COMBINING F&B WASTEWATER AND WASTE TO MAXIMISE BIOGAS PRODUCTION

Water Convention 2016 – Best Poster Winner (4th Runner Up)
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Food and beverage production plants, such as palm oil mills and dairy factories produce organic wastes and also wastewater with high levels of Chemical Oxygen Demand (COD), total suspended solids (TSS) and Fats, Oils and Greases (FOG) that can be challenging to treat and typically require high rate reactors. In 2016, Nijhuis Water Technology won Fourth Runner Up in the Best Poster Award for their paper on the Aecomix™ system, an anaerobic process based on solids retention, that could bridge the gap between digesters and high rate reactors. Conducted at a chocolate factory, results showed that the system was an economically feasible option to treat waste and wastewater in a single process, produced maximum biogas, and effluent that was almost free from solids.

Compared to the traditional set-up for treating high COD effluent from a chocolate/candy factory, the AECOMIX system was found to incur less than 50% annual operating costs due to the more efficient system design, which eliminates the requirement for chemical pre-treatment, in addition to the generation of biogas which can be burnt to offset the energy demand.

Following their presentation at the Water Convention, there was increased brand awareness of the AECOMIX system, and Nijhuis received several business leads, which has resulted in a project in a confectionary plant in Russia which is expected to produce approximately 1400 Nm³ biogas per day, and another at a refinery plant in Poland.

For the coming years, Nijhuis Water Technology BV sees a strong focus on resource recovery from waste and wastewater and have already launched several related innovations. They also think that water reuse and brine treatment is gaining strategic importance, especially in water scarce areas or countries where the price for water and energy is increasing rapidly.

Another upcoming trend is the internet of things and sensor technology, which they believe “are going to help us tremendously to predict the behaviour of the plant if the characteristics of the water are changing”.

Nijhuis’ participation at the Water Convention 2016 has also led to their project being selected for publication in IWA’s Water Practice and Technology journal – the full paper is now available in the June 2018 issue at wpt.iwaponline.com/content/13/2/257.

The abstract and poster submitted by Nijhuis Water Technology for the Water Convention 2016 have been included in this article for your reference.
THE AECOMIX™ SYSTEM: CONVERTING WASTE AND WASTEWATER IN ONE REACTOR TOWARDS CLEAN WATER AND BIOGAS

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SUMMARY
The Aecomix™ system, an anaerobic process based on solids retention, is bridging the gap between digesters and high rate reactors to be used for organic waste and wastewater, high in TSS or FOG, like Palm mill, diesel oil and food and beverage effluents and wastes. It provides a single step treatment without a need for chemical pre-treatment, in a rather short HRT, but a long SRT with a high efficiency and an effluent almost free from solids. Typically in the Aecomix™, the MLSS is relatively low compared to slurry digesters, which makes a dissolved biogas flotation (DBF) an ideal option for solids-liquid separation. A full scale Aecomix™ plant treated the effluent of a chocolate/candy factory with a COD concentration varying between 3,600 - 67,000 mg/l at an average of 37,000 mg/l. The removal for COD and TSS was more than 95% on average. Compared to a traditional set-up with full chemical treatment as pre-treatment before an EGSB type reactor, the Aecomix™, is up to 50% lower in annual costs.

KEYWORDS
Aecomix, Biodiesel, Biogas, COD reduction, Dissolved Biogas Flotation, Organic waste, POME

INTRODUCTION
Wastewater with high levels COD, TSS and FOG can be found in different type of food industries, such as ice cream, chocolate, candy, vegetable, dairy and cheese factories. Also Palm Oil Mill Effluent (POME) falls in this category. Anaerobic digesters are commonly used to convert highly concentrated waste, typically between 3-15% dry solids content. In the digester the SRT and HRT are equal because there is no solids-liquid separation and return of solids. The retention time is typically between 15-40 days. This long retention time is required to allow the liquefaction and breakdown of solids and fats and also to control the organic load of the reactor. In some instances the digesters have a settler to collect solids and return these to the reactor, to extend the SRT and increase the concentration of active bacteria. However in most instances the performance of such a settler is rather poor, with efficiencies < 50% so that the extension of SRT is quite limited.

UASB type reactors have an excellent solids retention in the form of granules, these reactors are typically used on effluents with high dissolved organic matter and very low total suspended solids (TSS) and Fats, Oils and Greases (FOG). In many occasions there are problems with maintaining granular sludge, due to the presence of solids, oils and greases or other inhibiting factors. These reactors are characterized by a rather short HRT, but a long SRT. Concentrated wastewater with high TSS or FOG and/or organic wastes with ds% of less than 2% cannot be treated in UASB type reactors and when digesters are used, these are very low loaded due to the SRT requirements.

The Aecomix™ process is the solution to treat both waste effluent and waste solids in a single process, with a high efficiency and a rather compact design. Key to the Aecomix™ process and success is a solids-liquid separation process under anaerobic conditions to return the biomass to the reactor. In this manner the Solids Retention Time (SRT) can be extended largely over the Hydraulic retention time. The solids-liquid separation is a Dissolved Biogas Flotation system.

MATERIALS
The Aecomix™ process may consist of a substrate preparation and feed system followed by a single reactor or more reactors in sequence and or parallel. At least one reactor may be fitted with a double membrane roof to act as a gas storage. In the reactor organic substances will be converted to biogas. The wastewater, waste and bacteria are mixed by mixing devices and is mixing is enhanced by the gas bubbles produced in the process.

The Dissolved Biogas Flotation (DBF) device is the essential part in the process. It meets all the requirements for optimum treatment of the bio solids (gentle treatment, no contact with air). In a recycle flow biogas is dissolved under elevated pressure. This “white” water is fed to the digestate and fine gas bubbles are released due to the release of pressure. These gas bubbles assist the particles in floating to the top, where they are skimmed off. There is no contact with air, so when these solids are recycled the active bacteria concentration in the Aecomix reactor is increased. The clarified liquid from the DBF is discharged or fed to a polishing step. In case aerobic treatment is used as polishing, the excess sludge of this treatment is returned to the Aecomix™ reactor. Figure 1 shows a schematic overview of the Aecomix™ process.
RESULTS

A full scale plant Aecomix™ was installed at a chocolate/candy factory. The process comprises the following main components:

- Equalisation tank.
- 2 Aecomix™ reactors of 750 m³ each in series with mechanical mixing.
- Pipe reactor with flocculant dosing.
- Dissolved Biogas Flotation.
- Post treatment.

The wastewater volume was 100 m³/d, with large variations in the inflow COD concentration varying between 3,600 - 67,000 mg/l at an average of 37,000 mg/l (Figure 3). Based on an effective liquid volume of 1,300 m³, the organic loading was 1.8 kg COD/m³/d on average, with a peak load of approximately 4 kg COD/m³/d. The flotation device was operated at 5 m³/h.

Figure 4 shows that the COD at the outlet of the Aecomix™ / DGF is generally below 1000 mg/l and varies a bit as a
consequence of the high variations in the influent concentrations. Figure 2 is shows that the effluent discharged from the Dissolved Biogas Flotation (DBF) device, is achieving high removal percentages for COD, generally well in excess of 95%. Also TSS removal in the DBF is averagely more than 95%.

CONCLUSION
The Aecomix™ system, an anaerobic process based on solids retention, is bridging the gap between digesters and high rate reactors to be used for organic waste and wastewater, high in TSS or FOG, like POME, diesel oil and food and beverage effluents and wastes. It provides a single step treatment without a need for chemical pre-treatment, in a rather short HRT, but a long SRT with a high efficiency and an effluent almost free from solids. It is proven to be a robust process with advantages such as integrated gas storage.

Typically in the Aecomix™, the MLSS is relatively low compared to slurry digesters, which makes the DBF an ideal option. Biogas can be used directly as a flotation gas source in the DBF device. The DBF proofs to be an economical method of solids-liquid separation. A full scale Aecomix™ reactor treated the effluent of a chocolate/candy factory with a COD concentration varying between 3,600 - 67,000 mg/l at an average of 37,000 mg/l. The removal for COD and TSS was more than 95% on average. Compared to a traditional set-up with full chemical treatment as pre-treatment before an EGSB type reactor, the Aecomix™, is up to 50% lower in annual costs. This proves that it is an economic feasible option for food and beverage plants to treat wastewater and waste together and produce maximum biogas. For POME with or without biodiesel effluent the Aecomix can be used as a new plant or used to integrate it with existing facilities to enlarge the capacity and reduce chemical consumption.

FULL PAPER AND PRESENTATION
In the full paper and presentation an overview will be given of the Aecomix™ process, the process conditions, design criteria and the OPEX and CAPEX of the Aecomix™ treating combined organic waste water and waste streams from different food industries.

REFERENCES
THE AECOMIX™ SYSTEM:
Converting waste and wastewater in one reactor towards clean water and biogas

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Introduction
In the food and beverage industry there is a need for sustainable solutions to convert their waste and wastewater into energy. An UASB reactor is a partial solution for factories with effluents with high Chemical Oxygen Demand (COD) and low TSS and FOG. It also recovers energy through biogas production, but it is not suitable for the treatment of wastes like distillery and brewery wastes.

This solution requires the addition of chemicals as well as additional process steps to achieve sustainability. The alternative is to combine the fat rich wastewater with factory wastes in a single process, without a pre-treatment with chemicals. This could be done in standard digester type reactors. The disadvantage is that a long retention time of 12-30 days will be required.

In case of high volumes of comparatively low polluted effluents this would require very high reactor volumes and will result in low organic loading. The AECOMIX™ process is based on this idea of sludge retention and is designed to combine treatment of wastewater and organic waste into one reactor and maximise the biogas production.

Methodology
Wastewater is either screened in the channel, to remove large debris or a chopper pump is used to reduce the solids size in the influent. Wastewater is fed over 24 hrs to the AECOMIX™ reactor. Organic wastes are proportionally fed to the AECOMIX™ to maintain a consistent loading. The AECOMIX™ process may consist of a single reactor or more reactors in sequence and or parallel. Typically at least one reactor will be fitted with a double membrane roof to act as a gas storage.

The wastewater, waste and bacteria are mixed by mixing devices and is mixing is enhanced by the gas bubbles produced in the process. The temperature in the reactor can be controlled by steel tubes alongside the inner wall. Hot water from a boiler or Combined Heat and Power (CHP) engine or cold water will flow through these tubes to control the temperature. The retention time may vary between 1-14 days. The COD loading will depend on the substrates and will typically be between 3-7 kg/m³/day. The mixed liquor is discharged to a Dissolved Gas Flotation device. The solids separated in the DGF are returned to the reactor and some excess sludge may be disposed of. The clarified liquid is discharged directly or delivered to a polishing step.

Results & Discussion
A case study is made based on an operating plant at a chocolate factory where waste water and organic waste is treated together. The plant treats 100 m³/day.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Untreated</th>
<th>AECOMIX™</th>
<th>After DGF</th>
<th>Final effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD (mg/l)</td>
<td>20,000 - 60,000 (37,000 average)</td>
<td>16,000 - 18,000</td>
<td>600 average</td>
<td>90</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>2,000 - 12,000 (6,000 average)</td>
<td>6.8 - 7.2</td>
<td>6.8 - 7.2</td>
<td>17</td>
</tr>
<tr>
<td>pH</td>
<td>3.8 - 6.0</td>
<td>37</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The total volume of the 2 reactors is 1400 m³. The plant is operating at 3-5 kg COD/m³/d. The COD reduction is 97-99 % and the methane content of the biogas is 60-65%. This plant is compared to a traditional plant comprising coagulation-flocculation-flotation–EGSB–biotreater-decanter. The decanter is for sludge dewatering. In this process part of the organic waste is discharged after the chemical treatment and decanter, due to which less than 50% gas is produced compared to the AECOMIX™. The following table provides a summary of the case study.

<table>
<thead>
<tr>
<th>Costs</th>
<th>Units</th>
<th>AECOMIX™</th>
<th>Final effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX (turn-key)</td>
<td>EUR 1,800,000</td>
<td>EUR 1,700,000</td>
<td></td>
</tr>
<tr>
<td>Gas revenues</td>
<td>EUR -250,000</td>
<td>EUR -100,000</td>
<td></td>
</tr>
<tr>
<td>OPEX</td>
<td>EUR 126,500</td>
<td>EUR 164,000</td>
<td></td>
</tr>
<tr>
<td>Total costs of ownership per year</td>
<td>EUR 105,500</td>
<td>EUR 283,000</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion
The AECOMIX™ system, an anaerobic process based on solids retention, is an economic alternative for food and beverage plants which have organic wastes and/or waste waters with high TSS and/or FOG. It provides a single step process solution for different substrates, with a high removal efficiency (on organic matter). It is proven to be a robust process. In the case study it shows that the annual costs are reduced with more than 60% compared to a traditional process.