Determination of Biokinetic Coefficient for Membrane Bioreactor Process in Treating Oily Wastewater

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Presentation Outline

- Introduction
- Research Objectives
- Materials and Methods
- Results and Discussion
- Conclusion
Introduction

Characteristics and Sources of Oily Waste

- Petroleum is an oily liquid, which typically contains C, H$_2$, S, N, O$_2$ and also Fe, Ca, K, Na, I, As and other elements.

- The combined refinery wastes may contain
  - crude oil
  - various dissolved or suspended organic compounds discharged in liquors
  - sludges from the various stages of processing

- Wastes from the oil refineries comes from leaks, spills, tank draw-off, and other sources such as cooling waters.
Basics of CF-MBR Process

- Activated Sludge Process
- Cross Flow Filtration
Conventional wastewater treatment

Conventional treatment with tertiary membrane filtration

Treatment with membrane bioreactor
Biochemical Kinetics of MBR System

- Kinetic study of MBR is needed to understand the interaction between biological and filtration unit

- Basic Equations are based on Monod (1949) equation

- Major factors affecting the biokinetic coefficients are (Rozich and Gaudy, 1992)
  - Reactor growth rate
  - Waste composition
  - Temperature
  - Population diversity
### Introduction (Cont’d)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Basis of analysis</th>
<th>( Y ) (mg/mg)</th>
<th>( k_d ) (day(^{-1}))</th>
<th>( \mu_m ) (day(^{-1}))</th>
<th>( K_s ) (mg/l)</th>
<th>Treatment system</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal waste</td>
<td>COD</td>
<td>0.5-0.62</td>
<td>0.025-0.48</td>
<td>7.4-18.5</td>
<td>11-181</td>
<td>ASP</td>
<td>Gaudy &amp; Gaudy, 1980</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>COD</td>
<td>0.4-0.8</td>
<td>0.025-0.075</td>
<td>2-10</td>
<td>15-70</td>
<td>ASP</td>
<td>Metcalf &amp; Eddy, 1991</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>COD</td>
<td>0.48-0.6</td>
<td>0.05-0.16</td>
<td>5.6-8.10</td>
<td>250-3720</td>
<td>CF-ASP</td>
<td>El-Kebir, 1991</td>
</tr>
<tr>
<td>Synthetic waste</td>
<td>COD</td>
<td>0.49-0.58</td>
<td>0.03-0.15</td>
<td>1.28-6.46</td>
<td>289-2933</td>
<td>SM-ASP</td>
<td>Kaly andurg, 2003</td>
</tr>
<tr>
<td>Industrial waste</td>
<td>COD</td>
<td>0.3-0.72</td>
<td>0.05-0.18</td>
<td>0.47-1.07</td>
<td>850-5200</td>
<td>ASP</td>
<td>Suman Raj, 2004</td>
</tr>
</tbody>
</table>
Research Objectives

To study the interaction between the biological and filtration unit of CF-MBR at MLSS concentration of 5000 mg/l. For this purpose following biokinetic coefficients were determined:

- Saturation constant \( (K_s) \)
- Specific growth rate \( (\mu) \)
- Yield coefficient \( (Y) \) and
- Endogenous decay coefficient \( (k_d) \)
## Materials and Methods

### Membrane Characteristics

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Hollow Tubular ceramic membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Alumina</td>
</tr>
<tr>
<td>Pore size</td>
<td>0.2 μm</td>
</tr>
<tr>
<td>Outer diameter</td>
<td>10 mm</td>
</tr>
<tr>
<td>Inner diameter</td>
<td>7 mm</td>
</tr>
<tr>
<td>Length</td>
<td>5 x 20 cm</td>
</tr>
<tr>
<td>Cross-sectional area</td>
<td>38.5 mm²</td>
</tr>
<tr>
<td>Total Surface area</td>
<td>0.022 m²</td>
</tr>
<tr>
<td>Effective Surface area</td>
<td>0.019 m²</td>
</tr>
<tr>
<td>Maximum Thermal stability</td>
<td>120⁰ C</td>
</tr>
<tr>
<td>Maximum Filtration pressure</td>
<td>15 bar</td>
</tr>
<tr>
<td>pH Range</td>
<td>1-14</td>
</tr>
</tbody>
</table>
Influent Substrate

- The oily waste was collected from a petroleum refinery
- The oil content was $160 \times 10^3$ mg/l
- The COD varied from $0.37 \times 10^6$ to $2.3 \times 10^6$ mg/l
- Essential nutrients were added in the bioreactor consisting of glucose, peptone and yeast extract
- The influent COD calculation was based on the mass loading per day (gm/day) rather than the concentration (mg/l)
Experimental Procedure Layout

Aeration Tank
Determination of Biokinetic Coefficients

Assumptions:

- Reactor is completely mixed
- Reactor volume is constant
- Complete rejection of MLSS
- No microbial solids in influent substrate

Results and Discussion
Substrate Balance

Rate of change of Substrate in the reactor = Rate of input of the feed substrate - Rate of removal due to biomass utilization - Rate of removal due to washout - Substrate lost during Deliberate wastage

\[
V \frac{dS}{dt} = QS_0 - \mu \frac{XV}{Y} - S(Q - Q_w) - Q_w S
\]

\[
\frac{Q}{VX} (S_0 - S) = \frac{1}{Y} \frac{1}{SRT} + \frac{k_d}{Y}
\]

For steady state condition
Biomass Balance

Rate of change of biomass in the reactor = Rate of increase due to growth - Rate of loss due to endogenous respiration - Deliberate wastage

\[ V \frac{dX}{dt} = \mu X V - k_d X V - Q_w X \]

\[ \frac{SRT}{1 + (SRTk_d)} = \frac{K_s}{\mu_m S} + \frac{1}{\mu_m} \]

For steady state condition
## Determination of Biokinetic Coefficients (Cont’d)

### Steady state data at MLSS 5000 mg/l

<table>
<thead>
<tr>
<th>Steady State Period</th>
<th>Q</th>
<th>$X_{avg}$</th>
<th>S</th>
<th>1/S</th>
<th>$QS_0$</th>
<th>QS</th>
<th>SRT</th>
<th>$Q(S_0 - S)/VX$</th>
<th>$\frac{SRT}{(1+SRT*k_d)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>day</td>
<td>l/d</td>
<td>mg/l</td>
<td>mg/l</td>
<td>l/mg</td>
<td>gm/d</td>
<td>gm/d</td>
<td>day</td>
<td>1/day</td>
<td>day</td>
</tr>
<tr>
<td>18-22</td>
<td>38</td>
<td>5458</td>
<td>72</td>
<td>0.0139</td>
<td>41.110</td>
<td>2.741</td>
<td>30.00</td>
<td>0.35</td>
<td>9.68</td>
</tr>
<tr>
<td>23-26</td>
<td>36</td>
<td>5300</td>
<td>84</td>
<td>0.0119</td>
<td>45.469</td>
<td>3.003</td>
<td>25.42</td>
<td>0.40</td>
<td>9.15</td>
</tr>
<tr>
<td>38-41</td>
<td>33</td>
<td>5393</td>
<td>109</td>
<td>0.0092</td>
<td>57.861</td>
<td>3.590</td>
<td>15.30</td>
<td>0.50</td>
<td>7.39</td>
</tr>
<tr>
<td>48-51</td>
<td>19</td>
<td>5511</td>
<td>120</td>
<td>0.0083</td>
<td>64.693</td>
<td>2.281</td>
<td>11.00</td>
<td>0.57</td>
<td>6.21</td>
</tr>
</tbody>
</table>
Determination of Biokinetic Coefficients (Cont’d)

Determination of Y and $k_d$ at MLSS 5000 mg/l

$y = 3.6264x + 0.2478$
$R^2 = 0.9696$

Determination of $\mu_m$ and $K_S$ at MLSS 5000 mg/l

$y = 607.38x + 1.5314$
$R^2 = 0.9405$
Summary of Kinetic Coefficients for CF-MBR at MLSS concentration of 5000 mg/l and Other Investigations.

<table>
<thead>
<tr>
<th>MLSS (mg/l)</th>
<th>Y (mg/mg)</th>
<th>$k_d$ (day$^{-1}$)</th>
<th>$\mu_m$ (day$^{-1}$)</th>
<th>$K_S$ (mg COD/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Study</td>
<td>0.276</td>
<td>0.07</td>
<td>0.653</td>
<td>396.62</td>
</tr>
<tr>
<td>Municipal Waste</td>
<td>0.4 - 0.8</td>
<td>0.025 – 0.48</td>
<td>2 – 18.5</td>
<td>11 – 3720</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>0.3-0.72</td>
<td>0.045</td>
<td>0.77</td>
<td>2980.5</td>
</tr>
</tbody>
</table>
Simulated Effluent COD for MLSS concentration of 5000 mg/l
Kinetic coefficients $Y$, $k_d$, $\mu_m$ and $K_S$ were evaluated and were found to be within those reported in literature.

The simulation study showed good agreement between model predictions and experimental data.

The model can be used to simulate and investigate different operational strategies.
Thank you
Questions?