The IWVA Torreele water re-use plant: operational experiences 2002-2006

Aachen (Germany), December 14th, 2006

Ultra- and Nanofiltration in Water Treatment
Workshop on ‘Operational experience and research results’
The sandy unconfined dune aquifer is easy to exploit and the natural groundwater is of excellent quality – treatment limited to areation/sand filtration.

Drinking-water produced out of dune aquifer and distributed in the area (60,000 inhabitants).

**Problem:**

- Capacity of phreatic dune aquifer is limited due to presence of salt water north (sea) and south (polder area); overexploitation would cause saline intrusion.
- Dunes are of high ecological interest.
- Touristic activity responsible for variable drinking-water demand e.g. daily consumption in summer can be 2.5 times that of a normal day.

**Solution:**

- Drinking-water is purchased from neighbouring companies.
- I.W.V.A. looked for alternatives for natural groundwater extraction.
SELECTED ALTERNATIVE

**Groundwater recharge combined to water reuse**

- Natural groundwater extraction reduced
- Implemented into ecological management of dunes
- Maximum use of existing infrastructure
- Wastewater treatment plant nearby
- Effluent available all year and of acceptable quality
- Pilot studies proved feasibility: technically and economically
<table>
<thead>
<tr>
<th>History of project</th>
<th>1997-1999, pilot testing using different MF/UF and RO systems on effluent of Wulpen WWTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status of project</td>
<td>Operating since July 2002</td>
</tr>
<tr>
<td>Capacity</td>
<td>2,500,000 m³/year</td>
</tr>
<tr>
<td>Source water</td>
<td>WWTP secondary effluent</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>Prescreen with 1mm slots</td>
</tr>
<tr>
<td>Membranes</td>
<td>UF: Zenon (ZW500C)</td>
</tr>
<tr>
<td></td>
<td>RO: Dow (30LE-440)</td>
</tr>
<tr>
<td>Design flux</td>
<td>UF: max of 40 l/h.m²</td>
</tr>
<tr>
<td></td>
<td>RO: max of 20 l/h.m²</td>
</tr>
<tr>
<td>Biofouling</td>
<td>Chlorine to effluent</td>
</tr>
<tr>
<td>prevention</td>
<td>Monochloramine to UF filtrate</td>
</tr>
<tr>
<td>Scaling prevention</td>
<td>pH adjustment using sulfuric acid</td>
</tr>
<tr>
<td></td>
<td>Antiscalant to UF filtrate</td>
</tr>
</tbody>
</table>
Multiple-barrier approach: membrane filtration selected because of its ability to remove salts and nutrients in one step and because of its smaller footprint and modular concept.

Process scheme of Torreele plant
OPERATIONAL EXPERIENCES
2002-2006
**UF : Choice of process**

Based on experiences during piloting!

**UF:**
- must handle varying quality
- out-to-in filtration
- use of air
- submerged

**Optimal flux:**
maximum of 40 l/h.m² for ZeeWeed

**ZeeWeed from ZENON**

- filtration time: 480 to 600 seconds
- Backwash: 30 seconds
- chlorinated backwash:
every 30 to 35 backwashes
- Maintenance cleaning every month
Experiences with UF

Quality

- Suspended solids and bacteria totally removed
- Organic and nutrient content partly removed (± 10%)
- Ions and smaller compounds, e.g. pesticides are not removed

Quality UF filtrate controlled online by turbidity: UF skid stopped when turbidity is high
Optimalisation of UF-process

Air is used intermittently: it creates turbulence along the membranes avoiding rapid increase of TMP

Negative effect on energy consumption

Use of air is reduced:

- Initially air was induced 50% of time along the membranes
- Changes in program makes it possible to reduce aeration time to 33 or 25% of the time

RESULT:

energy consumption has been reduced

![Energy consumption (in KWh) to produce 1 cubic meter of UF filtrate](image)
**Other changes to UF-process**

- Regular citric acid cleanings are performed since May 2004
  - Probably due to changes in the process at the WWTP iron oxidizes onto the membranes
  - Citric acid is used in a reverse flow of filtration

- Possibility to make filtration period variable: when a certain pressure drop (parameter) is exceeded, backpulse is initiated

RESULT: PREVENTS SHUTDOWN OF INDIVIDUAL UF STREETS

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![Graph showing iron content of cleaning solution after passage over the membranes over time]

- MF3 18/03/2005
- MF3 27/07/2005
- MF3 04/10/2005
- MF3 04/01/2006
- MF3 15/06/2006
- MF3 22/08/2006

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![Graph showing time since start of cleaning procedure (in hours) vs iron content of cleaning solution after passage over the membranes]

- MF3 18/03/2005
- MF3 27/07/2005
- MF3 04/10/2005
- MF3 04/01/2006
- MF3 15/06/2006
- MF3 22/08/2006
**RO : Choice of process**

Low energy membranes from DOW Filmtec

- 2/1 configuration with an initial recovery of 75% using low energy membranes;
- maximum flux of 20 l/h.m²
- Biofouling prevention based on use of chloramines
- Scaling prevention used on pH correction and dosing of scale inhibitor
Bio-fouling prevention

Based on the experience of the pilot tests, ammonia chloride and sodium hypochlorite are dosed to the MF filtrate before entering the MF buffer reservoir:

\[
\text{NH}_4\text{Cl} + \text{NaOCl} \rightarrow \text{NH}_2\text{Cl} \text{ (monochloramine)} + \text{H}_2\text{O} + \text{NaCl}
\]
Scaling prevention

Dosing to the MF filtrate of:
Sulfuric acid (pH adjustment) and scale inhibitor

Dosing of bisulfite (redox controlled) to protect RO membranes
Experiences with RO

Quality

- Constant quality with excellent removal of bacteria, salts, nutrients
- Small organic compounds, e.g. pesticides are removed between 97,6 and 98,6% (comparative tests when pesticides were found into effluent)

Online control of several parameters enabling immediate shutdown if RO fails.

Membrane performance

UF is a good pre-treatment for RO.

Methods chosen for biofouling and scaling prevention proved to be efficient.

Only 4 to 6 additional cleanings needed every year on each RO skid.
Optimalisation of RO-process

• RECOVERY CONTROL
  – Initially 75%
  – Since Sept 2004 recovery is a calculated value according to the conductivity: the lower the conductivity, the higher the recovery
    • Recovery is limited to a maximum of 80%

  RESULT: More efficient use of UF filtrate and chemicals without increasing energy consumption and risk of scaling

• VARIABLE DOSING
  – Since Sept 2004 chloramination is no longer continuous: the dosing interval is adjusted according to the temperature of the water (season of the year)

  RESULT: Use of chlorine and ammoniumchloride decreased significantly
**Evolution of chemical usage at the Torrele plant**

<table>
<thead>
<tr>
<th>Per cubic meter infiltration water produced</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006 (10 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfuric acid (mg/l)</td>
<td>36,8</td>
<td>38,2</td>
<td>38,4</td>
<td>34,7</td>
</tr>
<tr>
<td>Hypochlorite (mg/l)</td>
<td>4,5</td>
<td>4,2</td>
<td>3,8</td>
<td>3,9</td>
</tr>
<tr>
<td>Ammoniumchloride (mg/l)</td>
<td>4</td>
<td>3,8</td>
<td>2,5</td>
<td>2,7</td>
</tr>
<tr>
<td>Antiscalant (mg/l)</td>
<td>2,9</td>
<td>2,4</td>
<td>2,3</td>
<td>2,5</td>
</tr>
<tr>
<td>Sodiumbisulfite (mg/l)</td>
<td>1,5</td>
<td>1,8</td>
<td>1,2</td>
<td>0,9</td>
</tr>
<tr>
<td>Sodiumhydroxide (mg/l)</td>
<td>0,1</td>
<td>10,2</td>
<td>13</td>
<td>11,4</td>
</tr>
</tbody>
</table>
Other changes to RO

• Production
  – To compensate for the loss of UF filtrate in the summer of 2005 every stage was enlarged with an extra 6 membranes (1 PV !)

    RESULT : Higher production capacity

• Energy consumption
  – The diameters of filtrate evacuation pipes were enlarged

    RESULT :
    Gain in energy consumption

|                     | 2003       | 2004       | 2005       | 2006
|---------------------|------------|------------|------------|------
| Energy consumption  | 0,632 KWh/m³ | 0,630 KWh/m³ | 0,628 KWh/m³ | 0,613 KWh/m³ |
| Produced RO filtrate| 1.950.262 m³ | 1.992.480 m³ | 2.165.690 m³ | 2.040.905 m³ |
| Recovery            | 75,0%      | 75,0%      | 76,9%      | 77,0% |
Cleaning strategy for RO

- Return to the procedure that was set up during pilot tests:
  - To remove biofouling alkaline/biocide/alkaline cleanings are alternated;
  - To remove scaling alkaline/acid/alkaline cleanings are alternated.

Products used:

- Alkaline cleaning performed with sodium hydroxide at 35°C (1-2%);
- Acid cleaning with citric acid at 25°C (1-2%);
- Biocide cleaning with commercial product at 25°C (0,02%).

AFTER CLEANING NORMALIZED VALUES STILL RETURN TO INITIAL VALUES
Operational experiences : general

• I.W.V.A. benefitted from experience and knowledge built up during pilot testing
  – Choice of techniques and process
  – Choice of the process
  – Operation of the plant / Problem solving based on experience

• Control of system based online data and additional manual measurements

• Points of concern
  – Cartridge filter
  – Valves
  – Noise
  – Automation
  – Quality : regrowth, sealings, O-rings
  – Concentrate disposal
- Weekly analysis
- Online control of turbidity, pH, conductivity, temperature
- Daily measurements of SDI, conductivity, pH on MF and RO filtrate
- Regular conductivity measurement on every pressure vessel
### Quality of infiltration water produced at the ‘Torreele’ plant

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5,70 – 7,67</td>
<td>6,14 – 7,35</td>
<td>&gt;6,5 and &lt;9,2</td>
</tr>
<tr>
<td>Conductivity (µS/cm)</td>
<td>150 (35 – 262)</td>
<td>43 (7 – 75)</td>
<td>1000</td>
</tr>
<tr>
<td>Chloride (mg Cl/l)</td>
<td>22 (2 – 36)</td>
<td>2,7 (1,5 – 5,1)</td>
<td>250</td>
</tr>
<tr>
<td>Sulphate (mg SO₄/l)</td>
<td>10 (6 – 17)</td>
<td>&lt;1 (&lt;1-1)</td>
<td>250</td>
</tr>
<tr>
<td>Sodium (mg Na/l)</td>
<td>18 (5 – 30)</td>
<td>11 (5,2 – 19,4)</td>
<td>150</td>
</tr>
<tr>
<td>Total hardness (°F)</td>
<td>3,6 (1,8 – 5,8)</td>
<td>&lt;1</td>
<td>40</td>
</tr>
<tr>
<td>Nitrate (mg NO₃/l)</td>
<td>6,9 (1 – 16)</td>
<td>2,4 (&lt;1 – 4,5)</td>
<td>15</td>
</tr>
<tr>
<td>Ammonia (mg NH₄/l)</td>
<td>0,31 (&lt;0,05 – 0,84)</td>
<td>&lt;0,15 (&lt;0,05 – 0,47)</td>
<td>1,5</td>
</tr>
<tr>
<td>Total phosphorous (mg P/l)</td>
<td>0,1 (&lt;0,1 – 0,3)</td>
<td>&lt;0,1</td>
<td>0,4</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>0,9 (0,5 – 2)</td>
<td>&lt;0,2</td>
<td>-</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>Absent</td>
<td>Absent</td>
<td>-</td>
</tr>
<tr>
<td>Metals</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>-</td>
</tr>
<tr>
<td>Pesticides</td>
<td>&lt;0,01 (&lt;0,01-0,2)</td>
<td>&lt;0,01</td>
<td>&lt;0,1</td>
</tr>
</tbody>
</table>
DISCHARGE OF CONCENTRATE

RO-concentrate and MF-concentrate enter the drainage pipe of WWTP Wulpen

<table>
<thead>
<tr>
<th>Average quality of concentrate 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total nitrogen (mg N/l)</td>
</tr>
<tr>
<td>Total phosphorous (mg P/l)</td>
</tr>
<tr>
<td>Suspended Solids (mg/l)</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (mg O₂/l)</td>
</tr>
<tr>
<td>Biological Oxygen Demand (mg O₂/l)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>22,0</td>
</tr>
<tr>
<td>2,5</td>
</tr>
<tr>
<td>13,8</td>
</tr>
<tr>
<td>88</td>
</tr>
<tr>
<td>7</td>
</tr>
</tbody>
</table>

Together with part of effluent that has not been treated it is drained into canal;
This canal drains into the sea

I.W.V.A. is performing tests since November 2003 to look for alternative treatment of concentrates

Monthly monitoring of the canal water does not give an indication of a negative impact of the concentrate discharge
What did we learn so far?

- Strategy for biofouling and scaling prevention proved to be successful;
- More efficiency gained by optimizing the process;
- When reuse is meant for drinking-water production it is safer to use only RO filtrate:
- Quality of RO filtrate is very good and constant / UF good pretreatment for RO.
Cost of water reuse

(given per m³ of infiltration water produced)

Operational cost : ~ € 0,15 / m³
Investment cost : ~ € 0,15 / m³
Maintenance cost : ~ € 0,10 / m³

Concentrate discharge cost : € 0,06 / m³
GROUNDWATER RECHARGE AT ST-ANDRE

18,200 m² surface area
2,500,000 m³/y

112 extraction wells
3,500,000 m³/y

Collection point

30 wells

10 wells

72 wells
EXPERIENCES:

- Groundwater recharge enabled I.W.V.A. to reduce natural groundwater extraction: groundwater levels increased enhancing the natural values.

- Quality of extracted groundwater improved:
  - Lower hardness and salinity;
  - Lower organic content;
  - Less iron and manganese.

- Temperature variation makes water more vulnerable to regrowth: extra UV disinfection was installed prior to distribution. (UV-disinfection of infiltration water was stopped when UF filtrate was no longer part of it.)
# Quality of drinking-water produced at St-André

<table>
<thead>
<tr>
<th>Drinking-water source</th>
<th>2001</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% natural groundwater</td>
<td>31% natural groundwater 69% ‘recaptured’ infiltration water</td>
</tr>
<tr>
<td>pH</td>
<td>7,02 – 7,89</td>
<td>7,55 – 7,98</td>
</tr>
<tr>
<td>Conductivity (µS/cm)</td>
<td>697</td>
<td>327</td>
</tr>
<tr>
<td>Chloride (mg Cl/l)</td>
<td>87</td>
<td>19,0</td>
</tr>
<tr>
<td>Sulphate (mg SO₄/l)</td>
<td>91</td>
<td>24,5</td>
</tr>
<tr>
<td>Sodium (mg Na/l)</td>
<td>45</td>
<td>19,7</td>
</tr>
<tr>
<td>Total hardness (°F)</td>
<td>32,7</td>
<td>14,0</td>
</tr>
<tr>
<td>Nitrate (mg NO₃/l)</td>
<td>&lt;6</td>
<td>1,6</td>
</tr>
<tr>
<td>Ammonia (mg NH₄/l)</td>
<td>&lt;0,4</td>
<td>0,05</td>
</tr>
<tr>
<td>Total phosphorous (mg P/l)</td>
<td>±0,1</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>±5</td>
<td>1,7</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Metals</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
</tr>
<tr>
<td>Pesticides</td>
<td>&lt;0,01</td>
<td>&lt;0,01</td>
</tr>
<tr>
<td>Temperature</td>
<td>12,6</td>
<td>13,5</td>
</tr>
</tbody>
</table>
GENERAL CONCLUSIONS

Water reuse using UF/RO proved feasible: the quality produced is excellent. Combination to groundwater recharge enables a sustainable aquifer management and creates more drinking-water production capacity when mostly needed (in summer).
Reuse

- Will become more important and could solve problems of water scarcity
  - Climate change;
  - Dense populated and arid regions;
  - Depleted and polluted aquifers;
  - Polluted surface water
- Many possible users:
  - Drinking-water supply, agriculture, industrial water, ecological development
- When planning a wastewater treatment, water reuse should be considered immediately
  - Compared to the total investment it is only a minor part;
  - Valorizes investment for wastewater treatment;
  - Also feasible on smaller scales