THE CURRENT USE OF HOLLOW FIBRE ULTRAFILTRATION AS PRE-TREATMENT FOR REVERSE OSMOSIS
Membrane Processes

• Lower Pressure Membrane Processes
  ◊ Microfiltration (UF)
  ◊ Ultrafiltration (MF)

• Higher Pressure Membrane Processes
  ◊ Nanofiltration (NF)
  ◊ Reverse Osmosis (RO)
Membrane Configurations

• Open Feed Channel Configuration
  ◊ Tubular
  ◊ Hollow- Fibre

• Narrow Feed Channel Configuration
  ◊ Spiral (Flat Sheet)
Tubular Membrane System
Spiral Membrane Elements
Spiral Membrane System
Hollow Fibre Membrane Cartridge
Hollow Fibre Membrane Cartridge

**Year 1990**

5 inch (diameter) x 43 inch (length)
Membrane Area = 82 ft² (7.6 M²)
Nominal Capacity = 4.8 gpm (1.1 M³/h)

**Year 2000**

8 inch (diameter) x 72 inch (length)
Membrane Area = 544 ft² (50.5 M²)
Nominal Capacity = 32.1 gpm (7.3 M³/h)

**Year 2003**

10 inch (diameter) x 72 inch (length)
Membrane Area = 871 ft² (80.9 M²)
Nominal Capacity = 51.4 gpm (11.7 M³/h)
Hollow Fibre Membrane Stage
Hollow Fibre Membrane System
Hollow Fibre Packaged System
Membrane Processes Compared to Conventional Treatment

• Membrane processes produce consistent and high quality filtrate regardless of feed water quality

• Membrane processes have smaller footprint

• Membrane processes are fully automated to allow remote operation and minimum operator support.

• Membrane processes have comparable costs to conventional pretreatment depending on the feed water quality and site specific conditions
Surface Water
Feed Vs Filtrate NTU – UF Pilot Plant

Flux (gpm)
Feed Turbidity
Permeate Turbidity
Open Inlet Seawater
Feed Vs Filtrate SDI – UF Pilot Plant

Permeate Turbidity, NTU
Feed SDI
Permeate SDI

Time on Stream, hours

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Hollow Fibre Membrane Compared to Spiral Membrane

• Hollow fibres have open feed channels
• Spiral membranes have narrow feed channels
• Hollow fibres can be backflushed
• Spiral membranes can not be backflushed
Case Studies

Wastewater Reclamation and Reuse

• Tangshan Steel Works
  ◊ Abandoned Coal Mine Wastewater
• Chennai Petroleum Corporation Limited (CPCL)
  ◊ Municipal Wastewater
• CAPCO
  ◊ CPI Wastewater/Cooling Tower Blowdown
• Caoyang Steel Company
  ◊ Cooling Tower Blowdown
Project Incentives

5 Year Program - Industry Water Saving

• Water Law - 2002
• Industries regulated to conserve and reuse water
• City water and ground water sources used for the operation of the existing steel production plant
• Existing water sources not available for expansion of the steel production plant
• Wastewater from abandoned mine was available for expansion of the steel production plant
Project Background

Description of Wastewater
• Water collected in abandoned coal mine
• Rainwater, groundwater and mine leachate
• High in suspended and dissolved solids

Use of Reclaimed Water
• Steel Manufacturing Operations
• Boiler Makeup Water
Wastewater Treatment

Integrated Conventional and Membrane

• Conventional
  ◊ Coagulation, Flocculation, Sedimentation

• Membrane
  ◊ Ultrafiltration (UF)/Reverse Osmosis (RO)
  ◊ Ultrafiltration System Production Capacity
    ▪ 680 m³/h (4.3 MGD)
  ◊ Reverse Osmosis System Production Capacity
    ▪ 500 m³/h (3.2 MGD)

• Ion Exchange Polishing
Ultrafiltration System

Description

• Purpose
  ◊ Reduce suspended solids and turbidity

• Process Arrangement
  ◊ Three parallel cartridge racks
  ◊ Single pass/Circulation (SS > 30 mg/liter)

• UF Cartridges
  ◊ 8 inch x 72 inch pressure cartridges
  ◊ Inside to outside permeate flow direction
  ◊ 3 trains x 46 cartridges = 138 cartridges (total)
  ◊ 50.5 m² (544 ft²) membrane area per cartridge
Reverse Osmosis System

Description

• Purpose
  ◦ Reduce hardness and dissolved solids

• Process Arrangement
  ◦ Three parallel trains

• RO Elements
  ◦ TFC Membrane
  ◦ 8 inch x 60 inch (long) elements
  ◦ 108 elements per train (18/9 array)
  ◦ 324 total element
  ◦ 54 m² (575 ft²) per membrane element
Operating Data

Ultrafiltration System

- Flux = 85 lmh (50 gfd)
- Feed Pressure = 0.5 – 2.0 bar
- Backwash Frequency = 30 minutes
- CIP frequency = 4 to 8 weeks
- Feed Water Turbidity = 14 NTU (average)
- Product Water Turbidity = < 0.5 NTU
- Product Water SDI < 2.0
Operating Data

Reverse Osmosis System

- Flux = 30 lmh
- Feed Pressure = 9.5 bar (1st array)
- Feed Pressure = 8.4 bar (2nd array)
- CIP frequency > 6 months
- Product Water Conductivity = 4.5 - 10.0 µS/cm
Summary

Integrated UF/RO membrane treatment of coal mine wastewater has been successfully used to provide a high quality, reliable and secure water source where no other practical water source was available for the expansion of the Tangshan Steel Works.
## Operating Data

### Process Stream Description

<table>
<thead>
<tr>
<th>Process Stream</th>
<th>Turbidity (NTU)</th>
<th>SS (ppm)</th>
<th>Conductivity (µS/cm)</th>
<th>SDI&lt;sub&gt;15&lt;/sub&gt;</th>
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<tr>
<td>1 Raw Water</td>
<td>50 - 500</td>
<td>250</td>
<td>450-800</td>
<td></td>
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<tr>
<td>2 UF Feed</td>
<td>7 - 50 Average 14</td>
<td>10-50</td>
<td>450-800</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>3 RO Feed</td>
<td>ND</td>
<td>ND</td>
<td>450-800</td>
<td></td>
</tr>
<tr>
<td>4 RO Product</td>
<td>ND</td>
<td>ND</td>
<td>4.5-10.0</td>
<td></td>
</tr>
</tbody>
</table>
Wastewater Treatment

Integrated Conventional and Membrane

• Site: CPCL, Chennai, Tamil Nadu, India
• Start-Up: December 2004
• Feed Water: Secondary Clarified Municipal Wastewater
• Product Water: Process and Cooling Tower Makeup Water
• UF Pretreatment: Coagulation, Media Filter and Cartridge Filter
Wastewater Treatment

CPCL

- **Ultrafiltration System**
  - Capacity: 430 m³/hr (2.7 MGD)
  - Cartridges: 10 inch x 72 inch (80.9 m²/cartridge)
  - Configuration: 6 x 18 (108 cartridges)

- **Reverse Osmosis**
  - Capacity: 320 m³/h (2.0 MGD)
  - Elements: 8 inch x 40 inch TFC
  - Configuration: 4 trains (14/7) = 504 elements total
Wastewater Treatment

Integrated Conventional and Membrane

• Site: Caoyang Power, Liao Ning Province, China
• Start-Up Date: December 2004
• Feed Water: Cooling Tower Blowdown Water
• Product Water: Boiler Makeup Water
• Pretreatment: Fibre Filter
Wastewater Treatment

Caoyang Power Company

• Ultrafiltration System
  ◦ Capacity: 160 m³/hr (1.0 MGD)
  ◦ Cartridges: 10 inch x 72 inch (80.9 m²/cartridge)
  ◦ Configuration: 2 x 16 (32 cartridges)

• Reverse Osmosis System
  ◦ Capacity: 120 m³/hr (0.75 MGD)
  ◦ Elements: 8 inch x 40 inch TFC
  ◦ Configuration: 2 trains (9/5) = 168 elements total
Wastewater Treatment

Integrated Conventional and Membrane

- Site: CAPCO, Kaoshing, Taiwan
- Start-Up Date: June 2001
- Feed Water: Biologically Treated CIP Organic Wastewater, Cooling Tower Blowdown Water
- Product Water: Process and Cooling Tower Makeup Water
- Pretreatment: Coagulation, Carbon, Media Filter, Cartridge Filter
Wastewater Treatment

CAPCO

- Ultrafiltration System
  ◊ Capacity: 375 m³/hr (2.4 MGD)
  ◊ Cartridges: 6 inch x 48 inch (11.2 m²/cartridge)
  ◊ Configuration: 5 x 110 (550 cartridges)

- Reverse Osmosis System
  ◊ Capacity: 275 m³/hr (1.7 MGD)
  ◊ Elements: 8 inch x 40 inch TFC
  ◊ Configuration: 6 trains (6/3) = 324 elements total
Conclusions

• Integrated conventional and membrane processing for reclamation and re-use is used on a variety of wastewaters.
• Hollow Fibre UF provides a consistent and high quality filtrate for spiral RO.
• Feed water quality and consistency, and site conditions will determine the project economics.