BIOMIMETIC AQUAPORIN FORWARD OSMOSIS MEMBRANE FOR REMOVAL OF FREQUENTLY FOUND PESTICIDES FROM DANISH GROUNDWATER NETWORK

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Introduction

Active drinking water wells (2012-2015)

Concentration of pesticide residue: µg/l

- None
- 0.01 - 0.1
- > 0.1

- Found in 27% of active DW wells
- > 0.1 µg/L in 3.6%
- 130 wells were closed within 1993-2009
Membrane separation:
~ 90% ultra pure water
~ 10% residual ‘waste’ water with high concentration of pollutants, carbon, minerals etc.

Biofilter:
Added specific pesticide degrader organisms to sand filters

Mineralization
Treated concentrate is mixed with permeate

Ellegaard-Jensen et al. 2017
Studied pesticides

1. BAM (2-6 Dichlorobenzamide)
   MW: 190.028 g/mol
   transformation product of Dichlobenil

2. MCPA (2-methyl-4-chlorophenoxyacetic acid)
   MW: 200.62 g/mol

3. MCPP (methylchlorophenoxypropionic acid)
   MW: 214.65 g/mol

In 2015, found in 16% of sampled wells of which 9.4% was above 0.1 µg/L.
Forward Osmosis

Advantages of FO process:

- Less energy requirements
- Less risk of fouling/scaling
Use of FO in MEM2BIO project
Aquaporin FO membrane

- Incorporated aquaporin proteins in the membrane
- Higher permeability compared to traditional FO membranes

34 cm²

2.3 m²
FO setups
Membrane characterization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl rejection in RO (%)</td>
<td>99.4 ± 0.2</td>
</tr>
<tr>
<td>Pure water permeate flux (LMH)</td>
<td>15.2 ± 0.6</td>
</tr>
<tr>
<td>Reverse salt flux (g m(^{-2}) h(^{-1}))</td>
<td>5.6 ± 0.5 (1.7 ± 0.4 by HF)</td>
</tr>
<tr>
<td>Water permeability, A (L m(^{-2}) h(^{-1}) bar)</td>
<td>3.0 ± 0.2</td>
</tr>
<tr>
<td>Salt permeability, B (L m(^{-2}) h(^{-1}))</td>
<td>0.1 ± 0.03</td>
</tr>
<tr>
<td>Membrane structural parameter, S (µm)</td>
<td>305 ± 43</td>
</tr>
<tr>
<td>Contact angle (°)</td>
<td>28.6 ± 3.4</td>
</tr>
<tr>
<td>Zeta potential at pH=5.3 (mV)</td>
<td>-21 ± 2</td>
</tr>
</tbody>
</table>
Pesticides rejection in pure water

- Feed 2 L, 1 mg/L
- Draw 200 mL, 1 M NaCl
- Flat sheet membrane
Pesticides rejection in Varde water

- Feed 2 L, 1 mg/L
- Draw 200 mL, 1 M NaCl
- Flat sheet membrane

![Graph showing permeate flux and rejection over time for different pesticides. The graph includes data for BAM, MCPA, MCPP, and permeate flux. The x-axis represents time in minutes, and the y-axis represents permeate flux (LMH) and rejection (%).]

Permeate Flux (LMH)
Rejection (%)
Time (min)

BAM
MCPA
MCPP
Permeate flux
## Pesticides rejection by different setups

<table>
<thead>
<tr>
<th></th>
<th>BAM (%)</th>
<th>MCPA (%)</th>
<th>MCPP (%)</th>
<th>Pure water permeate Flux (LMH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow fiber</td>
<td>98.1</td>
<td>98.6</td>
<td>98.9</td>
<td>15.8</td>
</tr>
<tr>
<td>Flat sheet</td>
<td>93.3</td>
<td>94.7</td>
<td>94.9</td>
<td>15.2</td>
</tr>
<tr>
<td>Small FO compartment</td>
<td>97.2</td>
<td>-</td>
<td>-</td>
<td>9.4</td>
</tr>
</tbody>
</table>

H. Madsen et. al., Journal of Membrane Science 476 (2015) 469–474
Future work

- Use of the other water samples from Kolding and Hvidovre.
- Use of the other draw solutes: Glucose and Sodium acetate
- Study of effect of recovery on the membrane performance.
- Production of concentrates for biological treatment using different draw solutes
- Comparison of RO and FO in terms of scaling propensity
- Combination of FO and RO as an integrated membrane process.