PERFORMANCE OF A DYNAMIC, PULSATING ANAEROBIC FILTER WHILE TREATING INDUSTRIAL WASTEWATERS INCLUDING A COMPARISON WITH UASB REACTORS

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Introduction

Anaerobic digestion is a very good method for pre-treating industrial waste waters highly loaded with dissolved or fine particulate organic compounds before an aerobic post treatment. For this purpose, high rate digestion is necessary because of large volumes and high dilutions. Actually, mainly UASB and static fixed film reactors (i.e. anaerobic filters) are in operation for high rate AD. UASB reactors show very good performances (LR), but break down sometimes with shock loading (fat etc.). Static filters may clog.

The concept of a pulsating, dynamic anaerobic filter

In a pulsating, dynamic anaerobic filter, the support for the anaerobic bacteria is moved gently up and down. This rhythmical movement of the filter elements may be generated with a low external energy input due to equilibrium of the film support package weights (Fig. 1). This movement shows the following advantages:

?? Because of a continuously changing relative speed between the bacterial film fixed on the support and the waste water polluted with organic compounds, the nutrient supply of the bacteria is enhanced; hence *better and quicker degradation,*

?? The organic compounds penetrate better into the lower layers of the bacterial film, what increases the amount of active biomass (in a static filter just at the surface of the film), hence *more and better degradation.*

?? Because of continuos motion changing in speed, *better degasification of the fixed film.*

?? Clogging of the filter can be easily handled by increasing the speed of the motion for a short time, hence easy *control of the optimal thickness of the bacterial layer,* i.e. no clogging

?? High quantity of active biomass not only in the bacterial film but also suspended in the liquid (movement keeps surplus sludge in suspension), hence *increased active surface and better degradation,*

?? *Higher bacterial diversity* of fixed film bacteria as compared to in UASB granulates, where just a small spectrum of anaerobic bacteria is able to grow by forming pellets, hence significant *larger variety of compounds to be broken down,*

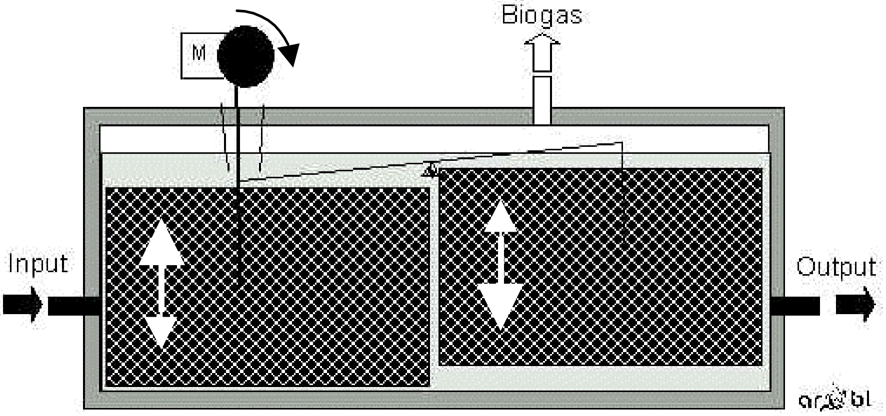
?? Because of fixed biomass and higher bacterial diversity *improved stability against shock loadings and/or poisons*,

?? Plug flow design with defined retention time is possible (no substrate re-circulation is necessary in order to keep granules or sludge in suspension), hence *follow up of optimally adapted bacterial biocenoses* along the way the substrate flows. (In UASB the substrate may be recycled constantly in order to obtain optimal speed for keeping the granules in suspension; there a plug flow design with maximal break down of the substrate is not possible)

The pulsating anaerobic filter therefore combines the advantages of an UASB reactor (very high active biomass due to large surface and intensive contact with the substrate) and the advantages of a conventional anaerobic filter (high stability regarding shock loading due to fixed biomass and high stability regarding changes in substrate composition due to higher bacterial diversity).

Figure 1:

The two filter packages are suspended in equilibrium and moved slowly (~40RPM) up an down (5-10 cm) by the motor M driving an excentric disk

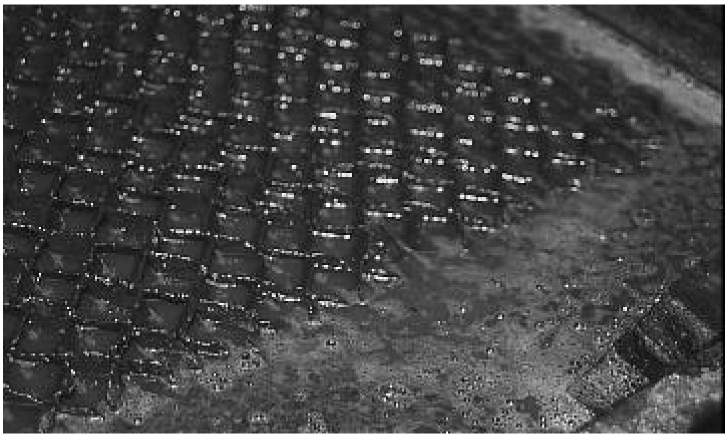


Results

Pilot experiments were carried out with two experimental plants of 1 m^3 and 0.5 m^3 respectively. The bacterial support consisted of corrugated plastic panels, which were glued together in a rectangular angle and had a surface of 200m^2/m^3 (Fig. 2). The digestions took place at mesophilic temperatures.

Figure 2:

Sight of a filter package reaching the surface of the waste water. There is a bacterial film of about 3 mm thickness on the support material (corrugated plastic panels)



Digestion of **cheese** factory **permeate** (mainly lactic acid) (BAER Weichkäsereien): The digestion took place without pH-control at pH of the acidified input of 4-4,5 (DM: 5.5%, ash: .5%, N: 0.025%, protein: .2%, fat: 0.1%). Inside the digester the pH reached 6.2-6.7 in the free waste water at a HRT of 7 d. >95% of the COD was degraded producing 4.5-5,5 m^3 biogas/m^3 reactor at a methane content: 60-67%. It has to be stressed that there was no pH-control of the input! The only explication for the results obtained is that inside the bacterial film there are regions with pH-values in the neutral zone. This stability to low pH-values in the waste water seems to be an additional advantage of the pulsating design.

Digestion of **distillery slops** (cherry) (ETTER Kirsch): Also in these experiments, the substrate (COD: ~30 mg/l) entered sour into the digester. At a LR of 9 kg COD/m^3.d (HRT 3d) digestion was stable at a breakdown of >70% despite of no pH-control. At a LR of 13 kg COD/m^3.d, the process started to be unstable. Start-up experiments after opening the filter and standstill of over 1 month showed, that the filter reached normal values after 5 days already.

2-step-digestion of solid **vegetable wastes** (*Edelmann et al, 1996 & 1999*): Solid vegetable wastes, as well as coffee waste and energy grass was hydrolized in a rotating drum (batch fed hydolysis, recirculation of percolate). The percolate rich in organic acids was digested in an aerobic, pulsating filter of 1 m^3 volume. The pulsating filter showed no problems in breaking down the incoming acids at concentrations of 2.7 g/l (total VFA) and 1.2 g/l propionic acid. The COD filter loading rate reached peaks of up to far more than 15 kg/m^3.d in some experiments. In the input, the pH used to drop shortly to 5.6, but it remained most of the time at ~6.5. When reducing the recirculation rate, the pH dropped to 4.4 and inhibition was observed. Despite of an acid input, in the centre of the filter the pH of the fluid remained around 6.6 without causing any problems. In some experiments, HRT was as low as 2.5 h and maximum LR > 15 kg COD/m^3.d. Nevertheless, the COD remained stable and low in the buffer tank after the filter before being re-fed on top of the hydrolysis drum.

Digestion of **waste water from catering vegetables and salads** (Forster GastroStar): Here, the waste water was derived from automated peeling of potatoes, carrots, celeriac and beetroot. The composition of the waste water varied depending on the works going on in the factory (13.8 ± 2.5 kg COD/m^3). Before entering into the filter, large particles were eliminated by a sieve and the remaining material underwent a hydrolysis of about one day (no pH-control). Over an observation period of several months, mean COD load was 8.8 kg COD/m^3.d at a HRT of 1.38 d. Depending on the percentage of particulate carbon, COD reduction was 75 ± 13% producing 0.39 ± 0.07 Nm3 biogas/kg COD added at a mean methane content of 64 ± 6%. Between days 90 and 130, input composition and concentrations varied very much (22 ± 19 kg COD/m^3). There were several days with LR > 14 kg COD/m^3.d and days when pH dropped to <4 in hydrolysis. Despite of high variations of composition as well as of the LR, the filter worked without any problems. Due to the motion, there was no significant amount of sediments remaining inside the filter; sand sedimented in the hydrolysis tank and particulate starch was totally degraded. Other, not yet totally degraded particles were exported. By introducing a sedimentation step after the filter, a mean COD reduction of 88% ± 6% could be achieved.

Digestion of waste waters of an industrial plant to process **meat wastes** (Tiermehlfabrik, click on Bazenheid, http://www.biogas.ch/landwirtschaft1.htm): There, two UASB reactors of 57.5 m^3 each treat the condensing waters of meat processing. The UASB reactors broke down several times in the past because of technical problems within the factory: it happened, that in addition to the dissolved organic compounds (COD of about 6000 mg/l) a fraction with high grease content and some suspended solids was fed by error to the UASB's. This generated additional costs, because the UASB's had to be started up again and new granules had to be bought.

There were three goals for the experiments with the pulsating anaerobic filter:

1. Observation of the start up (time needed until normal operation)
2. Comparison of the degradation with exactly the same input as used for the UASB's and
3. Shock loadings to the filter, higher than those leading to break down of the UASB's.

During the experimental period of about 8 months, the pulsating filter "Dynapuls" was started up during 4 months increasing the LR successively (period I and last 14 days of period I respectively, see table 1). At the end of this period, 94.9% of the COD was eliminated by the filter. In period II the LR was comparable to that of the UASB's (filter: 4.71 kg COD/m^3.d vs. UASB 4.61 kg COD/m^3.d) and the degradation was comparable to that of the UASB. In periods III and IV, the LR of the filter surpassed that of the UASB (period IV: average 173.9% of UASB). The degradation per volume was 136% of that of the UASB. The total breakdown decreased to about 80% of the COD input.

Dynapuls Liter/d (Period)	**UASB** Degradation kg CSB/m^3.d	**Dynapuls** Degradation kg CSB/m^3.d	**Dynapuls** Degradation % UASB
356 (I)	**4.60**	**3.12**	**67.8%**
356 (I, last fortnight):	**4.06**	**3.12**	**76.8%**
602 (II)	**4.37**	**4.07**	**93.1%**
548 (III)	**3.55**	**4.43**	**124.9%**
840 (IV)	**4.01**	**5.46**	**136.3%**

Tab. 1: Comparison of the COD degradation of the pulsating filter Dynapuls and UASB reactors (see text).

During Phase III (with an average LR of 125% of that of the UASB's), shock experiments were carried out. A first shock was produced by adding process waters (low fat, but very high ammonia contents). Over 24 hours the LR increased to 17.1 kg COD/m^3.d. The degradation decreased to 74% of COD input, but recovered immediately after reducing the LR.

A second shock lasted for two days: for 24h a LR of 36 kg COD/m^3.d and next 24 h 17.8 kg COD/m^3.d. This shock was significantly greater than the shocks leading to break down of the UASB's. This time, material coming directly from the autoclaves rich in fat and suspended solids was added. (Particles, such as solid fat, were increased very much; they are not included in the COD measurement, however). The Filter performance decreased to a minimum of 61.6% COD degradation two days after the shock was over. It recovered to normal values after another two days (~90% degradation). No clogging was observed.

The experiments had to be stopped already after a little more than eight months for logistic reasons. At this time, the performance of the filter was still increasing continuously. It may be suggested that the maximal performance would be reached after 1 (– 2) year(s). In addition, the results presented refer to the total liquid volume (and not filter volume) of the reactor. However, in a pilot plant, there is a lot of inactive volume (>20%) because of construction details, which were not yet optimised (or cannot be optimised easily in small scale plants). Taking into account this fact as well as other considerations, the performance of the dynamic filter will be even significantly better.

Fig. 3: piloting yeast waste waters

Conclusions

The disadvantage of the anaerobic filter is the relatively long start-up time of several months. Once started up however, it shows the advantages such as suggested in the introduction: The filter proved to be very stable and resistant to changes in the composition of the input as well as against rapid changes in HRT and LR. This is an important advantage as compared to UASB technology. The pulsating design allows a plug flow design, which guarantees better degradation and follow-up of adapted biocenoses along the way substrate flows. A further advantage, i.e. the stability against low pH in the input was most surprising. The only explanation found is the suspicion that inside the bacterial film there must prevail a chemical environment different from that in the free waste water outside the film, because methanogenesis could not take place at such low pH values for thermodynamic reasons. It is suggested to build full size plants for industrial waste water treatment.

Literature

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