Intensification of Single Stage Continuously Stirred Tank Anaerobic Digestion Process using Carriers

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I hereby declare that this thesis is my own account of my research and contains as its main content work which has not been previously submitted for a degree at any tertiary education institution. Any contribution made to the research by others is explicitly acknowledged in the thesis.

Herawati Budiastuti

The following paper has been published from this research:

Abstract

The Continuously fed Stirred Tank Reactor (CSTR) is a popular design for anaerobic treatment of wastewater. This reactor type is simple in design and operation, independent of biomass type and low in capital costs. The CSTR has, however, to be operated at long Hydraulic Retention Times (HRT) of the order of 16 to 30 days since biomass is continuously lost with the effluent. Various alternate concepts of reactor design have, therefore, been developed to allow more rapid treatment. Treatment can be enhanced by retaining biomass within the digester so that the HRT is decoupled from solid biomass retention time (SRT). Unlike in continuous stirred tank digesters where the SRT is equal to HRT, the SRT in other designs are much greater than the HRT. This allows the wastewater to be treated at high throughputs while retaining the biocatalyst (or biomass) mediating the treatment within the digester.

In this study the operation of a CSTR was intensified by separating SRT from HRT while taking into account the economical aspects. The intensification of operation is defined as increasing wastewater throughput or organic loading rate while at the same time maintaining efficiency of treatment and robustness to reject disturbances (changes in wastewater concentration and flow rate). The operation of existing CSTR was intensified by addition of carriers. It is hypothesized that by providing surfaces (or carriers) for bacterial attachment within the continuous stirred tank digester, biomass will be better retained and the wastewater throughput can be increased. The carriers or surfaces employed in this study were light carrier elements (shredded granular rubber tire having a density of 0.96 g/cm³) that move gently with the water in the reactor. This carrier material is much cheaper compared with other commercial
carrier materials. This reactor type, called an Anaerobic Moving Bed Reactor (AMBR), was applied in this study to treat high strength synthetic wastewater, containing molasses as the main substrate.

The improvement of reactor performance was clearly shown by the capability of the system to be operated without any difficulties at HRT of 6 days at an OLR of 5.8 g COD/l/d or at HRT of 1 day at an OLR of 4 g COD/l/d. The carriers were shown to be effective in retaining biomass aggregates.

The AMBR was further intensified by changing the feeding strategy. It was shown that in stirred tank digester without carriers an intermittent feeding strategy resulted in better microbial capacity to degrade higher chain volatile fatty acids like propionic and butyric acids than the continuous feeding mode. An increase in degrading capacity of the intermittently fed digester was shown via degradation rates of pulse additions of propionic and butyric acids and by its capability of handling all changes in loading rates imposed. The continuously fed digester, receiving constant feed, on the other hand, suffered more when loading rates were changed, and the degradation rates of propionic and butyric acids were slower.

The intermittent feeding mode was then implemented on the AMBR, and it was operated as a sequencing batch reactor with a fill, react, settle and decant period in each cycle. The sequencing batch mode when applied to the AMBR (now called an Anaerobic Moving Bed Sequencing Batch Reactor or AMBSBR) could increase capability of the digester to handle higher shock loads. At 3.8 d HRT the AMBSBR could handle an OLR of 10.8 g COD/l/d as opposed to 7.4 g COD/l/d by the AMBR. At 2.5 d HRT the AMBSBR could handle an OLR of 6.4 g COD/l/d while the AMBR
could only be loaded at an OLR of 4.2 g COD/l/d. The ratio of SRT to HRT was at least 15 for this reactor. The reactor was able to handle concentrated feed flow rates at longer cycles or more dilute feed flow rates at frequent shorter cycles.

The proposed operational strategies were verified by using a structured mathematical model which was developed based on the IWA ADM1 model. Several modifications were implemented to the model to obtain better predictions. The modified model was capable in predicting all the trends of the operating variables from both continuously and intermittently fed reactors. None of the two model versions (ADM1 and modified models) was, however, able to predict the increased propionate degradation capacity in intermittently fed digesters. The reason for this was the assumption of fixed stoichiometry of fermentative reactions for glucose mineralisation. By modifying the fractions of glucose mineralisation a better fit between experimental results and the model could be obtained.
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<td>Anaerobic Moving Bed Reactor</td>
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<td>AMBSBR:</td>
<td>Anaerobic Moving Bed Sequencing Batch Reactor</td>
</tr>
<tr>
<td>ADM1:</td>
<td>Anaerobic Digestion Model No. 1</td>
</tr>
<tr>
<td>COD:</td>
<td>Chemical Oxygen Demand</td>
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<tr>
<td>CSTR:</td>
<td>Continuously fed Stirred Tank Reactor</td>
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<tr>
<td>HRT:</td>
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