



Magnesium Fortification of Potable Water

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ORGANIZING PARTNERS



EXECUTED BY



TECHNICAL ADVISOR



6-8 March 2022 • Hilton Riyadh Hotel & Residences

Why Magnesium?



Very high biochemical activity

- Activator of over 300 enzymes
- Required for metabolism
- Required for repair of DNA damage

Food sources include green vegetables, fruit, beans, nuts and seeds, and seafood

Since 1900: Falling Magnesium in diet in developed countries

Few people have symptoms of acute Mg^{2+} deficiency, but many are below recommended levels

Health Claims for Magnesium

Link between low magnesium and coronary heart disease and stroke

Animal studies: Rats on low magnesium diet showed biochemical markers associated with heart disease, when given Mg^{2+} rich water these reduced (15 ppm) or disappeared (100 ppm)

Epidemiological studies: Populations dependent on water with less than 3-6 ppm have higher rates of coronary heart disease

Low magnesium levels may also contribute to:

- Dementia (Ozturk and Ciller, 2006)
- Diabetes (Al-Baker, 2022)
- Cancer (Tukiendorf and Rybak, 2004; Liao et al. 2013)

Magnesium Guidelines

Suggested as little as 14 mg of Mg^{2+} daily in water could be protective (Eur J Cardiovasc Prev Rehabil 2006;13 495-506)

Many countries have maximum requirements for Mg in drinking water: relatively few have minimum requirements

- Czech Republic, 10 ppm (guideline 20-30 ppm)
- Slovakia, guideline 10-30 ppm
- Israel, target of 30 ppm (non-binding)

Does Desalinated Water have a Magnesium Problem?

Desalinated water has hardness derived from remineralization with limestone or hydrated lime (~100% Calcium)

- Cannot contribute to Mg^{2+} intake
- May leach Mg^{2+} from food
- Limits use in agriculture

Large epidemiological studies studying populations before and after connection to desalinated water supplies strongly suggest negative effects on cardiovascular health (e.g., Shlezinger et al. Int. J. Cardiology 220 544 (2016))

SWCC guideline for new projects: 15-25 ppm

Strategies

- Mixing with natural waters
- Dissolution of commercial magnesium salts
- Dissolution of magnesium-containing minerals
- Mixing with nanofiltration reject
- Dissolution of magnesium hydroxide slurry generated on site

Adding Natural Waters

Source	Mg ²⁺ (ppm)	Ca ²⁺ (ppm)	Na ⁺ (ppm)	
Riyadh 1	57.5	149	160	SWCC
Riyadh 2	48.4	224	115	SWCC
Rhodes	58	42	28	Evdokia Koufou, Beng Thesis, Helsinkin Metropolia University of Applied Sciences, 2014
Palestine	75	168	138	Darwesh et al., Journal of Health and Pollution, 19(25), 200309 (2020)
Morocco	139	331	730	Sivan et al., Geochimica et Cosmochimica Acta, 69(3), 579-592 (2005)
Colorado River	35	95	333	Rahardianto et al., Journal of Membrane Science, 289, 123-137 (2007)
Seawater	1530	450	12,400	SWCC
Dead Sea	46,000	17,000	36,500	Khlaifat et al., Heliyon, 6(11), e05444 (2020)

Magnesium Salts

Magnesium sulfate heptahydrate (epsomite)

Magnesium chloride hexahydrate (bischofite)

Dissolve readily

Magnesium oxide (magnesia)

Magnesium hydroxide

Require acid
(CO_2 , H_2SO_4 ...)

Epsomite 2250 SAR/ton

Bischofite 2500 SAR/ton

Magnesium oxide 1875 SAR/ton

Magnesium Minerals

Magnesite (MgCO_3)

Dolomite ($\text{MgCa}(\text{CO}_3)_2$)

Require acid
(CO_2 , H_2SO_4 ...)

Magnesite 500 SAR/ton

Dolomite 200 SAR/ton

Compared to limestone, dissolution rates are slow (dolomite) and very slow (magnesite)

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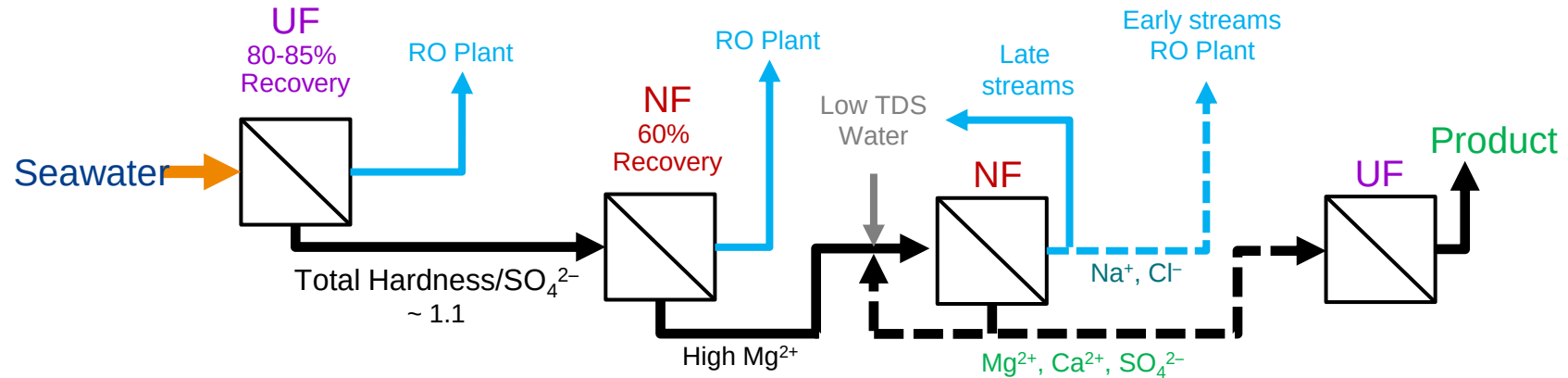
SWCC guideline for new projects: 15-25 ppm

Nanofiltration Reject

Source	Mg ²⁺ (ppm)	Ca ²⁺ (ppm)	Na ⁺ (ppm)
Low Selectivity NF	4850	830	15,600
High Selectivity NF	10,000	2600	14,700
Seawater	1530	450	12,400
Groundwater (Riyadh)	48-58	144-224	115-160

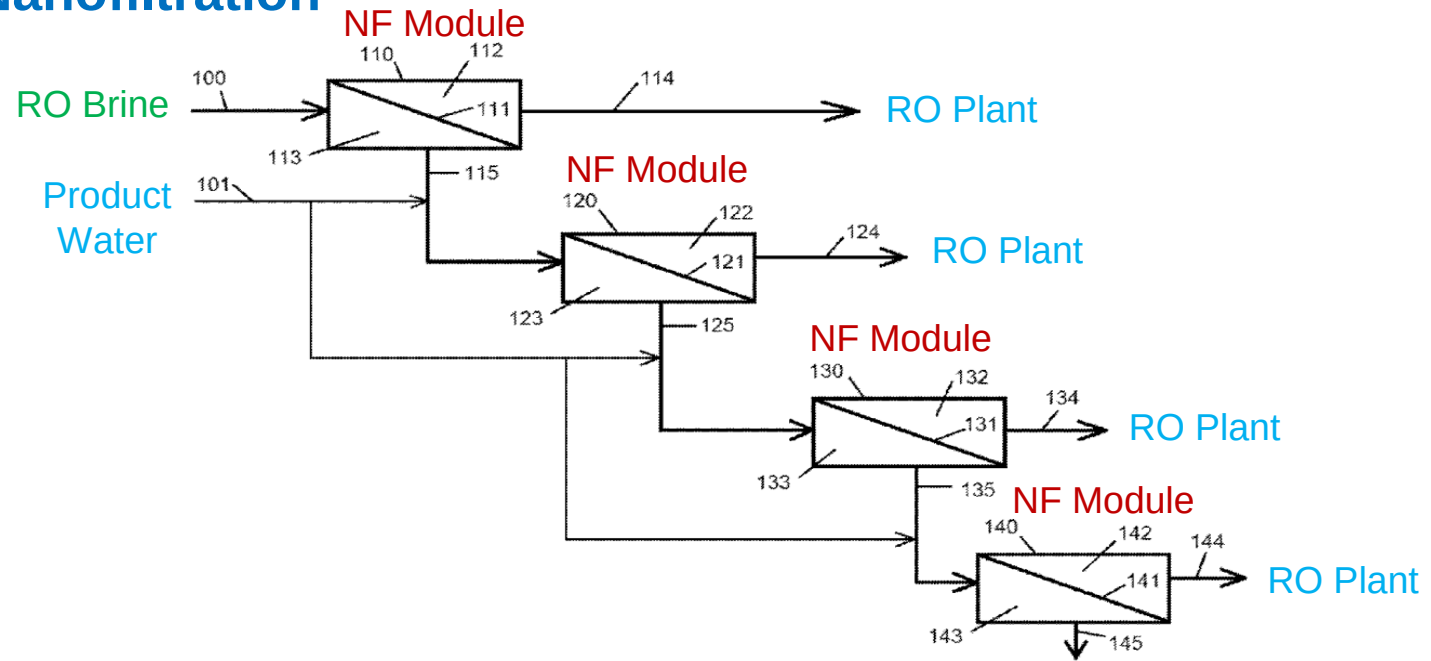
What if this exceeds required limits for chloride or total dissolved solids?

Multi-Stage Nanofiltration



Birnhack, Tang and Lahav, Chemengineering 2018, doi:10.3390/2030041

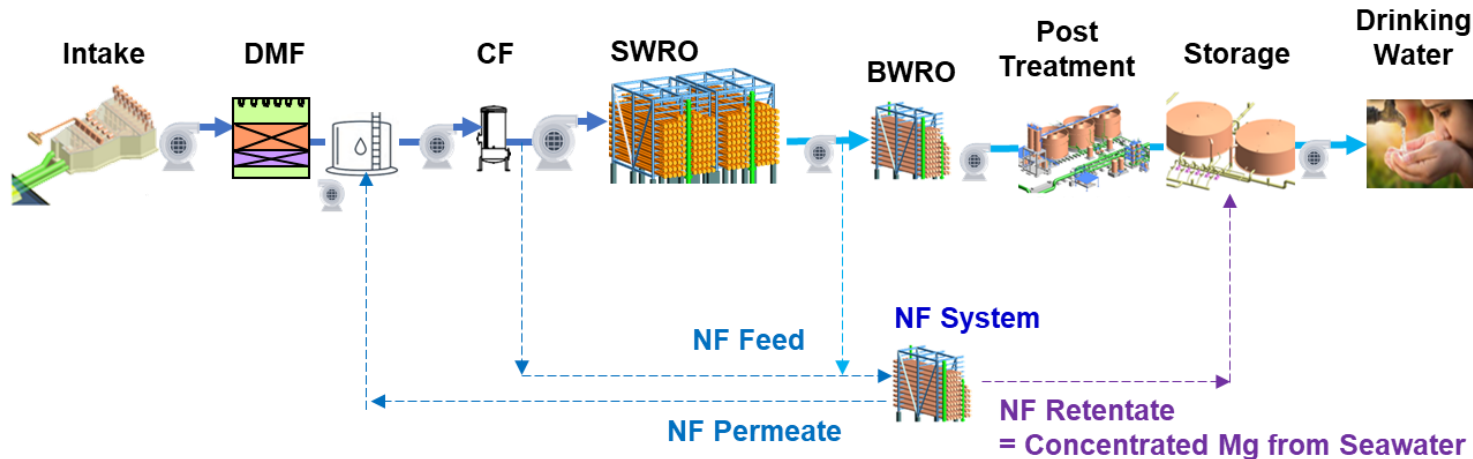
Multi-Stage Nanofiltration



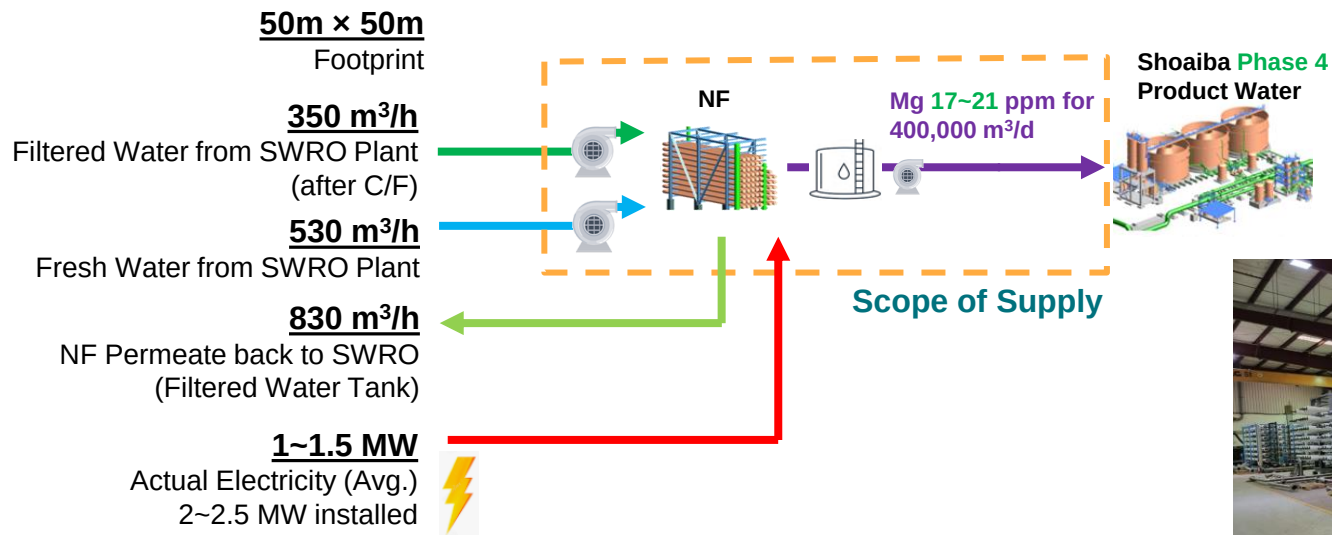
Brine with low Na^+ & Cl , High Mg^{2+} , Ca^{2+} , SO_4^{2-}

Shoaiba Phase 4 SWRO Plant

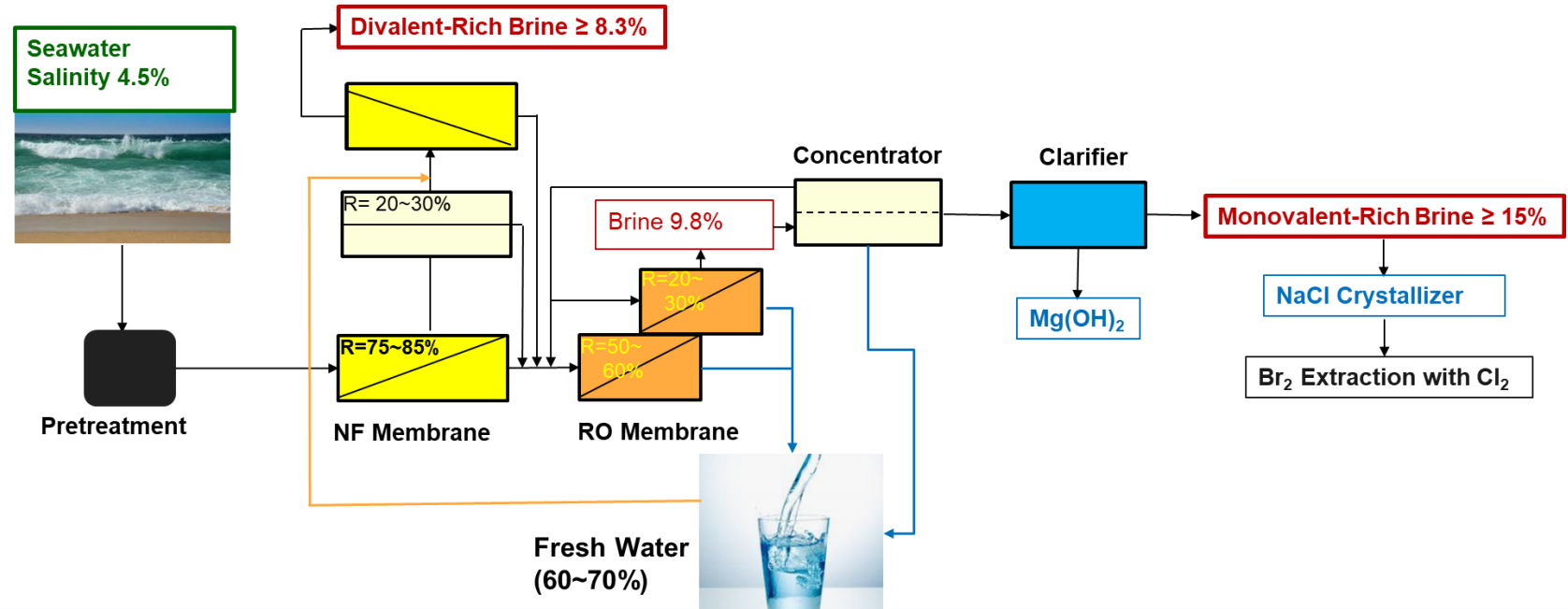
Existing 400,000 m³/d Desalination Plant



Shoaiba Phase 4 SWRO Plant



Adding Magnesium Hydroxide Slurry



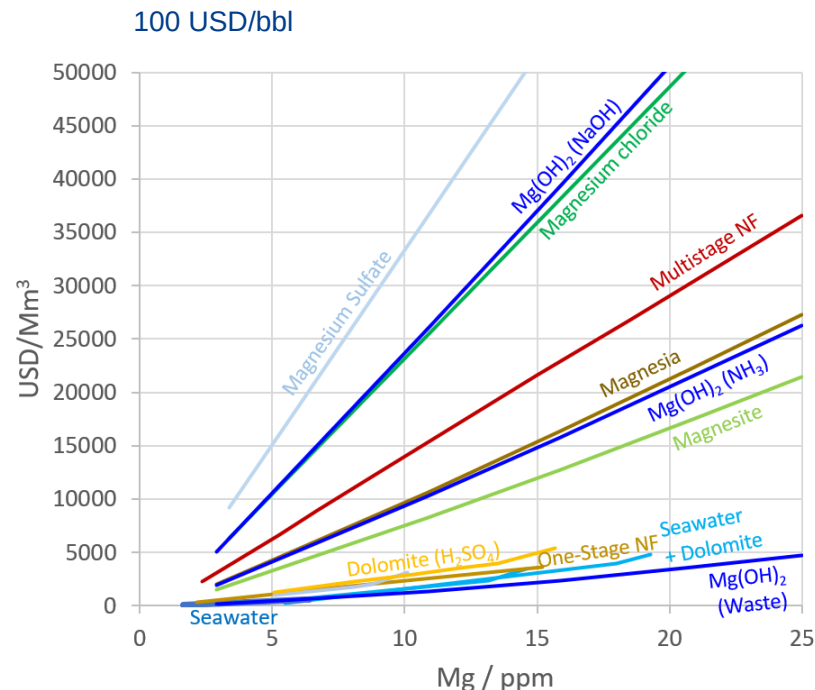
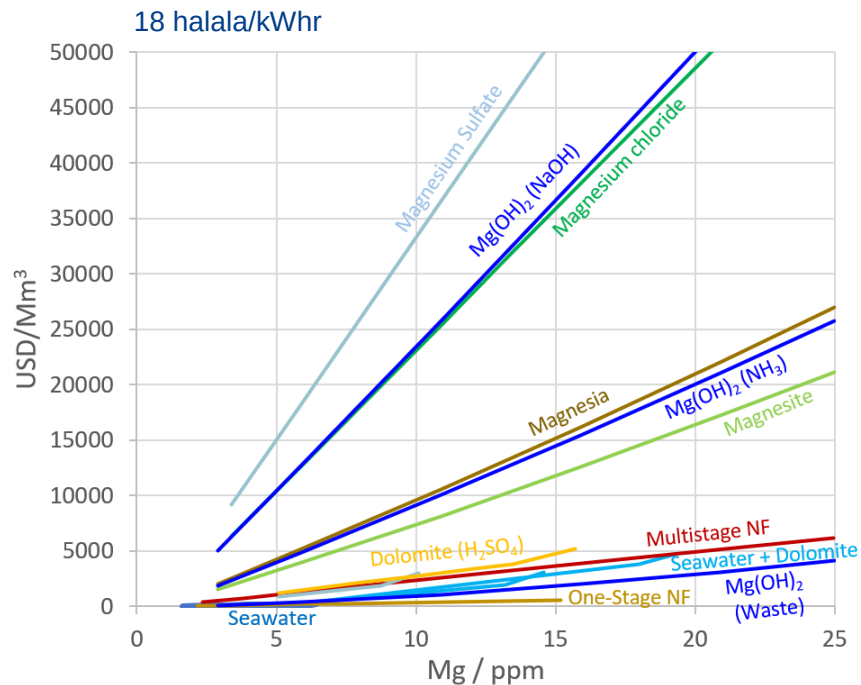
SWCC Water Quality Targets

SWCC has committed to 15-25 ppm Mg^{2+} in future projects

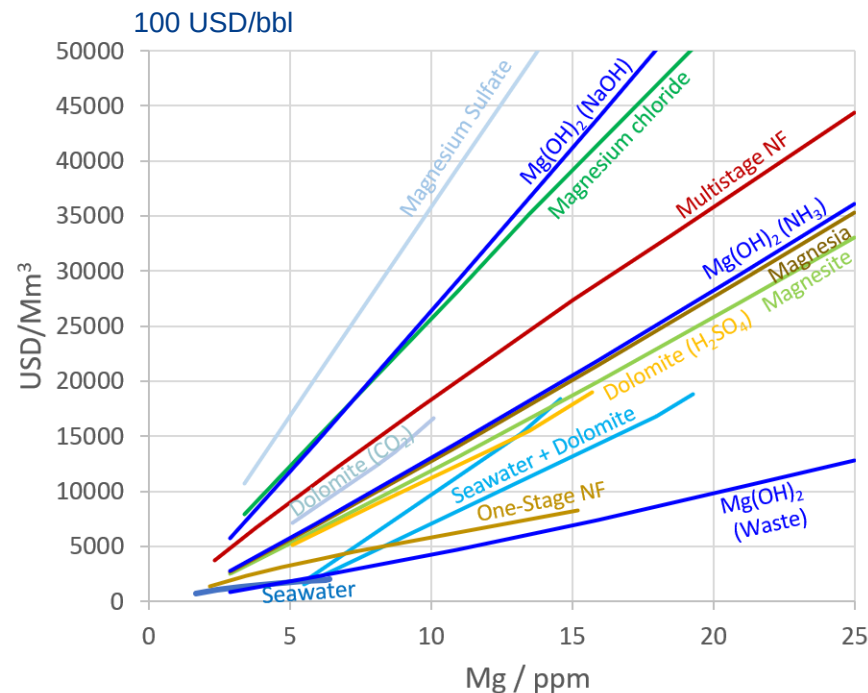
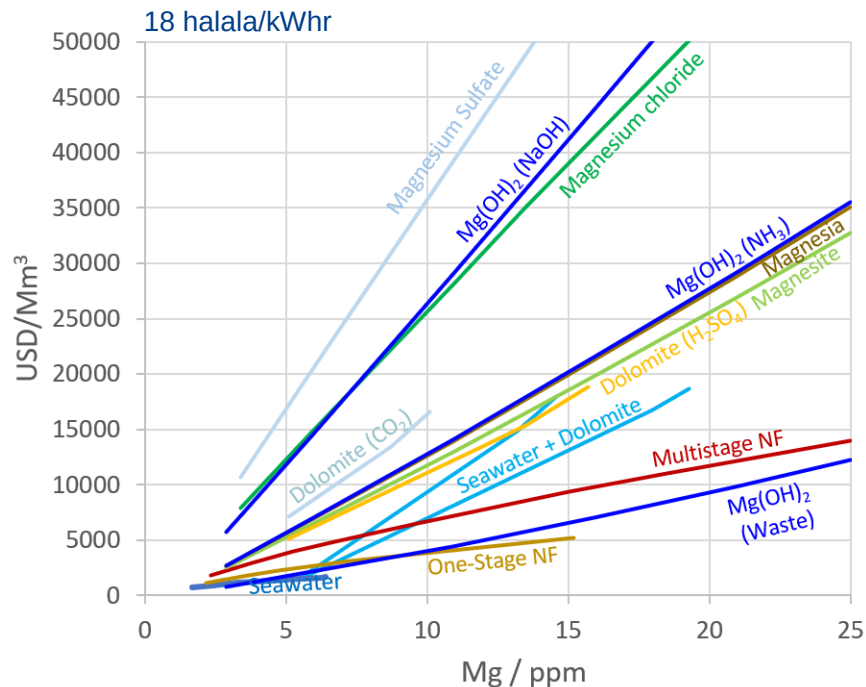
Other conditions:

- Langelier Saturation Index <0.3
- < 400 ppm TDS
- < 100 ppm Cl^-

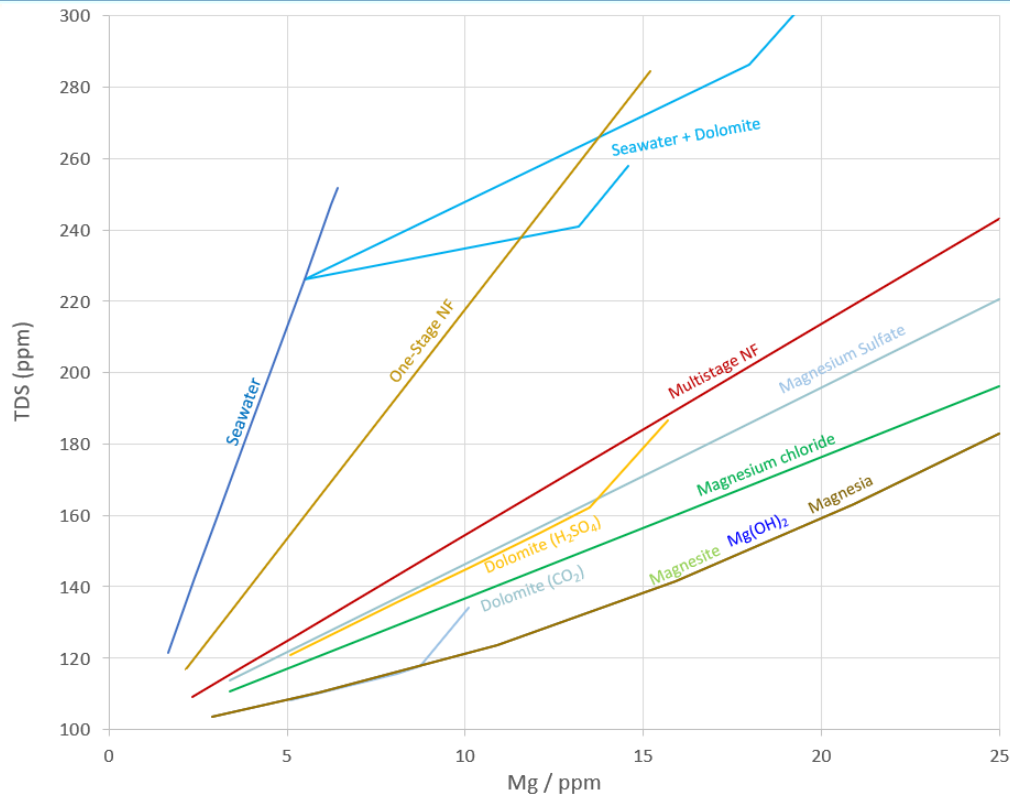
Comparison of OPEX



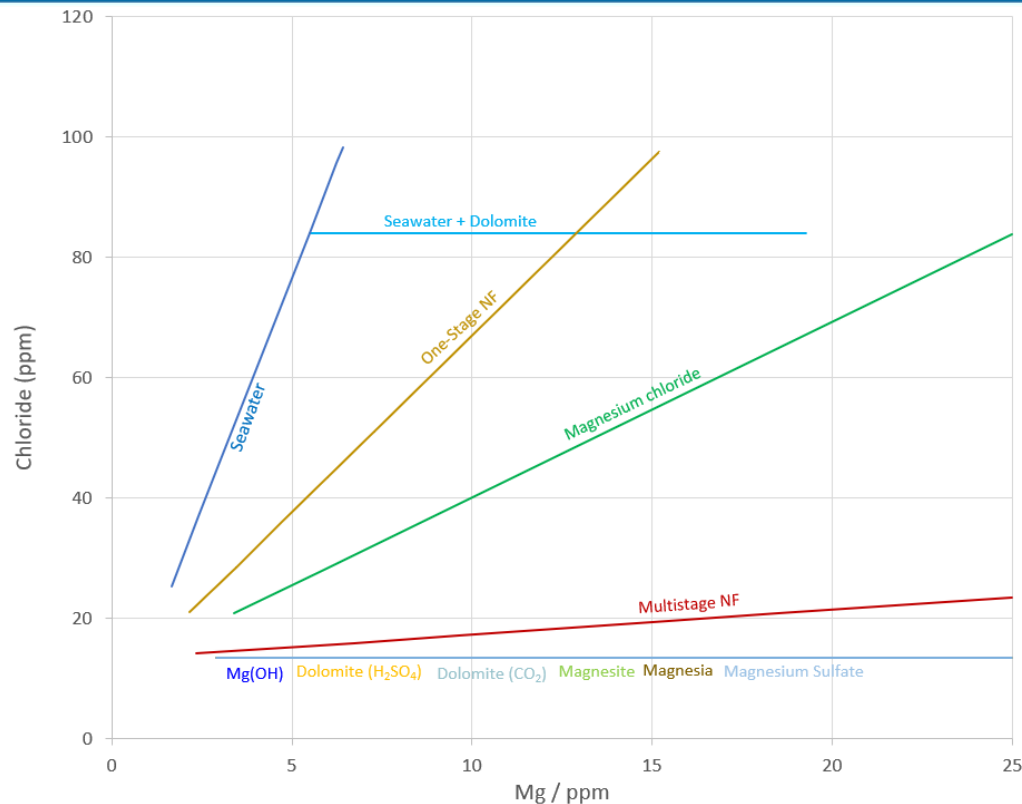
Comparison of Total Cost



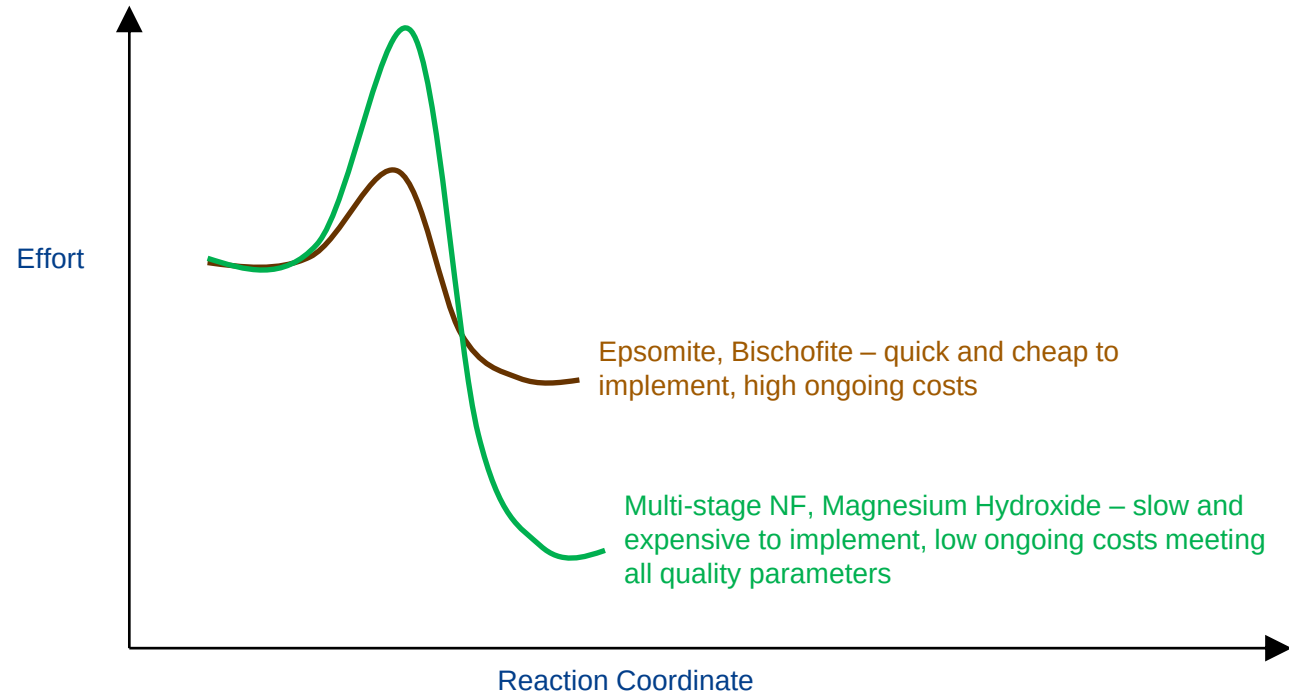
Comparison of TDS



Comparison of Chloride



Kinetic vs Thermodynamic Control



Where to from here?

- Engineering for better comparison of CAPEX
- Magnesium Hydroxide (Waste)
Brine mining process may not actually need caustic polishing ✕
- One-stage NF
>100 ppm Chloride may be acceptable ✓
- Multi-stage NF
If we are optimistic about the long term cost of power (?)

Under the Patronage of **HRH Prince Faisal bin Bandar bin Abdulaziz**
Governor of Riyadh Region

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THANK YOU



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