Anaerobic sequential batch reactors for high-efficiency treatment of slow degradable industrial wastewater

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Abstract
Anaerobic treatment is a standard solution for treatment of industrial waste streams. Despite high efficiency of granular biomass anaerobic systems, treatment of wastewaters with high suspended solids (SS) and/or fat oils and greases (FOG) represents a big challenge. In this case, flocculent biomass anaerobic systems are more suitable as no granulation process is involved. Among them, anaerobic sequential batch reactor (AnSBR) is a simple configuration, overlooked but with many advantages. Therefore, in this study three pilot-trials were carried out treating waste-streams very high in SS and/or FOG. Results showed very high efficiencies at relatively high volumetric loading rates, with TCOD and SCOD removals above 90% and 99%, respectively; thus reaffirming the great potential of this configuration.

Keywords
Anaerobic sequential batch reactor; slowly biodegradable wastewaters; COD removal

Session: Novel anaerobic high-rate reactors / advanced sludge retention systems

INTRODUCTION
Waste streams from industries such as Dairy, Food Processing, Wineries, Distilleries and Biofuel contain a wide range of COD (3 - 100 g/L) as well as high concentrations of suspended solids (SS) and/or FOG (Fat, Oil and Grease). Granular biomass anaerobic systems are only suitable for this type of waste streams when the amount of SS and/or FOG is limited (TSS < 0.5 - 1.0 g/L; particulate COD < 20% and FOG < 50 mg/L). At higher concentrations the performance of granular systems is seriously affected as SS are not efficiently degraded, and thus are either washed out from the reactor (reducing effluent quality) or accumulated in the sludge bed. Furthermore, high FOG concentrations may result in granules covered with fat, leading to biomass flotation and eventually to biomass wash-out.

Flocculent biomass anaerobic systems are more suitable for this type of waste streams as no granulation process is involved. However, compared to granular systems, their efficiencies are much lower due to limitations in the solid/liquid separation (sludge retention). There is currently a wide range of flocculent sludge configurations to treat the waste streams high in SS and/or FOGs; with the most popular being: Anaerobic-Contact Reactor, Anaerobic Membrane Bioreactor and CSTR coupled to Dissolved Biogas Flotation (DBF) (Figure 1a, 1b, 1c).
**AnSBR**

In addition to these configurations, the Anaerobic Sequential Batch Reactor (AnSBR) is worth mentioning due to its simplicity and low footprint (Figure 1d). The AnSBR is a flocculent biomass anaerobic system operated in sequential phases (feed, reaction, settling and decanting) that take place predominantly (but not exclusively) in one vessel (Steele, 2013). The main advantages of AnSBR are: (1) high degree of process flexibility and no need for complex instrumentation and control (Ruiz et. al, 2002); (2) good flocculation promoted by feast/famine feeding regime; (3) development of good settling sludge due to natural selection pressure of sequential-settling mode (Oliveira et. al, 2010), allowing for; (4) efficient solids separation and thus leading to; (5) long SRT and efficient conversion of both easily and slowly degradable organic substrates (Steele et.al., 2010).

![Diagram](image)

*Figure 1: Flocculent biomass anaerobic systems: (a) Anaerobic contact; (b) AnMBR; (c) Contact+DBF; (d) AnSBR*

Despite these benefits and successful application in pilot-scales for treatment of high strength waste streams (leachate, slaughterhouse, municipal sludge and dairy (Xiangwen et al., 2007)), there are only a few full-scale references of AnSBR worldwide. The main limitations for its widespread application seems to be the misapplication, errors in design, uncertainty on sludge settleability control and the challenge behind the management of batch volumes (liquid and gas).

Biothane-Veolia has recaptured the interest on AnSBR aiming to optimise and directly apply this configuration (without pre-treatment) for the treatment of waste-streams with high concentration of SS and FOGs. This study summarises the results of three recent long-term AnSBRs pilot trials carried out on industrial waste streams with very high concentrations of SS and/or FOG to validate the performance and confirm the complete degradation of slow degradable substrates, avoiding their accumulation in the reactor and thus achieving high treatment efficiencies.
METHODOLOGY

Three AnSBR pilot-trials were carried out with effluents from different industries to evaluate the suitability of this system for the high-efficiency treatment of slow degradable substrates (high in SS and/or FOGs). The methodology of each trial is summarised in (Table 1).

Table 1: Methodology of AnSBR pilot-trials treating different types of wastewater

<table>
<thead>
<tr>
<th>Wastewater</th>
<th>Winery &amp; distillery</th>
<th>Dairy (Wash water + whey)</th>
<th>Ice-cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (Months)</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Scale</td>
<td>Bench-scale (20 L reactor)</td>
<td>Bench-scale (20 L reactor)</td>
<td>Industrial-scale reactor (800 L reactor)</td>
</tr>
<tr>
<td>Comments</td>
<td>Combined waste stream with serious seasonal variation (flux and composition), wide range of COD (30-50 g/L), very high TSS (up to 10 g/L) and potentially toxic levels of SO4 (up to 5 g/L) and K (up to 8 g/L)</td>
<td>Combined waste stream of dairy production wash water and whey (4.5:1.0 ratio).</td>
<td>Complex waste stream with extreme COD variations ranging from 10-27 g in less than 2 days and FOG up to 4 g/L</td>
</tr>
</tbody>
</table>

RESULTS

The results of this study are summarised in Table 1 and the main highlights are listed below:

- **Winery and distillery combined waste-stream** - The system achieved TCOD and SCOD removal efficiencies of up to 94% and 99%, respectively; at average VLRs of 4.2 gCOD/L (up to 6 gCOD/L) and very high concentrations of TSS in the influent (up to 8 g/L).

- **Dairy effluent** - At average VLRs of 7 gCOD/L (up to 8.7 gCOD/L), average TSS in the influent of 2.9 g/L (up to 5 g/L) and FOG between 0.5-0.7 g/L the system consistently achieved TCOD and SCOD removal efficiencies of 91% and 99%, respectively.

- **Ice-cream production effluent** – The system achieved TCOD and SCOD removal efficiencies of up to 93% and 99%, respectively; at relatively lower VLRs (compared to other two trials) of 2-3 gCOD/L day but under very challenging conditions treating an influent with average TSS of 3.5 g/L (up to 5.7 g/L), very FOG of up to 4 g/L and extreme variations in TCOD (10-20 g/L) with a very high particulate COD fraction (always > 60%).

Table 1: Main operational parameters and reactors performances of the trials performed using AnSBR for anaerobic treatment of different types of wastewater.

<table>
<thead>
<tr>
<th>Operational Parameters</th>
<th>Winery &amp; distillery</th>
<th>Dairy (Wash water + whey)</th>
<th>Ice-cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRT (days)</td>
<td>40±18</td>
<td>35±30</td>
<td>71±66</td>
</tr>
<tr>
<td>VLR (g COD/L day)</td>
<td>4.2±2</td>
<td>7.1±1.6</td>
<td>2.6±0.7</td>
</tr>
<tr>
<td>Mixed Liquor SS (g/L)</td>
<td>15.97±4.1</td>
<td>10.6±3.5</td>
<td>10.5±1.4</td>
</tr>
<tr>
<td>VSS/TSS (%)</td>
<td>76±7</td>
<td>81±7</td>
<td></td>
</tr>
<tr>
<td>Reactor performance</td>
<td>Influent (g/L)</td>
<td>Effluent (g/L)</td>
<td>Efficiency (%)</td>
</tr>
<tr>
<td>TCOD (g/L)</td>
<td>39.3±7.4</td>
<td>2.6±1.4</td>
<td>94±3</td>
</tr>
<tr>
<td>SCOD (g/L)</td>
<td>32.5±2.5</td>
<td>1.2±0.4</td>
<td>96±1</td>
</tr>
<tr>
<td>TSS (g/L)</td>
<td>5.6±2.4</td>
<td>0.9±0.9</td>
<td>92±9</td>
</tr>
<tr>
<td>VSS (g/L)</td>
<td>5.0±2.0</td>
<td>0.7±0.7</td>
<td>93±9</td>
</tr>
<tr>
<td>FOG (g/L)</td>
<td>0.6±0.1</td>
<td></td>
<td>3.3±0.8</td>
</tr>
</tbody>
</table>
CONCLUSIONS
This study shows the high COD removal efficiencies achieved in three AnSBR pilot-trials treating slow degradable industrial waste streams with very high concentrations of SS (up to 8 g/L), FOG (up to 4 g/L), a wide range of TCOD (10 – 45 g/L). All trials were carried out at high VLRs (with respect to each particular situation); achieving TCOD and SCOD removal efficiencies always above 90% and 99%, respectively. The results confirm the suitability of this configuration for this type of waste-streams as it enables complete degradation of slow degradable substrates, avoiding their accumulation in the reactor and thus achieving high efficiencies.

REFERENCES

• Steele, M (2013). Anaerobic sequencing batch reactor treatment of low strength swine manure and co-digestion of energy dense by-products.