# Green Desalination: Reality or Pipe Dream?

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# Introduction

* Green: Make less harmful to the environment (Low carbon desalination, Renewable energy desalination)
* Pipe Dream: A fantastic notion or vain hope
* International Desalination Association (IDA): Dedicated to sustainable and environmentally responsible desalination practices
* Desalination is a relatively new industry

# Desalination: The Big Picture

* Started in 1960: 6,000 m3/day
* 1972: 2 Mm3/day
* 1999: 26 mM3/day
* 2018: 20,000 desalination plants worldwide, with a total installed production capacity of 97 million m3/day

# Desalination 2013

* 17,277 Commissioned Desalination plants
* 80.9 Mm3/day production
* 59% seawater, 22% brackish water, 9% river and 5% wastewater
* Saudi Arabia 9.2 Mm3/day, UAE 8.4 Mm3/Day and Spain 3.8 Mm3/day

# Desalination in Oman

* 90 Mm3/yr in 2006
* 221 Mm3/yr demand in 2013 (15% annual increase)
* Total annual deficit in Oman 400 Mm3; Met by desalination; Treated wastewater; Over abstraction
* 125 Units (111 RO), 1.01 Mm3/day capacity
* Demand is met mostly by large desalination plants (used to be all MSF, now changing!)
* Large number of small desalination plants are in operation in inland areas and for agriculture

# Challenges to Green Desalination

* High Cost and Environmental Impacts
* Environmental Impacts: Atmospheric Pollution, Water Pollution, Soil Pollution from Brine Discharges
* Atmospheric Pollution: $CO_2$ pollution
* Water Pollution: Brine Discharge

# Why Environmental Issues Were Not Given Priority

* Focus was large desalination plants with uninterrupted energy supply
* Availability of cheap energy in the GCC countries
* Institutional: no policy guidelines
* Market demand lacking for small-scale plants
* Technological barriers: storage of renewable energy (USD 300 for 1 kWh storage using battery; remember it takes 3.5 kWh/m3 for seawater desalination)
* Cost and subsidies

# Good News

* Cost is coming down (even at 0.5 USD/m3!)
* Energy use per m3 of water is coming down: RO in 1980: 16 kWh/m3, 2008: 1.8 kWh/m3; 1.4 kg CO2/m3
* Breakthrough in renewable energy generation (50% by 2040!)
* Shift towards RO systems, Membranes last longer; Flexibility; Low energy requirements!
* International commitments of large producing countries
* Focus on water conservation

# Desalination and GHG Emissions

* Reverse Osmosis (RO): 2.1-3.6 kg $CO_2/m^3$
* MED: 8-16 kg $CO_2/m^3$
* MSF: 10-20 kg $CO_2/m^3$

# Green Challenges: Brine Production and Disposal

* Depends on quality of the feed water; the desalination technology used; percent recovery; chemical additives used
* Pre-treatment wastes
* Cleaning waste
* Chemicals such as NaoCl, Free Cl2, FeCl3, Alum, Sodium Hexameta phosphate, EDTA, Citric acid, Sodium polyphosphate
* Sea disposal; Lined evaporation ponds; Deep well injection; Disposal in surface bodies; Through pipeline to municipal sewers; Concentration into solid salts; Irrigation of plants

# Environmental Impacts of Marine Discharge

- High Salinity: Dense brine water (in RO plants) sinks to the sea bottom, impacting the benthic communities; Depleting the available dissolved oxygen near the bottom, causing hypoxic (low oxygen) conditions
- Temperature: Death due to thermal shock, Increased proliferation of harmful algal blooms (HAB), Coral bleaching
- Residual Chlorine and other chemicals
- Guidelines and standards are in force in most countries

# Evaporation Ponds

* Average evaporation rate is used
* Lower evaporation due to salinity (70%)
* Large area needed
* Liners are to be used
* Negev desert, 5000 m3/day permeate, 384 m3/day brine (92% recovery), 65,000 m2 evaporation pond, 8.5 cents/m3 of permeate cost for brine disposal
* Enhanced evaporation
* Cost highly variable

# Zero Liquid Discharge (ZLD)

* Brine is treated further
* More water is produced (thermal desalination, ED, RO after removing scale forming constituents)
* Dry salts are the final products
* High cost
* Mostly used in the industries

# Other Possibilities

* Volume reduction by Forward Osmosis
* Salt Lake
* Disposal to sea
* Centralized collection system
* Integrated System – Desal plant-Evaporation Ponds-Salt Harvesting-Solar Ponds-Fish Farming-Salt Lake-Recreation


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| | Bahja | Nimr | Marmul | Rima |
|---|---|---|---|---|
| Capacity ML/yr | 219 | 310 | 548 | 110 |
| Saline discharge (ML/yr) | 75 | 135 | 150 | 45 |
| Brine salinity TDS g/l | 23.1 | 19.4 | 4.5 | 25.7 |
| An annual salt load t/yr | 1730 | 2600 | 680 | 1160 |
| Specific features | very low bicarbonate | | High bicarbonate, low salinity, low magnesium | Low bicarbonate |

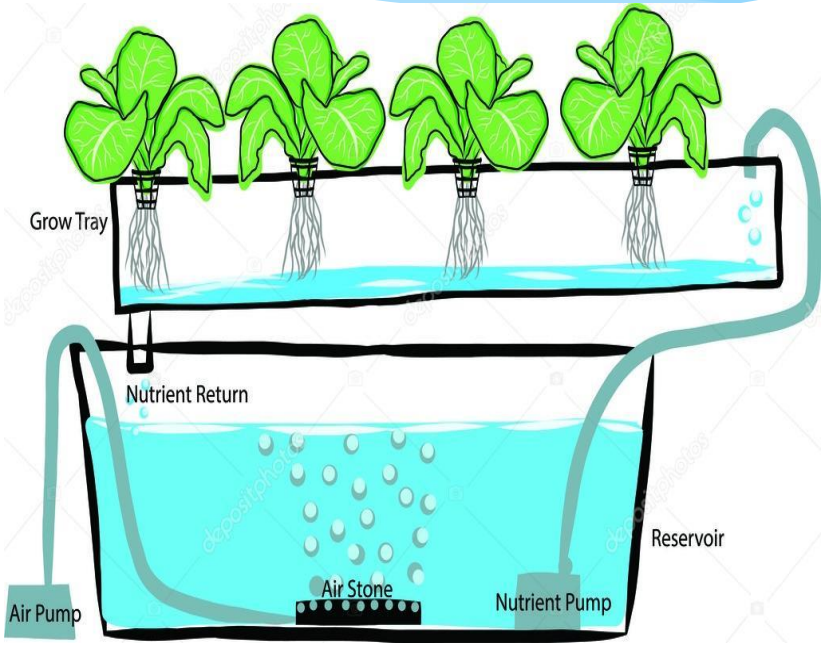
# Green (Agriculture?) Desalination

* Commercially practiced in Spain, Australia; Not so economic in UAE, Oman!
* More than 1,000 small desalination plants in Omani farms
* Great prospect of using renewable energy in controlled environment agriculture
* Oman plants are small, 10-50 m3/day capacity; salinity limit 10,000 mg/L; low value crops are irrigated (3-6,000 OR/unit)
* Energy source is normal power grid; brine disposal is the main constraint
* Ongoing research project at MEDRC using renewable energy (solar panels), 11 m3/day; different production systems and crops; evaporation ponds for brine disposal

# Solar desalination unit in MEDRC

# Ongoing work

* Construct three experimental fields
  * Open field
  * Shaded field
  * Hydroponic field
* Objectives
  * Water-use efficiency
  * Crop productivity
  * Economic feasibility
  * Impact of desalinated water on soil properties
  * PI: Dr Salem Al-Jabri & Dr. Jauad El Kharraz



# Green Desalination: The Australian Experience

* Generating renewable energy: Wind energy & Solar Farms (NO OPERATING CARBON FOOTPRINT)
* Sundrop Farms: Seawater & Sunshine integrated!
* Use of RO technology that reduces energy intensity
* Ongoing research: wave, geothermal

# Take Home Message on Green Desalination

* It is no longer a pipe dream, it is a reality
* Focus should not only be on green desalination but reduce the demand thru water conservation
* Government commitments are visible in most countries
* Great prospect of using renewable energy in controlled environment agriculture