SSAMBRA
Strengthening SmartAirMBR Applications

Hèctor Monclús, Albert Galizia, Gaetan Blandin, Olivier Lorain, Eduard Bardají, Ignasi Rodríguez-Roda and Joaquim Comas
Project objectives
Introduction and background
Methodology
Results
Conclusions
The general objective of the present project is to *increase the competitiveness* of the membranes for wastewater treatment.
The general objective of the present project is to **increase the competitiveness** of the membranes for wastewater treatment.

**Air-scour optimization**

To strengthen SmartAirMBR Applications

**Reducing Fouling**

To evaluate an external treatment of peptides solution for biofouling reduction in polymeric membranes.
What is the SmartAirMBR?

**Air-scour optimization**

To strengthen SmartAirMBR Applications

**Reducing Fouling**

To evaluate an external treatment of peptides solution for biofouling reduction in polymeric membranes

BACKGROUND
What is the SmartAirMBR?

**Background**

**Air-scour optimization**

- Conventional air scour control system
- Innovative air scour control system
- Saving energy
What is the SmartAirMBR?

SmartAirMBR® is an automatic control system patented and registered by the UdG and GS Inima Environment which regulates the air-scour flow for cleaning physically the submerged membranes.

**BACKGROUND**

**Up to ~(-14%) air-scouring costs**
What is the SmartAirMBR?

**Air-scour optimization**

Up to -23%

~ (-14%) air-scouring costs
**Reducing Fouling**

To evaluate an external treatment of peptides solution for biofouling reduction in polymeric membranes

**Phenomenon inherent per se**

Deposition of material on membrane surface
- Occluding membrane pores

**Causes:**
- Membrane materials
- Biomass characteristics
- Feed water
- Operating conditions

**Fouling control:**
- Decreasing permeate flux
- Backwashing the fibres
- Increasing turbulences (air-scour)
- Increasing the chemical cleanings

---

**BACKGROUND**

**Anti-microbial Peptides**

Fouling control:
- Decreasing permeate flux
- Backwashing the fibres
- Increasing turbulences (air-scour)
- Increasing the chemical cleanings

**Peptides**

**NaOCl**

**Acid**

Air

Backwash

Reversible

Irreversible

**Air-scour Control System**

**SmartAirMBR®** is an automatic control system patented and registered by the UdG and GS Inima Environment which regulates the air-scour flow for cleaning physically the submerged membranes.
How can we reduce fouling?

Reducing Fouling

To evaluate an external treatment of peptides solution for biofouling reduction in polymeric membranes

Anti-microbial Peptides
Project objectives
Introduction and background

**Methodology**

Results
Conclusions
Fuzzification of SmartAirMBR using MATLAB
Fuzzification of SmartAirMBR using MATLAB

1. PROCESS
   - Numerical Variable (measured data)
   - Linguistic Level

2. FUZZIFICATION
   - Linguistic variable
   - Numerical Variable (control action)

3. FUZZY INFERENCE
   - Rules
   - Linguistic variable

4. DEFUZZIFICATION
Fuzzification of SmartAirMBR using MATLAB

MBR filtration process

(Daily control action)
METHODOLOGY

Industrial-scale membrane bioreactor
With external configuration
Lab-Scale membrane bioreactor
With twin permeate lines

METHODOLOGY

Fibres characterisation
AMP solution treatment
Fibres characterisation
Modules fabrication
Modules and fibres integrity validation
Permeability with water

25L

Inlet
Discharge to sewer or to MBR
Over flow
Filtration and backwash pump
Permeate flow
TMP
TMP
M BR
Backwash tank
Aeration

Membranes for water treatment and reuse

THURSDAY 15th of JUNE 2017
Parc Científic i Tecnològic de la UdG - GIRONA
Project objectives
Introduction and background
Methodology
Results
Conclusions
**RESULTS SmartAirMBR**

**SmartAirMBR Fuzzification**

**Monitoring variables**

- \( ST = \left( \frac{dK}{dt} \right)_4 \)
- \( LT = \left( \frac{dK}{dt} \right)_{14} \)
- \( TMP \)

**Control variables**

- **Air-scour flow**
- **SAD\(_m\)**

---

<table>
<thead>
<tr>
<th>( SR = \frac{ST}{LT} )</th>
<th>( \Delta \text{Air-flow} ) (%)</th>
<th>( \Delta \text{air-flow} ) (m(^3)/min(^{-1}))</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{CASE A:} \ ST &lt; 0 ) (cleaning)</td>
<td>( \text{CASE B:} \ LT &lt; 0 ) (fouling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&lt; 2.5)</td>
<td>(-2.5)</td>
<td>(-3)%</td>
<td>(-0.5)</td>
</tr>
<tr>
<td>((-2.5, -2])</td>
<td>((-2, -1.5])</td>
<td>(2)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((-1.5, -1])</td>
<td>((-1, -0.5])</td>
<td>(-1)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((-0.5, 0])</td>
<td>((-0, 0.2])</td>
<td>(-0.5)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((0, 0.2])</td>
<td>((0.2, 0.4])</td>
<td>(-2)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((0.4, 0.6])</td>
<td>((0.6, 0.8])</td>
<td>(-1.2)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((0.8, 1])</td>
<td>((1, 1.2])</td>
<td>(-0.4)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((1.2, 1.4])</td>
<td>((1.4, 1.6])</td>
<td>(0.3)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((1.6, 1.8])</td>
<td>((1.8, 2])</td>
<td>(1.2)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>((2, 2.5])</td>
<td>((2.5, 3])</td>
<td>(1.5)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>(\geq 3.5)</td>
<td>(\geq 3.5)</td>
<td>(2.5)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>(\geq 3.5)</td>
<td>(\geq 3.5)</td>
<td>(3)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>(\geq 3.5)</td>
<td>(\geq 3.5)</td>
<td>(4)%</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>(\geq 3.5)</td>
<td>(\geq 3.5)</td>
<td>(5)%</td>
<td>(-0.4)</td>
</tr>
</tbody>
</table>

**Additional notes:**

- The table above outlines different cases for monitoring and control variables, indicating how changes in one variable affect others. For instance, an increase in \( SR \) may lead to a decrease in \( \Delta \text{Air-flow} \).
### Table 1. Fuzzification variables to estimate the saving potential

<table>
<thead>
<tr>
<th>Long Term Slope (14 days) (LMH/bar-day)</th>
<th>Language Category</th>
<th>Short Term Slope (4 days) (LMH/bar·day⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High LT&gt;0,006</td>
<td>Maximum</td>
<td>Very High High Moderate Low</td>
</tr>
<tr>
<td>High</td>
<td>LT&gt;0,002</td>
<td>Very High High Moderate Low</td>
</tr>
<tr>
<td>Medium</td>
<td>LT&gt;0,002</td>
<td>High Moderate Medium Low</td>
</tr>
<tr>
<td>Low</td>
<td>LT&gt;0,006</td>
<td>Moderate Medium Low Very Low</td>
</tr>
<tr>
<td>Very Low LT&lt;-0,006</td>
<td>Medium</td>
<td>Low Very Low Very very Low Minimum</td>
</tr>
</tbody>
</table>

**Defuzzification** : Modification of air scour flow (%)

<table>
<thead>
<tr>
<th>Saving potential</th>
<th>Defuzzificación</th>
<th>&gt;350</th>
<th>350-250</th>
<th>250-150</th>
<th>150-50</th>
<th>&lt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td></td>
<td>+4</td>
<td>+3</td>
<td>+2</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>Very very low</td>
<td></td>
<td>+3</td>
<td>+2</td>
<td>+1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Very Low</td>
<td></td>
<td>+2</td>
<td>+1</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>+1</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
<td>-5</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
<td>-5</td>
<td>-6</td>
</tr>
<tr>
<td>Very High</td>
<td></td>
<td>-3</td>
<td>-4</td>
<td>-5</td>
<td>-6</td>
<td>-7</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td>-4</td>
<td>-5</td>
<td>-6</td>
<td>-7</td>
<td>-8</td>
</tr>
</tbody>
</table>
RESULTS SmartAirMBR

SmartAirMBR Fuzzification
**RESULTS SmartAirMBR**

**SmartAirMBR Fuzzification**

- **Air-scour flow (m³/h)**
  - Fuzzy SmartAirMBR
  - Normal SmartAirMBR
  - TMP

- **TMP (mbar)**

- **Time (days)**
  - 100 200 300 400 500
### SmartAirMBR Fuzzification

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Air-scour flow (m³/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>14</td>
</tr>
<tr>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>300</td>
<td>16</td>
</tr>
<tr>
<td>400</td>
<td>17</td>
</tr>
<tr>
<td>500</td>
<td>18</td>
</tr>
</tbody>
</table>

### RESULTS

- **Air-scour flow reduction**: 14,8%
- **Energy consumption reduction**: 16,5%

### Parameters

<table>
<thead>
<tr>
<th>Blower size</th>
<th>GM 25 S / DN 125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vₗ [m³/min]</td>
<td>6.18 8.80 11.1 14.5 16.6 18.7 20.6 22.7 24.2</td>
</tr>
<tr>
<td>t₂ [°C]</td>
<td>53 51 50 48 48 48 47 47 47</td>
</tr>
<tr>
<td>nG [rpm]</td>
<td>1445 1890 2310 2920 3530 4140 4750 5360 6060</td>
</tr>
<tr>
<td>nM [rpm]</td>
<td>2990 2990 2990 2990 2990 2990 2990 2990 2990</td>
</tr>
<tr>
<td>Pₘ [kW]</td>
<td>5.5 7.7 11 14 16 18.5 20 22</td>
</tr>
<tr>
<td>Motor size</td>
<td>132S 132S 180M 180M 180M 180M 180L 180L 180M</td>
</tr>
<tr>
<td>Lp(A)[dB]</td>
<td>81/66 85/68 87/70 92/69 92/69 92/69 92/69 94/71 98/72</td>
</tr>
</tbody>
</table>

**Fuzzy SmartAirMBR**
Physical properties of fibres

Elasticity and break point

<table>
<thead>
<tr>
<th>Fibre PVDF with peptides</th>
<th>Fibre PVDF without peptides</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_R = 10.63 \text{ N}$</td>
<td>$F_R = 10.40 \text{ N}$</td>
</tr>
<tr>
<td>$F_E = 8.60 \text{ N}$</td>
<td>$F_E = 8.08 \text{ N}$</td>
</tr>
</tbody>
</table>

### Table 2: membrane and module characteristics

<table>
<thead>
<tr>
<th>Fibre material</th>
<th>PVDF</th>
<th>PVDF + peptides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Bobine</td>
<td>2NAMB51</td>
<td>2NAMB51</td>
</tr>
<tr>
<td>Module code</td>
<td>SS-019</td>
<td>SS-014P</td>
</tr>
<tr>
<td>Number of fibres</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Fibres length</td>
<td>230 mm</td>
<td>205 mm</td>
</tr>
<tr>
<td>Surface module</td>
<td>0.042</td>
<td>0.037</td>
</tr>
<tr>
<td>$D_e$</td>
<td>2.331</td>
<td>2.331</td>
</tr>
</tbody>
</table>

RESULTS biofouling
RESULTS biofouling

Biofouling reduction

- peptide-modified fibres
- non-modified fibres

Permeability (LMH/bar):
- 0
- 100
- 200
- 300
- 400
- 500
- 600

Time (days):
- 0 7 14 21 28 35 42 49 56 63 70 77

Peptide-modified fibres:
- 15,4-14 LMH

Non-modified fibres:
- 6,7-6 LMH
- 10,6-9,2 LMH

THURSDAY 15th of JUNE 2017
Parc Científic i Tecnològic de la UdG - GIRONA
RESULTS biofouling
RESULTS biofouling
Project objectives
Introduction and background
Methodology
Results
Conclusions
Air-scour optimization

- The software has been updated with a fuzzy logic control.
- It has permitted to increase its robustness with softer air-scour modifications.
- The energy reduction has improved using fuzzy logic control for aeration optimization.
- The high flexibility of the fuzzy logic toolbox permit a fast adaptation to other configurations.

Reducing Fouling

- The physical properties of peptides-modified fibres were not modified.
- The initial permeability with peptide-modified fibres has increased significantly.
- The permeability working at sub-critical conditions were always higher than in the peptides-modified fibres.
- We need to do more experiments using different peptides.
- To evaluate the efficiencies of chemical cleanings.
- To evaluate this treatment using different polymeric membranes.
CONCLUSIONS

Air-scour optimization

Reducing Fouling

• We need to do more experiments using different peptides
• To evaluate the efficiencies of chemical cleanings
• To evaluate this treatment using different polymeric membranes
SSAMBRA
Thank you for your attention

Hèctor Monclús, Albert Galizia, Gaetan Blandin, Olivier Lorain, Eduard Bardají, Ignasi Rodríguez-Roda and Joaquim Comas