO$_2$					-1	$-Y_{h2}.N_{bac}$			$-(1-Y_{h2})/0.57$	$(1-Y_{h2})/0.57$	Y_{h2}	$k_{m,noi,h2} \cdot (S_{h2})/(K_{S,noi,h2} + S_{h2}) \cdot (S_{noi})/(K_{S,noi} + S_{noi}) \cdot X_{bh}$
20	Decay								1				-1	$k_{dec,Xbh}.X_{bh}$

the methane concentration. So the production and the liquid-gas transfer of N_2 have been also considered in the modified model (Table 3).

MODEL INTERFACING

The ASM and ADM state variables are clearly different (Table 1), which make it difficult to combine these 2 models and at the same time to respect elemental and charge balances. One way to fulfil this task is through the development of interfaces between the two models, keeping charge and mass balances. A general method for this purpose has been proposed by Volcke *et al.* (2006). Specific contributions dealing with the construction of interfaces between the ASM and ADM1 models are also found in literature (Copp *et al.* 2003; Zaher *et al.* 2007), although dealing with classical wastewater rather than piggery manure. Based on these references, in this study, two interfaces have been developed for this specific application. An ADMtoASM interface concerns the flow from the anaerobic reactor to the aerobic/anoxic reactor, while an ASMtoADM interface is used for the flow from the aerobic/anoxic reactor to the anaerobic reactor.

From a theoretical point of view, total COD and total nitrogen from one model are distributed in the other model compounds. The distribution is carried out step by step to maximize some compound in a given order. For the nitrogen and COD mass balances, finally, nitrogen and COD could be distributed into compounds without nitrogen or carbon. The charge continuity through the interface must also be optimized in order to model as well as possible the processes pH variations.

ASMtoADM interface

The main objective of this interface is to optimize the distribution of the organic nitrogen and COD from ASM

among nitrogenous organic compounds (amino-acids and proteins) of ADM. For the mass balances, the developed interface includes a freedom degree between the two models. Thus, compounds without nitrogen (S_{su}, X_{ch} and X_{li}) and without carbon (S_{IN}) are used to equilibrate nitrogen and carbon mass balances. Firstly, dissolved oxygen (S_O) from ASM is considered as a negative COD and is, then subtracted from the total COD incoming. This COD is removed, firstly, from S_S and, then, if S_S is insufficient, from X_S, X_{BH} and finally X_{BAI} and X_{BAA}. Afterwards, the soluble organic nitrogen (S_{ND}) from ASM is considered as amino-acid (S_{aa}) in ADM as long as there is enough S_S (Figure 4). Finally, the remaining S_{ND} is considered as inorganic nitrogen (S_{IN}) while the remaining S_S is considered as monosaccharide (S_{su}).

In the same way, the particulate organic nitrogen (X_{ND}) from ASM is considered as proteins (X_{pr}) as long as there is enough X_S (Figure 5). The remaining X_S is divided into carbohydrates (X_{ch_temp1}) and lipids (X_{li_temp1}) considering a specific ratio (f_{li_xs}). This specific ratio was not determined for manure and was adapted from data concerning wastewater sludge. The remaining X_{ND} is included into a particulate organic nitrogen pool ($N_{X\_remaining}$).

The autotrophic biomass (X_{BAA} and X_{BAI}) from ASM was considered as inactive in the anaerobic reactor. Thus, this biomass is considered as a particulate substrate into ADM and distributed between X_{biom_inert} considering the specific ratio (f_{xi_biom}) and a particulate biodegradable fraction (X_{biom_biodeg}). This last fraction has a similar behaviour as X_S and is distributed between, firstly, proteins using the organic nitrogen fraction remaining ($N_{X\_remaining}$) and then between lipids and carbohydrates (Figure 6) considering a specific ratio (f_{li_biom}).

A fraction (f_{BH_active}) of heterotrophic biomass is considered as active in the anaerobic digestor while the remaining part, like autotrophic biomass, is associated to particulate inert (X_{biom_inerte}), proteins, lipids and carbohydrates. If necessary, the nitrogen fraction remaining ($X_{X\_remaining}$) is considered as inorganic nitrogen (S_{IN}). Like inert fractions have the same nitrogen content in both models, mass balances could be written:

$$X_{I\_ADM} = X_{I\_ASM} + X_p + X_{biom\_inert}$$

$$S_{I\_ADM} = S_{I\_ASM}$$

Table 3 | Gas transfer process includes into the modified Anaerobic Digestion Model no1

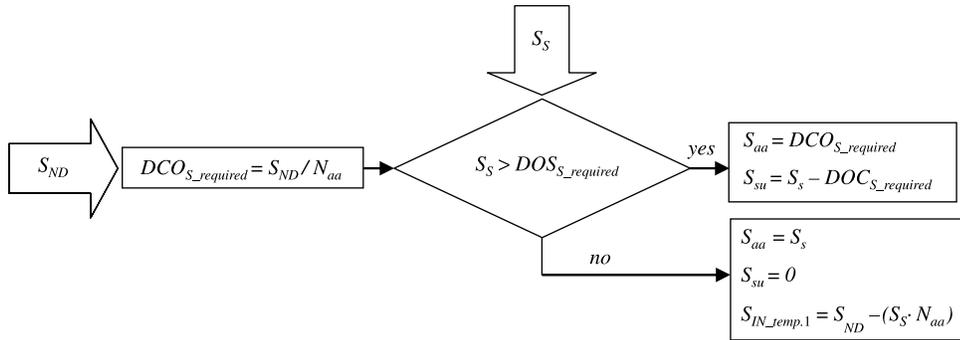| Compound →	i	41	
j	Process ↓	S_{n2}	Process rate (ρ_j)
T41	Nitrogen tranfer	−1	$k_La \cdot (S_{ligN2} - 28 \cdot K_{H,N2}, \rho_{gaz,N2})$

Figure 4 | Soluble organic nitrogen distribution diagram.

This last hypothesis considering similar inert fraction between anaerobic and aerobic conditions was recently confirmed by Ekama *et al.* (2007). Finally, nitrites (S_{NOI}) and nitrates (S_{NOA}) are directly transferred from ASM to ADM.

ADMtoASM interface

The gaseous (S_{ch4}, S_{h2}, S_{N2}) of the effluent from the anaerobic reactor are stripped quickly and, then, these fractions are not considered in the interface. Nitrites (S_{NOI}), Nitrates (S_{NOA}) and soluble inert fraction (S_I) are directly transferred into the similar fraction of ASM. A fraction of heterotrophic biomass (f_{BH_active}) from ADM is considered as active in the aerobic reactor (X_{BH}) while the remaining part is distributed between X_S and X_I. Soluble biodegradable COD fractions from ADM are summed and transferred as readily biodegradable substrate (S_S) in ASM. Likewise, particulate biodegradable COD fractions from ADM are summed and transferred as slowly biodegradable substrate

(XS). Inorganic nitrogen is directly converted into ammonia nitrogen (S_{NH}). Soluble organic nitrogen (S_{ND}) comes from the soluble inert soluble fraction (S_I) and amino-acids (S_{aa}). Likewise, particulate organic nitrogen (X_{ND}) comes from particulate fractions excepted inert fraction.

$$S_{ND} = (N_I \cdot S_I) + (N_{aa} \cdot S_{aa})$$

$$X_{ND} = (N_{XC} \cdot X_C) + (N_{aa} \cdot X_{pr}) + N_{bac} \cdot (X_{su} + X_{aa} + X_{fa} + X_{c4} + X_{pro} + X_{ac} + X_{h2} + X_{BH})$$

Particulate inert nitrogen (X_{NI}) comes from particulate inert fractions (XI).

Charge balance continuity

pH and alkalinity have a great importance during the anaerobic processes. Thus, in order to finalize the interfaces, the charge equilibrium must be taking into account to calculate alkalinity in both models (Salk, SIC). For that,
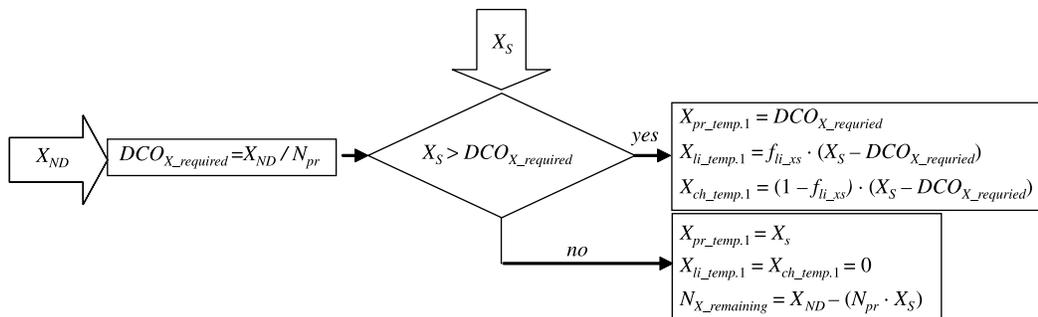

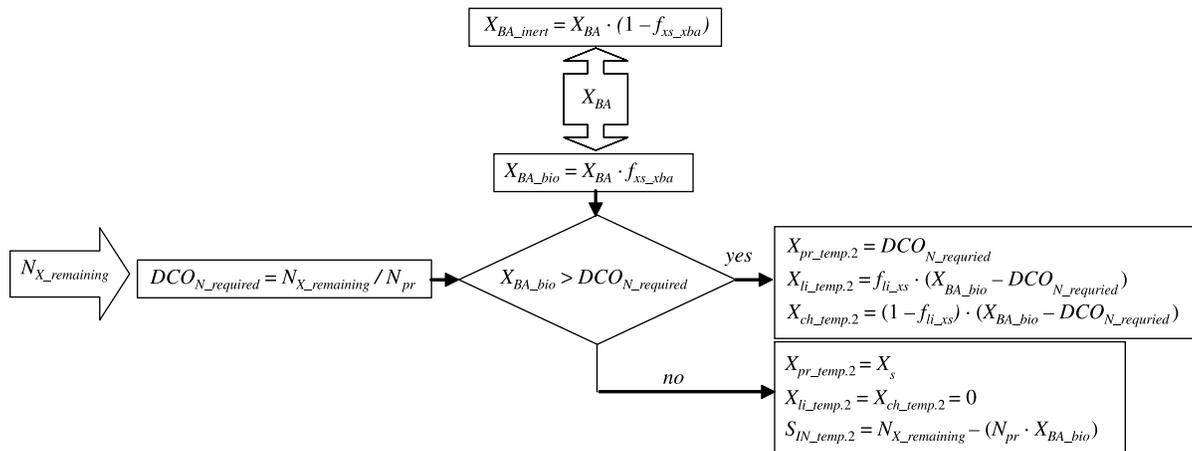**Figure 5** | Particulate organic nitrogen distribution diagram.

Figure 6 | Autotrophic biomass distribution diagram.

charge continuity through the interface can be written:

$$\left[S_{alk} \cdot \alpha^{ch}_{alk} + S_{NH} \cdot \alpha^{ch}_{NH} + S_{NOx} \cdot \alpha^{ch}_{NOx} \right]_{PiWaT1}$$
$$= \left[S_{AGV} \cdot \alpha^{ch}_{AGV} + S_{IN} \cdot \alpha^{ch}_{IN} + S_{IIC} \cdot \alpha^{ch}_{IC} + S_{NOx} \cdot \alpha^{ch}_{NOx} \right]_{ADMDénit}$$

where S_i represents compound i concentration and α^{ch}_i is the compound charge which depends on pH and pKa as:

$$\alpha^{ch}_{AGV} = \frac{-1/M_{AGV}}{1 + 10^{pK_a - pH_{ADM}}} \quad \alpha^{ch}_{IC} = \frac{-1}{1 + 10^{pK_a - pH_{ADM}}}$$

$$\alpha^{ch}_{IN} = \frac{10^{pK_a - pH_{ADM}}}{1 + 10^{pK_a - pH_{ADM}}} \quad \alpha^{ch}_{NH} = 1$$

CONCLUSION

A model framework for the simulation of piggery wastewater treatment trough a combined anaerobic digestion and activated sludge nitrogen removal treatment has been proposed, based on the two well established models: ADM1 and ASM1. Firstly, ADM1 has been modified to take into account the denitrification process inside the anaerobic reactor. For that, nitrites and nitrates fractions, biomass and linked processes have been considered and their effects on anaerobic digestion have been taking into account. The effects of denitrification processes on the pH have also been considered. A two-step nitrification/denitrification of ASM1 has been used. Two interfaces

(ADMtoASM and ASMtoADM) have been developed to combine both models. These interfaces allow model coupling with maintenance of COD, Nitrogen, alkalinity and charge balances. The resulting model will be used for process optimization. However, the hypothesis made during the building of the interfaces must be evaluated.

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