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Performances of anaerobic membrane bioreactors treating thin stillage from bioethanol plants at different sludge retention times

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Anaerobic processes coupled to membrane separation were already developed in the early 1980s but they have gained increasing interest in recent years. Indeed, the Anaerobic Membrane Bioreactor (AnMBR) appears as an alternative concept to recover energy from different concentrated waste streams such as from dairy or beverage industry, biofuel production and also for the treatment of municipal sludge. Conventional anaerobic digesters are widely used but they have the disadvantages of operating with long hydraulic retention time and they require large capacity tanks. High rate anaerobic processes are efficient for the treatment of various industrial wastewaters but they face biomass retentions problems when treating wastewaters having high suspended solids concentrations (Van Lier et al., 2001) such as the residue streams coming from bioethanol industries. Moreover, the AnMBR offers many advantages compared to the other anaerobic processes such as its superior effluent quality (smaller aerobic post treatment is required); its lower sensitivity to toxic compounds; a better control of the sludge retention time allowing the development of specific biomass; and a reduced plant footprint compared to a conventional digester. In the case of bioethanol industries, AnMBR appears to be an interesting solution for upgrading the energy balance of the plant. Following the bioethanol industry type (production from corn, barley, oat, rice, wheat, sorghum and sugar cane), the waste streams composition can vary in term of fats, oil and grease (FOG), nitrogen content, suspended solids content, etc. In this context, Biothane Systems International developed lab-scale protocols and tools to evaluate the potential to use an AnMBR for treating different types of waste streams, to validate the start up procedure and to optimise the operating conditions to each kind of substrate. This paper will present a selection of results obtained with a corn based thin stillage, having high fat, oil and grease (FOG) content (~5 g/l).

Four flexible lab-scale AnMBR were built. These lab units consist of a feed vessel continuously mixed and kept at a temperature of 4-5 °C, a continuously mixed 10-L anaerobic digester, and a side-stream tubular cross flow microfiltration membrane with a surface area of 0.0115 m^2 (Fig.1). The membrane is made of PVDF and has a mean pore size of 0.03 μm. To control the reversible fouling, the cross-flow velocity was 0.5 m s^{-1} and the membrane was operated in filtration/ backwash mode (300/30 seconds). To enable high membrane fluxes, permeate was partially recycled into the reactor, as shown in Fig. 1. The biogas production, pH and the trans-membrane pressure were monitored on-line. Feed flow and permeate flow rates were checked every day. Frequent analyses were performed to check the characteristic (Total Suspended solids, COD, TKN, TP, P-PO_4^{3-}, N-NH_4^+, Ca^{2+}, Mg^{2+}) of the raw wastewater, the permeate and the sludge and to evaluate the sludge filterability (soluble COD, capillary suction time (CST), specific cake resistance (SCR), particles size distribution, soluble polysaccharides and proteins). Additionally, to evaluate the optimum operating flux for different operating conditions, critical flux measurements (according to the method of Le Clech et al., 2003) were carried out regularly.

Two AnMBR reactors were fed with corn based thin stillage (the influent characterisation is given in Table 1) for 3 months. They operated under mesophilic conditions (37± 0.5 °C) with SRTs respectively of 20 days and of 30 days. The SRT was then increased in the second

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reactor to 50 days for 3 other months. For all the experiments, the MLSS concentration was in the range of 18-30 g/l and the volumetric loading rate (VLR) was gradually increased up to 8 kg $COD.m^{-3}.d^{-1}$.

Table 1. Influent and effluent concentrations for SRT of 20d, 30d and 50d

	Influent	**Effluent SRT = 20d**	**Effluent SRT=30 d**	**Effluent SRT=50d**
Parameters	**Average**	**Average**	**Average**	**Average**
pH	3.9 ± 0.03	7.3 ± 0.5	7.6 ± 0.5	6.9 ± 0.2
TSS (g/l)	18.0± 2.5	N.A	N.A	N.A
VSS (g/l)	17.9± 2.6	N.A	N.A	N.A
TCOD (g/l)	71.8± 9.0	0.69 ± 0.2	1.0 ± 0.4	1.3 ± 0.7
SCOD (g/l)	37.0± 6.1	0.69 ± 0.2	1.0 ± 0.4	1.3 ± 0.7

The reactors were initially seeded with a selected anaerobic sludge screened through a 0.74 mm mesh screen. The systems were first operated in conventional digester mode (as a CSTR) for several weeks to allow anaerobic biomass to acclimatise to the thin stillage. During the entire experiment, the performances of the reactors were according to the expectations with a total retention of the biomass in the reactor and a high COD retention (> 96%) for all SRTs (Table 1). The membranes also enabled to retain FOG (FOG concentration in the effluent was inferior to the detection limit (20 mg/l)). The generated biogas consisted of ca. 60% methane, ca. 40% carbon dioxide and a few minor components such as hydrogen sulphide. The biogas production was depending on the applied organic loading rate. Results also showed a better FOG degradation when increasing the SRT.

For the 3 experiments, relatively high operating net flux was achieved (9- 11 $L.h^{-1}.m^{-2}$, 37°C) in comparison with results obtained with a different kind of thin stillage. In a same way. critical flux measurements were always higher than 11 $L.h^{-1}.m^{-2}$, 37°C. The sludge characteristics were also analysed for the different SRT as shown in Table 2. Results particularly underlined better sludge filterability properties when operating with the 20days SRT reactor (lower CST, SCR, SCOD and bigger flocs).

Table 2. Sludge characteristics for SRTs of 20d, 30d and 50d.

Parameters	Sludge SRT = 20d Average	Sludge SRT=30 d Average	Sludge SRT=50 d Average
SCOD (mg/l)	1414 ± 4206	2371 ± 534	1906 ± 841
MLSS (g/l)	18 ± 2	20 ± 4	21 ± 2
CST (s)	963 ± 145	1665 ± 311	2054 ± 381
SCR (10^{12}m.kg^{-1})	2030 ± 90	3130 ± 445	2970 ± 187
D50 (µm)	49.7	41.3	27.6

Worst membrane performances were then noticed when some biological stress occurs. Figure 2 shows, for example, the membrane performances when operating the reactor at a SRT of 50d with a net flux of 11 L.h^{-1}.m^{-2}, 37˚C. The permeability was relatively stable except at the end of February and March 2012: the membrane permeability decreased when the VFA concentration increased in the reactor which was the consequence of the application of a too high organic loading rate (> 6 kg COD.m^{-3}.d^{-1}). It was also shown during the experiments that a too high TSS concentration (> 28 g/l) led to worst membrane performances which limit the VLR for a given SRT.

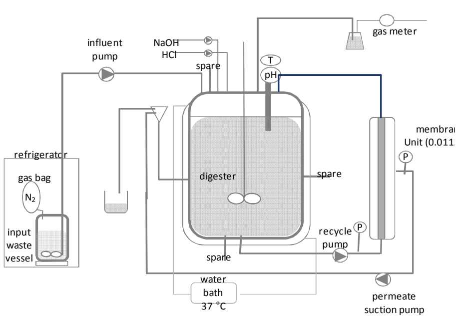

Figure 1. Lab-scale AnMBRs

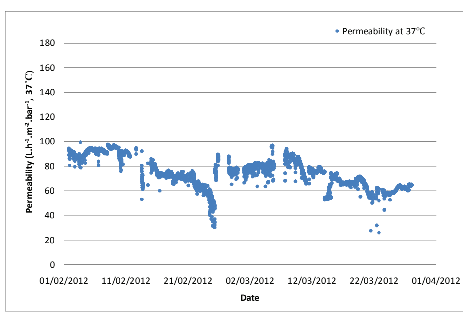

Figure 2. Membrane permeability evolution for a SRT of 50d (net flux of 11 L.h^{-1}.m^{-2}, 37˚C)

Results finally pointed out that the sludge retention time and the volumetric loading rate must be adapted to each kind of substrate according to the accumulation of inorganic solids and organic matter in the reactor and to the membrane performances.

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