IMPLEMENTATION OF ANAEROBIC DIGESTION MODELS FOR PLANT WIDE MODELING AND PERFORMANCE BENCHMARKING

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Abstract
Integration of Anaerobic Digestion Model (ADM) with the standard Activated Sludge Models (ASMs) is introduced for plant wide application. A flexible methodology is presented through an example in which the standard benchmark model of activated sludge systems is extended with an anaerobic digestion unit. To simulate the practice of sludge treatment in this example, two process units are added and configured to act as thickener and centrifuge before and after digestion respectively. To increase flexibility for further application two interfaces between activated sludge and digester model components are created. The structure of the transformers is briefly described. Results of the benchmark simulation are shown to highlight the effect of supernatant recycling.

Keywords
Anaerobic Digestion Models; Activated Sludge Models; Benchmark; Simulation

INTRODUCTION

Anaerobic digestion has a growing concern in the field of wastewater treatment. It is a cost effective process since it recovers energy, produce less sludge…etc. To avoid instability of the process, effective operating system is required. Thus, projects such as the EU TELEMAC project apply considerable effort to develop new sensors and effective control systems. The process is suitable for high load situations COD/VSS. However, it has limitations on the expected effluent quality in terms of SS, COD and more so, ammonia and phosphorus. Thus it needs post-treatment.
A simulation benchmark can be used to evaluate the desired control systems, sensors and combination with other treatment processes. Therefore in this paper, a methodology is developed to extend a standard benchmark of activated sludge systems by inclusion of an anaerobic digestion unit.

METHODOLOGY

The Siegrist ADM has been chosen for illustration in this paper (Siegrist et al, 1995, 1993 & 1990). All modeling and simulation was performed in the WEST software (Hemmis nv, Kortrijk, Belgium) – (Vanhooren et al, 2002), using the Model Specification Language, MSL (Vangheluwe, 2000). Two transformers has to be developed for connecting the ADM with ASM1 (IWA, 2000) or vice versa.

ASM1 to Siegrist ADM transformer

Soluble components:

- Hydrogen and methane are zeros, they are not expected in the aerobic effluent.
- Knowing the pH CO_2 and HCO_3^- can be estimated from equilibrium.
- Substrate is reduced to compensate for the depletion of the remaining dissolved oxygen and nitrates. The remainder will be split into acetate, propionate, amino acids and sugar, and Fatty acids according to predefined ratios (hydrolysis is not considered in this ADM).
- Inerts will be passed through as such.

Particulate components:

- Fermenters (degraders of sugars and amino acids) could be estimated as a predefined fraction of heterotrophs, As some of the heterotrophs are capable of fermenting,.
- Degraders of Fatty acids, Propionate, Acetate and Hydrogen are zeros in the aerobic biomass.
- Particulate biodegradable matter in anaerobic conditions consists of several fractions of particulate matter different from ASM fractions. Thus they can be calculated according to predefined fractions.
- Inerts are estimated as predefined fractions of the species of aerobic particulate.

Nitrogen:

- Ammonia concentration should be estimated to maintain the mass balance between incoming ASM fractions and out going Siegrist ADM fractions in either soluble or particulate form. Thus, appropriate fractions should be assigned for each.

Siegrist ADM to ASM1 transformer

Soluble components:

- Ammonia and Inerts will pass through.
- Substrates is estimated from the total acetate, propionate, amino acids and sugar, and fatty acids.
- Dissolved oxygen and nitrates will be assigned zero values.
- Biodegradable nitrogen will be estimated as a fraction of the amino acids.
- Alkalinity is estimated as moles of bicarbonates by summing the bicarbonate and carbon dioxide concentrations.

Particulate components:

- Inerts will pass through, adding inert fraction of anaerobic biomass.
- Heterotrophs are estimated as a fraction of the fermenters.
- Particulate substrate is estimated as the remaining fraction of the anaerobic biomass.
- Autotrophs are assigned a zero value.
- Particulate nitrogen should be estimated to keep the mass balance between incoming Siegrist ADM fractions and out-going ASM fractions.

The same transformers could easily be adjusted for other models. It could even be simpler if the models themselves at first sight get more complicated. For example, if the first transformer needs to be adjusted for ADM1 (IWA, 2002) the number of fractions and parameters of the transformers is reduced simply because it could be achieved by summing only the aerobic biomass and passing it on as particulate. With a fair approximation most of the other inputs could be set to zeros, whereas hydrolysis fractions are considered within the model itself.

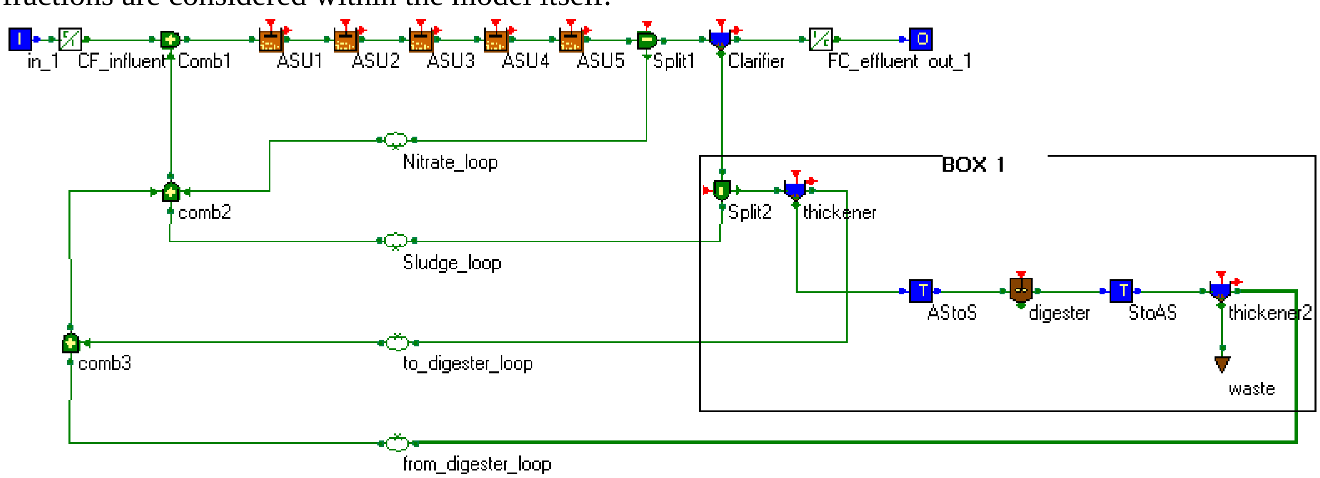


Figure1: Proposed Extended Benchmark

APPLICATION

Using the WEST simulator, this ADM and its transformers were applied on the standard benchmark developed for evaluations concerned with the activated sludge systems. This Benchmark represents ideal large treatment plant of 100,000 P.E. and influent of 18446 m^3 day^{-1}. For the detailed description of the standard benchmark reference is made to (Copp, 2001). The proposed extended benchmark is shown in figure 1.

In addition to the from_thickener_loop, from_digester_loop, comb3 and adjustment of comb2, 5 nodes were added as shown in box1. First from left is an ideal separator that acts like a thickener. According to the standard benchmark defintion, an under flow of 45 m^3/d and considering some non-settleable solids would lead to an under-flow sludge concentration around 5% solids. Similarly other ideal separator is configured to behave like a centrifuge with dried sludge of about 20 % solids. The three nodes between them are the digester and its transformers. The digester was sized according the benchmark load to be 1000 m^3 to give up to 50% solids reduction and in simulation it gave 45-55% reduction.

SIMULATION RESULTS

First, the plant was run on the standard steady state flow to initialize the state variables. Then the standard dynamic dry weather flow was run through the simulated plant. In the following some results of the dynamic simulation and its interpretation.

Figure 2: Total Gas Production (digestor)

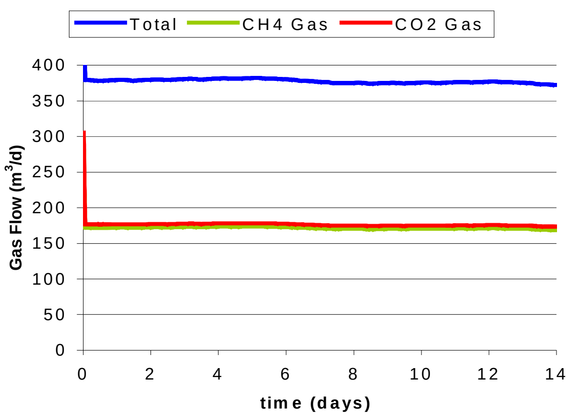


Figure3: DIGESTER TOTAL VSS

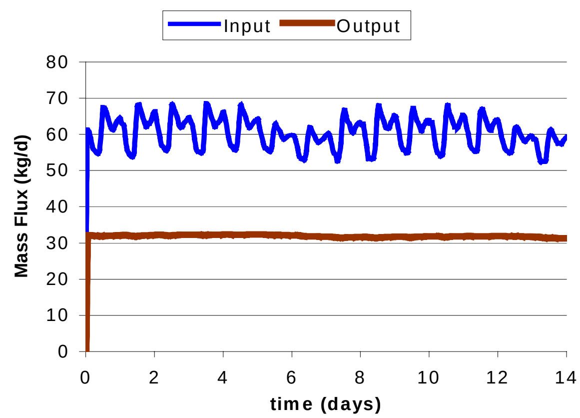


Figure 4:PLANT EFFLUENT WITHOUT AD (1)
PLANT EFFLUENT ADDING AD (2)

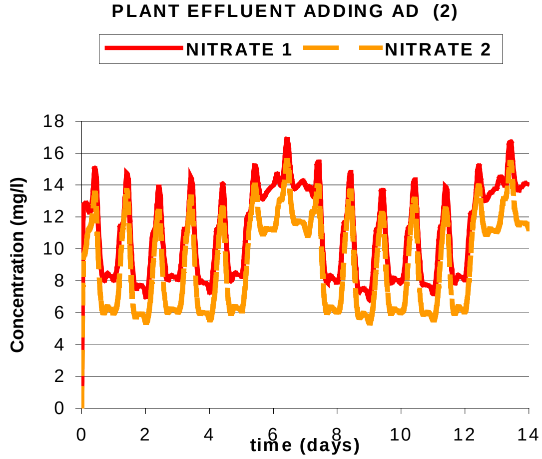
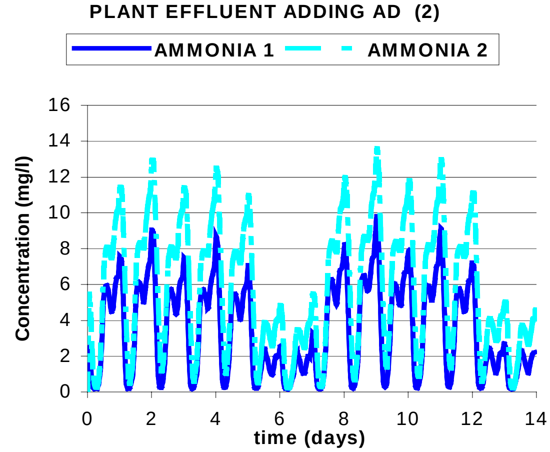


Figure 5:PLANT EFFLUENT WITHOUT AD (1)
PLANT EFFLUENT ADDING AD (2)



It can be seen in figure 2 that the amount of gas produced in terms of CO_2 and CH_4 is close to what expected in common practice. The amount of CH_4 produced is considerable and it could be higher according the optimum of 60-65% CH_4/CO_2.This optimum could be simulated by adjusting the ADM parameters. Figure 3 shows the expected reduction of solids. Figure 4 shows almost the same expected effluent characteristics for a system with or without sludge digester. Even for nitrates, the system with sludge digester has an improved operation because recycled easily biodegradable substrates (VFA) is enhancing denitrification. Ammonia is slightly higher as it is produced in the digester. However, a separate treatment of sludge return liquors could be added, for instance by incorporating a SHARON reactor (van Kempen et al, 2001, van Dongen et al, 2001 and Hellinga et al, 1999) between the digester and the activated sludge systems.

CONCLUSIONS

This methodology of connecting digesters by transformers successfully facilitated the inclusion of ADM in plant wide application. Further, it could be applied for benchmarking systems that are extended for anaerobic digestion. Because of the flexibility introduced in the methodology, connecting other flows with characteristics more specific to the ADM state variables is now possible. The inclusion of a new process like **SHARON** can now be evaluated in an easy way too.

ACKNOWLEDGEMENT

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