3-8-2017

Optimizing the regeneration process parameters for forward osmosis to produce clean water at low temperature

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OPTIMIZING THE REGENERATION PROCESS PARAMETERS FOR FORWARD OSMOSIS TO PRODUCE CLEAN WATER & POWER AT LOW TEMEPRATURE

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Separations Technology IX: New Frontiers in Media, Techniques, and Technologies
Albufeira, Portugal, Mach 5-10, 2017

March 8, 2017

Key Global Challenges (F.E.W)

- Water
- Energy
- Food

- Highest international priority is to ensure & safeguard a sustainable & secure supply of safe Food, Water and Energy, globally.

QEERI's Vision to Qatar Water & Energy Security

Innovation is solving tomorrow's problem today!

Research Drivers

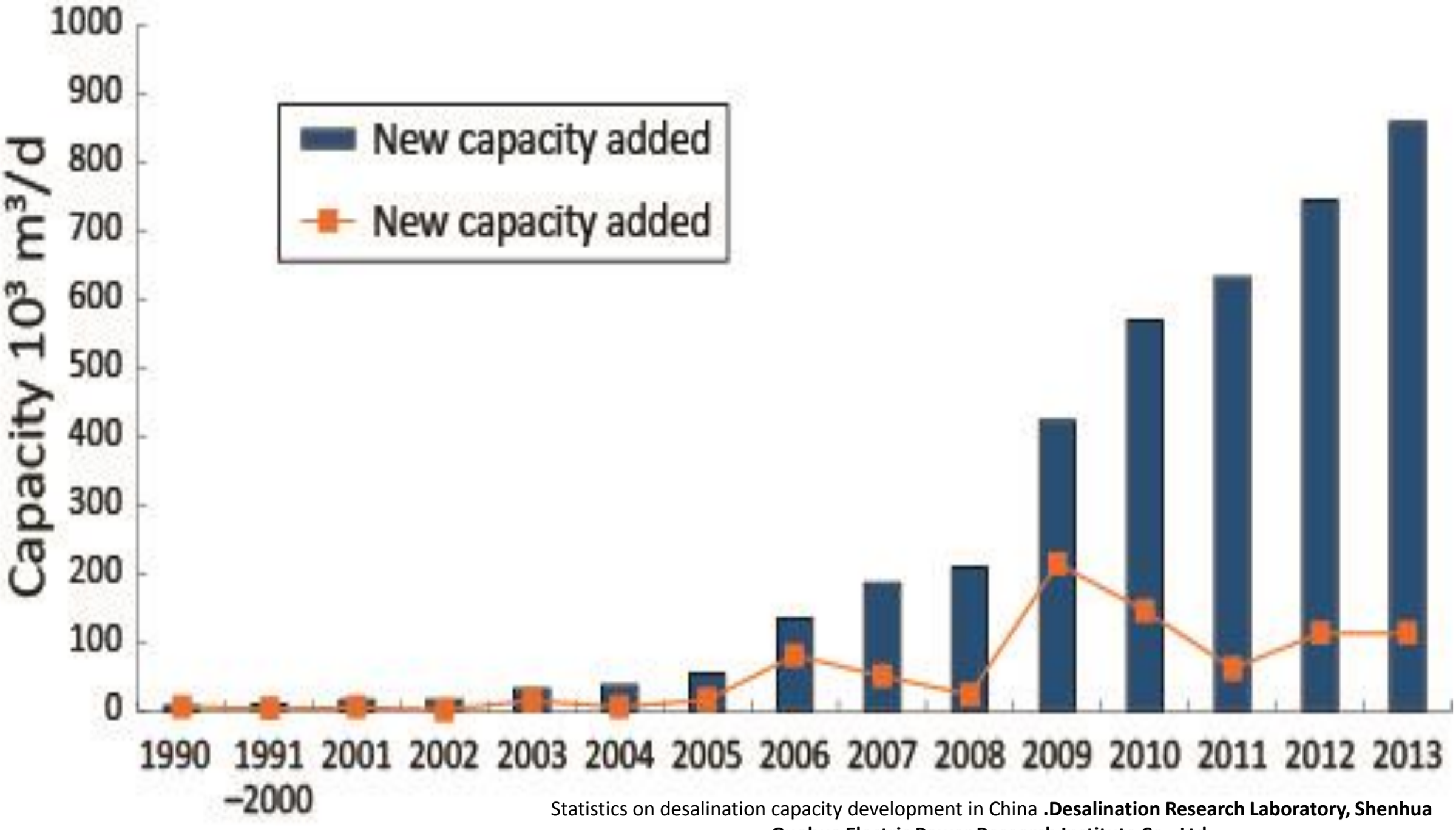
Energy Efficiency, quality, cost, environmental impacts and sustainability

❑ Step change (Innovation, breakthrough)

✓ New Processes (novel technologies)

✓ New Materials for membranes & electrodes

Today’s Desalination Industry



Statistics on desalination capacity development in China **.Desalination Research Laboratory, Shenhua Guohua Electric Power Research Institute Co., Ltd.**

Comparison of parameters in three main desalination technologies

Main Technical Parameters	MED	MSF	SWRO
Raw water pre-treatment	Low requirement	Low requirement	Very high
Operating temperature (°C)	<70	<120	Ambient
Raw water utilization efficiency	15–40%	12–25%	35–40%
Product quality in TDS (mg/L)	5–10	5–10	300–500
Main energy source	Vapor, electricity	Vapor, electricity	Electricity

Ref. Desalination Branch of China Water Enterprises Confederation. (2013). 2012–2013 China desalination annual report

CO2 Emission and Climate Change

Desalination is only 0.2% of the world's energy consumption in 2013*.

CO2 emission **RO ≈ 2.4-3.6 kg/m3 ; thermal 8-20 kg/m3***

(small globally; large locally)

Solutions:

- ✓Retrofitting existing plants with more efficient technologies
- ✓Power new desalination plants by RE sources
- ✓Replacing fossil fuel based Desal plants with RE sources

*MIT workshop on Low Carbon Desalination, 17 Oct. 2016

A Technology Roadmap for Low-Energy (Cost) Desalination

Current
4 – 5.0 kWh/m3

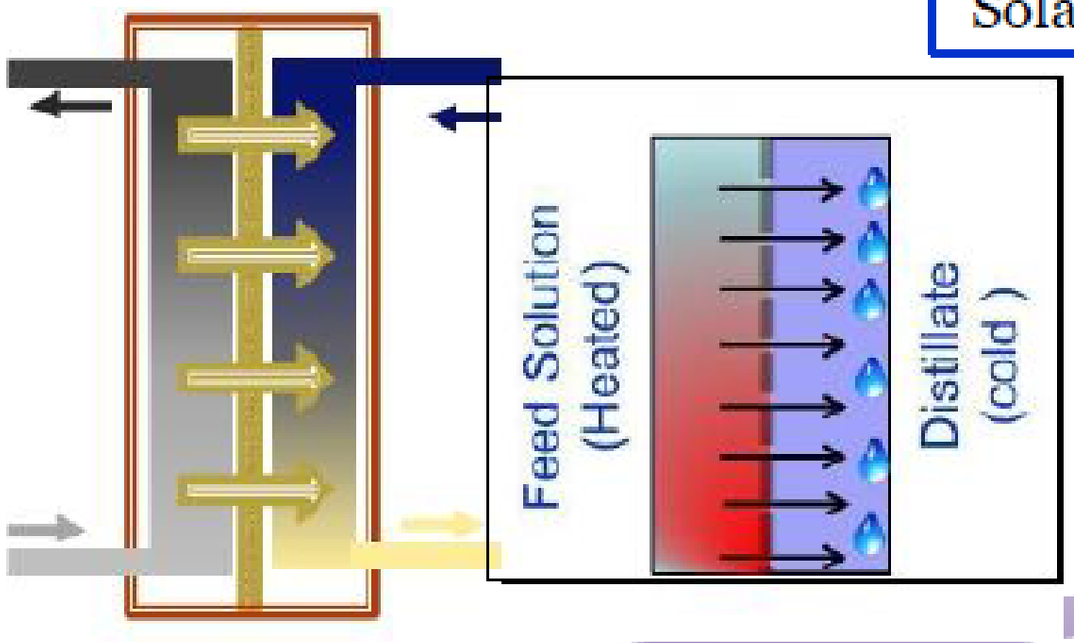
Near Horizon
< 2.0 kWh/m3

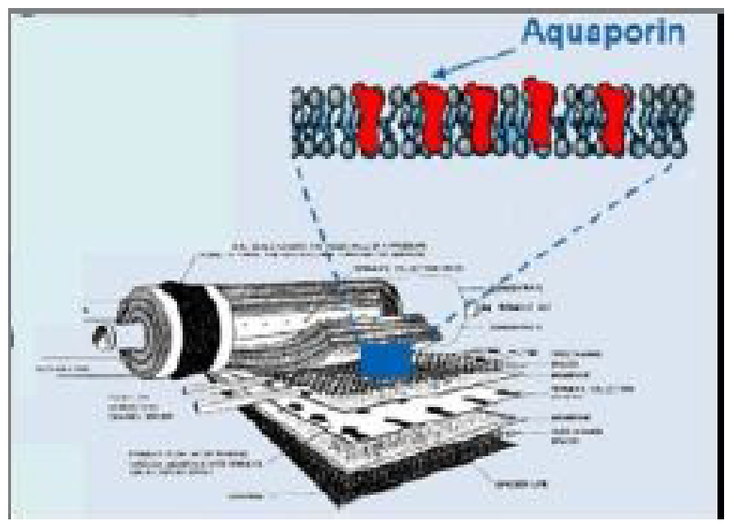
Far Horizon:
Approach
1.0 kWh/m3

- Seawater Reverse Osmosis (SWRO)

- Forward Osmosis (FO)
- Membrane Distillation (MD)
- Adsorption Desalination (AD)

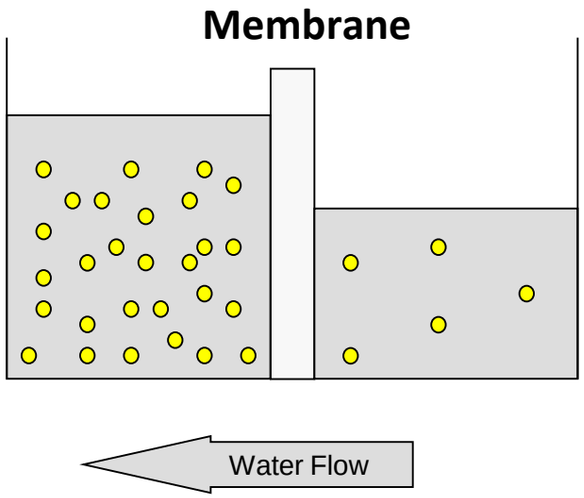
- Microbial Desal. Cell (MDC)
- Microbial Osmotic FC (MOFC)
- Heat stable Aquaporin Membrane Coupled to Non-conventional Solar Energy Generation





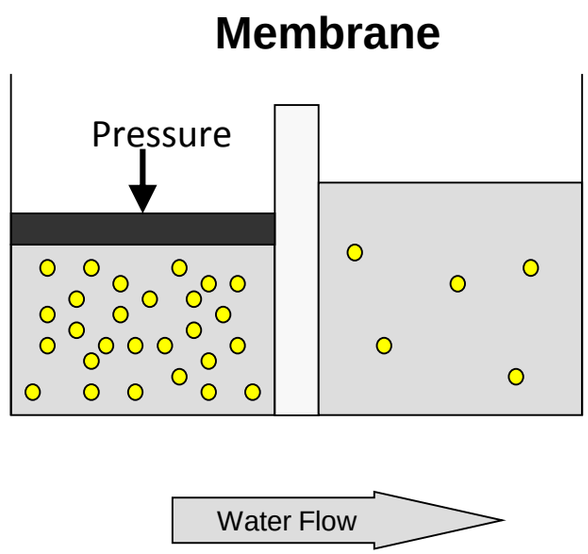
Osmosis and Reverse Osmosis

Forward Osmosis



Water diffuses naturally through membrane from low concentration side to high concentration side

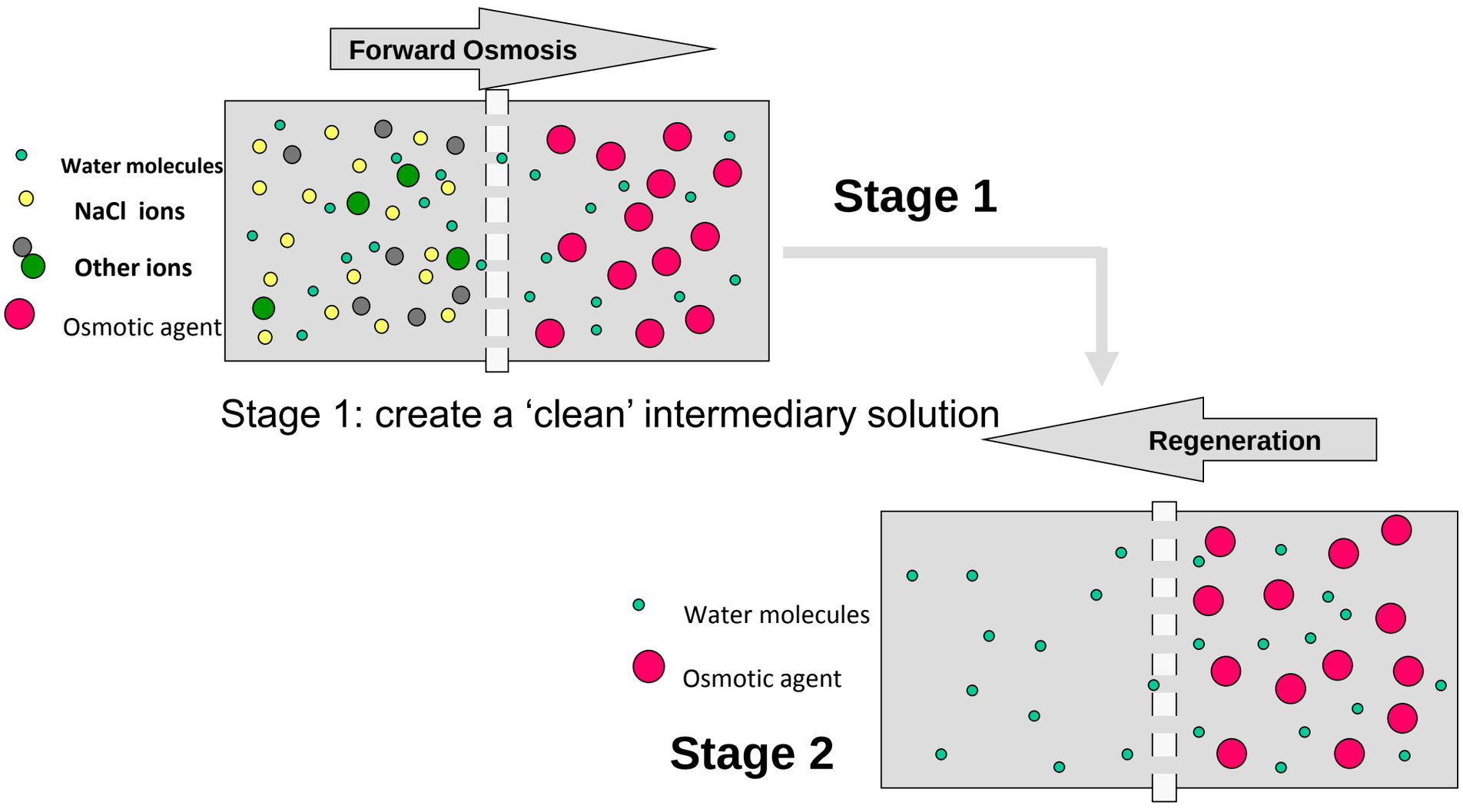
Reverse Osmosis



Pressure is applied to concentrated solution to overcome osmotic pressure and force water through the membrane from the high concentration side to the low concentration side

Forward Osmosis Desalination

Two stage process



Stage 1: create a ‘clean’ intermediary solution

Sharif and Al-Mayahi, US Patent US 7,879,243; & European Patent EP1,651,570.

Royal Society Funded FO Pilot Plant (2006)

Modern Water Desalination Proving Plant

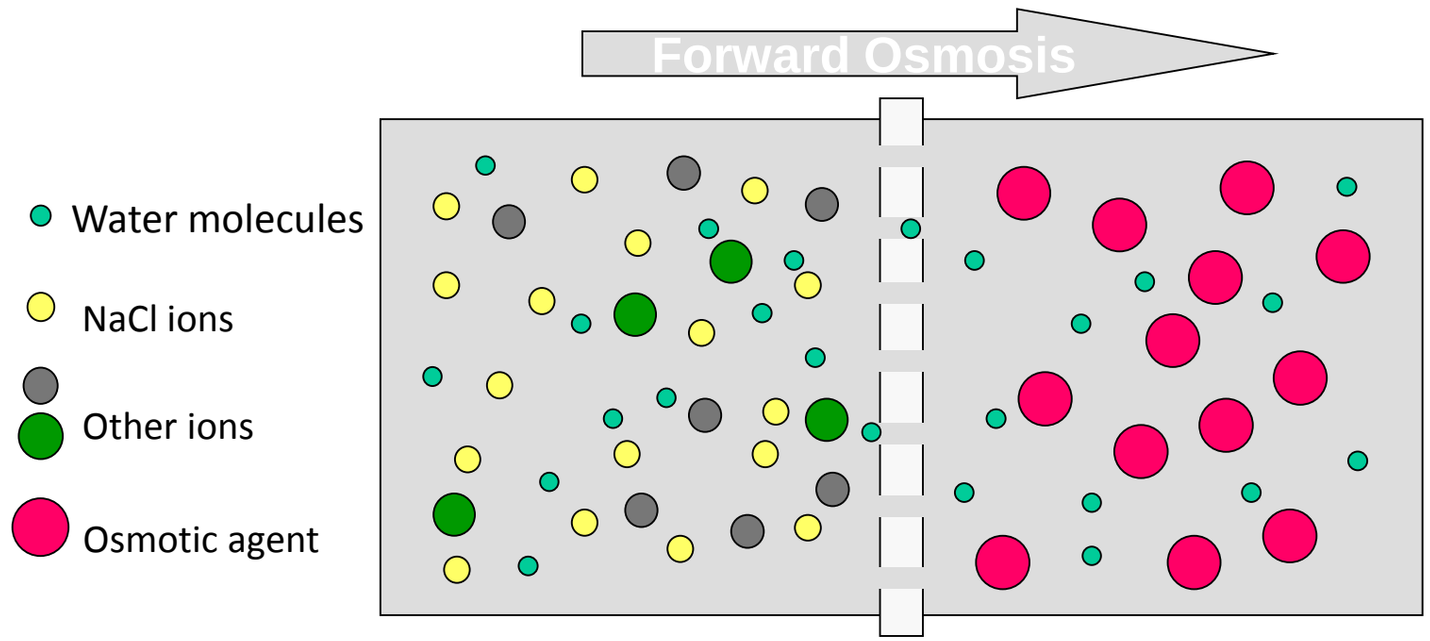
(Gibraltar, March-2009)

Low Grade Heat FO Desalination Process

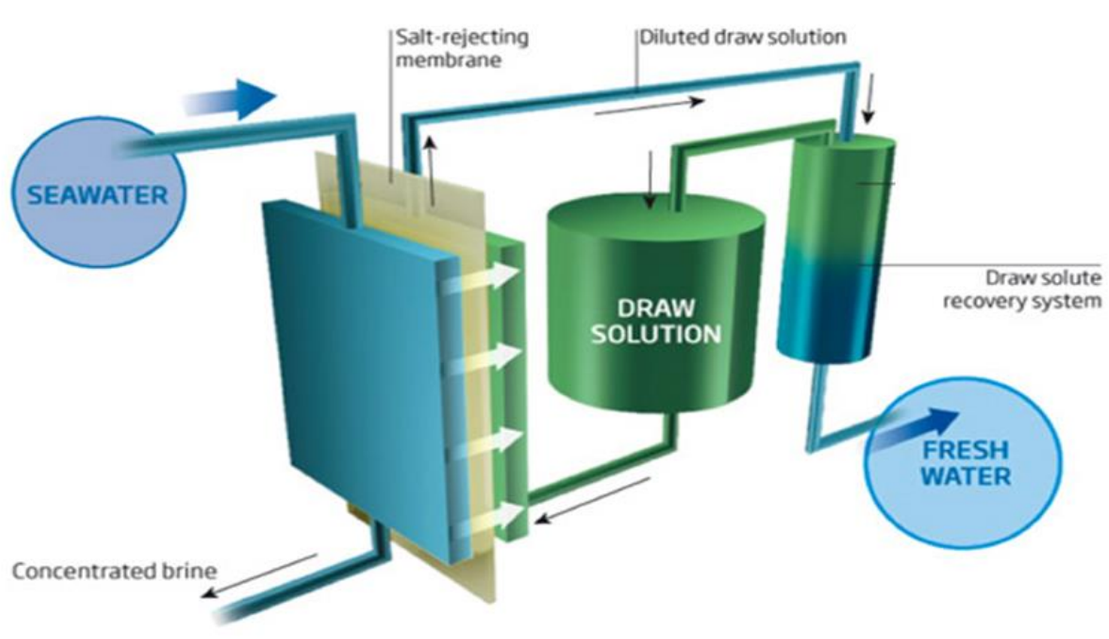
- Low Grade Heat FO desalination and WT process has been invented (UK patent Apl. GB 1403883.0) using low boiling point draw solutions with heat regeneration at a temperature <40 C)

- Using specifically designed carbon based FO membrane.

- Using direct contact Heat Transfer technique for smaller footprint and higher energy recovery efficiency.

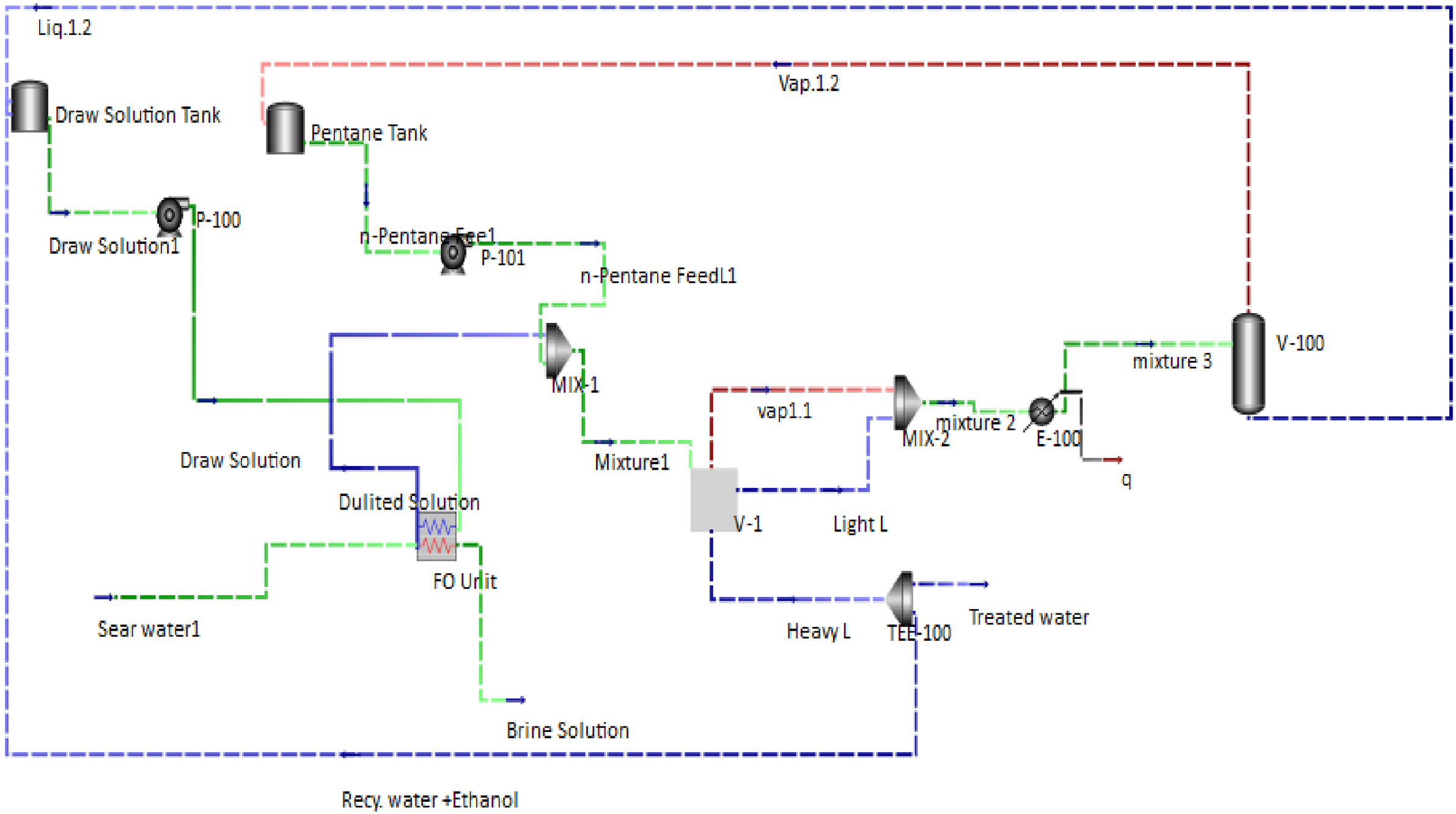


Stage 1: create a 'clean' intermediary solution



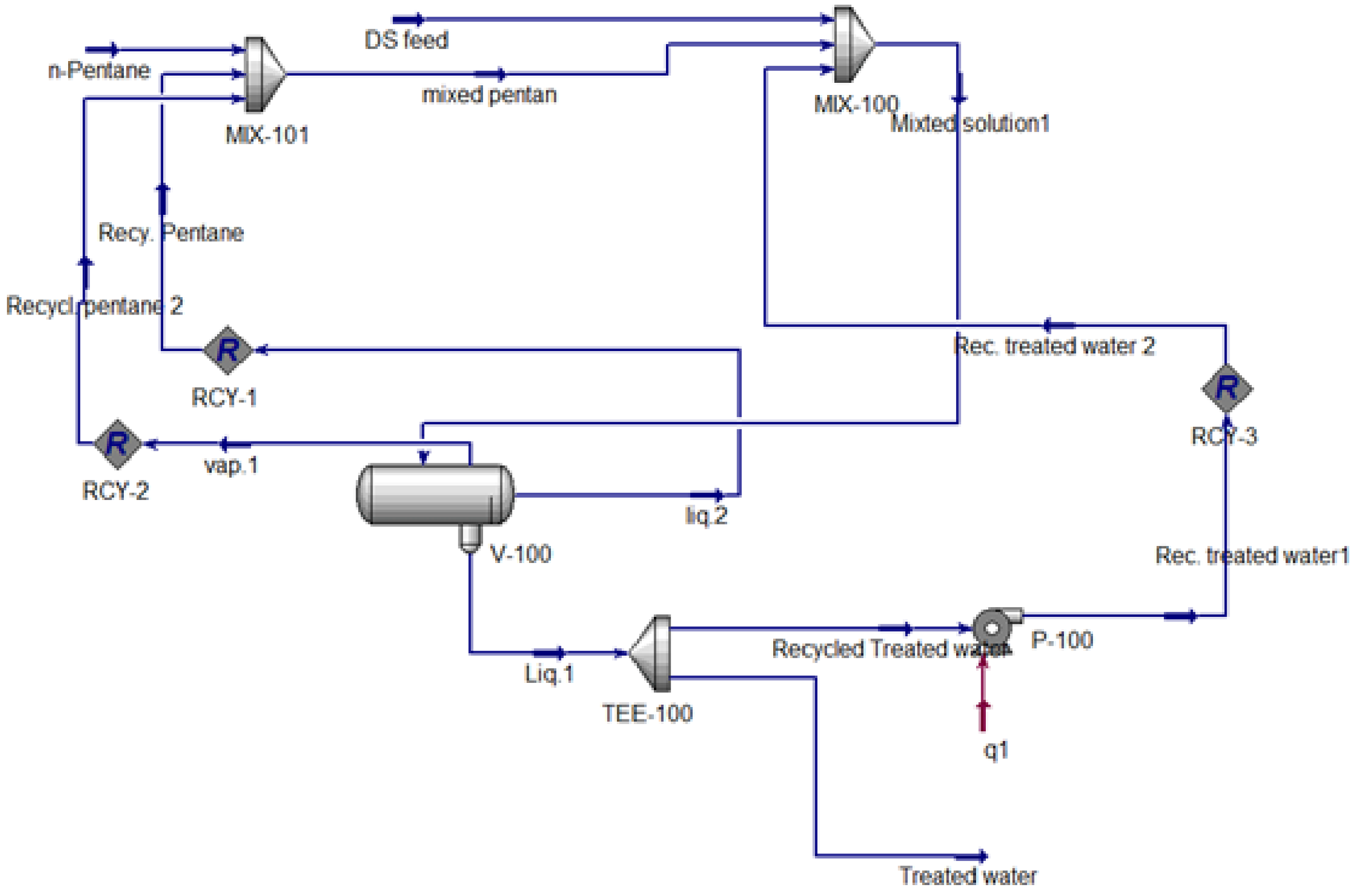
Regeneration of the Draw Solution at a temp <40 C

Projected specific energy consumption (thermal) about 2.75 kWh/m3

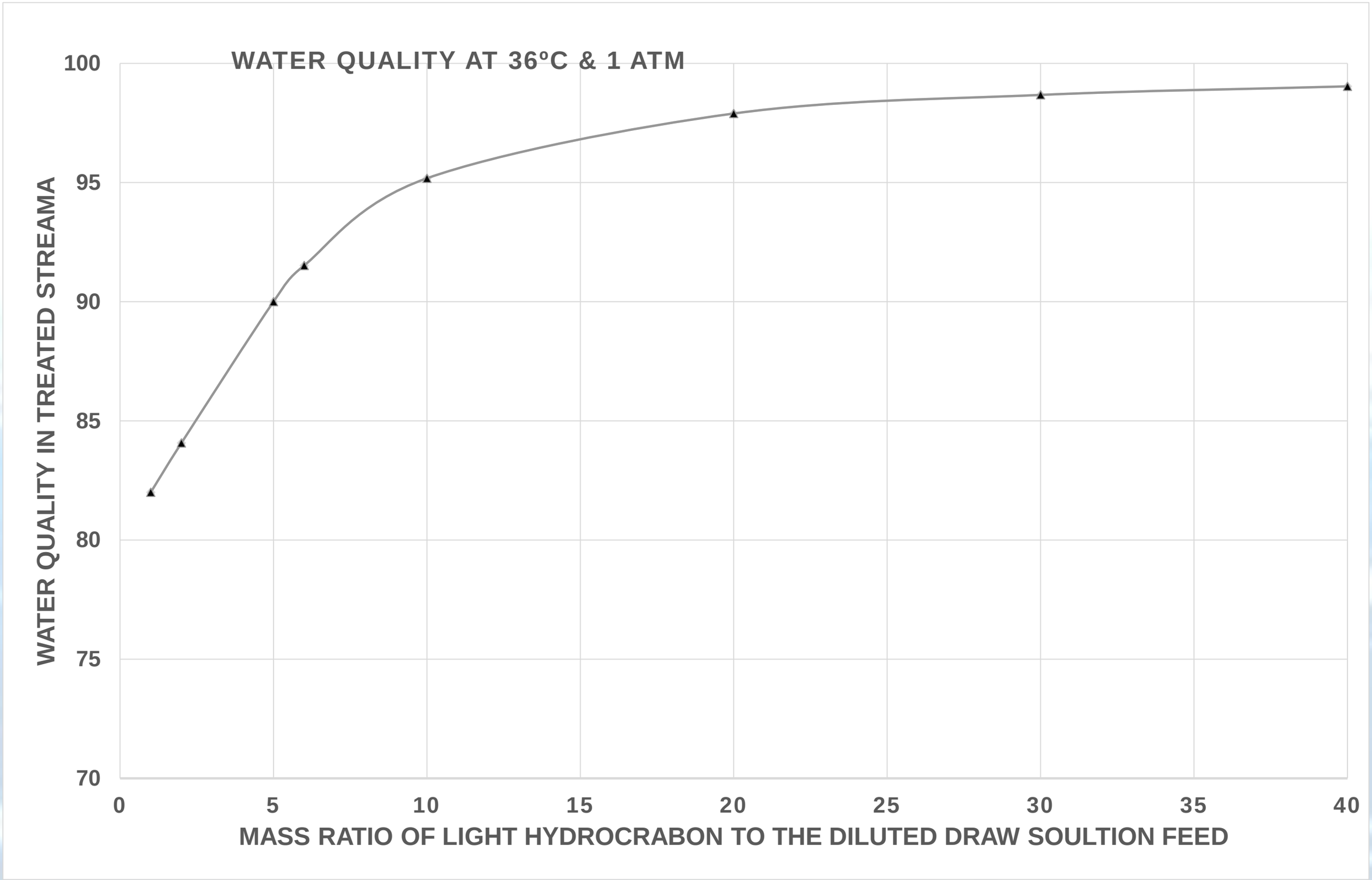


Ethanol cannot be obtained through simple distillation from an ethanol water mixture because of an azeotrope..
Here we will introduce azeotropic distillation using n- Pentane as entrainer .

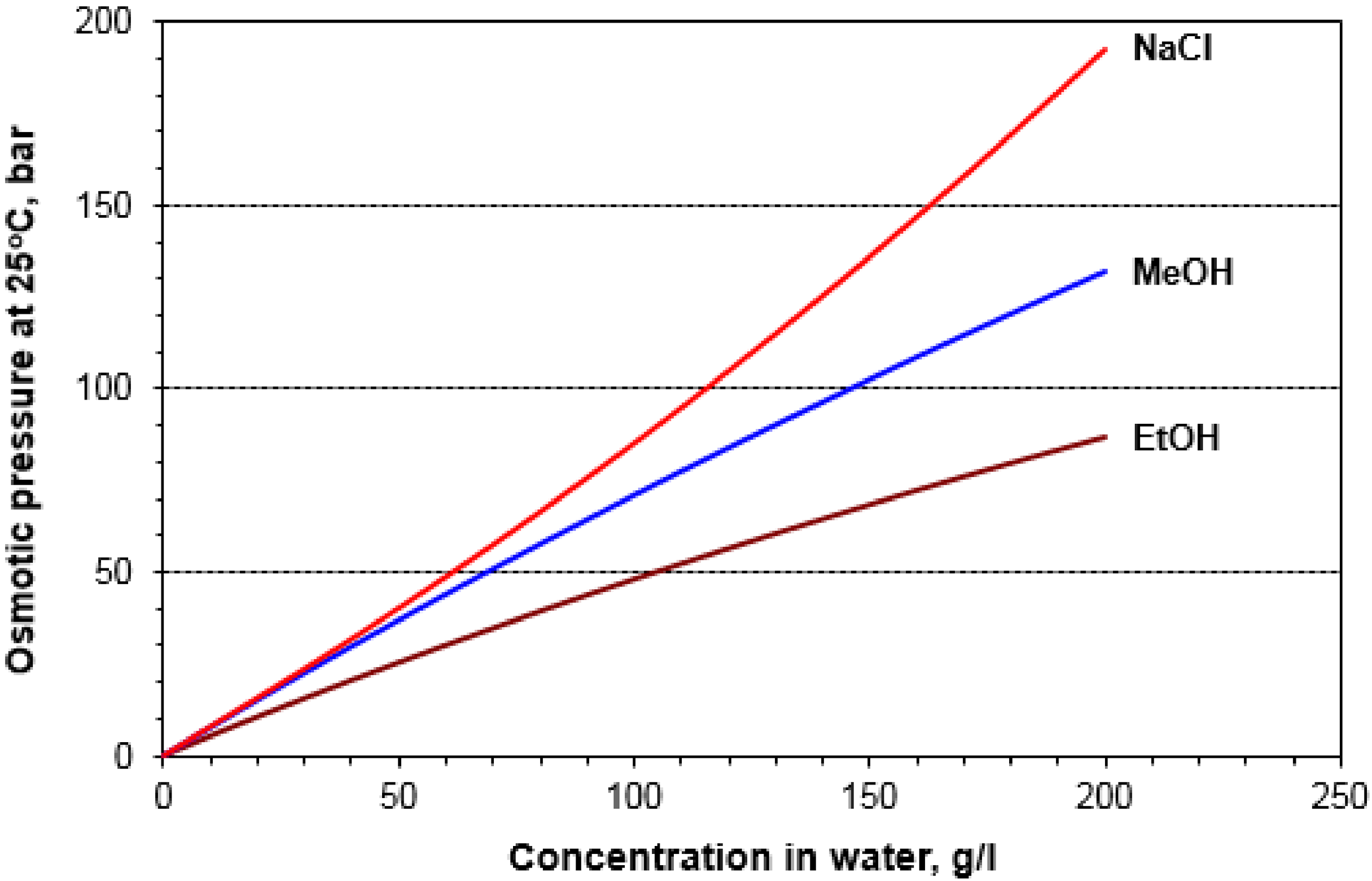
Optimum Regeneration Process for Ethanol as Draw Solution in FO system



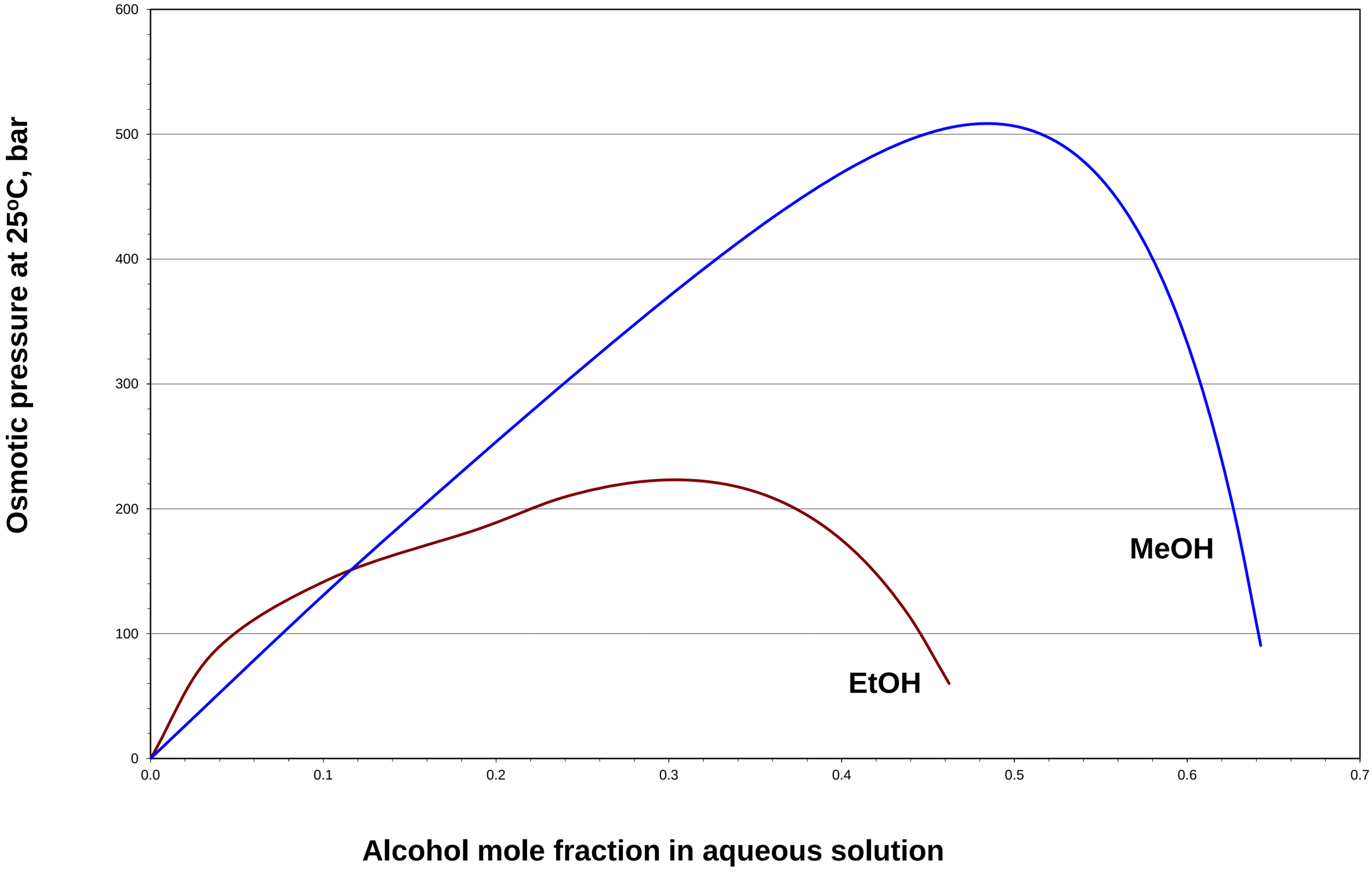
Water quality to mass ratio of light hydrocarbon to the diluted draw solution feed at 36°C and 1atm



Ethanol, Methanol & NaCl Osmotic Pressure



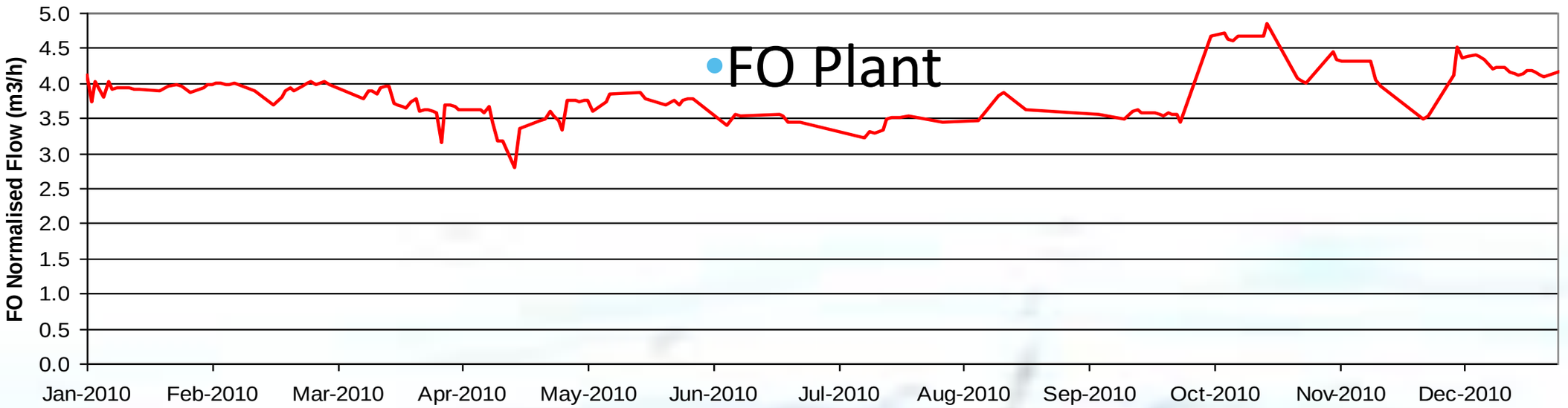
Ethanol and Methanol Osmotic Pressure

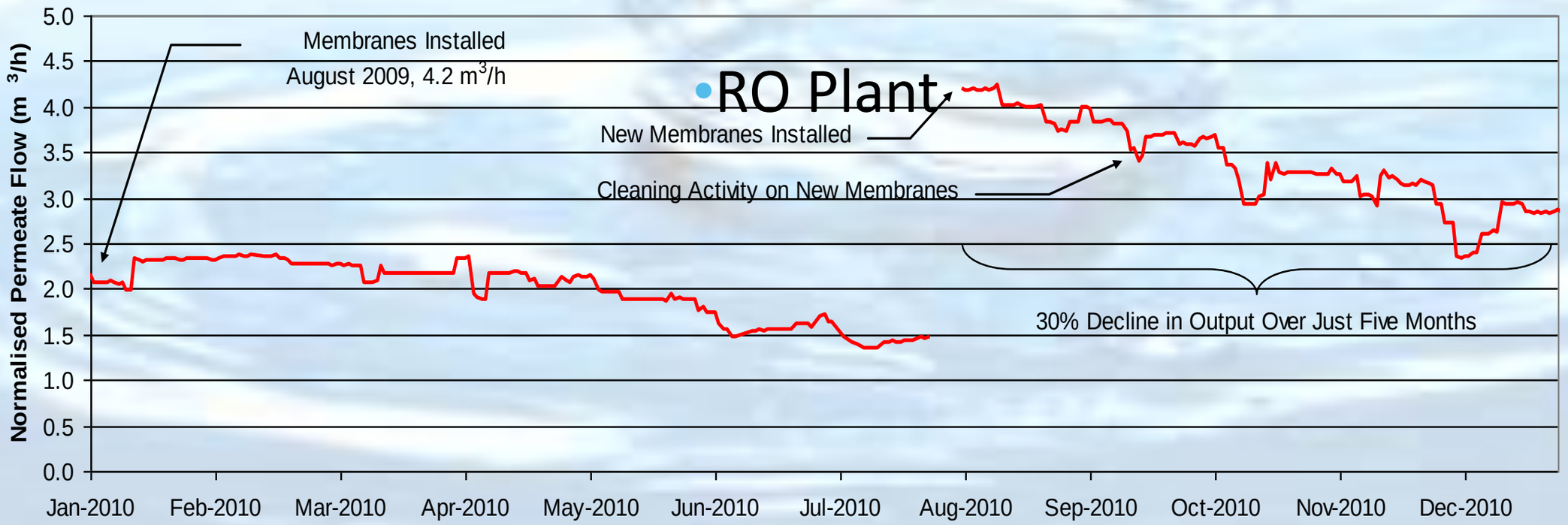


Forward Osmosis World's 1st Commercial Plant

(Oman, Al-Khuluf, Nov-2009)

Normalised Flow





Source: Thompson N & Nicoll P 'Forward Osmosis Desalination: A Commercial Reality', Proceedings IDA World Congress, Perth, Western Australia, September 2011

Benefits of FO Technology

- Significant energy savings
- Minimizes discharges back to the environment
- Lower levels of boron without additional treatment
- Reduced chemical consumption

- Reduced carbon footprint
- Reduced OPEX and CAPEX
- More sustainable and cost effective alternative to traditional systems

Acknowledgments

مؤسسة قطر
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الصندوق القطري لرعاية البحث العلمي
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PUBLIC AUTHORITY FOR ELECTRICTY & WATER
" With electricity we progress & water gives us life "

bp

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medicor foundation
Liechtenstein

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Thank you