UP-SCALING OZONE TREATED SLUDGE AS CARBON SOURCE FOR DENITRIFICATION: FROM THE LAB TO RAS WORKING AT COMMERCIAL SCALE

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Background

AcOMaCS
Activated Particulate Organic Matter as Carbon Source for Denitrification

Aims: To improve ecological and economic efficiency of RAS by recycling particulate waste. Final product: Processing device for sludge.

- Studies on nutrient budgets of RAS with special interest on sludge and foam nutrient contents and system performance at commercial scales

- Evaluation of the suitability of ozone treatment for the disintegration of particulate organic matter into biodegradable and readily available carbon sources

- Assessment of the effectiveness of ozone-treated sludge as Carbon source for denitrification tested in mini-denitrification reactors (Lab-scale) and RAS (commercial scale)
Background

Why ozone?

- Highly reactive
- Highly effective in eliminating bad odours, organic pollutants and humic substances.
- Already used in RAS protein skimmers and for disinfection
- Can be produced in situ
Nitrification is performed by:

- *Nitrosomonas* spp. (optimum pH 7.2-7.8)
- *Nitrobacter* spp. (optimum pH 7.2-8.2)

**Nitrification**

\[
\text{Organic nitrogen compounds/Urea} \rightarrow \text{NH}_4^+ \\
\downarrow \\
\text{NO}_2^- \\
\downarrow \\
\text{NO}_3^-
\]

**Requirements:**

- pH 7.2-7.8
- **Oxygen available** (at least 2 mg/L DO)
- Alkalinity between 100-150 mg/L
- Abrupt salinity changes > than 5 g/L shock nitrifying bacteria
- Not too much ammonium (inhibition)
- **Not too much organic matter** (inhibition via competition with heterotrophs)

RAS make-up water is treated by means of nitrification and denitrification filters to get rid of accumulating nitrogen compounds while drum filters and protein skimmers contribute to the elimination of solid wastes.

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**Introduction**

Background

Background

Denitrification

Carbon source $\rightarrow$ NO$_3^-$ $\downarrow$ $\leftarrow$ Nitrate reductase

NO$_2^-$ $\downarrow$ $\leftarrow$ Nitrite reductase

NO / N$_2$O $\downarrow$ $\leftarrow$ Nitrogen oxide-

N$_2$ Nitrous oxide reductase

Theoretical optimal C:N ratio depends on the carbon source.

Requirements:

- pH 7-8.5
- Anoxic-anaerobic conditions
- Temperature 25-30 °C
- Nitrate lower limits: 10-50 mg/L
- No salinity constraints
- Carbon source and denitrifiers (e.g. *Paracoccus denitrificans*, *Pseudomonas stutzeri*) available
- Dim light

Alternative to denitrification for nitrogen elimination:

**Anammox** (Planctomycetes-*Brocadia anamoxidans*)

$$\text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2 + \text{H}_2\text{O}$$

Background
Background
Denitrification and up-scaling experiments

Measurements:
- pH / ORP / Sal / T / O₂
- DOC-TDN / NO₃-N / NO₂-N / NH₄-N / PO₄³⁻ / State of filter bodies

Volume Exchange:
- 10% → 500 ml sludge + 4500 ml RAS water
- 25% → 1250 ml sludge + 3750 ml RAS water
- 50% → 2500 ml sludge + 2500 ml RAS water
- Control → 5 ml Acetol + 5000 ml RAS water
  50 mg/L NO₃-N

Experiments:
I. Denitrification experiment: 4 replicates x 4 treatments x 8 days (30 min ozone-treated sludge with 10%, 25% and 50% volume exchange vs. Acetol).

II. Up-scaling experiment in RAS
Material and methods

Diagram: M. Bögner
Up-scaling

Material and methods

Experiment set-up:
I) 10 days denitrification as usual: acetol as carbon source
II) 10 days denitrification adding ozone-treated sludge as carbon source in addition to acetol

Pictures: D. and M. Bögner
Results and discussion

Denitrification experiments

Measurements immediately after feeding the reactors with nitrate stock solution and carbon source and 24 h later.
### Denitrification experiments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Condition</th>
<th>PO4 (mg/L)</th>
<th>DOC (mg/L)</th>
<th>TDN (mg/L)</th>
<th>NO3-N (mg/L)</th>
<th>NO2-N (mg/L)</th>
<th>NH4-N (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>10%</td>
<td>IC</td>
<td>45.2</td>
<td>127.9</td>
<td>124.1</td>
<td>48.3</td>
<td>0.71</td>
<td>2.64</td>
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<tr>
<td></td>
<td>FC</td>
<td>41.0</td>
<td>69.7</td>
<td>100.7</td>
<td>39.6</td>
<td>0.72</td>
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<td>25%</td>
<td>IC</td>
<td>52.6</td>
<td>141.4</td>
<td>116.1</td>
<td>43.7</td>
<td>0.57</td>
<td>5.59</td>
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<td></td>
<td>FC</td>
<td>46.3</td>
<td>84.3</td>
<td>91.8</td>
<td>32.7</td>
<td>0.71</td>
<td>6.02</td>
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<td>50%</td>
<td>IC</td>
<td>66.0</td>
<td>170.5</td>
<td>117.8</td>
<td>38.3</td>
<td>0.25</td>
<td>11.08</td>
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<td></td>
<td>FC</td>
<td>57.2</td>
<td>98.6</td>
<td>74.0</td>
<td>19.9</td>
<td>0.42</td>
<td>11.35</td>
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<td>Acetol</td>
<td>IC</td>
<td>40.7</td>
<td>253.1</td>
<td>81.4</td>
<td>44.0</td>
<td>0.49</td>
<td>0.29</td>
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<tr>
<td></td>
<td>FC</td>
<td>39.6</td>
<td>89.6</td>
<td>58.8</td>
<td>21.8</td>
<td>1.88</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Results and discussion
Denitrification experiments

Water parameters of the samples:
- pH: 7.4-7.6 (Sludge reactors); 7.2-7.8 (Acetol reactors)
- Sal: 30.2 ppt
- T: 20 °C
- $O_2$: 0 mg/L (Sludge reactors); 0.02-0.05 mg/L (Acetol reactors)

Pictures: D. Bögner
Denitrification experiments

Results and discussion

1h after reactor feeding

24h after reactor feeding

Pictures: D. Bögner
Results and discussion

Acetol demand for 10 days

What is being disposed?

Acetol demand (L) of the system

TSS (ml)

SL=Sludge samples
FO=Foam samples
Results and discussion

- Turbidity measurements >240 NTU in sludge and foam samples
- The rest of the compartments of the system were lower than 6 NTU
### Up-scaling

<table>
<thead>
<tr>
<th>Source</th>
<th>NO(_3)-N</th>
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<th>NO(_2)-N</th>
<th>NO(_2)-N</th>
<th>NH(_4)-N</th>
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<tbody>
<tr>
<td>DE</td>
<td>7.18±7.20</td>
<td>4.86±4.14</td>
<td>0.12±0.10</td>
<td>0.08±0.06</td>
<td>0.14±0.24</td>
<td>0.10±0.08</td>
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<tr>
<td>SL</td>
<td>0.00±0.00</td>
<td>1.93±1.15</td>
<td>0.05±0.02</td>
<td>0.04±0.03</td>
<td>32.2±7.39</td>
<td>5.48±13.2</td>
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<tr>
<td>FO</td>
<td>2.93±1.91</td>
<td>0.11±0.34</td>
<td>0.06±0.10</td>
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<td>21.1±19.7</td>
<td>165.6±88.5</td>
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<table>
<thead>
<tr>
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<th>PO(_3)-4</th>
<th>PO(_3)-4</th>
<th>DOC</th>
<th>DOC</th>
<th>TDN</th>
<th>TDN</th>
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<tbody>
<tr>
<td>DE</td>
<td>34.7±8.86</td>
<td>44.5±13.4</td>
<td>56.4±17.6</td>
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<td>15.9±16.5</td>
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<tr>
<td>SL</td>
<td>88.5±22.4</td>
<td>69.8±22.8</td>
<td>164.7±36.5</td>
<td>212.4±305.4</td>
<td>59.6±9.61</td>
<td>55.6±101.3</td>
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<tr>
<td>FO</td>
<td>61.2±11.0</td>
<td>94.6±35.7</td>
<td>292.7±165</td>
<td>968.8±340.4</td>
<td>62.8±36.6</td>
<td>275.7±102.1</td>
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Acetol | Acetol+ Sludge | Acetol | Acetol+ Sludge | Acetol | Acetol+ Sludge
## Up-scaling

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Source: Acetol, Acetol+Sludge, Acetol, Acetol+Sludge
The application of ozone-treated sludge as carbon source for denitrification is effective in reducing the Acetol requirements of the system and the amounts of sludge disposal.

Ozone treatment leads to an increase in the turbidity of the sludge liquid phase which do not affected other compartments of the system.

The use of ozone-treated sludge leads to an increase in DOC and TDN which did not influenced the rearing tanks but would probably influence selective bacterial growth.

Analysis of changes in bacterial community composition of the filters and other compartments of the system in relation to the physiochemical changes of the water matrix are still required.

The commercial benefits for longer application of ozone treated sludge as carbon source have to be assessed.
Special thanks to:

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Thank you for your attention!

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