8 Months of Successful Pilot Operation for Highly Purified and Concentrated NaCl Brine Production

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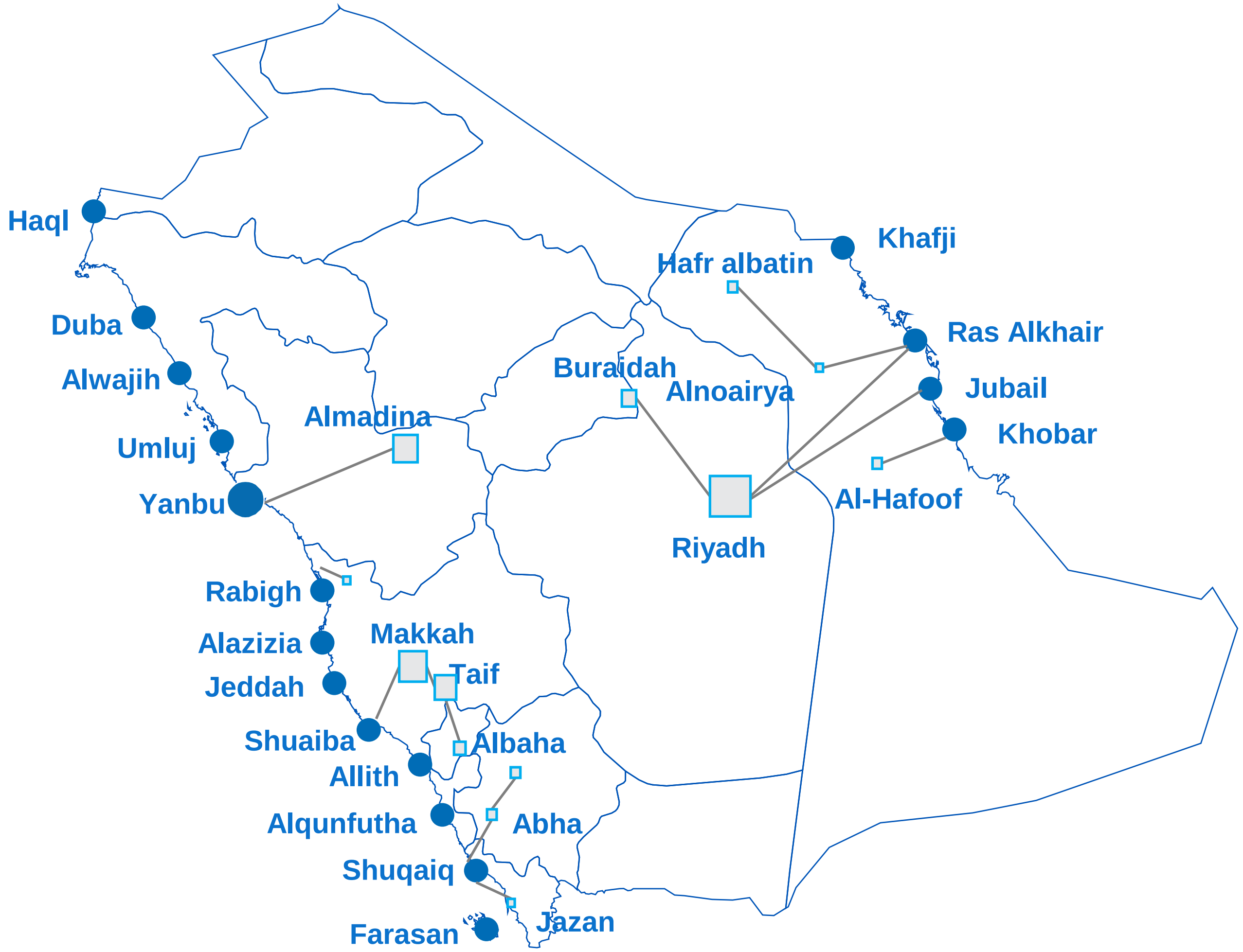
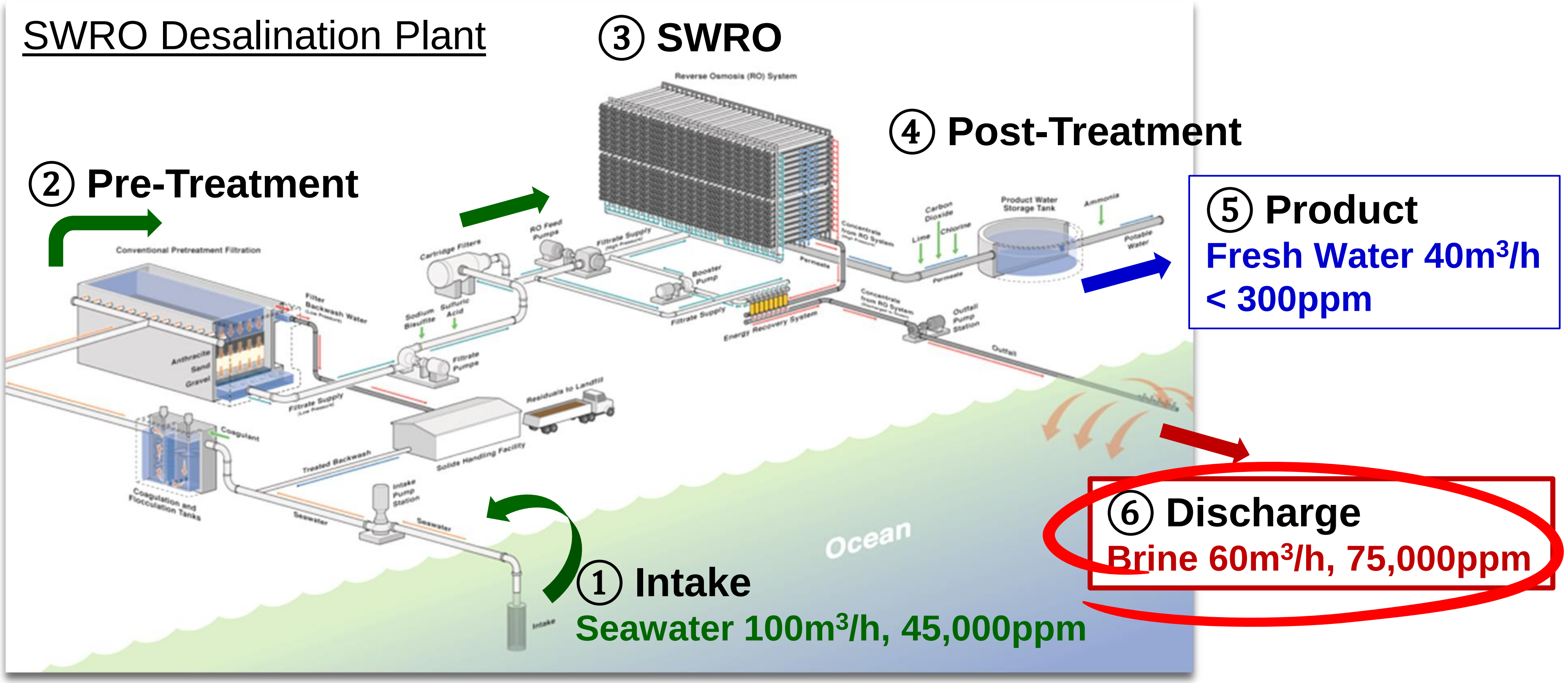
Introduction – Saline Water Conversion Corporation (SWCC)



- 33 Desalination Plants
- Over 5.9 million m^3 of water per day
- Over 200 Cities & District
- 6 Main Transmission Systems
- 9200 KM Pipeline length
  8.7 million m^3 of Transmitted water
- 286 Storage Water Tanks
- 16.8 million m^3 of water capacity
  35 Pumps Stations
- 11 Patents
- 7,276 MW Generation per day
- Over 250 Publish Research
- 10,000 Employee

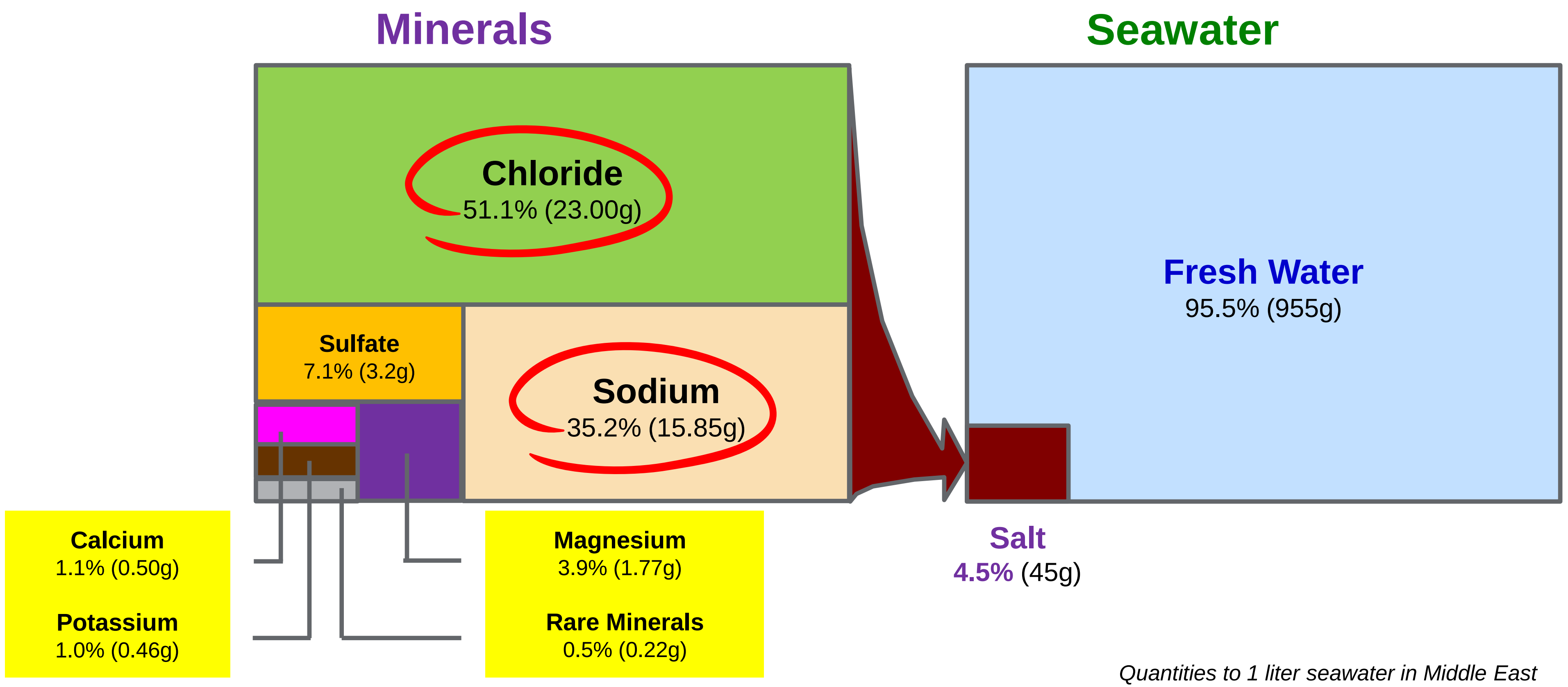
Introduction

SWCC produces 6 million m³/day of fresh water – **What about Brine?**



Introduction

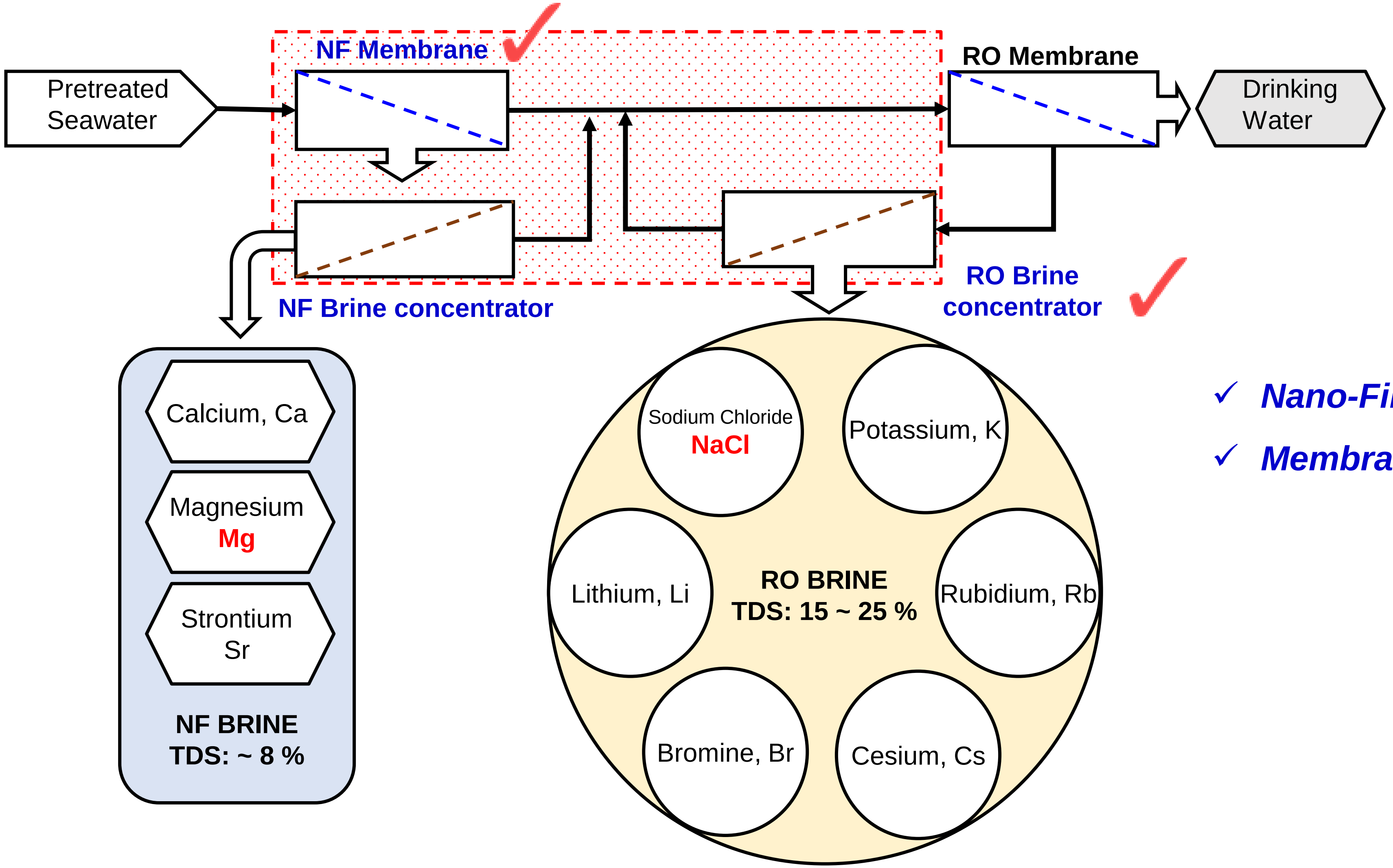
Seawater Brine could be a valuable resource!!



Quantities to 1 liter seawater in Middle East

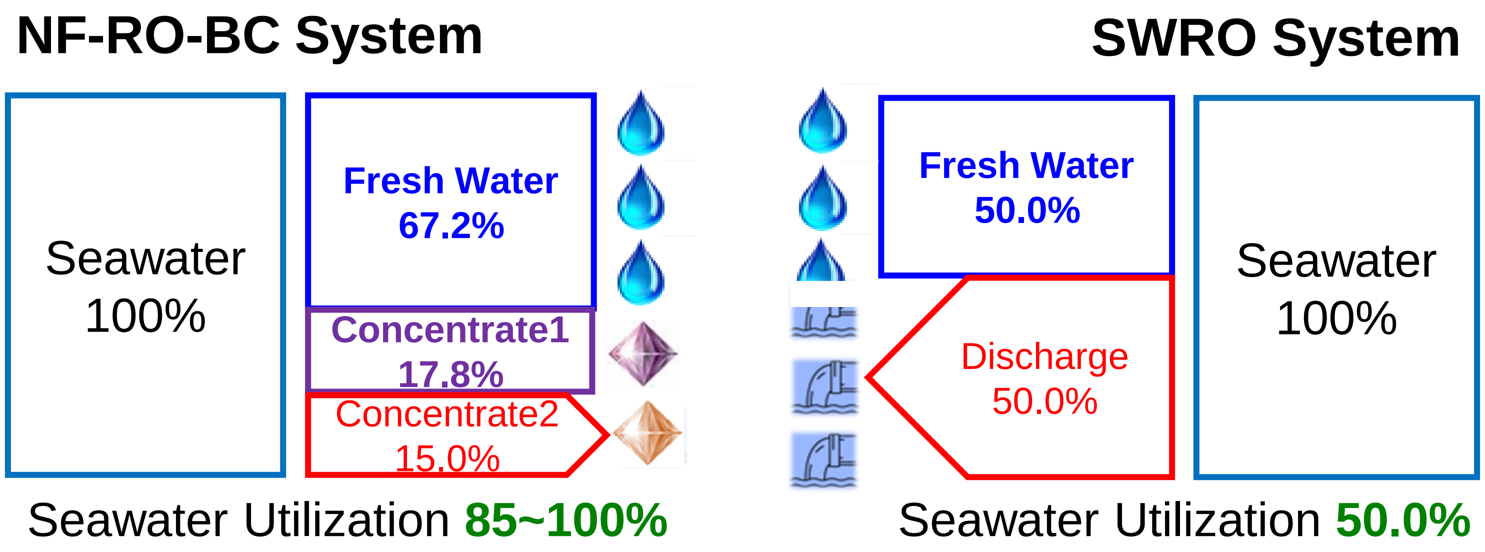
SWCC-DTRI **NF-RO-BC** System

SWCC approach: Make the brine streams **VALUABLE = Purity (Separation) and Concentration!!**



- ✓ ***Nano-Filtration (NF)*** *for Separation*
- ✓ ***Membrane BC*** *for Concentration*

SWCC-DTRI **NF-RO-BC** System



- ✓ **Fresh Water** Production increased by ▲34.4%
- ✓ **Concentrate1 = Production** of 170,000△mg/L NaCl for Chlor-Alkali industry ✓
- ✓ **Concentrate2 = Source** of divalent mineral harvest **towards ZLD**

SWCC-DTRI **NF-RO-BC** System

Back Up

(12) **United States Patent**
Alamoudi et al.

(10) **Patent No.: US 10,947,143 B2**
(45) **Date of Patent: Mar. 16, 2021**

(54) **DESALINATION BRINE CONCENTRATION SYSTEM AND METHOD**

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(73) Assignee: **Saline Water Conversion Corporation**, Al-Jubail (SA)

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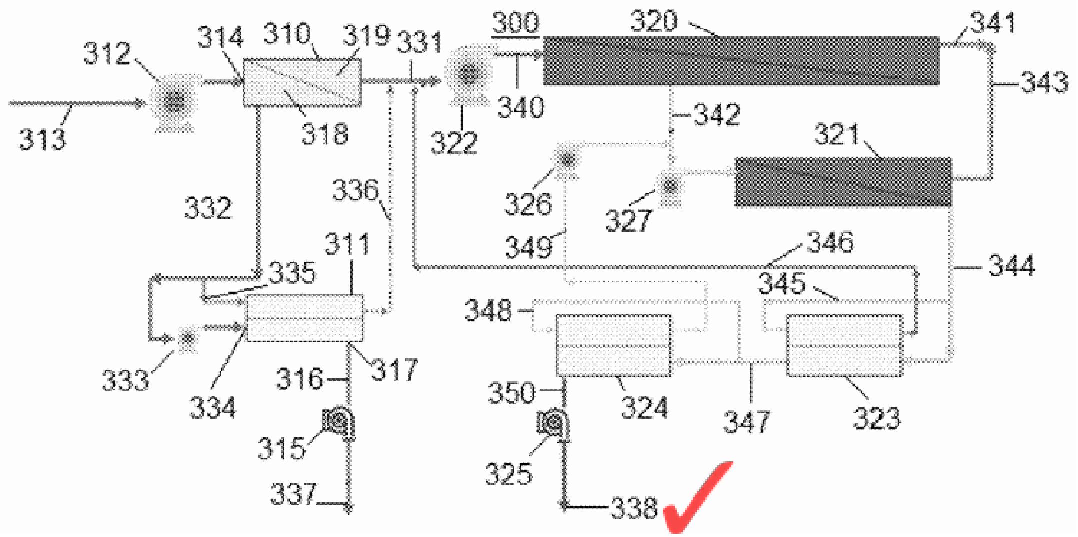


(57) **ABSTRACT**

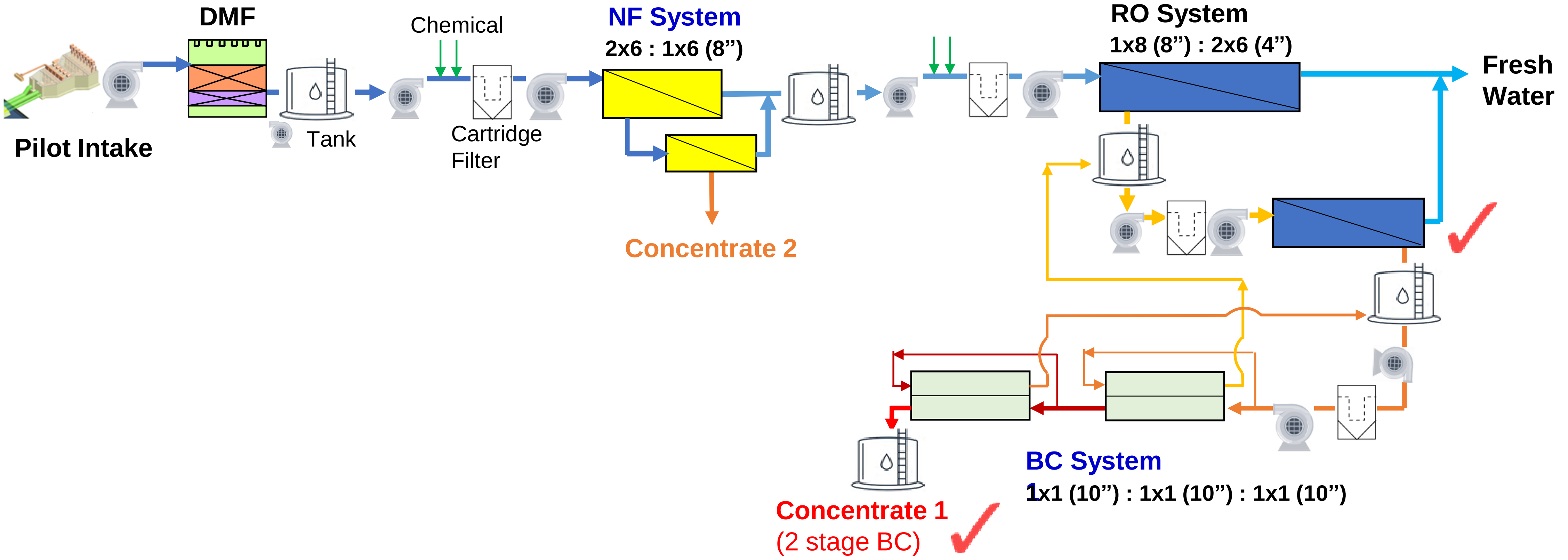
A system and method for producing very high concentration brine streams from which commercially efficiently obtained minerals may be obtained is produced by a dual membrane brine concentrator system (DTRI Concentrator). The system includes a nano-filtration system which removes divalent ions from the seawater, a brine concentrator such as a hollow fine fiber forward osmosis system which receives and further concentrates the brine rejected from the nano-filtration system, a SWRO system which receives the NF system permeate and removes monovalent ions, and another brine concentrator which further concentrates the brine rejected from SWRO system. Various permeate and reject brine flow may be forwarded through the Dual Membrane Brine Concentrator system, and multiple stages of the system components may be used, to enhance brine concentration and improve system efficiency.

The invention is a new membrane-based system for concentration of brine, which overcomes the above difficulties and allows concentration of brine to high levels, on the order of 120,000 to 250,000 ppm. These levels are sufficiently high to permit efficient and commercially viable extraction of minerals of commercial value such as calcium sulfate, table salt, magnesium sulfate, lithium, etc. The high salinity levels also allow cost-effective implementation of zero liquid discharge (ZLD).

One unique aspect of the invention is its approach to treatment of two brine output streams from two different concentration processes, one stream being from a nano-filtration process, with rejected brine that is rich in divalent ions, and another other brine stream from a reverse osmosis process having rejected brine that is rich in monovalent ions. The combined processes are arranged in a manner that

SWCC-DTRI **NF-RO-BC** Pilot Study

Phase 2 Pilot Plant Configuration at Jubail, Saudi Arabia (Dec. 2019 – Nov. 2020)



SWCC-DTRI **NF-RO-BC** Pilot Study - HPRO

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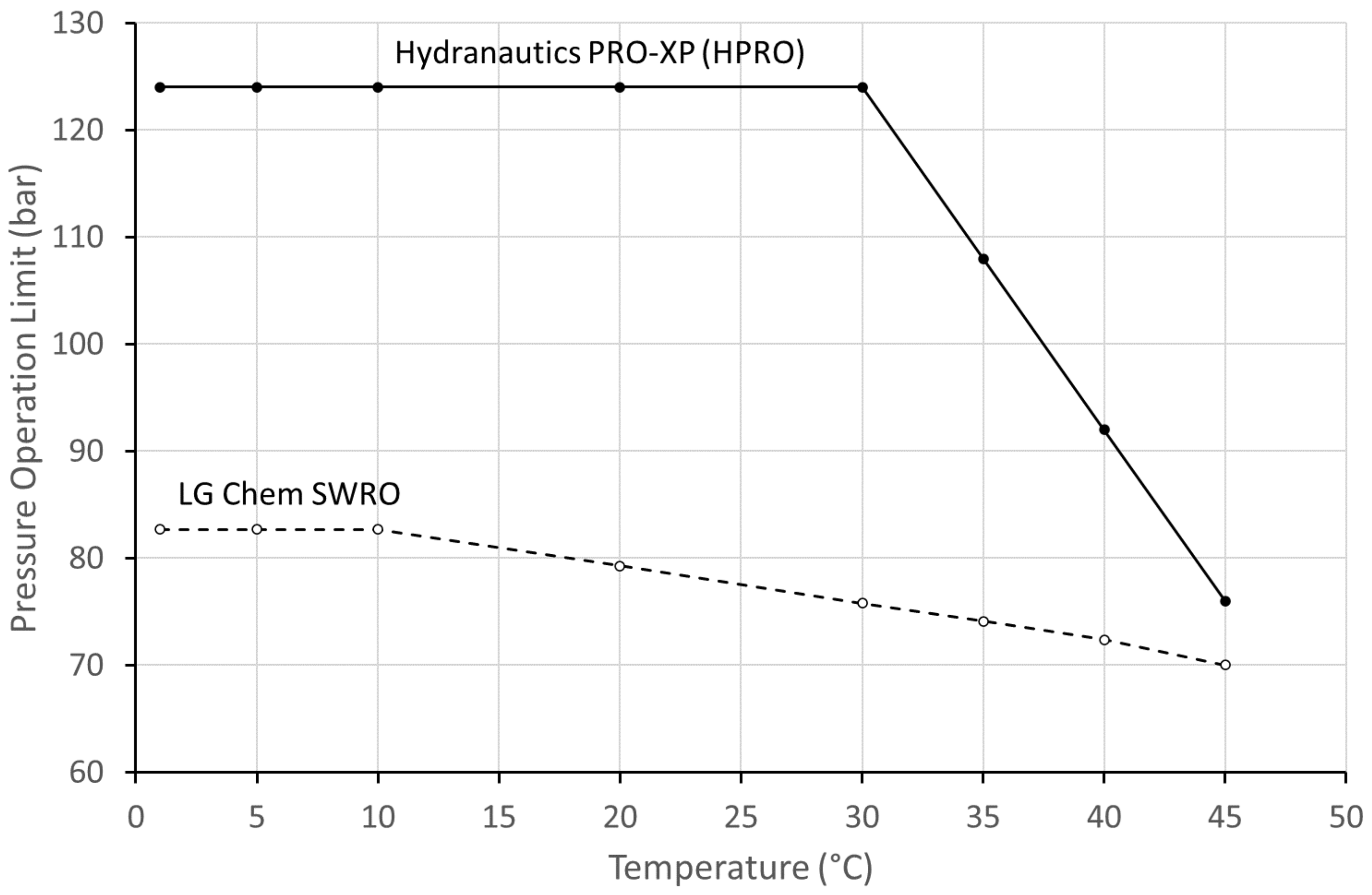

SWCC-DTRI **NF-RO-BC** Pilot Study - OARO

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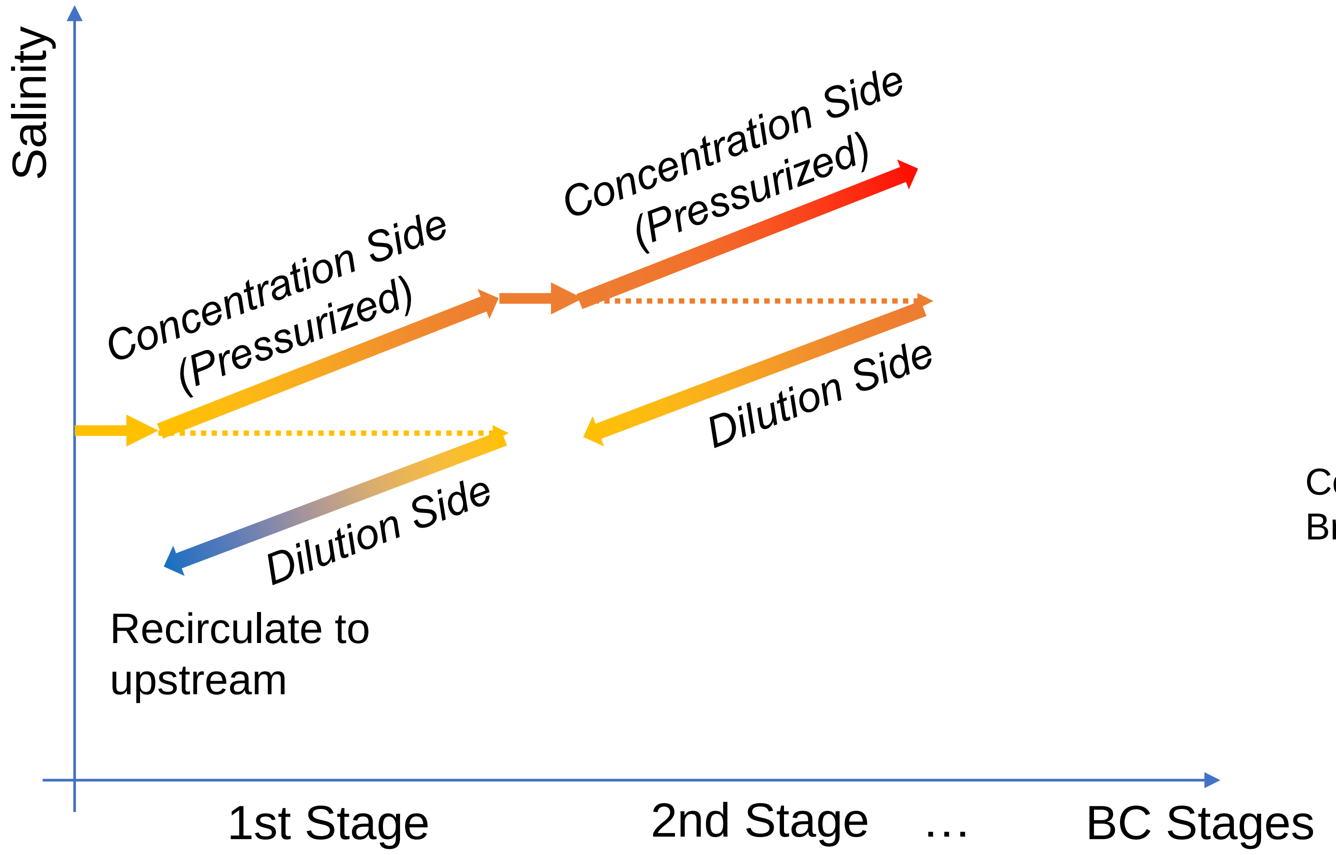
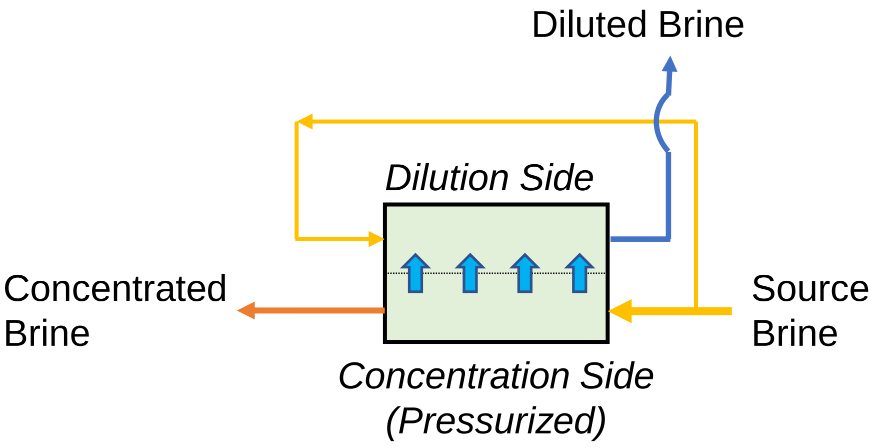




Schematic Diagram of a Single Stage Membrane BC System

Salinity Profile in a BC System (Principle of OARO)

SWCC-DTRI **NF-RO-BC** Pilot Study

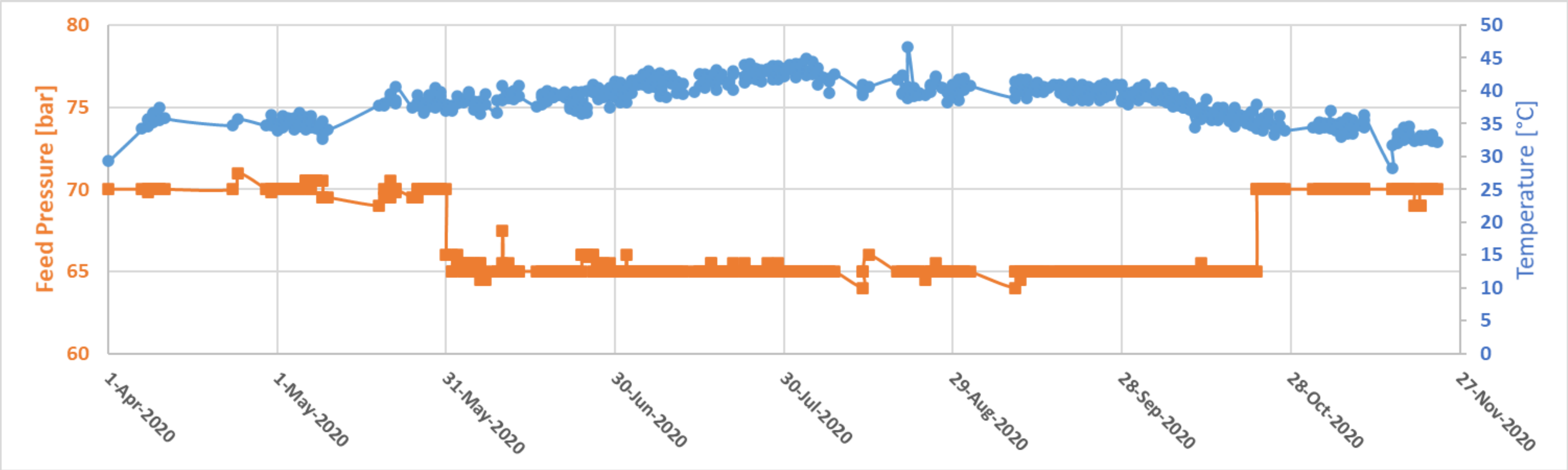
Phase 2 Study – Demonstration of **Separation** (NaCl/TDS 86 → 96~97%) and **Concentration** (170,000mg/L by 2 Stg. BC, up to > 210,000mg/L after 3rd Stg. BC)

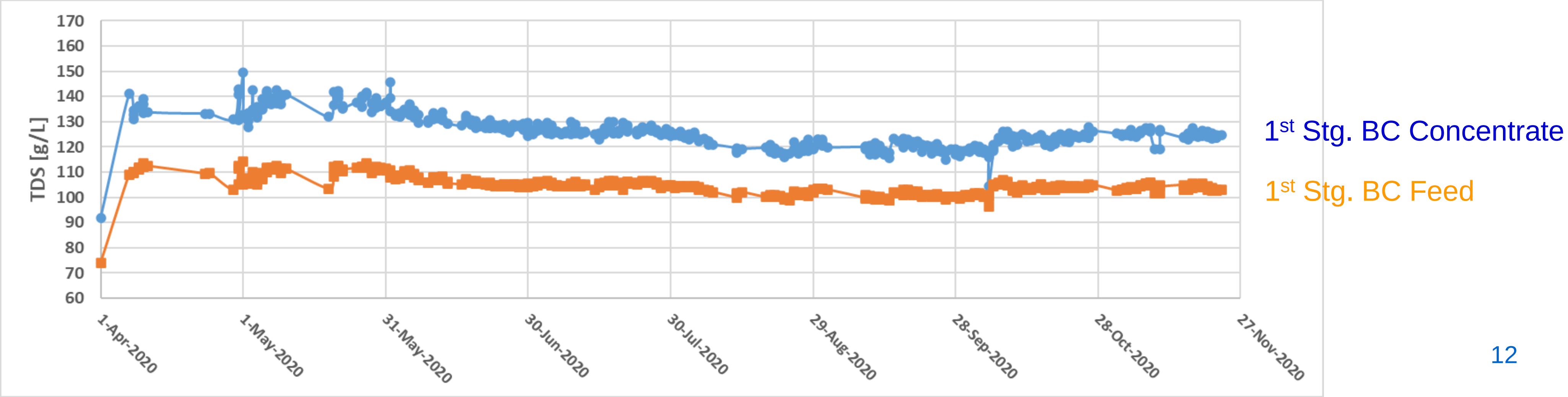
Items 1)	Jubail Seawater Data (SWCC)			DTRI-SWCC Pilot Data on 7 to 8 Jan. 2020				
	MIN	AVG	MAX	NF Feed 2)	% Ion Composition of NF Feed	% Ion Composition of NF Permeate	% Ion Composition of Concentrates after NF Permeate 3)	% NF Reject
T	11	24	37	23.6~27.4	-	-	-	-
pH	8.0	8.2	8.3	5.98~6.07	-	-	-	-
Ca++	450	450	580	472	1.06%	0.72%	0.68~0.72%	1.78%
Mg++	1,400	1,500	1,700	1,563	3.50%	0.75%	0.72~0.76%	8.93%
Na+	13,400	14,200	14,350	13,950	31.19%	36.22%	36.08~38.14%	20.69%
K+	370	420	500	452	1.01%	1.22%	1.19~1.23%	0.54%
HCO3-	124	130	150	54	0.12%	0.12%	0.08~0.12%	0.13%
SO4--	3,000	3,100	3,700	3,200	7.16%	0.16%	0.15~0.33%	23.20%
Cl-	23,550	25,000	25,800	24,500	54.79%	60.63%	58.36~60.66%	44.53%
F-	10	10	10	6	0.01%	-	0.00~0.01%	-
NO3-	4	5	12	3	0.01%	-	0.00~0.01%	-
B	6	6	6	5	0.01%	0.01%	0.01%	0.01%
Br-	60	70	80	64	0.14%	0.17%	0.15~0.19%	0.13%
TDS	**42,500**	**45,000**	**47,000**	**44,720**	**44,720**	**35,880**	**81,340~214,180 3)**	**90,520**

1) Temperature in [°C], all ion concentrations and TDS in [mg/L]
2) Operating condition of NF during sampling: NF feed flowrate = 16.0 m3/hr, pressure = 19.3 bar, recovery = 85.0%
3) 7 concentrate samples - **108,060 mg/L** for HPRO reject (8 Jan.); and 5 BC concentrates (7 Jan.) which are ⓐ **173,500** for the 2nd stage concentrated, ⓑ **208,480** and ⓒ **214,180** for the 3rd stage concentrated, ⓓ 148,080 and ⓔ 154,398 mg/L for the 3rd stage diluted

SWCC-DTRI **NF-RO-BC** Pilot Study

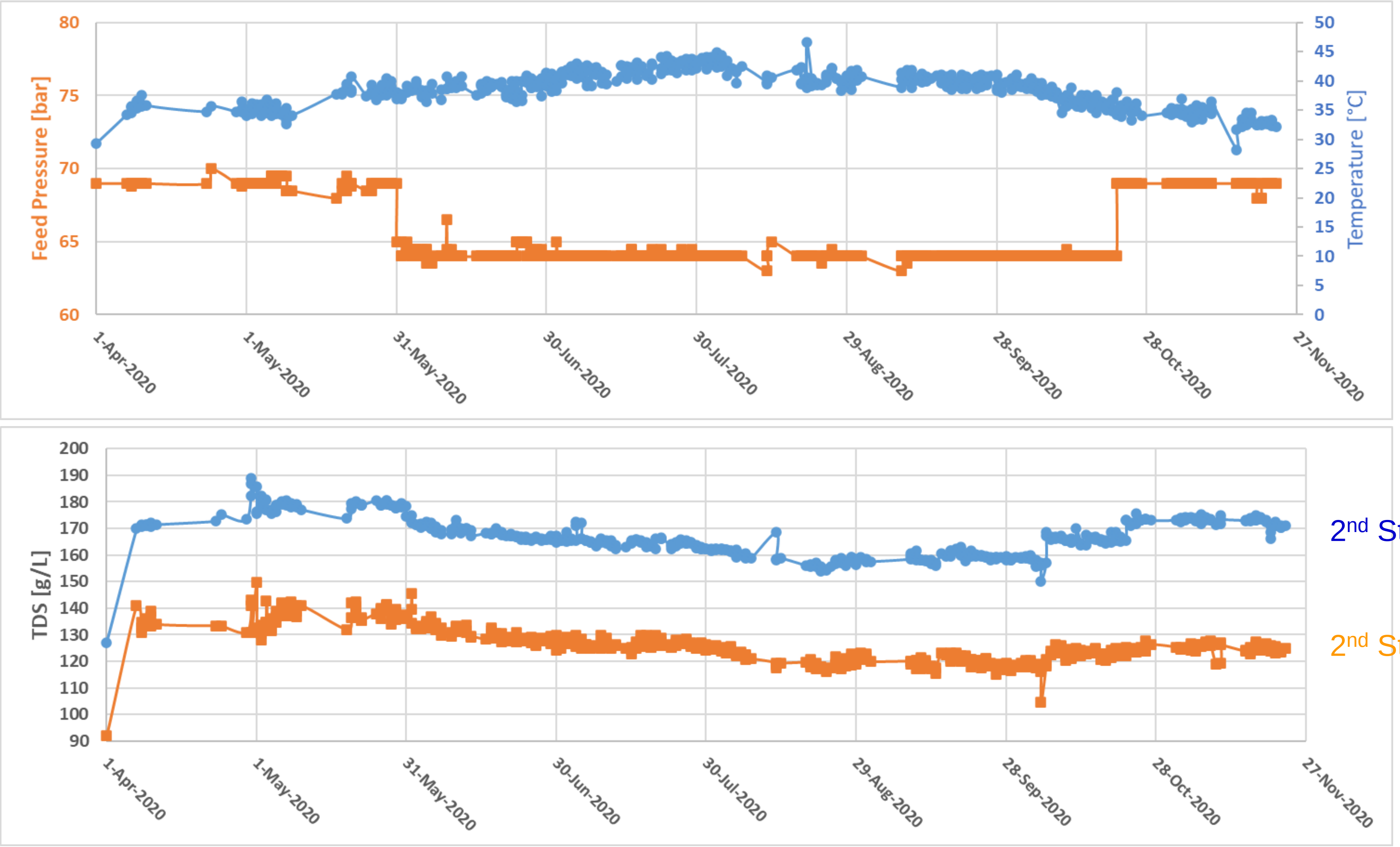
Phase 2 Study – Demonstration of Long-term Operation of **8 months** – BC 1st stage





SWCC-DTRI **NF-RO-BC** Pilot Study

Phase 2 Study – Demonstration of Long-term Operation of **8 months** – BC 2nd Stage

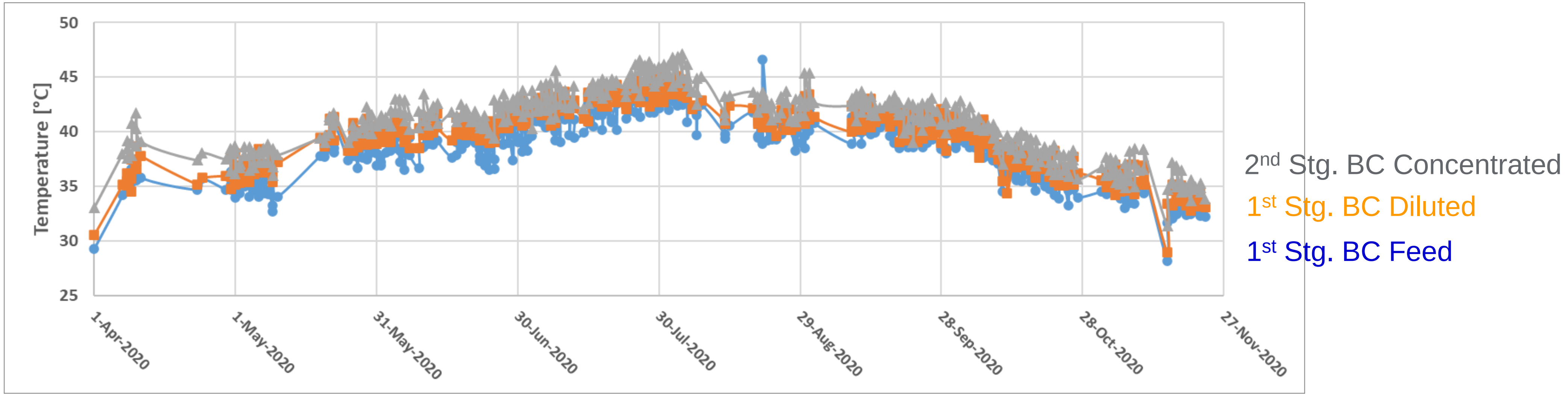


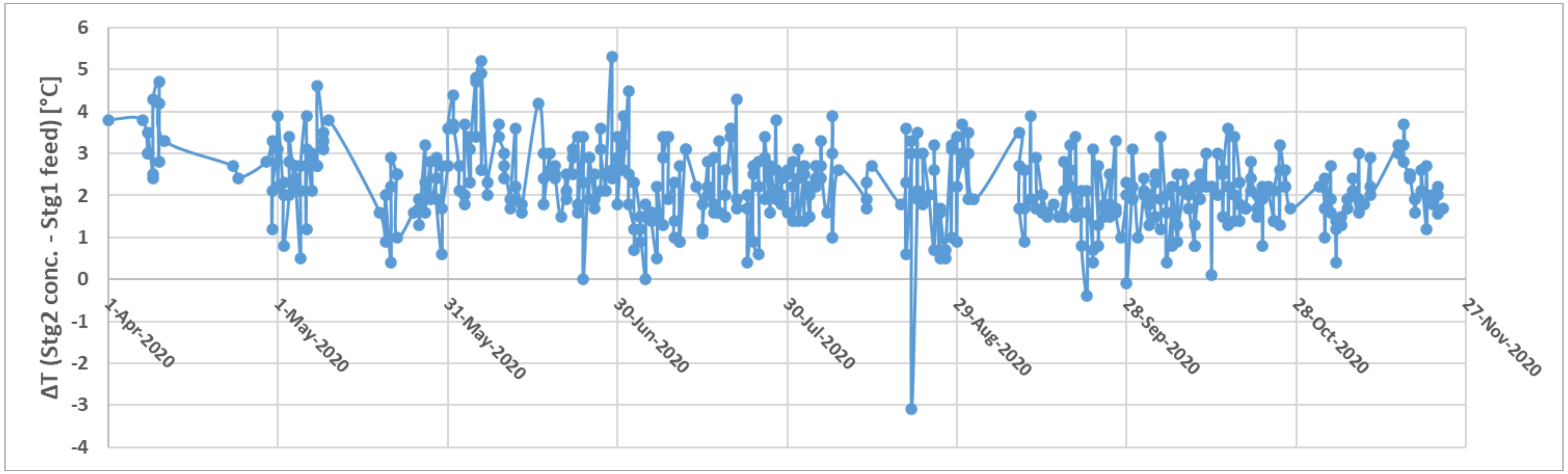
2nd Stg. BC Concentrate

2nd Stg. BC Feed

SWCC-DTRI **NF-RO-BC** Pilot Study

Phase 2 Study – Temperature Increase issue



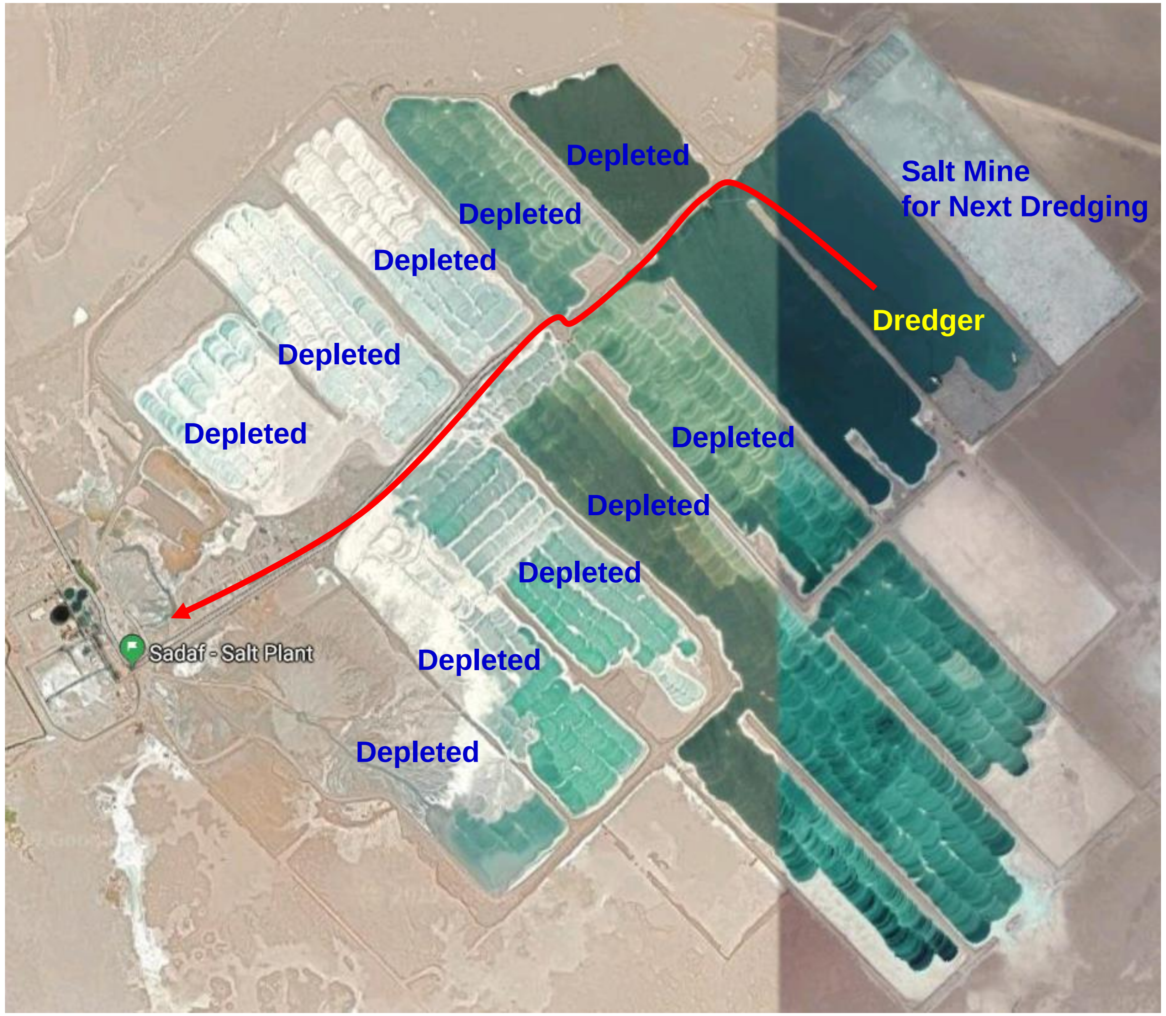


Concluding Remarks

Highly purified and concentrated NaCl brine could be produced for 8 months with NF-RO-BC system with commercial-size membranes.

- ✓ **Purity:** NaCl/TDS = 86 → **96~97%** after NF
- ✓ **Concentration: 170,000mg/L** (> 15%) was achieved by NF-RO-BC system.
  - ➢ ~108,000mg/L after HPRO (R=25%)
  - ➢ ~130,000mg/L after BC 1st Stage and **~170,000mg/L after BC 2nd Stage**
  - ➢ > 210,000mg/L after BC 3rd Stage
- ✓ **Cooling System** will be preferred to maintain the high level of concentration.
  - ➢ Operating pressure will be affected by the temperature of working fluid, to prevent membrane damage.
  - ➢ OARO has recirculation streams, which might increase the temperature higher: fluid dynamic losses during pump shaft work as well as during membrane separation process may be the major sources of heat.
  - ➢ Precise estimation of the temperature increase will be essential in a commercial large-scale OARO system design for long-term robust operation.

Appendix. Existing SABIC-Petrokemya Salt Mine in Jubail



Appendix. Jubail NaCl and Bromine Production Plant

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