IL RIUTILIZZO DELLE ACQUE DI SCARICO INDUSTRIALI E CIVILI: LE OPPORTUNITA’ E LE TECNOLOGIE PIU’ RECENTI

Giovedì 14 giugno 2012

Prato

Auditorium del Palazzo dell’Industria

Via G. Valentini, 14
The use of low pressure in-out membranes in industrial and municipal water reuse

- Ultrafiltration Technology –
inge watertechnologies AG
History and Milestones

- Established in 2000
- Based in Greifenberg near Munich, Germany
- Develops, produces and sells innovative UF/MF technology
- 80 employees
- Sales offices in Germany, China, Turkey, UAE
- Market Leader in German speaking countries
- Sales partners in more than 25 countries worldwide
- Drinking water certificates for major water markets
- DIN ISO 9001 certified
INGE MULTIBORE FIBERS

∅ 0.9 mm multibore®
60 m² module

- superior mechanical strength

∅ 1.5 mm multibore®
40 m² module

- no fiber breakages
- maximized operating safety
- minimized maintenance
- robust operation
- OPEX savings

- Fiber material PES:
  - real UF, 4-log retention of viruses
  - chemical cleanings from pH1 up to pH 13 for efficient organics removal
The Multibore Fiber – NO BREAKAGES

3 layer membrane 0,02 µm – 10 µm – 2 µm
SEM: MULTIBORE CROSS SECTION

Area with pore size < 1µm has a width of 3-5 µm

- Foam like structure
- Pores of 1-30 µm
SEM: MULTIBORE OUTER SURFACE

Pore size: 1-5 µm
The Multibore Fiber
IN-OUT FILTRATION – OPERATION MODE
IN-OUT FILTRATION – OPERATION MODE

Filtration mode

Feed

Drain

Filtrate
Backwash mode
Ultrafiltration is the most versatile solution

Ultrafiltration

Ground, Lake and River Water

Sea Water

Waste Water

Municipal Treatment

Industrial Treatment

Local

PoU = Point of Use
PoE = Point of Entry
## Selected Large References

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity (m³/h)</th>
<th>Type</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>4,600</td>
<td>Sea Water</td>
<td>Industry</td>
</tr>
<tr>
<td>Abu Dhabi</td>
<td>3,500</td>
<td>Sea Water</td>
<td>Steel works</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>2,400</td>
<td>Sea Water</td>
<td>Drinking Water</td>
</tr>
<tr>
<td>Ukraine</td>
<td>2,000</td>
<td>Surface Water</td>
<td>Chemical Industry</td>
</tr>
<tr>
<td>Germany</td>
<td>1,250</td>
<td>Pool Water</td>
<td>Recreation Industry</td>
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<tr>
<td>China</td>
<td>1,200</td>
<td>Waste Water</td>
<td>Petrochemical Industry</td>
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<td>Italy</td>
<td>980</td>
<td>Sea Water</td>
<td>Power Industry</td>
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<tr>
<td>China</td>
<td>900</td>
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<tr>
<td>Switzerland</td>
<td>800</td>
<td>Surface Water</td>
<td>Drinking Water</td>
</tr>
<tr>
<td>Germany</td>
<td>600</td>
<td>B/w Water</td>
<td>Drinking Water</td>
</tr>
</tbody>
</table>
TERTIARY WASTE WATER TREATMENT WITH UF

Increasing necessity of waste water effluent treatment
- feed water availability
- lower costs in comparison to sea water desalination
- increasing environmental pressure to treat effluent
- increasing global population

Applications
- purified effluent before discharge
- re-use: irrigation
  - process water for industrial use
  - direct drinking water production
WATER TREATMENT WITH UF

Increasing necessity of waste water effluent treatment
- Feed water availability
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- Increasing environmental pressure to treat effluent
- Increasing global population

Applications
- Purified effluent before discharge
- Re-use: irrigation
- Process water for industrial use
- Direct drinking water production
Los Angeles Times: The accepted scientific explanation of summer fish die-offs involves the oxygen-depleting combination of sun and salt. Salt water carries less oxygen than fresh water; hot water carries less oxygen than cool water. When the sea's increasingly briny water heats up in summer temperatures that can reach 125 degrees, fish begin to suffocate.
inge System Design  Version: 1.0.0.27

Calculated by: Maggie
Company: Inge GmbH
Customer: GIDA S.p.A.
Project name: Purifast
Project number:
Pre-treatment: Prefilter < 300μm

Remarks: municipal waste water with high influence of waste water of textile industry

Water type: WNTP effluent
Turbidity: 10 NTU
DOC: 8 ppm
Module type: Lacher XL 0.7 MB 60
Rack type: T-Rack vario
Modules per rack: 30
Number of racks: 12
Total number of modules: 600
Total membrane area: 36000 m²

Max. feed flow: 2486.4 m³/h
Average feed flow: 2331.6 m³/h
Filtrate flow: 2100 m³/h
Recovery: 90.1%
Gross flux: 69.1 L/m²h
Net flux: 59.3 L/m²h

Design per rack

Max. feed flow: 2073 m³/h
Average feed flow: 194.3 m³/h

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Revision
# Financial Assessment – inge UF (Estimation)

<table>
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<tr>
<th>UF treatment</th>
<th>industrial scale plant KING Color</th>
<th>Industrial scale plant GIDA</th>
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<tr>
<td>Flux [l/m²h]</td>
<td>60</td>
<td>60</td>
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<tr>
<td>Flow [l/h]</td>
<td>30000</td>
<td>2100000</td>
</tr>
<tr>
<td>Membrane surface [m²]</td>
<td>640 (=16*40)</td>
<td>36720 (=612*60)</td>
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<tr>
<td>Number of modules [ - ]</td>
<td>16</td>
<td>612</td>
</tr>
<tr>
<td>CEB Intervall [1/d]</td>
<td>3*acid</td>
<td>1<em>caustic+2</em>acid</td>
</tr>
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<td>Chemical price [€/L]</td>
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<td>0,46</td>
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<tr>
<td>Chemical consumption [L/m³]</td>
<td>0,034+0,006</td>
<td>0,002+0,009+0,006</td>
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<tr>
<td>Chemical costs per m³ [€/m³]</td>
<td>0,018</td>
<td>0,008</td>
</tr>
<tr>
<td>Energy price [€/kWh]</td>
<td>0,12</td>
<td>0,12</td>
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<tr>
<td>Energy consumption [kWh/m³]</td>
<td>0,035</td>
<td>0,032</td>
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<tr>
<td>Energy costs per m³ [€/m³]</td>
<td>0,0042</td>
<td>0,0038</td>
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<tr>
<td>Membr. replacement per m³ [€/m³]</td>
<td>0,018</td>
<td>0,012</td>
</tr>
<tr>
<td>Total price per m³ [€/m³]</td>
<td>0,040</td>
<td>0,025</td>
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</tbody>
</table>
COST FACTORS IN-OUT VERSUS MBR

**Cost 1000m³ filtrate: Inge UF**

- Membrane repl. cost
- Chemical total cost
- Energy cost
- Real Estate cost
- Ancillary cost
- Membrane cost

**Cost 1000m³ filtrate: Submerged**

- Membrane repl. cost
- Chemical total cost
- Energy cost
- Real Estate cost
- Ancillary cost
- Membrane cost

Inge UF: Flux 60LMH, Coagulation 1.5ppm

Submerged MBR: Flux 20LMH, Blower Energy 0.4kWh/m³
Drinking water
MÄNNEDORF – SURFACE WATER
MÄNNEDORF, SWISS – SURFACE WATER

- Capacity: 800 m³/h
- Application: drinking water
- Contractor: WABAG Switzerland
- Technical Data: 164 dizzer 5000
  - 4 trains, each equipped with 41 elements
  - max. flux rate 110 lmh. No chemical cleaning apart from a daily chlorine CEB

Remarks:

Diagram:

```
Ozone

Activated Carbon Filter

UF

Strainer
```
ROETGEN – BACKWASH WATER TREATMENT OF A PRIMARY STAGE UF (RESERVOIR WATER)
ROETGEN – BACKWASH WATER TREATMENT OF A PRIMARY STAGE UF (RESERVOIR WATER)

- **Capacity:** 630 m³/h
- **Application:** backwash water, >100NTU
- **Contractor:** Veolia, Krüger WABAG Germany
- **Technical Data:**
- **Remarks:**
  - 234 dizzer 5000 SB
  - 3 trains, each equipped with 78 elements
  - Flux rate 90 l/m²h
  - Recovery > 98% (only UF 2)
  - CEB every 3-14 days (caustic pH 12 / acid pH 2)
  - No chlorine necessary
  - Overall recovery > 99.6%
  - (CEB waters are not treated)
Pretreatment RO Waste Water Reuse
RECLAMATION OF MUNICIPAL WASTEWATER FOR A PETROCHEMICAL COMPLEX, CHINA

- **Capacity:**
  - Phase 1: 270 m³/h (2005)
  - Phase 2: 1212 m³/h (2009)

- **Application:**
  - RO Pre-treatment

- **Contractor:**
  - Georgi Water Treatment, Dasmart

- **Enduser:**
  - China National Petrochemical Group

- **Technical Data:**
  - Phase 1: 82 dizzer5000, 2 trains, each equipped with 41 elements
  - Phase 2: 416 dizzer5000plus, 8 T-Racks, each equipped with 52 elements

- **Remarks:**
  - Flux at approx. 72 l/m²h, daily chlorine CEB,
  - CIPs expected 1-2 per year after first 6 months in operation
Reclamation of Municipal Wastewater for a Petrochemical Complex (Phase II – T-Rack)
TERTIARY WASTE WATER - CAPITAL BEIJING AIRPORT - CHINA

- **Capacity:** 600 m³/h (2008)
- **Application:** RO Pretreatment
- **Contractor:** Beijing E&E Technologies Co., Ltd
- **Technical Data:** 192 dizzer5000plus, 3 trains, each equipped with 64 elements
- **Remarks:** flux approx. 70 l/m²h, recovery > 90%

**UF feed water:**
- COD < 60 ppm
- BOD < 20 ppm
- TSS < 20 ppm
- Fe < 0.4 ppm
Case Study – Textile Industry India

Capacity: 120 m³/h
Application: RO Pretreatment (100% reuse)
Contractor: KPR Mills Limited
Technical Data: 60 dizer XL MB 1.5,
4 trains, each equipped with 15 elements,
1 train in standby for compensation of
worse water qualities
Remarks: flux approx. 71 l/m²h,
recovery ~ 89%
UF feed water:
- Temp.: 25 – 35°C
- TSS: 10 - 100 mg/l
- Turbidity: 10 - 100 NTU
- COD: 297 mg/l
- BOD: 25 mg/l
- Cond.: 12 mS/cm
Pretreatment RO
Seawater Desalination
SEAWATER - TORREVALDALIGA - ITALY

Capacity: 980 m³/h (2008)
Application: RO Pretreatment
Contractor: Termomeccanica
Technical Data: 372 dizzer5000plus, 6 trains, each equipped with 62 elements flux approx. 78 l/m²h, recovery > 90%
Remarks: 2/day Chemical Enhanced Backwash (CEB) 5ppm
SEAWATER - ABU DHABI

Capacity: 1200 m³/h (2009)
Application: RO Pretreatment
Contractor: Bernadinello
Technical Data: 410 dizzer5000plus, 5 trains, each equipped with 82 elements
Remarks: flux at approx. 72 l/m²h,
Pool application

Ruhstorf (pool) - circulation water approx. 240 m³/h
Bad Aibling - 90 modules
The authors like to thank the European Community under Contract LIFE 07 ENV/IT/000439 in the Life+ programme for funding.
Thank you for your attention!
# Tertiary waste water treatment with UF
- Eching, wwtp Germany -

## Feed water quality

<table>
<thead>
<tr>
<th>Plant size</th>
<th>Serving</th>
<th>90.000</th>
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<tbody>
<tr>
<td>Design flow (dry weather)</td>
<td>m³/d</td>
<td>11.700</td>
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<tr>
<td>Secondary effluent water analysis</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>15</td>
</tr>
<tr>
<td>BOD$_5$</td>
<td>mg/l</td>
<td></td>
</tr>
<tr>
<td>DOC</td>
<td>mg/l</td>
<td></td>
</tr>
<tr>
<td>SAK254</td>
<td>mg/l</td>
<td>8</td>
</tr>
<tr>
<td>tot P</td>
<td>mg/l</td>
<td>0,3</td>
</tr>
<tr>
<td>NH$_4$-N</td>
<td>mg/l</td>
<td></td>
</tr>
<tr>
<td>Plate count 20°C</td>
<td>KBE</td>
<td></td>
</tr>
<tr>
<td>Plate count 36°C</td>
<td>KBE</td>
<td></td>
</tr>
<tr>
<td>Total coliformes</td>
<td>KBE</td>
<td></td>
</tr>
<tr>
<td>E-coli</td>
<td>KBE</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>12</td>
</tr>
<tr>
<td>Conductivity @ 20°C</td>
<td>µS/cm</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>2</td>
</tr>
</tbody>
</table>
### Tertiary waste water treatment with UF - Operational Parameters -

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulant dosing</td>
<td>mg/l</td>
<td>3.0 - 5.0 Al</td>
</tr>
<tr>
<td>Flux</td>
<td>l/(m²h)</td>
<td>70 - 85</td>
</tr>
<tr>
<td>Filtration cycle</td>
<td>min</td>
<td>60</td>
</tr>
<tr>
<td>TMP during filtration</td>
<td>mbar</td>
<td>400 - 1000</td>
</tr>
<tr>
<td>Backwash flux</td>
<td>l/(m²h)</td>
<td>230</td>
</tr>
<tr>
<td>Backwash duration</td>
<td>s</td>
<td>30-45</td>
</tr>
<tr>
<td>TMP during backwash</td>
<td>mbar</td>
<td>2500 - 3000</td>
</tr>
<tr>
<td>CEB</td>
<td></td>
<td>1/d caustic+acid</td>
</tr>
<tr>
<td>Recovery</td>
<td>%</td>
<td>&gt; 96</td>
</tr>
</tbody>
</table>
Tertiary waste water treatment with UF
- Performance improvement by inline coagulation -

Why inline coagulation?

- dissolved organics are partially coagulated
  - less organic fouling on UF
  - less fouling on RO or other process steps downstream

- coagulated flocs produce a porous fouling layer which is more easily backwashable

- increases UF performance - maximizes flux and recovery

Optimized inline coagulation shows:

- slower TMP rise

- better backwash effectivity (> 99%)

- higher flux

- higher recovery (>>90% compared with 85%)

- less CEBs

- better filtrate quality (SDI, COD, P)
Tertiary waste water treatment with UF
- Inline coagulation-efficiency -

Graph showing:
- Transmembrane Pressure (TMP) in mbar on the vertical axis.
- Flux in l/m²h on the horizontal axis.

Comparison between:
- Coagulation using 5 mg Al/l with contact time: 7s.
- No coagulation.
- Coagulation using 5 mg Al/l with contact time: 60s.

Graph notes:
- CEB Caustic/Acid

Legend:
- TMP
- Flux
Filtrate Quality

- SDI UF filtrate + coagulation
- SDI UF filtrate

- DOC UF filtrate + coagulation
- DOC UF filtrate

- P UF filtrate + coagulation
- P UF filtrate
Filtrate Quality

- CSB: 35 [mg/l], 43% reduction
- BSB5: 20 [mg/l], 62% reduction
- DOC: 5 [mg/l], 36% reduction
- Pgesamt: 0.6 [mg/l], 92% reduction
- NH4 - N: 0.77 [mg/l], 14% reduction
Content

1. Tertiary waste water treatment with UF (Eching)
2. Cost estimation
3. Investigation on UF operation as pre-treatment before RO at Sde Teiman(ReSeRO)
4. Potential for membrane improvements with BASF
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1. Tertiary waste water treatment with UF (Eching)
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4. Potential for membrane improvements with BASF
UF as pre-treatment before RO

ReSeRO: investigation of different RO pretreatments in pilot stage

Pre-treatment options:
1. Coagulation + Ultrafiltration + RO
2. Biofiltration + Coag. + Ultrafiltration + RO
3. Biofiltration + Ultrafiltration + RO
4. Biofiltration + RO
**inges’ goals in ReSeRO:**

- Influence of different pore sizes of UF/MF on the RO (UF, MF, smaller UF)
- Filtrate quality optimized coagulation and its behavior on the RO
- UF optimized coagulation for stable operation (minimum amount where operation is still stable) and its influence on RO
- Influence of bio-filtration as a pre-filter before UF and its behavior on the RO
### Ultrafiltration [weeks]

<table>
<thead>
<tr>
<th>Coagulation Dosing</th>
<th>UF 100kDa</th>
<th>MF 0.2µ</th>
<th>UF 50 kDa</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c_{\text{coag}}) = minimum</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>(c_{\text{coag}}) = ideal</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

### Biofiltration + Ultrafiltration [weeks]

<table>
<thead>
<tr>
<th>Coagulation Dosing</th>
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<th>UF 50 kDa</th>
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<tbody>
<tr>
<td>(c_{\text{coag}}) = minimum</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>(c_{\text{coag}}) = ideal</td>
<td>4</td>
<td>4</td>
<td>4</td>
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</tbody>
</table>

### Ultrafiltration [weeks]

<table>
<thead>
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<th>UF 100kDa</th>
<th>MF 0.2µ</th>
<th>UF 50 kDa</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c_{\text{coag}}) = 0 + PAC</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>(c_{\text{coag}}) = ideal + PAC</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
UF as pre-treatment before RO

50kDa Multibore®
UF as pre-treatment before RO

DOC Fractions detected by LC-OCD
UF as pre-treatment before RO

**Biopolymers**

- UF 100kDa
- UF 50kDa

**Humics**

- UF 100kDa
- UF 50kDa

<table>
<thead>
<tr>
<th>UF 100kDa</th>
<th>UF 50kDa</th>
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</thead>
<tbody>
<tr>
<td>82.2%</td>
<td>84.6%</td>
</tr>
<tr>
<td>98.0%</td>
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</tbody>
</table>
Standard inge UF, 0.9 mm Multibore

TMP [mbar]  Permeability 20°C  Flux [l/m²h]

Date/Time

0.58 ppm Fe³⁺, 30 min
0.58 ppm Fe³⁺, 40 min
0.67 ppm Fe³⁺, 45 min
0 ppm Fe³⁺, 45 min