Municipal Wastewater after Anaerobic Treatment and Membrane Filtration: Possibilities for Irrigation and Fertilization

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1 Introduction

A process for the treatment of municipal wastewater has been developed and demonstrated in a development area in Knittlingen (southern Germany) with 100 plots. The wastewater is treated in an anaerobic membrane bioreactor process at ambient temperatures, using a rotating disk filter with ceramic membranes for microfiltration. The COD of the wastewater is reduced by about 85% and transformed into biogas, while the nutrients are still in the filtrate. This solid-free water could be ideal for the reuse in agriculture, contributing to increase food-security in water scarce countries.

2 Objectives

Pathogenic microorganisms in wastewater are usually bacteria, viruses, and parasites like protozoa and helminths. As long as the membrane is not damaged, it can be assumed that parasites are completely held back by microfiltration. While the size of bacteria is in the range of the pore size of the microfiltration membrane, viruses can be much smaller (0.025-0.35 μm). To assess the microbiological quality of the filtrate of the rotating disk filter, bacteria as well as bacteriophages as indicator for viruses have been analysed. Furthermore, the suitability of the filtrate for agricultural irrigation and fertilization was investigated.

3 Results and discussion

Retention of bacteria

Samples for the analysis of bacteria in the effluent of the demonstration plant in Knittlingen were taken on three different days. A sample was taken behind the membrane at each of the four filter modules (filter 1-4), in the collection tank, and on the concentrate side of the filter (sludge). For the analysis, a volume of 0.1 ml of the sample is dispersed on an agar plate. The mean values of the total microbial count, the total coliforms, and E. coli are shown in the following table.

<table>
<thead>
<tr>
<th>CFU/ml</th>
<th>Total microbial count (30 °C)</th>
<th>Total coliforms</th>
<th>E. Coli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter 1</td>
<td>151</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Filter 2</td>
<td>84</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Filter 3</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Filter 4</td>
<td>174</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Collection tank</td>
<td>25,300</td>
<td>4040</td>
<td>0</td>
</tr>
<tr>
<td>Sludge</td>
<td>2.0 × 10^7</td>
<td>1.5 × 10^7</td>
<td>2.9 × 10^6</td>
</tr>
</tbody>
</table>

Retention of viruses

To assess the retention of viruses by the membranes, the bacteriophage X174 has been used as indicator. A rotating disk filter with ceramic membranes with pore sizes of 0.2 μm and 0.06 μm is operated in dead-end-mode. After some hours of continuous filtration, a reduction of up to two logs could be observed with the 0.2 μm-membrane without a difference between water and sludge as concentrate. The membrane with a pore size of 0.06 μm held back the phages more effectively and reached a removal of three to four logs after some hours of filtration (figure below).

The results of the experiments indicate that during the first 24 hours after chemical cleaning of the membranes, a secondary layer is formed which reduces the cut-off of the membrane and improves thereby the removal of bacteriophages. As the bacteriophage φX174 is relatively small compared to most viruses and viruses tend to adsorb on particles, the measured retention rates for bacteriophages are the absolute minimum of the removal that can be expected for viruses.

Irrigation and fertilization

The filtrate of the anaerobic reactor contains the nutrients nitrogen and phosphorous in relatively high concentrations: about 140 mg N/l (mainly as ammonium) and about 20 mg P/l as phosphate. If the water is used for irrigation and fertilization, the medium nitrogen demand of plants is covered while about 25–70 % of the water demand and 20–80 % of the phosphorous demand is met.

4 Conclusion

For the first time, an anaerobic membrane bioreactor process has been successfully demonstrated in technical scale with municipal wastewater at ambient temperatures. It could be shown that the membrane holds back most pathogenic bacteria and, due to a secondary layer, many viruses. For higher efficiency in the removal of viruses, a membrane with smaller pore size is recommended. The next step will be an implementation of the technology with water reuse in agriculture. Currently, Fraunhofer IGB is looking for adequate demonstration sites as well as interested local partners in different regions of the world.

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