Chemical flocculation as pretreatment for energy efficient biological treatment

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## Differences in energy use for waste water treatment

<table>
<thead>
<tr>
<th></th>
<th>Mill 1</th>
<th>Mill 2</th>
<th>Mill 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tot el. power (kW)</td>
<td>1778</td>
<td>1873</td>
<td>762</td>
</tr>
<tr>
<td>Aeration (kW)</td>
<td>1130 (63%)</td>
<td>1300 (69%)</td>
<td>442 (52%)</td>
</tr>
<tr>
<td>kWh/t COD red</td>
<td>1390</td>
<td>1357</td>
<td>674</td>
</tr>
</tbody>
</table>
Experiments to find out some of the reasons for poor oxygen transfer in forest industrial wastewaters and some ideas to increase aeration efficiency

- Aeration lab.scale trials
  - Pulp mill effluents
    - CTMP effluent
    - Kraft mill bleach plant effluent
    - Mixed effluents
  - Surface active wood extractives
    - Abietic acid
    - Dodecanoic acid
- Pre treatment screening trials to find pH and dose for optimal surface tension
- Aeration lab.scale trials with effluents pre treated with chemical flocculation
- Possible scenario for energy efficient aerobic biological treatment
Lab. scale equipment

- Measure oxygen transfer coefficient (Kla) and oxygen uptake rate (OUR)
- 2 m high, 95 liter
- Variable bubble diffuser
  Small bubbles (3 - 5 mm)
- Variable air flow
  (20-100 l/h)
- Process effluent from CTMP, Kraft pulp bleach plant and tot effluent from Skoghall Mill
- Wood extractives
  Resin and fatty acids
Portable measurement at Stora Enso Skoghall mill

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Oxygen transport in clean water and P&P mill effluent, 50 l/h airflow.

\[
\frac{dC}{dt} = KL_a(C_s - C_t)
\]

\[
\alpha = \frac{K_L a_{\text{wastewater}}}{K_L a_{\text{cleanwater}}}
\]

\[
\beta = \frac{C_{s_{\text{wastewater}}}}{C_{s_{\text{cleanwater}}}}
\]
Slow oxygen transfer in pulp mill effluents

- Water
- Mixed effluent (0.62)
- Bleach plant (0.26)
- CTMP (0.18)

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Surfactive wood extractives reason for decreased oxygen transfer

- Lignosulfonate (200 mg/l)
- Abietic acid (50 mg/l)
- Dodecanoic acid (30 mg/l)
- Dodecanoic acid (40 mg/l)
Surface active wood extractives affect aeration

Solubility

\[ \beta = \frac{C_{S_{water}}}{C_{S_{effluent}}} \]

Surface area

Boundary layer

Turbulent surface zone

Bulk zone

Bubble formation zone
Possible to reach $\alpha$ over 1

- Increased surface tension
- Smaller bubbles $\alpha > 1$
- Increased Boundary layer $\alpha < 1$
- Coalescence of Bubbles $\alpha << 1$

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Chemical flocculation to remove surfactive wood extractives before aeration in order to increase the oxygen transfer rate

• Screening tests with 5 different flocculation chemicals, both Aluminium and Iron.
• Screening trials with aim to reach high surface tension.
• Aeration tests with pre treated effluents.
Screening trials with CTMP effluent to find optimal pH according to surface tension. Chemical flocculant (PAX-XL60)
Screening trial CTMP effluent pretreated with chemical flocculation at pH 7.5.

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Improved oxygen transfer with pretreatment

<table>
<thead>
<tr>
<th></th>
<th>Surf. tens. (mN/n)</th>
<th>Kla (h⁻¹)</th>
<th>$\alpha$</th>
<th>$\alpha$ improv. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>73,0</td>
<td>3,12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTMP eff.</td>
<td>45,7</td>
<td>0,56</td>
<td>0,18</td>
<td></td>
</tr>
<tr>
<td>Pre treat CTMP</td>
<td>48,1</td>
<td>0,79</td>
<td>0,25</td>
<td>40 %</td>
</tr>
<tr>
<td>Bleach plant eff.</td>
<td>39,6</td>
<td>0,81</td>
<td>0,26</td>
<td></td>
</tr>
<tr>
<td>Pre treat. Bl. pl. eff.</td>
<td>45,9</td>
<td>1,07</td>
<td>0,34</td>
<td>30%</td>
</tr>
</tbody>
</table>

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Theoretical estimation of oxygen demand

\[ R_0 = \text{bacterial oxygen demand} \]

\[ R_0 = Q(COD_{in} - COD_{out}) - 1.42 \times \text{biosludge}.prod \]

SOTR = standard oxygen transfer rate, oxygen demand when losses have been included

\[ SOTR = R_0 \left( \frac{\beta C_{STH} - C_L}{C_s,20} \right) (1,024^{T-20}) (\alpha)(F) \]
Theoretical savings of air to activated sludge.
(COD red 2500 mg/l, COD red with pre treatment 2000mg/l, SRT 5 d, deep 10 m, DO 1,5 mg/l)
Conclusions

- Oxygen transfer is slow in forest industrial effluents
- Surface active wood extractives have large impact on the oxygen transfer rate, in most cases the higher concentration the slower oxygen transfer rate.
- Chemical flocculation can be used to increase surface tension, remove surface active extractives.
- In this study, pre treatment with chemical flocculation decreased needed airflow with 40%
- Potential for further efficiency

However, chemical flocculation costs, produces a lot of sludge
Vision for sustainable energy efficient water treatment. Chemical recovery and sludge used as an energy source

Decrease SWE, SS, COD

Decrease BOD, COD

Energy eff. aeration

Energy recovery

Chemical flocculant, nutrients

Cleaning effluent

Recover

CH₄

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Thank you for listening.