Methane production from distillery wastes in anaerobic charcoal filters

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Introduction

There are about 15 distilleries in Tamil Nadu spread over the entire State. The industrial process adopted by the distilleries is almost same viz., fermenting the diluted molasses with yeast and distilling the alcohol produced by passing a counter current of steam while allowing the fermented wash to come down a tall column. Only about 10 percent molasses is utilised in the process and the major remaining part comes out as effluent in the process. The liquid wastes from the process mainly consist of spent wash besides yeast waste sludge and floor washings. Yeast waste sludge is separated out and dried on the nearby land and used as animal feed. Anaerobic lagoons or digestors are being suggested and tried out for treating distillery waste. In the anaerobic digestion, removal of organic matter results in generation and release of methane gas. One gram of Methane gas released equals 4 gms of biochemical oxygen demand satisfied. Recovery of methane gas also results in fuel recovery which can be used.

Previous Work Done at Kodungaiyur

Earlier studies conducted in this unit indicated that an admixture of carbon particles with spent wash resulted in copious methane gas production due to anaerobic activity. Hence it was planned to use charcoal pieces instead of broken stone in a specially fabricated anaerobic filter for treatment of distillery spent wash. Consequently studies were undertaken to explore the feasibility of anaerobic charcoal filter to treat distillery spent wash for methane recovery. This paper discusses methane recovery in the anaerobic charcoal filters on continuous loading resulting from these studies.

Materials and Methods

The spent wash used for the purpose of the study was obtained from a distillery unit at Chingleput and the characteristics of spent wash are given in Table I. Earlier studies at Kodungaiyur had shown that anaerobic ponds operating in series gave good performance in respect of removal of organic content though smell problems were noticed when the primary lagoon went sour. In the present studies two anaerobic charcoal filters were installed and the performance studied. Details of the filters are shown in Fig.1 and Fig.2.

Anaerobic Charcoal Filter I

This was essentially a downward flow reactor. This was 0.2 m dia cylindrical tank and of 1.52 m depth filled with charcoal pieces of size varying from 25 mm – 35 mm to a depth 0.90 m. The remaining portion was arranged such that influent could be admitted and effluent drawn out.

![Figure 1: Down Flow Charcoal Anaerobic Filter]
Table I: Characteristics of Typical Spentwash from a Distillery

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colour</td>
<td>Dark Brown</td>
</tr>
<tr>
<td>2. Odour</td>
<td>Molasses</td>
</tr>
<tr>
<td>3. pH</td>
<td>3.5 - 4.0</td>
</tr>
<tr>
<td>4. Total Solids</td>
<td>59000 mg/litre</td>
</tr>
<tr>
<td>5. Volatile Solids</td>
<td>33000 mg/litre</td>
</tr>
<tr>
<td>6. Total C.O.D</td>
<td>84000 mg/litre</td>
</tr>
<tr>
<td>(Dichromate Value)</td>
<td></td>
</tr>
<tr>
<td>7. Volatile Acids</td>
<td>1000 mg/litre</td>
</tr>
<tr>
<td>as acetic acid</td>
<td></td>
</tr>
</tbody>
</table>

Anaerobic Charcoal Filter II

This was an upward flow reactor of 0.11 m dia cylindrical tank and of 1.2 m depth filled with charcoal of same size used in the downward flow reactor to a depth of 0.6 m from bottom. The inlet and outlet for the spent wash was similar to the first filter.

Initially both the filters were seeded with digested sludge from anaerobic pond treating sewage. Performance of the filters was observed for nearly one year and the results are shown in Table II. To commence with, in the downward flow reactor 1 litre of spent wash per day was introduced. The filters established themselves very quickly and it was found that they were giving effluent having a pH of 8.0 or more. Gas evolution was also fairly good. Since pH 7 is found to be optimum for production of gas, loading of spent wash was gradually increased. It was found that the pH was 7.5 when the loading was 2.5 - 3.5 litres per day for the downward flow reactor and 0.3 to 0.4 litres for upward flow reactor. At a loading 2.0 - 3.5 litres per day for downward flow and 0.25 to 0.4 litres per day of spent wash to upward flow reactor respectively, it was possible to maintain pH in the region 7.0-7.5. So this loading was taken as the normal and the experiment continued on that basis. It was found that the methane gas evolved readily from both reactors and had a tendency to build to a peak and then to reduce. In the upward flow reactor a steady increase of gas production as shown in graph was observed. The gas production in terms of volatile
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Date</th>
<th>Volatile solids loaded in mg/l</th>
<th>Quantity destroyed in litres</th>
<th>Total Gas collected in m3</th>
<th>Gas destroyed in litres</th>
<th>V.S GAS loaded in gms</th>
<th>Gas destroyed in gms</th>
<th>D.F.</th>
<th>U.F.</th>
<th>Gas generated per kg of volatile solids destroyed in m3</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>28.8.78</td>
<td>21000</td>
<td>1.75</td>
<td>36.75</td>
<td>25.00</td>
<td>14950</td>
<td>0.2</td>
<td>2.99</td>
<td>6.0</td>
<td>8.0</td>
<td>0.680</td>
</tr>
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<td>2.</td>
<td>14.9.78</td>
<td>16500</td>
<td>2.00</td>
<td>33.00</td>
<td>30.00</td>
<td>16700</td>
<td>0.2</td>
<td>3.34</td>
<td>5.0</td>
<td>8.0</td>
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</tr>
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<td>24.60</td>
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<td>16500</td>
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<td>5.5</td>
<td>7.5</td>
<td>1.425</td>
</tr>
<tr>
<td>4.</td>
<td>18.10.78</td>
<td>12250</td>
<td>2.00</td>
<td>24.50</td>
<td>36.00</td>
<td>11750</td>
<td>0.2</td>
<td>2.35</td>
<td>5.5</td>
<td>7.5</td>
<td>1.460</td>
</tr>
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<td>5.</td>
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<td>6250</td>
<td>2.00</td>
<td>12.50</td>
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<td>8750</td>
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<td>5.7</td>
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<td>2.800</td>
</tr>
<tr>
<td>6.</td>
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<td>12500</td>
<td>2.25</td>
<td>28.13</td>
<td>35.00</td>
<td>14750</td>
<td>0.25</td>
<td>3.69</td>
<td>5.7</td>
<td>7.5</td>
<td>1.244</td>
</tr>
<tr>
<td>7.</td>
<td>5.12.78</td>
<td>12500</td>
<td>2.25</td>
<td>28.13</td>
<td>44.00</td>
<td>13500</td>
<td>0.25</td>
<td>3.38</td>
<td>5.2</td>
<td>7.5</td>
<td>1.564</td>
</tr>
<tr>
<td>8.</td>
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<td>13000</td>
<td>2.25</td>
<td>29.25</td>
<td>43.00</td>
<td>14000</td>
<td>0.25</td>
<td>3.50</td>
<td>5.7</td>
<td>7.5</td>
<td>1.470</td>
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<td>11800</td>
<td>2.25</td>
<td>26.53</td>
<td>27.00</td>
<td>1300</td>
<td>0.25</td>
<td>3.27</td>
<td>8.0</td>
<td>7.5</td>
<td>1.017</td>
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<tr>
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<td>11400</td>
<td>2.25</td>
<td>25.65</td>
<td>39.00</td>
<td>12900</td>
<td>0.25</td>
<td>3.23</td>
<td>9.0</td>
<td>7.5</td>
<td>1.520</td>
</tr>
<tr>
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<td>2.25</td>
<td>29.03</td>
<td>36.00</td>
<td>13900</td>
<td>0.25</td>
<td>3.48</td>
<td>9.0</td>
<td>7.5</td>
<td>1.240</td>
</tr>
<tr>
<td>12.</td>
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<td>13300</td>
<td>2.25</td>
<td>29.92</td>
<td>37.00</td>
<td>14300</td>
<td>0.25</td>
<td>3.58</td>
<td>9.15</td>
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<tr>
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<td>12800</td>
<td>2.50</td>
<td>32.00</td>
<td>41.00</td>
<td>13500</td>
<td>0.30</td>
<td>4.05</td>
<td>9.00</td>
<td>7.5</td>
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</tr>
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<td>14.</td>
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<td>14750</td>
<td>2.75</td>
<td>40.43</td>
<td>41.00</td>
<td>15400</td>
<td>0.30</td>
<td>4.62</td>
<td>9.10</td>
<td>7.5</td>
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<tr>
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<td>3.00</td>
<td>37.20</td>
<td>52.00</td>
<td>14300</td>
<td>0.30</td>
<td>4.29</td>
<td>9.10</td>
<td>7.5</td>
<td>1.398</td>
</tr>
<tr>
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<td>12700</td>
<td>3.00</td>
<td>38.10</td>
<td>52.00</td>
<td>14700</td>
<td>0.30</td>
<td>4.41</td>
<td>9.50</td>
<td>7.5</td>
<td>1.364</td>
</tr>
<tr>
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<td>6.5.79</td>
<td>13100</td>
<td>3.50</td>
<td>48.50</td>
<td>57.00</td>
<td>14500</td>
<td>0.30</td>
<td>4.35</td>
<td>8.70</td>
<td>7.5</td>
<td>1.175</td>
</tr>
<tr>
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<td>12100</td>
<td>3.50</td>
<td>42.30</td>
<td>60.00</td>
<td>14500</td>
<td>0.40</td>
<td>5.60</td>
<td>8.10</td>
<td>7.5</td>
<td>1.418</td>
</tr>
<tr>
<td>19.</td>
<td>6.6.79</td>
<td>10700</td>
<td>3.50</td>
<td>37.50</td>
<td>49.00</td>
<td>13000</td>
<td>0.40</td>
<td>5.20</td>
<td>7.10</td>
<td>8.0</td>
<td>1.307</td>
</tr>
</tbody>
</table>

Table II: GAS PRODUCTION IN CHARCOAL ANAEROBIC FILTERS
solids destroyed ranges from 1014 litres to 1564 litres/kg of volatile solids destroyed for the downward flow anaerobic charcoal filter and 1307 litres to 2963 litres/kg of volatile solids destroyed for upward flow reactor respectively. This quantity of gas is very high and how such an increase comes about has to be explained yet.

The detention period calculations are given below:

**Calculation of Detention time in Charcoal Filter I**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of Filter</td>
<td>20 cm</td>
</tr>
<tr>
<td>Area of cross section</td>
<td>314 cm²</td>
</tr>
<tr>
<td>Depth of filter</td>
<td>90 cm</td>
</tr>
<tr>
<td>Volume of filter</td>
<td>28260 cm³</td>
</tr>
<tr>
<td>Assume 50% void in charcoal</td>
<td></td>
</tr>
<tr>
<td>Volume of void</td>
<td>14130 cm³</td>
</tr>
<tr>
<td>Volume loaded/day</td>
<td>1.75 litres</td>
</tr>
<tr>
<td>Detention time</td>
<td>14130 to 1750</td>
</tr>
<tr>
<td></td>
<td>14130 to 3500</td>
</tr>
<tr>
<td></td>
<td>8 days to 4 days</td>
</tr>
</tbody>
</table>

**Detention time in charcoal filter II**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of filter</td>
<td>11 cm (outer diameter)</td>
</tr>
<tr>
<td>Assuming 5 mm wall thickness, inner diameter</td>
<td>10 cm</td>
</tr>
<tr>
<td>Area of cross section</td>
<td>79 cm²</td>
</tr>
<tr>
<td>Depth of filter</td>
<td>60 cm</td>
</tr>
<tr>
<td>Volume of filter</td>
<td>79 x 60 cm³</td>
</tr>
<tr>
<td>Assuming 50% void, volume of void</td>
<td>2370 cm³</td>
</tr>
<tr>
<td></td>
<td>2.37 litres</td>
</tr>
<tr>
<td>Volume of spent wash loaded</td>
<td>.2 to .4 litre/day</td>
</tr>
<tr>
<td>Detention period</td>
<td>2370 to 200</td>
</tr>
<tr>
<td></td>
<td>2370 to 400</td>
</tr>
<tr>
<td></td>
<td>12 days to 6 days</td>
</tr>
</tbody>
</table>

**Discussions of Results**

The gas production seems to be ensured in anaerobic charcoal filter in a small volume compared to 60 days detention time required for primary anaerobic ponds for distillery spent wash. For this particular set up the detention time was ranging from 4 to 8 days for downward flow and 6 to 12 days for upflow filters. Also the gas production was quite satisfactory and establishment of gas production was quick too. These are possible due to the following reasons.

i) Perhaps the filters operated as a complete mixing unit so that the micro organisms were spread uniformly, both in total mass and species. It was also possible to achieve uniform mixing of the feed at all times in all points of the filters due to this complete mixing pattern.

ii) Organic concentration of feed to the micro organisms at all times was kept constant in the reactors.

iii) The charcoal particles possess the adsorptive capacity which helps in adsorbing NH4 ion concentration and consequent inhibition in digestion.

iv) The charcoal provides a surface for anaerobic micro organisms to establish themselves and thrive. Probably this resulted in prevention of upsets due to changes, in loading rate.

Further gas generation even when pH was 8 and more shows that volatile acids were present and were getting gassified. They were probably adsorbed by charcoal and released gradually for methane generation. Investigations are required to establish the parameters in respect of the variation in the quality of effluent, period of operation, and rate of gas evolution with reference to loading.

The gas generation for downward flow shows a maximum value of 1564 litres/kg of volatile solids destroyed for a loading rate of 2.25 litres/day. The value for upward flow is 2696 litres/kg of volatile solids destroyed at a loading rate of 75 litre/day. However, by volume
the max. quantity is got for downward flow is 57 litres per day at
the loading rate of 3.50 litres per
day. It is 9.50 litres per day at
the loading rate of .30 litres per
day. Still higher loadings adver-
sely affected both gas yield and
rate of gas yield per kg of volatile
solids destroyed. All these rates
are high compared to the accepted
rate of about 18 cubic feet of gas
per pound of volatile solids destro-
yed (1300 litres/kg of volatile
solids destroyed). As mentioned, a
satisfactory explanation is yet to
be formulated for the higher gas
yield from anaerobic charcoal fil-
ters.

The B.O.D values for effluent from
anaerobic charcoal filters could be
done only in a few cases and hence
not included here. The values were
about those obtained by treating
distillery spent wash in two anaero-
bic lagoons of 60 days and 40 days
in series. This probably represents
the maximum removable B.O.D by ana-
erobic digestion in both cases.

Summary and Conclusions

1. Use of charcoal in size indica-
ted viz 25 mm - 38 mm is novel and
due to its structure as well as its
adsorption the charcoal anaerobic
filter has shown a favourable meth-
ane production rate by permitting
anaerobic organism to grow on its
surface and also by adsorbing excess
NH4 ions which tend to be toxic in
excess for anaerobic digestion.

2. Probably the adsorption helps
in keeping the volatile acid con-
centration down so that even at
higher loadings the pH was in the
region of 7.0. At lower loadings,
the pH was observed to be 8.0 and
more which again may be due to adsor-
ation of volatile acids. The vola-
tile acids were probably slowly
released for methane production by
anaerobic microorganism.

3. The upward flow anaerobic filter
gave nearly 50 per cent more gas
which may be attributed to the better
bacterial action due to the vertical
upward flow of the anaerobic filter
as against the downward flow anaero-
bic filter. The vertical flow prob-
ably results in better mixing and
bacterial action.

4. Though the waste was very high
in organic content and BOD, the
detention period was low compared
to the detention provided in anaer-
obic lagoons coming to 1/3 of con-
ventional requirement.

5. The gas yield was quite high
both for downward flow and upward
flow anaerobic charcoal filters.
It was remarkably high for the
upflow anaerobic charcoal filters.
This is yet to be satisfactorily
explained.

6. The arrangement was found easy
to set up and gas generation was
found to be quick.

7. The water displacement method
for gas collection was also unique
in that there was no moving gas
dome.

8. Further studies are to be
conducted for confirming and
applying the findings in treating
strong organic effluents effectively
and with recovery of methane.

9. The B.O.D. of the effluent from
the anaerobic charcoal filters com-
pares favourably with the BOD of
effluent from anaerobic lagoons in
series. This means that all
removable BOD is removed as effici-
ently in anaerobic charcoal filters.

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