Produced Water Brine Valorization: Osmotically Assisted Reverse Osmosis in Direct Lithium Extraction Processes

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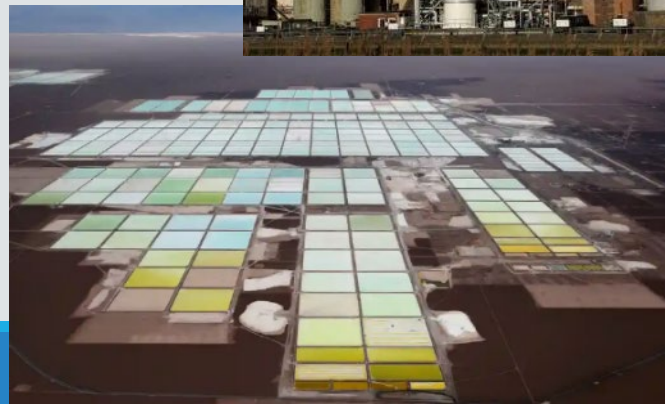
IWC 26-05

The Opportunity

- Smackover: 5 - 19M tons Lithium
- Evaporation ponds: slow & messy
- Direct lithium extraction (DLE) saves time
  - Thermal brine concentration is expensive
  - **Osmotically assisted reverse osmosis (OARO) = emerging technology**

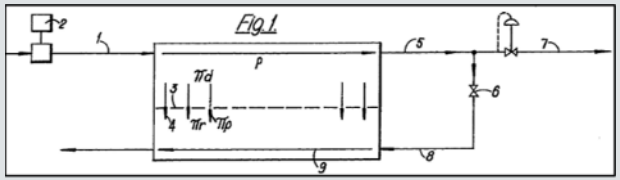




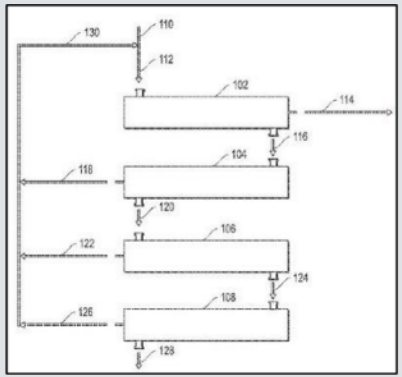


Osmotically Assisted Reverse Osmosis (OARO)

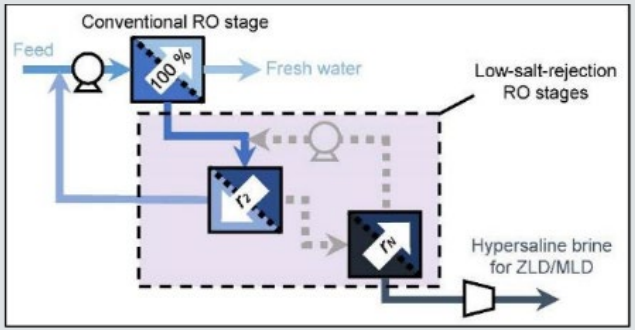
- Salty permeate reduces osmotic pressure difference.
- Hollow fiber versus loose spiral.
- Hydraulic pressure independent of feed osmotic pressure.



Loeb (1971)



Herron, Beaudry, Lampi (2013)



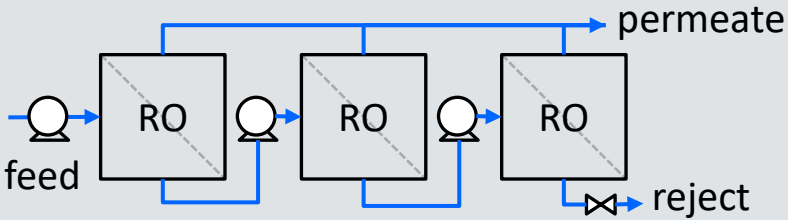
Wang, Deshmukh, Du, Elimelech (2020)

CFRO CMCR COMRO CRRO FusionRO HBCR HiCor HiRO HPNF Hy

OARO Systems

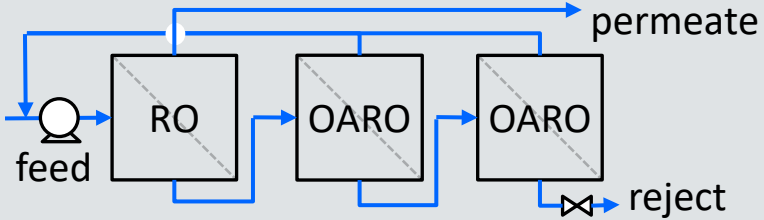
Traditional multi-stage RO

- Interstage pressure boosted to overcome osmotic pressure.
- Turbine energy recovery.
- Ultra-high pressure may be required.



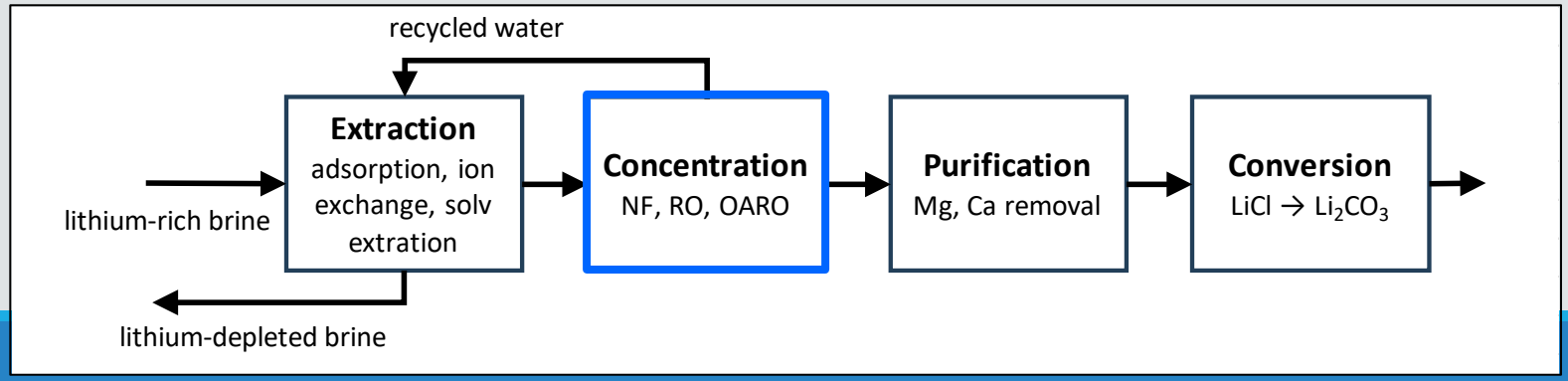
RO+OARO

- “Loose” membranes in later stages.
- Salty permeate recycled/polished.
- Isobaric energy recovery.
- <1200 psi / 83 bar



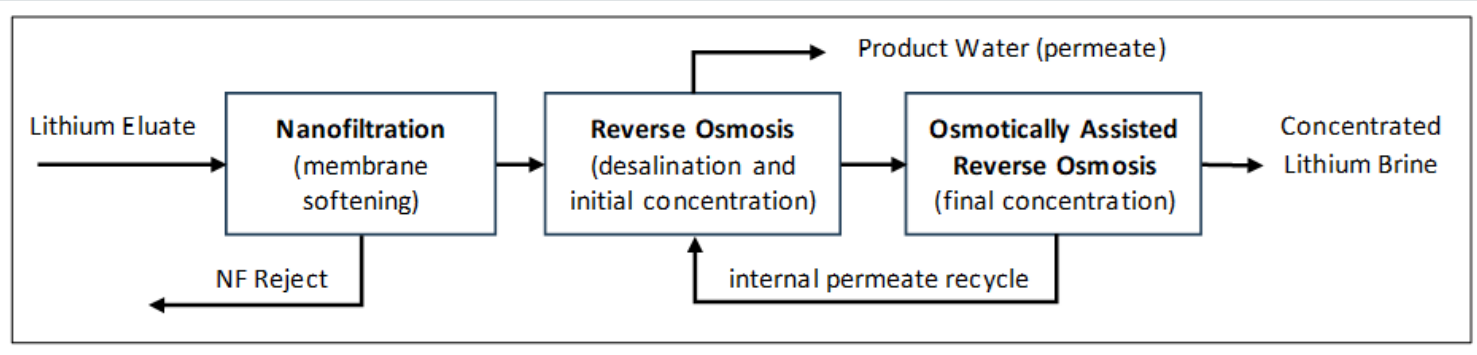
Direct Lithium Extraction with OARO

- Eliminate or reduce thermal treatment operations
- Maximize lithium concentration
- Minimize lithium losses
- Optimize water recovery rate and quality
- Minimize capital and operating costs



DLE OARO Concentrator Design

- NF = membrane softening. Permeate forward to RO, reject back to extraction operation.
- RO = dewatering. Permeate used onsite, reject to OARO.
- OARO = brine concentration. Permeate to back to RO, brine forward to purification operation.



DLE OARO Performance

- Water recovery = 91% baseline, 93% high perf system
- Lithium recovery = greater than 99%
- Lithium concentration = 15x baseline, 19x high perf

Stream	Lithium (mg/l)	TDS (mg/l)
Feed	680	5,800
Permeate	2	200
Brine (baseline system)	~10,000	>120,000
Brine (high performance)	~13,000	>160,000

DLE OARO Cost Estimates

Specific Cost ($/m³ perm)	10,000 mg/l Li	13,000 mg/l Li
CAPEX (process equipment)	0.22	0.27
OPEX (energy, chems, spares)	0.65	0.70
TOTAL	0.87	0.97

- 1,500 gallons per minute feed
- 4.6-4.8 kWh/m³, $0.10/kWh power tariff
- 6% cost of money, 10 year amortization
- Compared to thermal: 1/2 the capital cost, 1/10 the operating cost
- Compare to $0.70-1.25/m³ SWRO, $0.33-0.63/m³ BWRO

CONCLUSIONS

FATHOM

- Smackover Formation: major domestic lithium resource
- DLE process faster and cleaner than traditional ponds
- OARO membrane brine concentration – not limited by TDS
- NF softening + RO dewatering + OARO brine conc
- 15x – 19x Li concentration and 99% Li recovery
- Evaporator eliminated
- <$1.00/m3 of permeate produced = comparable to desal