2004 Water deficiency

Source: Seckler et al, 2002
Driving Forces for Water R&D

Need for Water

Global need, Industry, Agriculture, Remote Locations, Desertification, Etc.

Cost Difference - (Industry/Urban - Agriculture)

Cost Difference - (Thermal Processes - Membrane Processes)

Technologies for Export
Desalination Sites

Large plants:

600 Mm³/y by 2013
750 Mm³/y by 2020

Hadera (100+)
Ashdod (100)
Palmahim (30)
Brackish inland (50)
Ashkelon (100)
Ktziot (3)

Tenders - BOOT projects for 25 years
Eilat Plants

Sabha A: 25,500m³/day BW
Sabha B: 10,000 BW
Sabha C: 10,000 SW

RDL GWRI Technion
Increasing Brackish Water Desalination Efficiency

EILAT DESALINATION COMPLEX

Year


Recovery [%]

Specific energy consumption [kWh/m³]

1978 49.5% 4.2 kWh/m³

2003 79% 1.7 kWh/m³
Operational Experience:

Saving on chemicals.

Eilat plants
100,000,000 M3/year
The Filtration Spectrum

Relative Size of Common Materials

Micrometers (Log Scale)
- Ionic Range
- Molecular Range
- Macro Molecular Range
- Micro Particle Range
- Macro Particle Range

Angstrom Units (Log Scale)
- Approx. Molecular Wt. (Saccharide Type No Scale)
- 10
- 100
- 1000
- 10,000
- 100,000
- 1,000,000
- 10,000,000

Relative Size of Common Materials:
- Aqueous Salts
- Albumin Protein
- Carbon Black
- Paint Pigment
- Bacteria
- Tobacco Smoke
- Milled Flour
- A.C. Fine Test Dust
- Granular Activated Carbon
- Sand
- Pollen
- Human Hair
- Mist

Process For Separation:
- REVERSE OSMOSIS (Hyperfiltration)
- ULTRAFILTRATION
- NANOFILTRATION
- MICROFILTRATION
- PARTICLE FILTRATION

Notes:
- 1 Micron (1x10^-6 Meters) = 4x10^-4 Inches (0.00004 Inch)
- 1 Angstrom Unit = 10^-10 Meters = 10^-10 Micrometers (Microns)

Osmonics

Corporate Headquarters
5951 Clearwater Drive, Minnetonka, MN 55343-8995 USA
Phone (612) 933-2277, Fax (612) 933-0141, Toll Free (800) 848-1750
http://www.osmonics.com

Asia/Pacific Headquarters
Bangkok, Thailand
Fax 811-66-2-39-18183

Euro/Africa Headquarters
Le Mee Sur Seine
(Paris), France
Fax 01-1331-10-7474

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Picometer 10^-12 m Femtometer 10^-15m ...
Significant membrane properties

Main Characteristic properties:

- Selectivity
- Permeability
- Mechanical stability (creep and compaction)
- Chemical Stability (Hydrolytic stability, Organic material stability, pH, Microbial resistance, Cl₂ attack, etc.

- Surface anti-fouling properties
  - Phtalates, cellulose acetate, Chlorine in water, NaOH in cleaning,

Initial fluxes reduction, suspended materials and precipitants (CaCO₃, CaSO₄, SiO₂, CaF₂, SrSO₄, BaSO₄, etc.)

Membrane thickness, Permeability, rejection, Size, size distribution Anti-fouling treatment Catalitic reactivity.
Expensive product, 50/50 mm. A tool for production of the cheapest product on Earth, 5-6 m²

The RO cellulose acetate asymmetric membrane developed Loeb-Sourirajan in the middle 60. The thickness of the active layer is reduced since while improvement of surface properties.
Spiral Wound Membranes

membranes thickness-200 nm and down.

Holes size and size distribution, membrane properties
Bio-Fouling

Figure 2. Dissected membrane with a fouled inner layer and a clean outer layer. The outer layer is bleached.

Figure 3. Bacterial growth around fibers of the membrane spread out on

the cluster *Pseudomonas mendocina* – alkaligenes – *Pseudoalkaligenes* – *stutzeri* – *balearica*; phenotypically most related to *P. mendocina*. However, the percent DNA homology with the *P. mendocina* type species was only 49%. Therefore, the isolate is related to *P. mendocina* but cannot be assigned to this species.
Man made polluted waters: Industrial, agriculture and urban effluents

Modern Sewage Treatment

Secondary treatment → Straining → Micro/Ultra-Filtration → Adsorption → Sludge/solids treatment → Energy → Compost

MBR → Concentrate disposal → Reverse-Osmosis or Nano-Filtration → Polishing
Prof. Moris eizen
Performance of new membranes

Rejection of CaCl2 0.1% by different membranes

<table>
<thead>
<tr>
<th>Membrane type</th>
<th>Commercial Polysulfone sulfonated membrane</th>
<th>Patent Polysulfone carboxylated membrane</th>
<th>Laboratory Polysulfone carboxylated membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (bar)</td>
<td>10</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Flux (L/hr*m^2)</td>
<td>500</td>
<td>2100</td>
<td>2200</td>
</tr>
<tr>
<td>Rejection (%)</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>
Module view and sampling

Prof. Carlos Dozoretz
# Energy usage in Desalination - comparison

<table>
<thead>
<tr>
<th>Subject</th>
<th>Gas</th>
<th>Gasoil</th>
<th>Heavy fuel</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caloric value Kcal/Kg fuel</td>
<td>9000</td>
<td>10750</td>
<td>10000</td>
<td>7700</td>
</tr>
<tr>
<td>Caloric Value Kwh$_e$/Kg fuel</td>
<td>10.5</td>
<td>12.5</td>
<td>11.6</td>
<td>9</td>
</tr>
<tr>
<td>Electricity production (45% eff.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kwh$_e$/Kg fuel large Power station</td>
<td>4.7</td>
<td>5.6</td>
<td>5.2</td>
<td>4</td>
</tr>
<tr>
<td>Electricity production (80% eff.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High efficiency gas turbine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kwh/Kg fuel</td>
<td>8.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity - Seawater Desal (50% Recovery) m3/ kg fuel</td>
<td>1.3</td>
<td>1.6</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>80% efficiency</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption/ ton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desalinated water Kg fuel /m3</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>80% efficiency</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many km can I drive with 1 m3 Desal water fuel consumption?</td>
<td>2-7</td>
<td>2-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many hours of AC - single room (2.5 Kw-h) can I operate?</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Household Energy Consumption

Electricity, transportation and desalinated water...

A small family, consumes water at a rate of 18 m³/month, 1200 KWh of electricity/month, Drives 1500 km/month, consumes 160 liter gasoil/month

Energy consumption assuming only desalinated seawater used - 140 KWh/month (fuel value)

Energy consumption - driving a car - 1500 KWh/month (fuel value)

Energy consumption - electricity - 1200/0.45=2667 KWh/month (fuel value)

Energy for desalination/ energy for transportation - 9.3%
Energy for desalination/ energy for electricity - 2.6%
Energy for desalination/ total energy consumption - 3.4%

Can we save 3.4% in our household energy consumption?

Where we should put our energy for use? In water? In high energy consuming cars? In overused AC?
Desalination and proper water usage

Other costs should be included besides Energy

• Cost of water in negligible for regular household
• Cost of water is tolerable for most industries
• Cost of water is significant in agriculture

Make better usage of water:

– Use of greenhouses
– Use Drip-Irrigation – save 30-90% of water consumption by other irrigation techniques – reduce the cost problem
Pushing the Limits of Desalination
Reduction of RO desalination process costs

Main directions for reducing desalination costs
Membrane improvement
Permeability, rejection, resistance to fouling
Concentration polarization - Flow
Improvement of membrane modules
Fouling and scaling prevention
Optimization of the water recovery level
The boron problem
Pretreatment – MF, UF etc.

Energy aspects
Concentrates - Environmental
Process optimization

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