DOC removal by fluidized ion exchange and coagulation-flotation

Liesbeth Verdickt
De Watergroep
21 September 2016
Contents

• Surface water treatment and DOC at De Watergroep
• 10 years of research on DOC removal
• Fluidized bed IEX combined with coagulation-flotation
• IEX waste water treatment
• Conclusions and ongoing research
De Watergroep
Public drinking water company

- Largest water company in the Flanders
- Our customers
  - 175 municipalities
  - 1.3 million connections
  - 3 million domestic customers
- Growing markets for
  - Industrial water treatment
  - Engineering services in the water cycle
  - Waste water collection and treatment
De Watergroep
Infrastructure for production

• Yearly production ≈ 120 million m³
  • 71% ground water
  • 29% surface water
• Production plants & water abstractions
  • Ground water abstractions 85
    ⇒ Water treated in 64 production plants
  • Surface water abstractions 5
    ⇒ Water treated in 5 production plants
Surface water treatment plants with elevated DOC levels

Kluizen
- Near Ghent, 60 000 m³/day
- In operation since 1974

Blankaart
- 20 km from the North Sea, 40 000 m³/day
- In operation since 1972
### Surface water treatment plants with elevated DOC levels

**Raw water quality**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kluizen</th>
<th>Blankaart</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPOC (mg C/l)</td>
<td>9.8 (8.5 – 11.9)</td>
<td>12.0 (8.8 – 15.5)</td>
</tr>
<tr>
<td>(UV_{254}) (m(^{-1}))</td>
<td>24 (13 – 30)</td>
<td>22 (18 – 28)</td>
</tr>
<tr>
<td>SUVA</td>
<td>2.5 (1.5 – 3.0)</td>
<td>2.1 (1.5 – 2.6)</td>
</tr>
<tr>
<td>Conductivity ((\mu)S/cm)</td>
<td>615 (536 – 673)</td>
<td>799 (645 – 979)</td>
</tr>
<tr>
<td>Chloride (mg/l)</td>
<td>48 (43 – 51)</td>
<td>98 (66 – 141)</td>
</tr>
<tr>
<td>Sulfate (mg/l)</td>
<td>65 (55 – 76)</td>
<td>86 (76 – 98)</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>1.5 (0.7 – 3.6)</td>
<td>3.4 (0.85 – 9.0)</td>
</tr>
<tr>
<td>Alkalinity (mmol/l)</td>
<td>4.3 (3.4 – 5.0)</td>
<td>4.0 (3.1 – 5.0)</td>
</tr>
<tr>
<td>pH (-)</td>
<td>7.3 – 8.6</td>
<td>8.0 – 8.9</td>
</tr>
<tr>
<td>Chlorofyl ((\mu)g/l)</td>
<td>25 (0.2 – 93)</td>
<td></td>
</tr>
<tr>
<td>Phosphate (mg/l)</td>
<td>0.26 (0.04 – 0.76)</td>
<td>0.72 (0.37 – 1.37)</td>
</tr>
<tr>
<td>(NH_4^+) (mg/l)</td>
<td>0.23 (0.05 – 0.60)</td>
<td>0.48 (0.05 – 1.10)</td>
</tr>
<tr>
<td>Nitrate (mg/l)</td>
<td>7 (1 – 11)</td>
<td>10 (0 – 21)</td>
</tr>
</tbody>
</table>
Kluizen - treatment scheme

Prefiltration → Biological ammonia oxidation → Enhanced coagulation → Flotation → Filtration → Ozonation → Dual stage GAC filtration → Disinfection NaOCl

Prefiltration → Ion Exchange → Biological ammonia oxidation → Enhanced coagulation → Flotation → Filtration → Ozonation → Dual stage GAC filtration → Disinfection NaOCl

Prefiltration → Ion Exchange → Biological ammonia oxidation → Enhanced coagulation → Flotation → Filtration

- 1974
- 2003
- 2008
- 20XX
Contents

• Surface water treatment and DOC at De Watergroep
• 10 years of research on DOC removal
• Fluidized bed IEX combined with coagulation-flotation
• IEX waste water treatment
• Conclusions and ongoing research
10 years of DOC research @ De Watergroep

- Kluizen 2005 – 2007: Miex® contactor-settler – ultrafiltration – ozonation – dual stage GAC filtration (50 m³/h)
10 years of DOC research @ De Watergroep

- Kluizen 2005 – 2007: Miex® contacter-settler – ultrafiltration – ozonation – dual stage GAC filtration (50 m³/h)

IEX
- ✓ DOC removal
- ✗ Miex® patented and expensive
- Foot print
- Resin manipulations

Ultrafiltration
- ✗ DOC removal
- Membrane fouling
10 years of DOC research
@ De Watergroep

• Kluizen 2005 – 2007: Miex® contactor-settler – ultrafiltration – ozonation – dual stage GAC filtration (50 m³/h)
• Kluizen 2011 – 2012: Coagulation / flotation (25 m³/h)
10 years of DOC research @ De Watergroep

- Kluizen 2005 – 2007: Miex® contactor-settler – ultrafiltration – ozonation – dual stage GAC filtration (50 m³/h)
- Kluizen 2011 – 2012: Miex® high rate coagulation / flotation (25 m³/h)

Miex® IEX

- DOC removal
- Foot print
- Miex® patented and expensive Resin manipulations

Coagulation - flotation
- DOC removal
- Stable operation
10 years of DOC research @ De Watergroep

• Kluizen 2005 – 2007: Miex® contactor-settler – ultrafiltration – ozonation – dual stage GAC filtration (50 m³/h)
• Kluizen 2011 – 2012: Miex® high rate – coagulation – flotation (25 m³/h)

• Kluizen 2012 – 2013: Fluidized bed IEX – coagulation – flotation (25 m³/h)
• Blankaart 2015 – present: Fluidized bed IEX – coagulation – flotation (50 m³/h)
  ✓ DOC removal
  Foot print
  Resin manipulations
  Conventional IEX resin
Contents

• Surface water treatment and DOC at De Watergroep
• 10 years of research on DOC removal
• Fluidized bed IEX combined with coagulation-flotation
• IEX waste water treatment
• Conclusions and ongoing research
Kluizen IEX in fluidized bed

Kluizen 2013

- Regeneration system
- Inlet construction
- Conventional IEX resin
Kluizen IEX in fluidized bed

Conclusions Kluizen 2013

• Coagulant dose reduction > 80%
• Improved overall DOC removal efficiency
• Lower mineralisation
• Investment cost compensated by lower operational cost (chemicals, sludge removal)
• Stable operation

• Waste water treatment: coagulation + dewatering
  ⇒ further research towards more sustainable solution
Kluizen IEX combined with flotation
Blankaart IEX in fluidized bed

50 m³/h IEX pilot plant
Blankaart flotation pilot
25-40 m³/h flotation pilot plant
Blankaart pilot – first results

- NPOC raw (mg C/l, left axis)
- Resin dose (ml/l, left axis)
- NPOC Flotation (mg C/l, left axis)
- Coagulant dose (mg Fe/l, right axis)
- NPOC decantation II (mg C/l, left axis)
- NPOC IEX (mg C/l, left axis)
- H2SO4 dose (mg/l, right axis)
## Blankaart pilot – first results

Comparison with results Kluizen

<table>
<thead>
<tr>
<th></th>
<th>IEX</th>
<th>IEX + flotation</th>
<th>Full scale floc removal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NPOC reduction (%)</td>
<td>UV$_{254}$ reduction (%)</td>
<td>NPOC reduction (%)</td>
</tr>
<tr>
<td>Kluizen, IEX 0.5 ml/l</td>
<td>43</td>
<td>68</td>
<td>49</td>
</tr>
<tr>
<td>Blankaart, IEX 0.5 ml/l</td>
<td>37</td>
<td>52</td>
<td>47</td>
</tr>
<tr>
<td>Blankaart, IEX 1.0 ml/l</td>
<td>44</td>
<td>60</td>
<td>52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>NPOC reduction (%)</th>
<th>UV$_{254}$ reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full scale floc removal</td>
<td>41</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>72</td>
</tr>
</tbody>
</table>
Blankaart pilot – first results

• Stable operation
• Coagulant dose reduction > 50%
• No improvement of overall DOC removal efficiency
  at low resin dose (0.5 – 1.0 ml/l)

• Further increase of the resin dose?
  \[\Rightarrow\] larger regeneration vessel
Contents

• Surface water treatment and DOC at De Watergroep
• 10 years of research on DOC removal
• Fluidized bed IEX combined with coagulation-flotation
• *IEX waste water treatment*
• Conclusions and ongoing research
IEX waste water treatment

• Goals
  • Zero liquid discharge
  • Separation of salts and DOC
    • Reuse of salts for regeneration
    • Removal of DOC from the system (as a valuable secondary resource?)
IEX waste water treatment
coagulation & dewatering

• Technologically and economically feasible
• Filtrate can be recycled for brine production
• Filter cake = waste
IEX waste water treatment – alternative treatment scheme

• Goal: DOC concentrate with low salinity
• Nanofiltration + electrodialysis
  • Uncontrolable fouling of NF membranes
IEX waste water treatment – alternative treatment schemes

- Electrodialysis
  - Seems feasible, but significant operational cost
  - Long term behavior? Repeatability experiments
  - Concentration of DOC? e.g. evaporation technique?
IEX waste water treatment – DOC as a valuable end product?

- DOC concentrate as a growth stimulator in agriculture
  - Salts content still too high?
  - Wrong type of DOC components?

- Important to get an idea of the economic value!
  ⇒ DOC characterisation?
  Required desalination level?
Contents

• Surface water treatment and DOC at De Watergroep
• 10 years of research on DOC removal
• Fluidized bed IEX combined with coagulation-flotation
• IEX waste water treatment
• Conclusions and ongoing research
Conclusions so far

Fluidized bed IEX – coagulation – flotation

• IEX
  • Stable operation possible, even during algae blooms
  • Slightly higher NOM removal efficiency in Kluizen compared to Blankaart
• Impact on optimal coagulant dose
  • > 80% reduction in Kluizen
  • > 50% reduction in Blankaart
• IEX pretreatment resulted in higher overall DOC removal efficiency in Kluizen, no improvement (with low resin doses tested so far) at the Blankaart
• Lower mineralisation of treated water
Conclusions so far

IEX waste water treatment

• Coagulation and dewatering
  • Technologically and economically feasible
  • Zero liquid discharge
  • Salts recycled to regeneration process
  • Filter cake = waste

• Alternative treatment strategies
  • Nanofiltration: serious problems with membrane fouling
  • Electrodialysis: feasible at significant operational cost
  • No conclusions so far with respect to economical value of DOC end product
Ongoing research

**IEX**
- Impact of resin dose on DOC removal efficiency and DBP FP
- Impact of regeneration process and brine composition on DOC removal efficiency
- Translation to full scale

**Flotation**
- Optimal coagulant dose and coagulation pH
- Flocculation time and hydraulic loading of flotation plant

**Waste water**
- Economical value of DOC concentrate
- Alternative treatment schemes aimed at valorisation of DOC