Cross-flow filtration with different ceramic membranes for polishing wastewater treatment plant effluent

Farsi, Ali; Hammer Jensen, Sofie; Roslev, Peter; Boffa, Vittorio; Christensen, Morten Lykkegaard

Publication date:
2014

Document Version
Accepted author manuscript, peer reviewed version

Link to publication from Aalborg University

Citation for published version (APA):
CROSS-FLOW FILTRATION WITH DIFFERENT CERAMIC MEMBRANES FOR POLISHING WASTEWATER TREATMENT PLANT EFFLUENT

ALI FARSI, SOFIE H. JENSEN, PETER ROSLEV, VITTORIO BOFFA, MORTEN L. CHRISTENSEN

ICIM 2014, 8TH JULY, BRISBANE, AUSTRALIA
Outlook

- Problem and Hypothesis
- Materials and Methods
- Results and Discussion
- Conclusion
Micro/nano–pollutants in wastewater are a challenge to wastewater professionals. The presence of contaminants in wastewater treatment plant (WWTP) effluents may cause a severe risk for the drinking water preparation. The effluent cannot be simply discharged to environment because it contains toxic ions and organic micro-pollutants which are harmful for aquatic organism.

Diagram:
- **Households**
- **Industrie**
- **Water works**
- **WWTP**
- **Animal farming**
- **Rivers**
- **Agriculture**
- **Ground water**
- **Landfills**

Connections:
- Drinking water to Households
- Households to Water works
- Water works to Drinking water
- Drinking water to Sewer
- Sewer to WWTP
- WWTP to Effluents and manure
- Effluents and manure to Animal farming
- Animal farming to Effluents and manure
- Effluents and manure to Rivers
- Rivers to Run-off
- Run-off to Agriculture
- Agriculture to Landfills
- Landfills to Ground water
- Ground water to Drinking water
- Drinking water to Industrie
## Challenge

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Examples</th>
<th>Detected in Denmark WWTP*</th>
<th>Detected in EU/US WWTP**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Contaminants from Industrial sources</td>
<td>Sulfonated organic compounds, MTBE</td>
<td>▲</td>
<td>▲</td>
</tr>
<tr>
<td>Household and personal care products</td>
<td>Sunscreen Agents</td>
<td>▲</td>
<td>▲</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>Acetaminophen, Ketoprofen, Ibuprofen, Diclofenac</td>
<td></td>
<td>▲</td>
</tr>
<tr>
<td>Party drugs</td>
<td>Defattening pills, Viagra, XTC</td>
<td>▲</td>
<td>▲</td>
</tr>
<tr>
<td>Pesticides</td>
<td>Glyphosate</td>
<td></td>
<td>▲</td>
</tr>
<tr>
<td>Metal Ions</td>
<td>Cu, Pb, Zn, Cd, Cr, Hg</td>
<td>▲</td>
<td>▲</td>
</tr>
</tbody>
</table>

*Punktkilder 2012, Miljøministeriet, [www.nst.dk](http://www.nst.dk) (in Danish).
Hypothesis

- A possible strategy to avoid this is to polish the effluent by membrane processes.
Materials and Methods

- **Sample.** The samples were taken from Aalborg WWTP which is located in the west of Aalborg city, Denmark.

- **Filtration.** The effluent was pumped at 6 bar to a cross-flow filtration.

- **Membranes.** Various monotube active layers such as on macroporous α-alumina support (~100nm) were used.

- **Analysis.** The total ions and specified toxic ions rejections were measured using conductivity measurements respectively. The type and the molecular size of removed organic compounds were determined using pH, full spectrum UV and size exclusion HPLC. Inorganic N-compound rejections were calculated by N-autoanalyzer. Bioassays were done with *Daphnia magna* method.

- **MBR.** The MBR Pilot plant is already working in the WWTP site.
<table>
<thead>
<tr>
<th>Material</th>
<th>Type</th>
<th>Nominal Main Pore size</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-alumina</td>
<td>MF- Macroporous</td>
<td>~100 nm</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>UF- Mesoporous</td>
<td>15 nm</td>
</tr>
<tr>
<td>γ-alumina</td>
<td>NF- Mesoporous</td>
<td>5 nm</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>NF- Microporous</td>
<td>1 nm</td>
</tr>
<tr>
<td>Hybrid silica</td>
<td>RO-Microporous</td>
<td>&lt;1 nm</td>
</tr>
</tbody>
</table>

Before the test
Size: 1.022 mm

Water, after 21 days
Size: 3.132 mm ($A_0$)

Sample after 21 days
Size: 3.8 mm ($A_1$)
Permeability [L/m²/h/bar]

- α-alumina: Water 46.36, Effluent 46.36
- Mesoporous TiO2: Water 14.70, Effluent 14.70
- γ-alumina: Water 6.78, Effluent 6.78
- Microporous TiO2: Water 11.52, Effluent 11.52
- Hybrid silica: Water 0.03, Effluent 0.06
The diagram shows the comparison of various materials in terms of their performance in wastewater treatment:

- **Conductivity [ms/cm]**
  - Effluent: 0.1
  - MBR: 1
  - α-alumina: 0.8
  - Mesoporous TiO2: 0.6
  - γ-alumina: 0.4
  - Microporous TiO2: 0.2
  - Hybrid silica: 0

- **Total ion rejection [%]**
  - Effluent: 100
  - MBR: 90
  - α-alumina: 80
  - Mesoporous TiO2: 70
  - γ-alumina: 60
  - Microporous TiO2: 50
  - Hybrid silica: 40

- **pH**
  - Effluent: 6.5
  - MBR: 7
  - α-alumina: 7.5
  - Mesoporous TiO2: 8
  - γ-alumina: 8.5
  - Microporous TiO2: 9
  - Hybrid silica: 9.5

The diagram also indicates the retention of organic molecules [%]:

- Hybrid silica shows the highest retention of organic molecules.
Aromatic molecule retention [%] vs. Membrane permeability [L/hr/m²/bar] and Total ion rejection [%].

N Concentration [mg/l] for different samples: Effluent, MBR, α-alumina, Mesoporous TiO₂, γ-alumina, Microporous TiO₂, Hybrid silica. The graph shows the concentration of NH₄, NO₂, and NO₃ ions in each sample.
A 100  
B 90  
C 85  
D 90  
E 40  

Peak | MW (KDa) |
---|---|
A  | 100 |
B  | 90  |
C  | 85  |
D  | 90  |
E  | 40  |
- **Hybsi** active layer (<1nm, RO) could remove most of inorganic ions and organic molecules and increase the water quality up to drinkable water. But its permeability is very low (0.03 LMH/B).

- **α-alumina** (>100 nm, MF) did not show a better performance for removing organic compounds and ions rejections.

- **Mesoporous TiO₂** (15nm, UF), **γ-alumina** (5 nm, NF) and **microporous TiO₂** (1nm, NF) could remove most of the aromatic organic compounds more than MBR but their ion rejections are not obvious (less than 10%).

- Chromatography results showed that MBR could remove a range of organic components (around 90 KDa) **even** better than NF ceramic membrane.

- MBR shows a better performance in competition with all ceramic membrane to remove N-compounds.

- Bioassays with **Daphnia magna** suggested that effluent polishing with γ-alumina membrane reduced toxicity of the treated water better than MBR and even TiO₂ micro porous membrane.

- Our study showed that **γ-alumina** is the optimized membrane for this application.
TIPS OF DAY:

“EXPERIMENTAL DESIGN IS FUNDAMENTAL FOR THE DEVELOPMENT OF NEW MEMBRANE APPLICATION”

THANK YOU FOR YOUR ATTENTION.