High rate anaerobic treatment of fruit juice & processing effluents: a reliable and sustainable solution

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INTRODUCTION

Production of fruit juices and drinks, fruit concentrates, peel pressing products, fruit meat fibres recovery all have impact on our environment. Produced effluents originating from fruit processing industries, and to some part in the soft drinks industry too, are characterised by high concentrations of soluble and insoluble (suspended) organic material (COD, BOD), nutrients, lubricants and, typically citrus fruit related, toxins (etheric oils). All these compounds are capable to destroy the ecological equilibrium in our lakes and rivers. The discharge of untreated wastewater has been mostly restricted throughout the world by legislation. As a result, the industry is faced with soaring costs for discharge of its wastewater, which has been the main driving force for the industry to seek solutions for reducing those costs.

Effluent from fruit processing industries varies from factory to factory and is dependent on various parameters such as the type of production, kind of end products and type and quality of the fruit used as ground products. In general, huge variations in daily/weekly/seasonally effluent discharge load and concentration in BOD/COD are typically for all. Especially this makes anaerobic treatment as the preferred and most optimal solution for this typical environmental problem.

This abstract describes the process logic of the most sustainable solutions to meet discharge effluent quality objectives available and provides an evaluation of the performance of various fruit processing applications using Biothane’s anaerobic process technologies.

Biothane® UASB and Biobed® EGSB processes applied in the fruit juice processing industry

As starting point for the process design the fruit processing effluents are basically limited to:

1. Wash water; low-polluted wastewater from fruit washing/preparation.
2. Process water; high-polluted wastewater streams from fruit processing, milling, concentrate preparation, canning and/or bottling.
3. Residual solids; extreme high-polluted effluents (soluble and insoluble, suspended matter) from i.e. peel pressing, product recovery or fruit meat/fibre recovery or removal.

Full separation of different kinds of effluents is preferred; the low polluted effluent (COD/BOD <100 – 200 mg/l) should be treated in post-treatment (aerobic) stage only. The high polluted process waters with COD concentrations of 1,000 up to 20,000 mg/l are ideal substrate to be treated in an anaerobic biological treatment process.

The Upflow Anaerobic Sludge Bed (UASB) and Expanded Granular Sludge Bed (EGSB) processes typically consist of the following steps:
1. **Pre treatment**

   The available volatile Total Suspended Solids (TSS/VSS) in the process wastewater are, because of the relative short retention time, hardly degraded in a high rate anaerobic process. For TSS content up to a maximal of 5-6 % of the total COD content of the wastewater no additional removal step is required. In case of a higher content of TSS in the process water screening or other TSS removal is important to prevent an excess TSS accumulation in anaerobic process. Accumulation of TSS will finally result in a decrease of COD/BOD removal capacity in the anaerobic process.

   In case citrus peel pressing or etheric oil recovery takes place on the production site it is absolutely required to detoxify the effluent of such process before treating the water anaerobically. Etheric oil (therpane or D-limonene) acts as biocide and is extremely toxic for the anaerobic bacteria. Concentrations of 70 ppm etheric oil show inhibiting effects on the methanogenic activity of the anaerobic bacteria. The oil absorbs at the granular biomass causing acute toxification and degranulation. Toxification of methanogenic bacteria by etheric oil is a serious and almost irreversible process. After a period of three years acclimatization the impact was still available and etheric oil was not degraded.

2. **Buffering facilities**

   In order to equalise the flow and level out the wastewater concentration a Buffer Tank is normally installed. The applied HRT varies between 8-24 hours. Besides the equalisation, hydrolisation and acidification reactions will take place.

3. **Conditioning facilities**

   Before the wastewater is treated in the anaerobic reactor, the temperature (optimal 35 °C) and the pH will be adjusted in order to achieve optimal conditions for the anaerobic bacteria. Pending on the wastewater characteristics it can be necessary to dose macro –and micronutrients.

4. **Biothane® UASB and Biobed® EGSB reactor**

   The conditioned wastewater is fed into the anaerobic reactor at the bottom through a sophisticated designed influent distribution system. The water flows through a sludge bed consisting of anaerobic bacteria, which develop into a granular form. The excellent settle ability (60-80 m/h) of these anaerobic granules in combination with the specially designed and patented separator section (settler) at the top of the anaerobic reactor enables high concentrations of biomass in a small reactor volume. As a result of this optimal sludge-retaining device in both processes, Biothane® UASB as well the Biobed® EGSB process, the biomass concentration in the sludge bed will be over 50 kg VSS/m³. In the sludge bed, the conversion of COD into biogas takes place.

   The cross section of both the Biothane® UASB as well as the Biobed® EGSB is shown in Figure 1.
5. Biogas, biomass and ventgas handlings
The generated biogas (75 – 85% methane) can be utilised in the production plants boiler house or in a CHP generator.

6. Aerobic treatment
Depending on the local regulations it could be required to upgrade the discharge effluent quality. Simple Flash Aeration (HRT <0.5 h) can be used to eliminate odour compounds as sulphide.

Process Performance
Typical total COD efficiencies reachable in anaerobic treatment of fruit processing related wastewater are approximately 70 - 90% depending of the influent characteristics. Figure 2 shows the COD removal efficiency in relation to the TCOD concentration. Reachable TBOD₅ efficiencies however are ranged between 85 – 95%. Every kg COD converted is generating 0.4-0.5 Nm³ of biogas.

As shown in Table 1 applied loading rates vary from 6-15 kgCOD/m³.day and 9 – 29 kgCOD/m³.day for respectively the Biothane® UASB and the Biobed® EGSB process. In both processes TSS degradation hardly takes place.
Table 1: Operational performances of Biothane Systems’ processes in fruit juice/processing industries

<table>
<thead>
<tr>
<th></th>
<th>Reference 1</th>
<th>Reference 2</th>
<th>Reference 3</th>
<th>Reference 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of process</strong></td>
<td>Biothane®</td>
<td>Biothane®</td>
<td>Biobed® MP</td>
<td>Biobed® MP</td>
</tr>
<tr>
<td><strong>COD load (kg/m³ per day)</strong></td>
<td>6 – 8</td>
<td>11 - 15</td>
<td>9 – 19</td>
<td>13 – 29</td>
</tr>
<tr>
<td><strong>Process temperature (°C)</strong></td>
<td>35</td>
<td>37</td>
<td>33</td>
<td>26</td>
</tr>
<tr>
<td><strong>Influent total COD (mg/l)</strong></td>
<td>9,100</td>
<td>7,500</td>
<td>3,090</td>
<td>6,767</td>
</tr>
<tr>
<td><strong>Influent BOD₅ (mg/l)</strong></td>
<td>5,300</td>
<td>5,260</td>
<td>n.a.</td>
<td>4,000</td>
</tr>
<tr>
<td><strong>Influent TSS (mg/l)</strong></td>
<td>625</td>
<td>750</td>
<td>&lt;200</td>
<td>&lt;400</td>
</tr>
<tr>
<td><strong>Effluent total COD</strong></td>
<td>1,780</td>
<td>1,600</td>
<td>480</td>
<td>1,439</td>
</tr>
<tr>
<td><strong>Effluent BOD₅ (mg/l)</strong></td>
<td>510</td>
<td>530</td>
<td>95</td>
<td>390</td>
</tr>
<tr>
<td><strong>Effluent TSS (mg/l)</strong></td>
<td>700</td>
<td>630</td>
<td>&lt;200</td>
<td>&lt;800</td>
</tr>
<tr>
<td><strong>COD efficiency (%)</strong></td>
<td>80</td>
<td>79</td>
<td>85*</td>
<td>79</td>
</tr>
<tr>
<td><strong>BOD₅ efficiency (%)</strong></td>
<td>90</td>
<td>89</td>
<td>- -</td>
<td>90</td>
</tr>
<tr>
<td><strong>Biogas CH₄ content (%)</strong></td>
<td>75</td>
<td>70-80</td>
<td>74</td>
<td>68</td>
</tr>
</tbody>
</table>

*: including Aerothane Flash Aeration

The surplus sludge/anaerobic biomass production is limited to 2 – 4% of the amount of COD reduced. Under normal operational conditions in respect to water- and gas velocities, the insoluble material is flushed through the anaerobic process and will reduce the TCOD efficiency.

Anaerobic biomass stored, under ambient conditions in the reactor itself or in surplus storage tank, does not lose its specific methanogenic activity. Especially for seasonal fruit processing production facilities this is an important advantage. Within several days after the beginning of the fruit processing season the anaerobic wastewater treatment plant is fully operational.

The treated effluent leaves the anaerobic process via a conditioning, recycle mixing tank. The conditioning tank is equipped with an effluent splitting device. This way the anaerobic effluent is recycled back to the digester or discharged to an aerobic polishing step or directly into the sewer.

**CONCLUSIONS**

Biological anaerobic treatment of fruit juice and/or processing effluents is a proven and reliable process. Based on total COD purification efficiencies between 70 – 90% can be achieved. With the Biothane® UASB/Biobed® EGSB anaerobic pre-treatment process in combination with an Aerothane Flash-Aeration purification efficiencies of over 95% based on BOD₅ can be obtained.