Mine Affected Water Minimization Technology – 3 Years of Development

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THE CHALLENGE

Wastewater Minimization

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Mine Affected Wastewater

Mine affected water has neutral to low pH, high salt and heavy metal content.

Sulfate (typically the predominant ion) is introduced into mine water due to the oxidation of sulfide-bearing ores

Sulfate is considered a more significant long-term water quality issue for mining operations

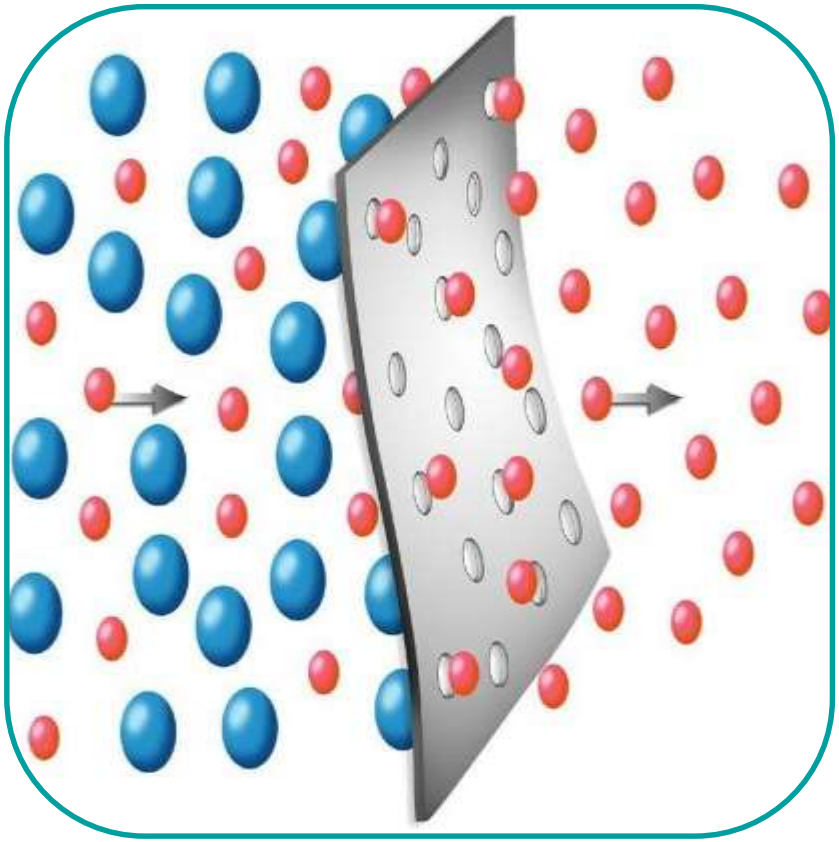
The control level of sulfate is based primarily on secondary drinking water recommendations of ~500 mg/L

Typical Composition of Mine Affected Wastewater

Parameter	Unit	Value
Sodium	mg/L	10 – 700
Calcium	mg/L	300 – 400
Iron	mg/L	0.1 – 3.0
Aluminium	mg/L	0.8 – 1.2
Copper	mg/L	0.3 – 0.6
Chloride	mg/L	20 - 100
Sulfate	mg/L	1,700 – 2,000
Nitrate	mg/L	120 – 350
Alkalinity	mg/L as CaCO3	20 – 450
pH		6.0 - 8.2
TDS	mg/L	3,000 – 3,200
TSS	mg/L	5 - 20
Dissolved Organic Carbon	mg/L	1.3 – 6.0
Saturation Index Calcium Sulfate	%	50% – 95%

Methods for Removing Sulfate from Mine Affected Wastewater

Separation,
eg. membrane separation



Salt precipitation,
eg. formation of gypsum

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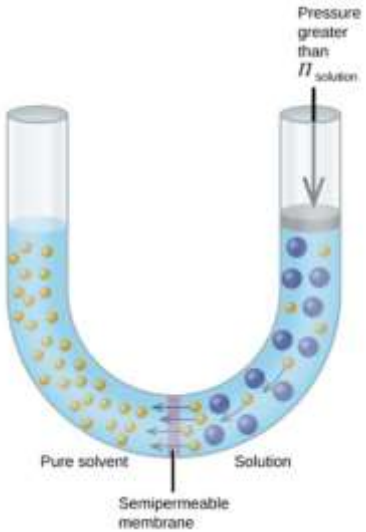
Limitations of Membrane Separation (1)

1. Osmotic pressure

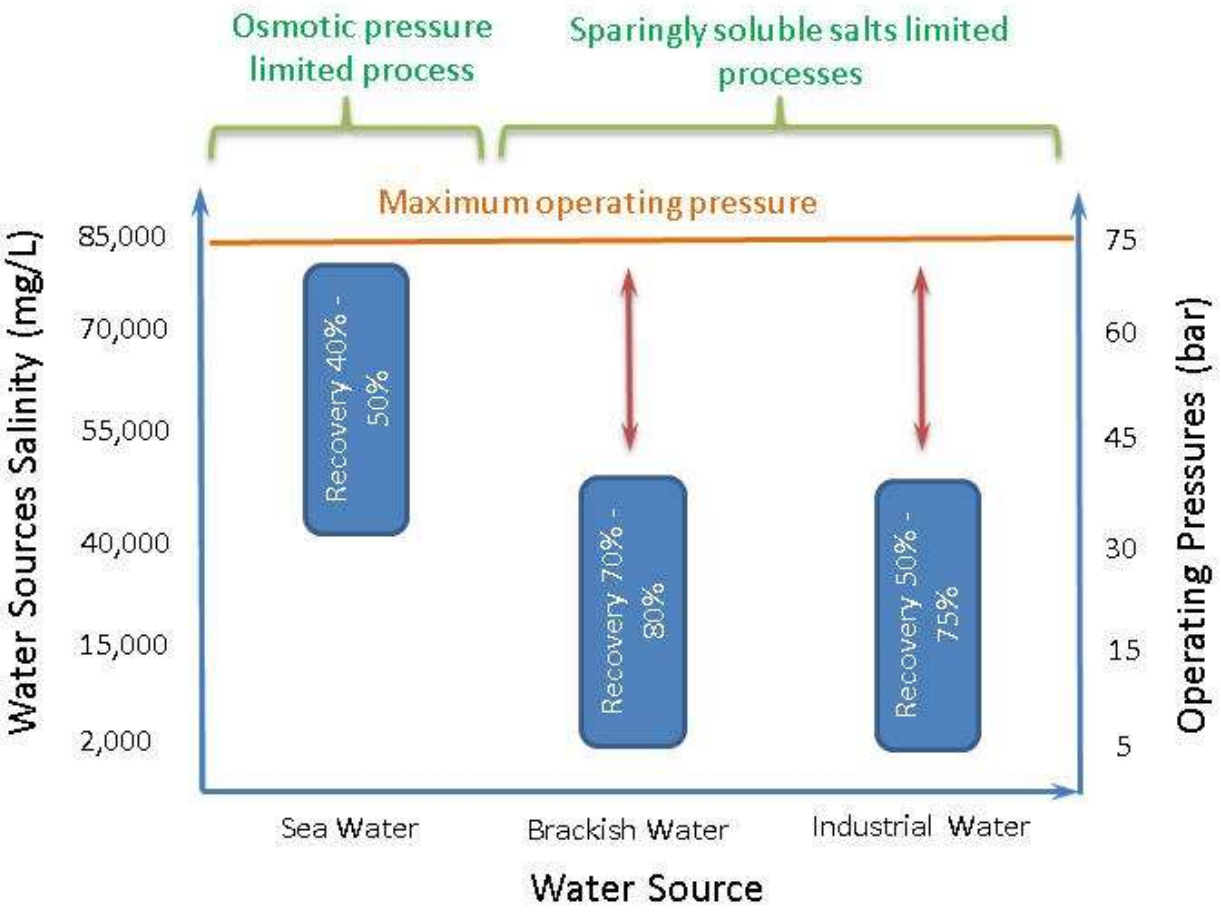


2. Fouling & Sparingly soluble salts scaling

Limitations of Membrane Separation (2)

Industrial effluents have low salinity and osmotic pressure.

Water source chemistry limits the recovery of the industrial RO plants.

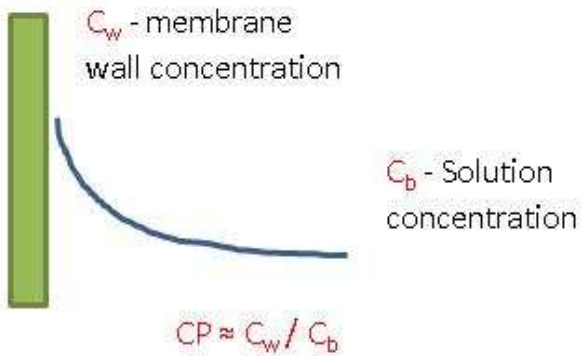


Methods for Increasing the Recovery of RO Plants

- Improving flow regime by increasing flow velocity
- Removing sparingly soluble salts prior to RO stage

Improve flow regime

Design concentration polarization (CP) factor < 1.2



by increasing flow velocity and by decreasing flux CP can be decreased

Remove sparingly soluble salts

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INNOVATIVE WASTEWATER MINIMIZATION TECHNOLOGY

MAXH2O

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Innovative Industrial Wastewater Minimization Technology – MAXH_2O Desalter

Overcomes changes in the feed flow and composition

Operates at very high recovery without reducing the membrane cross-flow

Pushes the limits of calcium carbonate, calcium sulfate and silica precipitation

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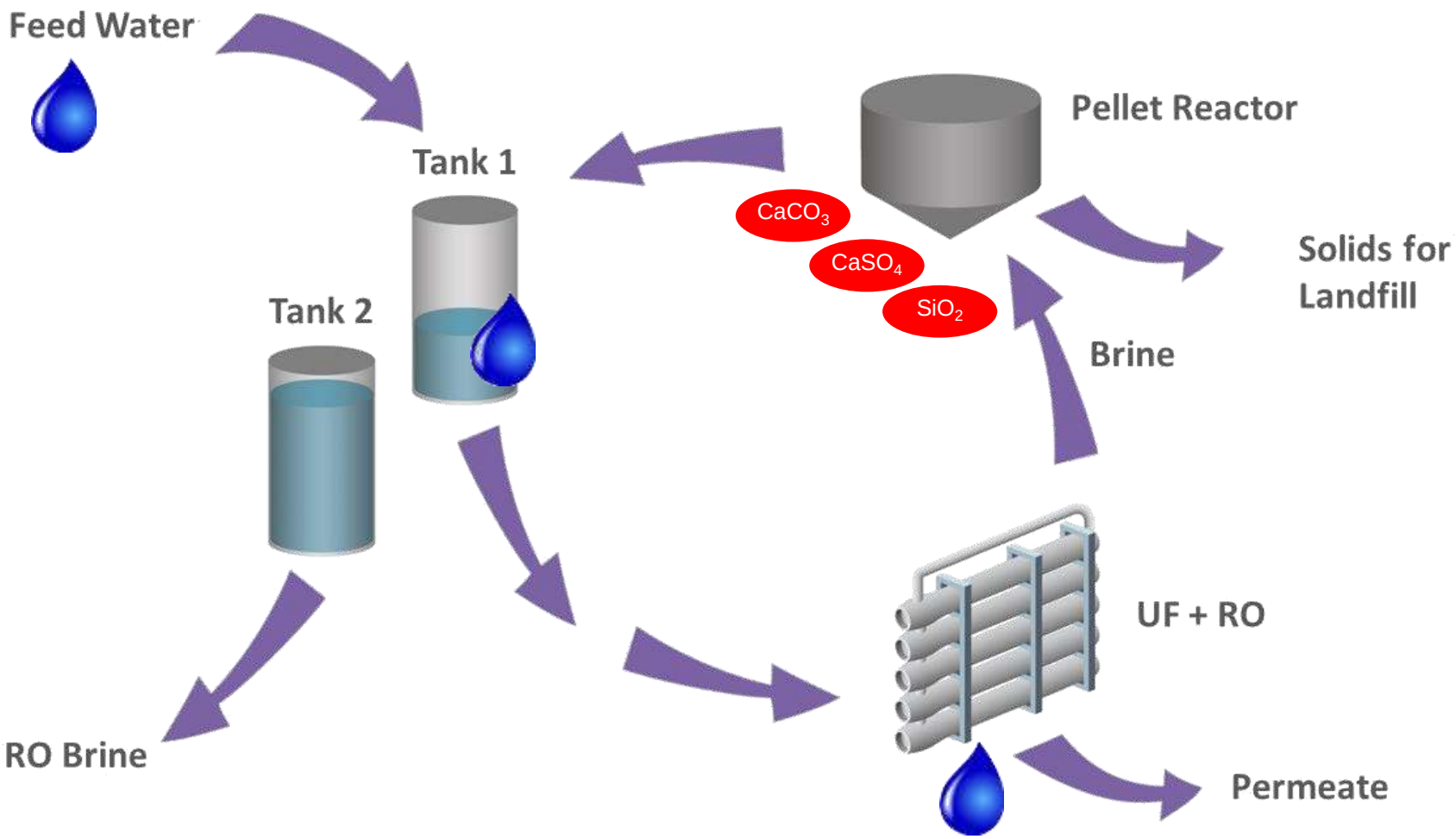
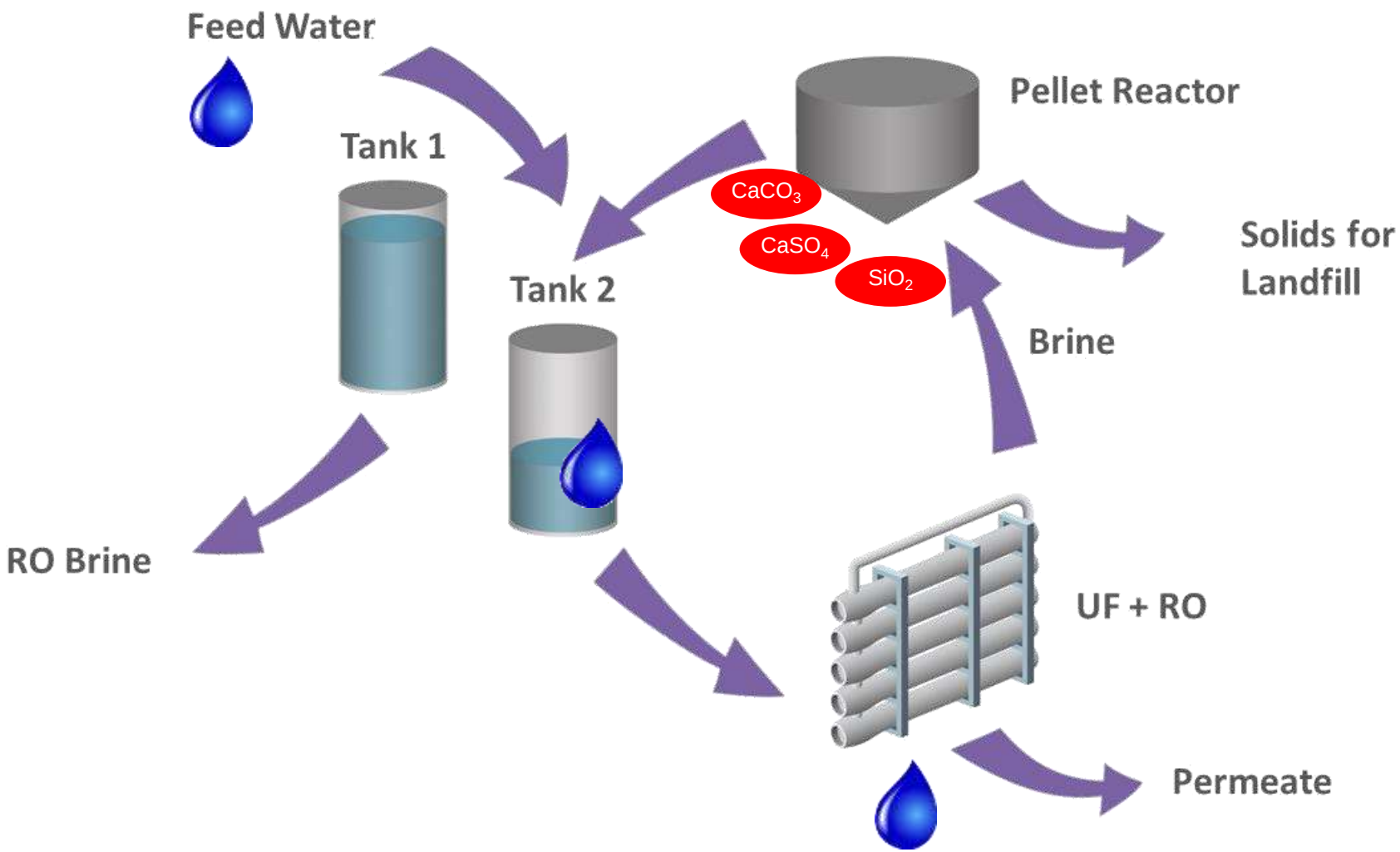
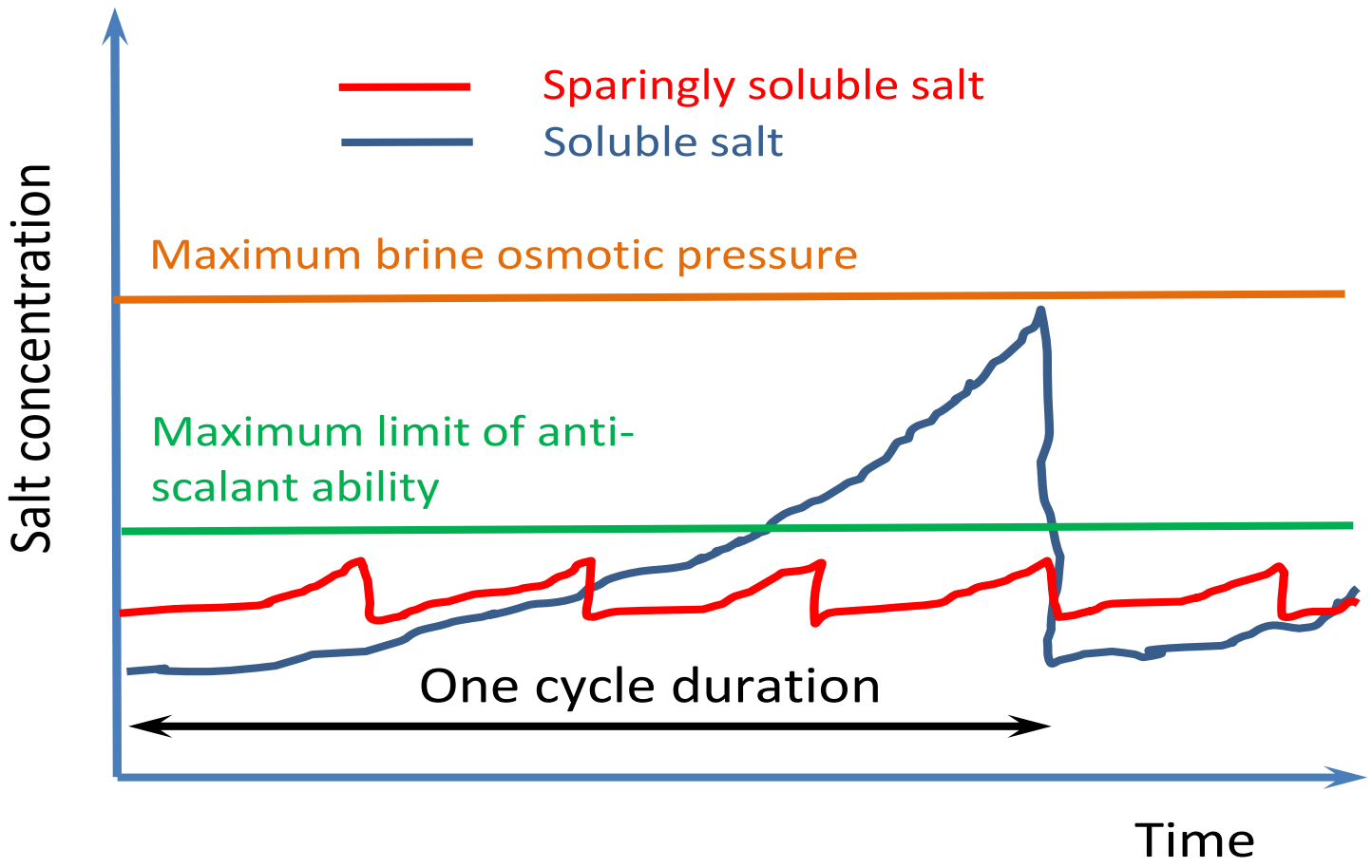
MAXH_2O Desalter - RO System with an Integrated Salt Precipitation Cycle (1)



MAXH_2O Desalter - RO System with an Integrated Salt Precipitation Cycle (2)



MAXH_2O Desalter - Operation



Salt Precipitation Unit – Pellet Reactor

Able to operate with:

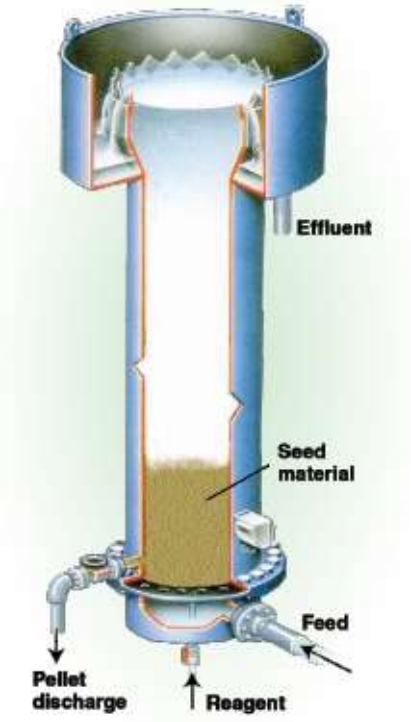
- Variable super-saturation conditions
- Variable TDS levels
- Different types of sparingly soluble salts: $CaCO_3$, $CaSO_4$, Silica, etc.

Short residence time

Small footprint

Low chemical consumption

Minimum sludge handling (high % solid content)



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Advantages of MAXH_2O Desalter

Operation Mode
- Semi-batch

Stages
- 1 stage (2 – 4 elements / pressure vessel in each stage)

Instantaneous recovery
- 15 – 30%

Total recovery
- Variable (15 - 99%)

Flux
- Almost equal in all elements

Residence time
- Low

Feed TDS
- Can handle different TDS levels and adjust recovery accordingly, keeping brine solution constant at highest level

Turbulence
- High (14 m^3/hr per PV at the inlet, 10 m^3/hr per PV at the outlet)

Bio-fouling tendency
- Low. Changes in osmotic pressure of the flowing liquid dramatically reduce tendency for bio-fouling

Scaling tendency
- Low. Entire stream is filtered every cycle and produced nuclei are removed. Last element in every cycle starts from under-saturated conditions

Operational expenditure
- Low (low chemicals consumption and minimum sludge handling)

Brine scaling potential
- Final brine has low scaling potential so can be transferred

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Reference Point – Standard Brackish Water Reverse Osmosis

Parameter	Units	Feed	Brine								
			50%	60%	70%	75%	80%	90%	92.5%	95%	96.3%
Sodium	mg/L	21.50	43.00	53.75	71.67	86.00	107.50	215.00	286.67	430.00	573.33
Potassium	mg/L	6.40	12.80	16.00	21.33	25.60	32.00	64.00	85.33	128.00	170.67
Calcium	mg/L	520.00	1040.00	1300.00	1733.33	2080.00	2600.00	5200.00	6933.33	10400.00	13866.67
Magnesium	mg/L	300.00	600.00	750.00	1000.00	1200.00	1500.00	3000.00	4000.00	6000.00	8000.00
Barium	mg/L	0.01	0.02	0.03	0.04	0.05	0.06	0.12	0.15	0.23	0.31
Strontium	mg/L	0.28	0.56	0.71	0.94	1.13	1.41	2.82	3.76	5.64	7.52
Bicarbonate	mg/L	558.32	1116.64	1395.80	1861.07	2233.28	2,792	5,583	7,444	11,166	14,889
Chloride	mg/L	14.41	28.82	36.03	48.04	57.65	72.06	144.12	192.15	288.23	384.31
Sulfate	mg/L	1,785.00	3570.00	4462.50	5950.00	7140.00	8,925	17,850	23,800	35,700	47,600
Nitrate as NO3	mg/L	310.00	620.00	775.00	1033.33	1240.00	1,550	3,100	4,133	6,200	8,267
Phosphate as PO4	mg/L	0.01	0.02	0.03	0.03	0.04	0.05	0.10	0.13	0.20	0.27
Reactive silica	mg/L	5.00	10.00	12.50	16.67	20.00	25.00	50.00	66.67	100.00	133.33
TDS	mg/L	3,530	7,060	8,825	11,767	14,120	17,650	35,300	47,067	70,600	94,133
Temperature	C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
pH		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Alkalinity	mg/L as CaCO3	465.00	930.00	1162.50	1550.00	1860.00	2325.00	4650.00	6200.00	9300.00	12400.00
LogSI (CaCO3)		**1.40**	**1.81**	**1.93**	**2.08**	**2.17**	**2.28**	**2.53**	**2.58**	**2.49**	**2.22**
SI CaSO4		**95%**	**233%**	**307%**	**435%**	**542%**	**707%**	**1612%**	**2290%**	**3867%**	**5847%**
SI SiO2		**6.09%**	**12%**	**15%**	**20%**	**24%**	**30%**	**58%**	**77%**	**115%**	**153%**

Standard BWRO recovery

MAXH_2O Desalter

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CASE STUDIES

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Pilot System

Pilot Operating Conditions

RO permeate flux	**<40 LMH**
RO instantaneous (local) recovery	**15% - 30%**
RO total recovery	**90% - 95%**
Salt precipitation reactor hydraulic loading rate	**60 - 100 $m^3/hr/m^2$**
Gravity media filter hydraulic loading rate	**<12 $m^3/hr/m^2$**

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Case Study 1 – Water Analysis

Parameter	Unit	Value
Calcium	mg/L	294
Iron	mg/L	1.96
Aluminum	mg/L	0.858
Copper	mg/L	0.587
Chloride	mg/L	96
Sulfate	mg/L	2,020
Alkalinity	mg/L as CaCO3	<5
pH		5.7
TDS	mg/L	3,157
TSS	mg/L	12.8
Dissolved Organic Carbon	mg/L	6.1
Saturation Index Calcium Sulfate	%	59.9 at 16.7 C

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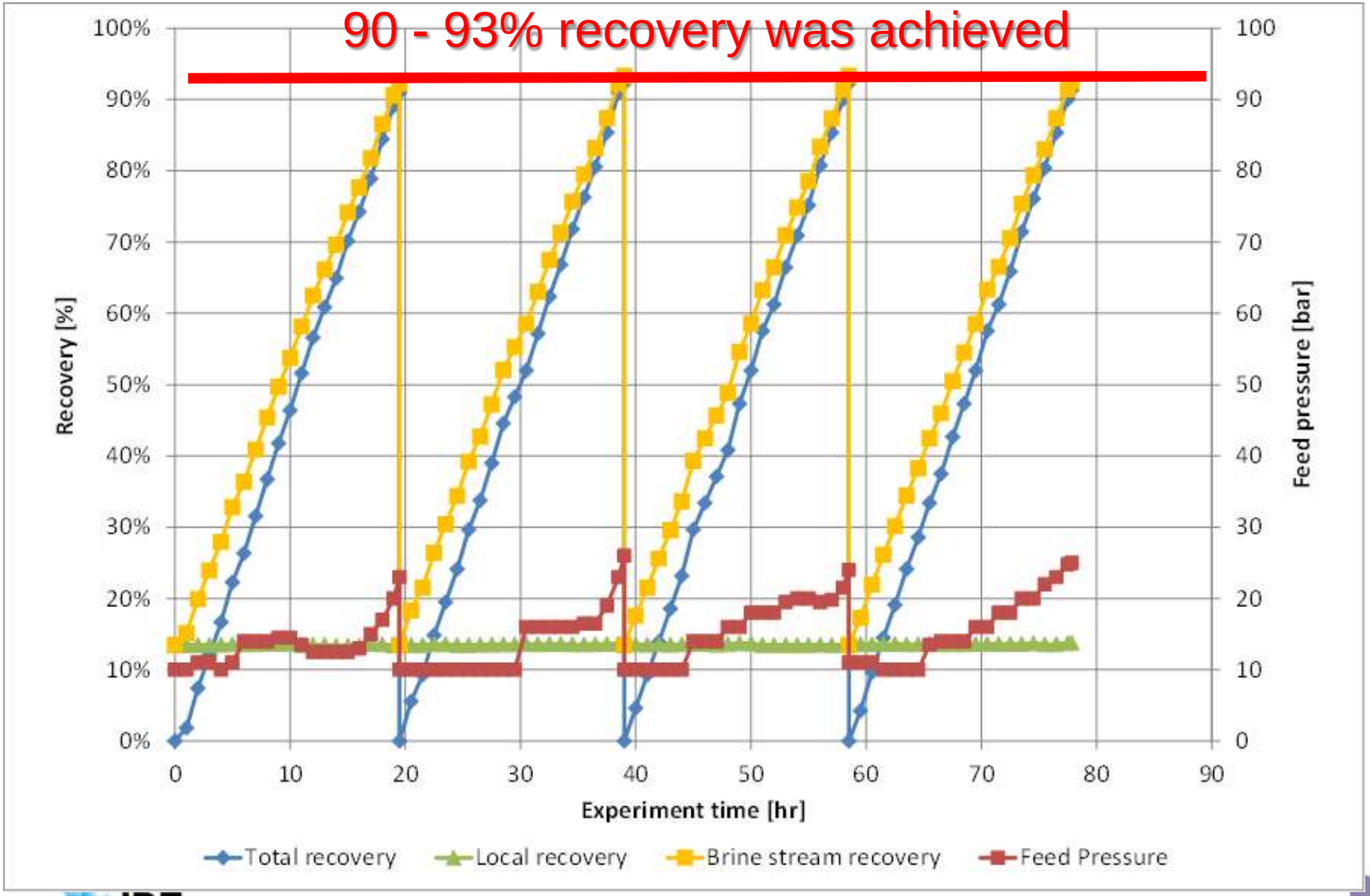
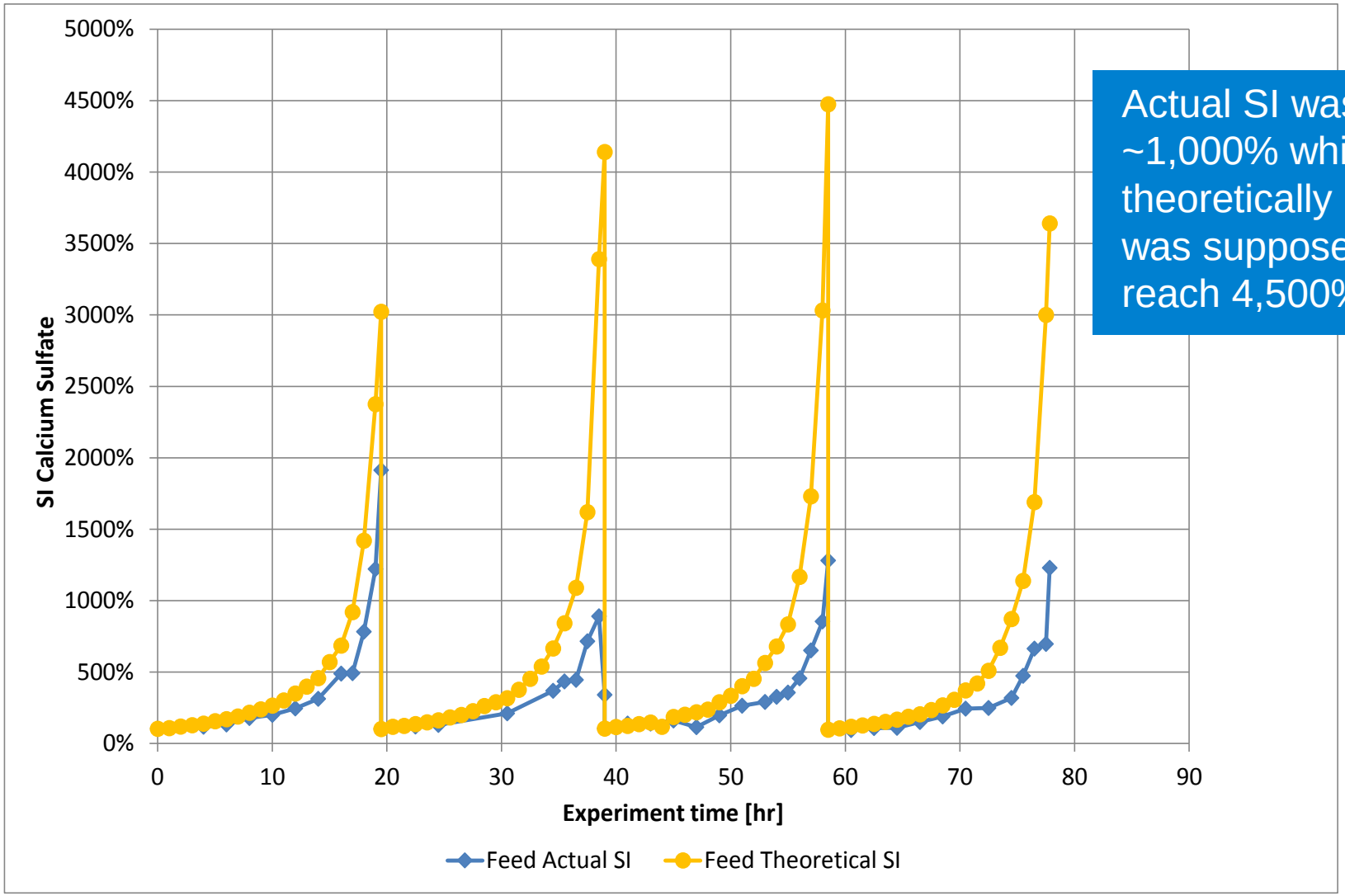
Case Study 1 – Water Recovery

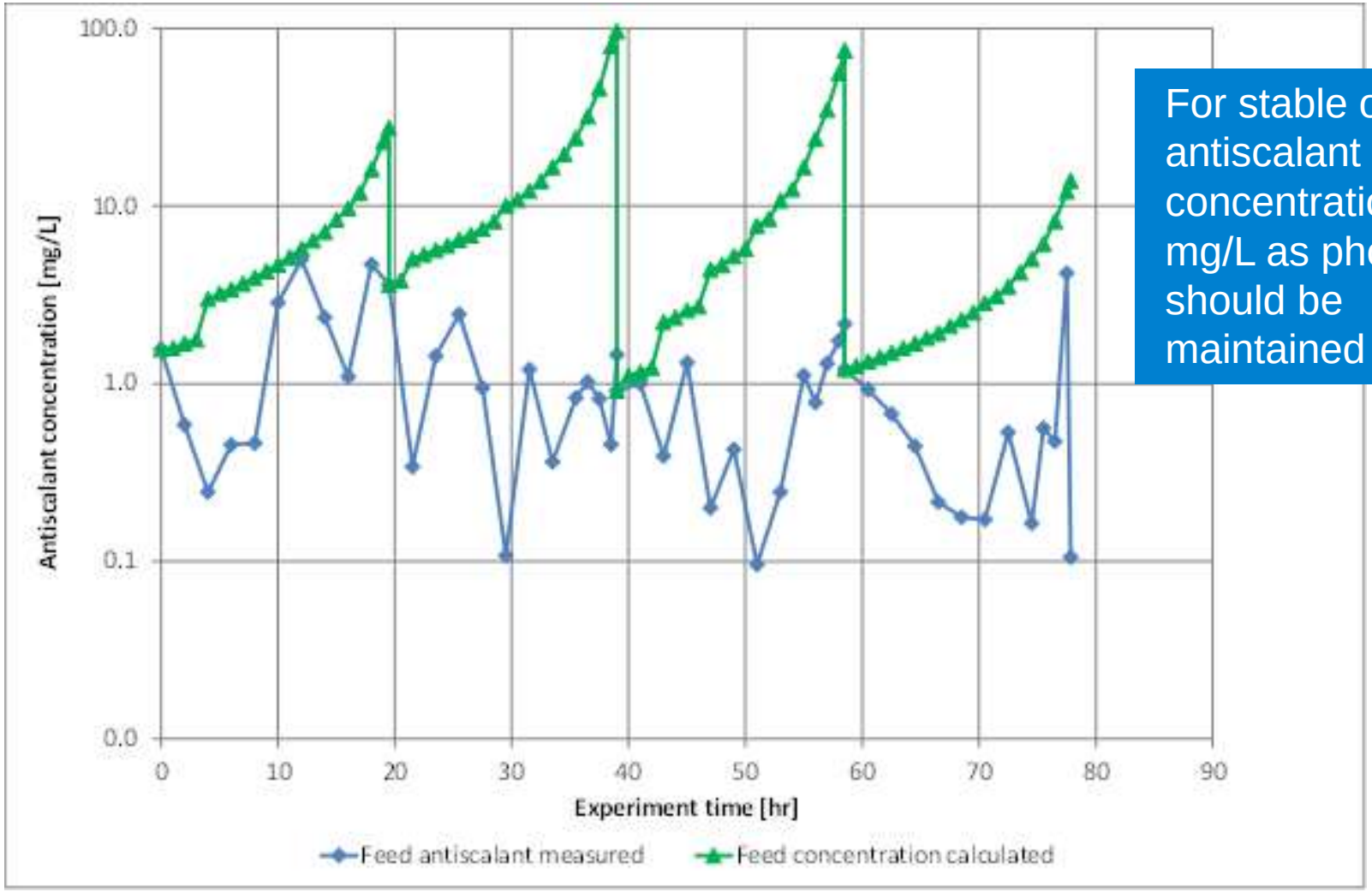


Case Study 1 – Calcium Sulfate Saturation Index



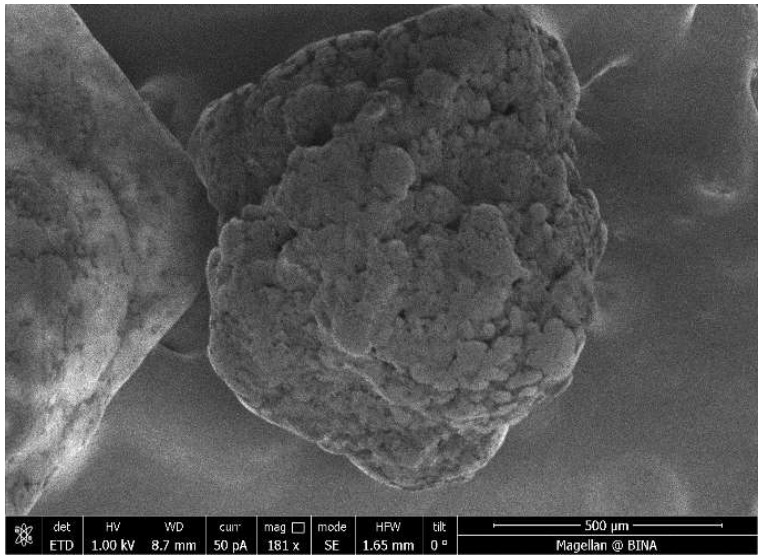
Actual SI was ~1,000% while theoretically SI was supposed to reach 4,500%

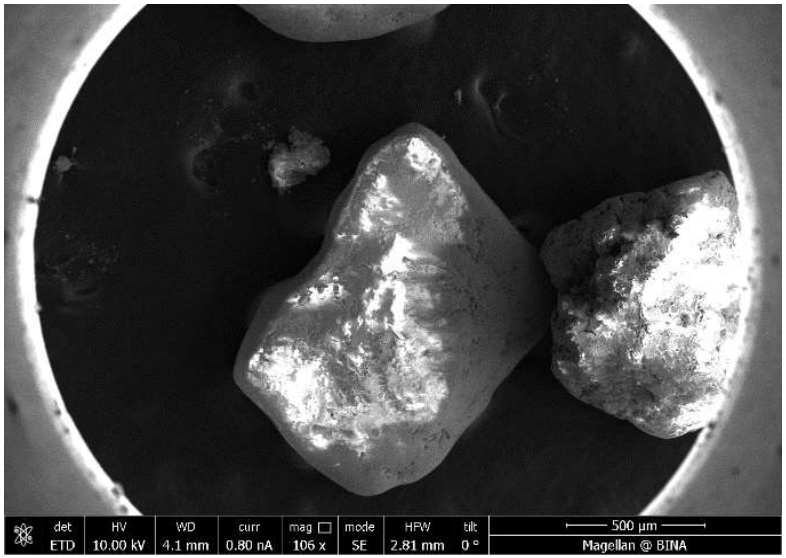
Case Study 1 – Anti-scalant Concentration



For stable operation, antiscalant concentration of 1 mg/L as phosphate should be maintained

Case Study 1 – Pellets Analysis





HR SEM analysis revealed phosphorus and sulphur atoms on the produced pellets. This is proof that antiscalant absorbs, and calcium sulfate precipitates on the pellets.

Case Study 1 – Main Findings

The pilot operated continuously with mine affected wastewater, removing calcium and sulfate in the pellet reactor, without scaling on the RO membrane.

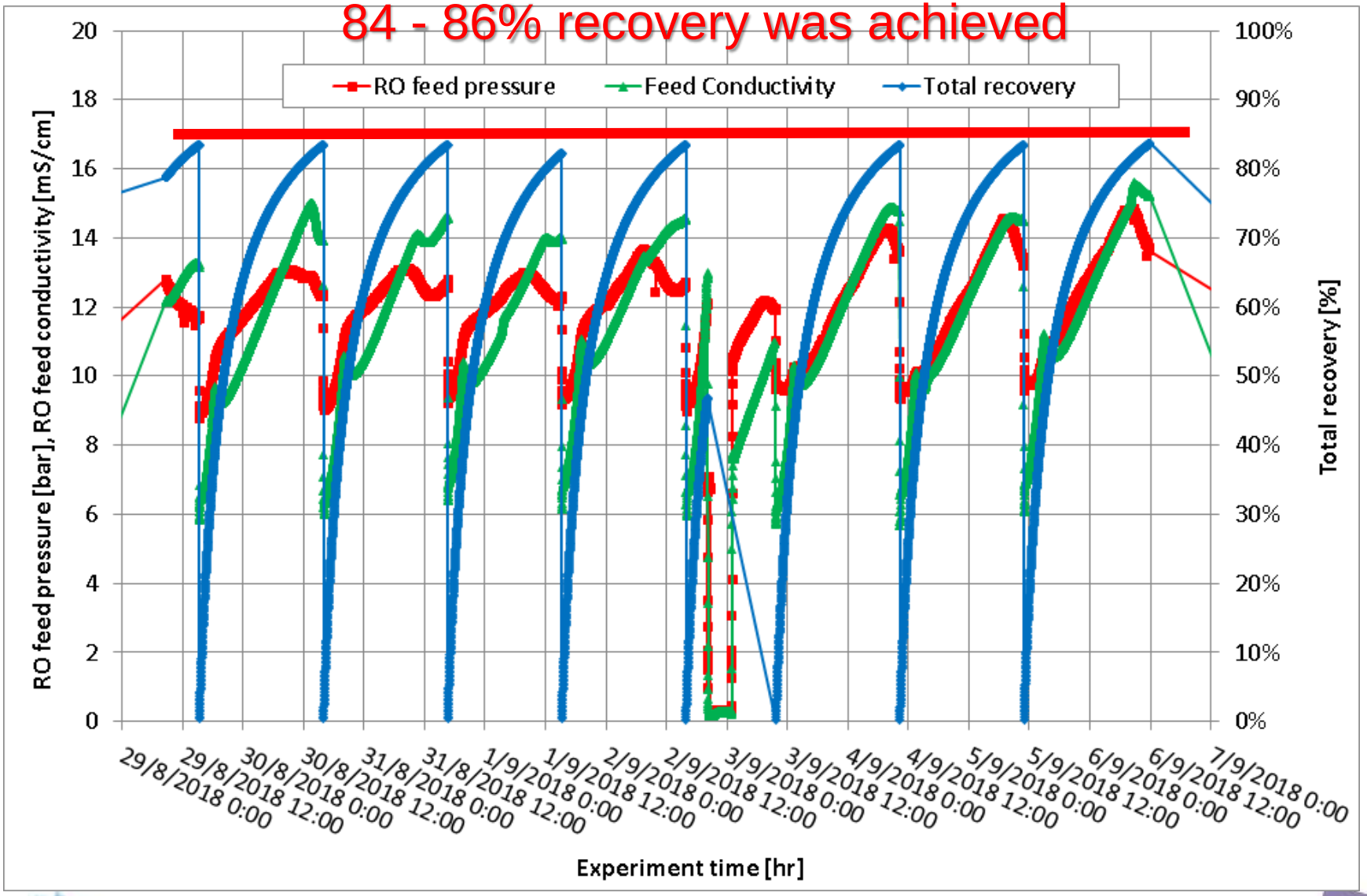
Recovery of 91% – 93% was reached.

During the entire operation, antiscalant was added to the recirculated solution. The antiscalant concentration was maintained at ~1 ppm as phosphate.

Case Study 2 – Water Analysis

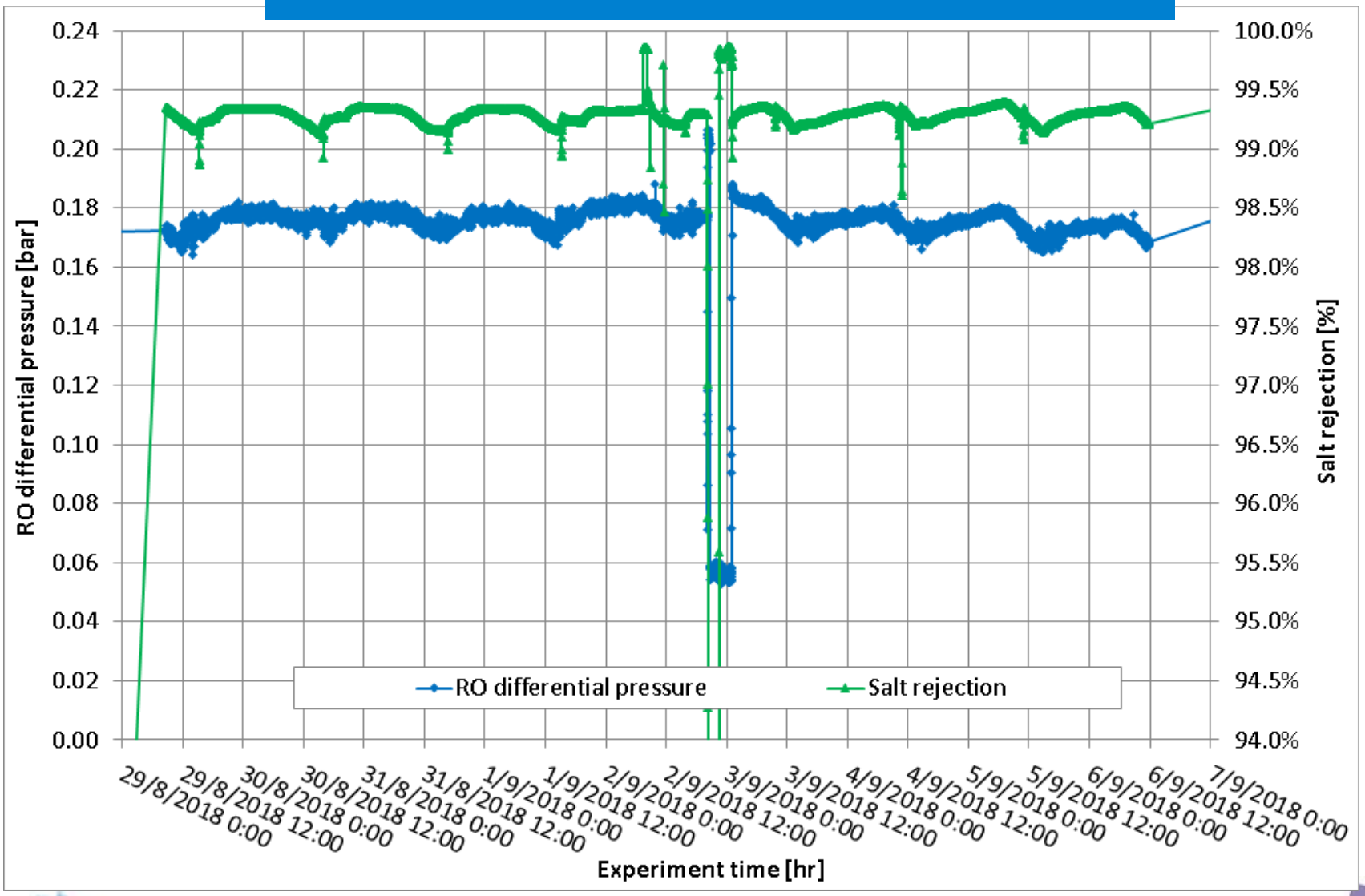
Parameter	Unit	Value
pH		7.87
TDS	mg/L	3,290
Alkalinity	mg/L as CaCO3	446
Sulfate	mg/L	1,760
Chloride	mg/L	16
Calcium	mg/L	454
Log SI calcium carbonate		1.24
SI calcium sulfate	%	78.9%

Case Study 2 – Water Recovery

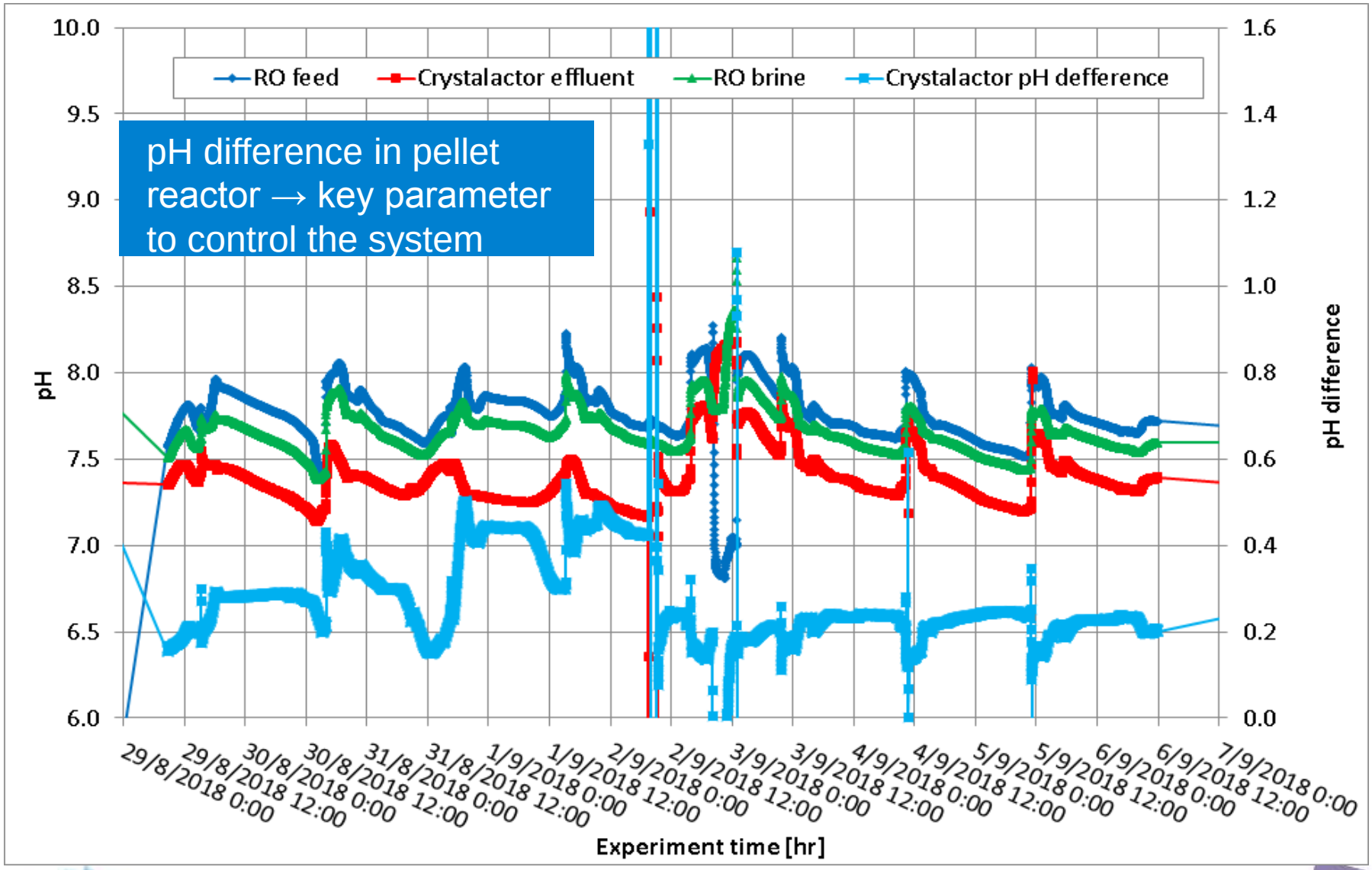


Case Study 2 – RO Differential Pressure

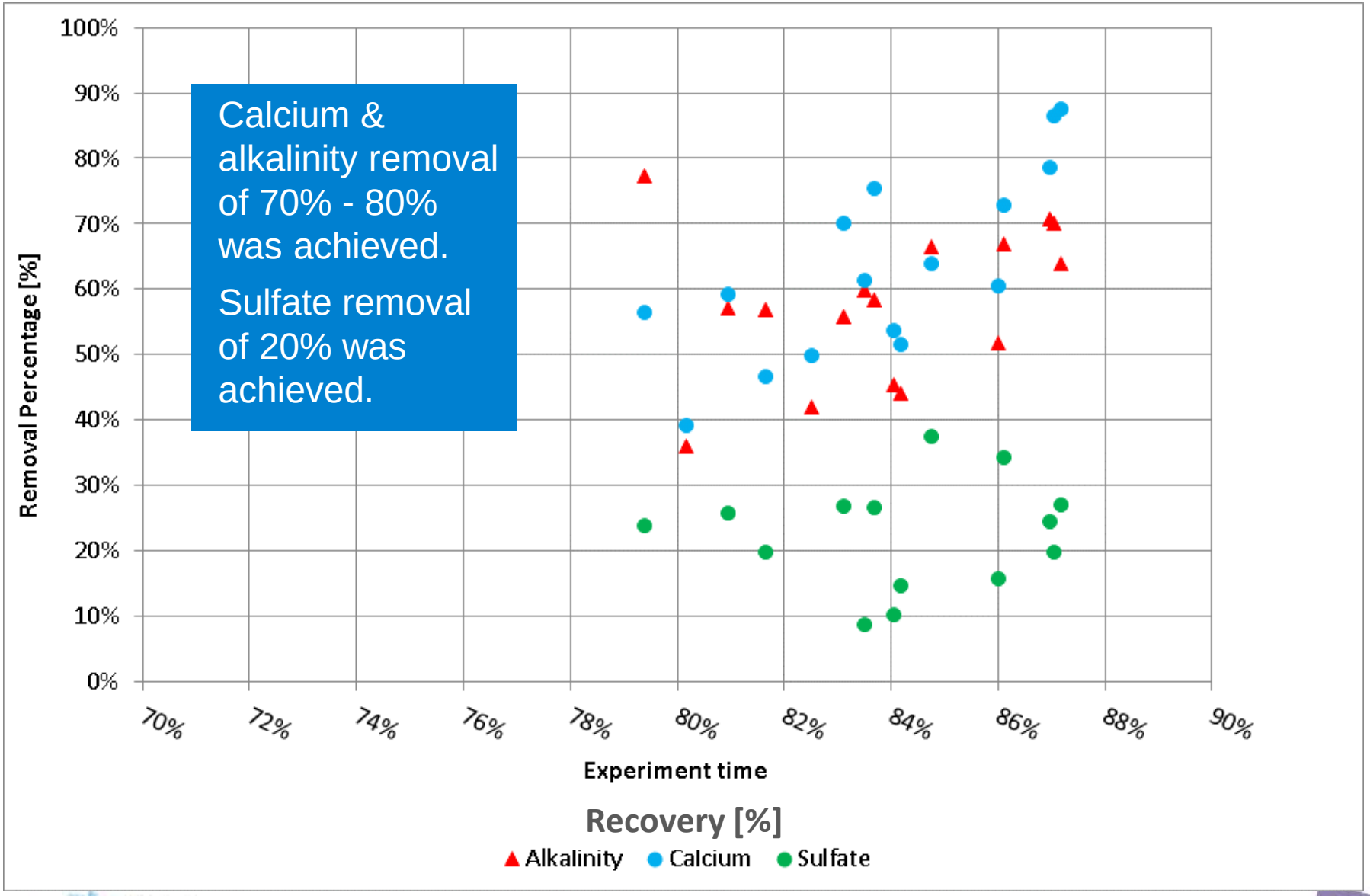
Constant behavior → no scaling on RO membrane



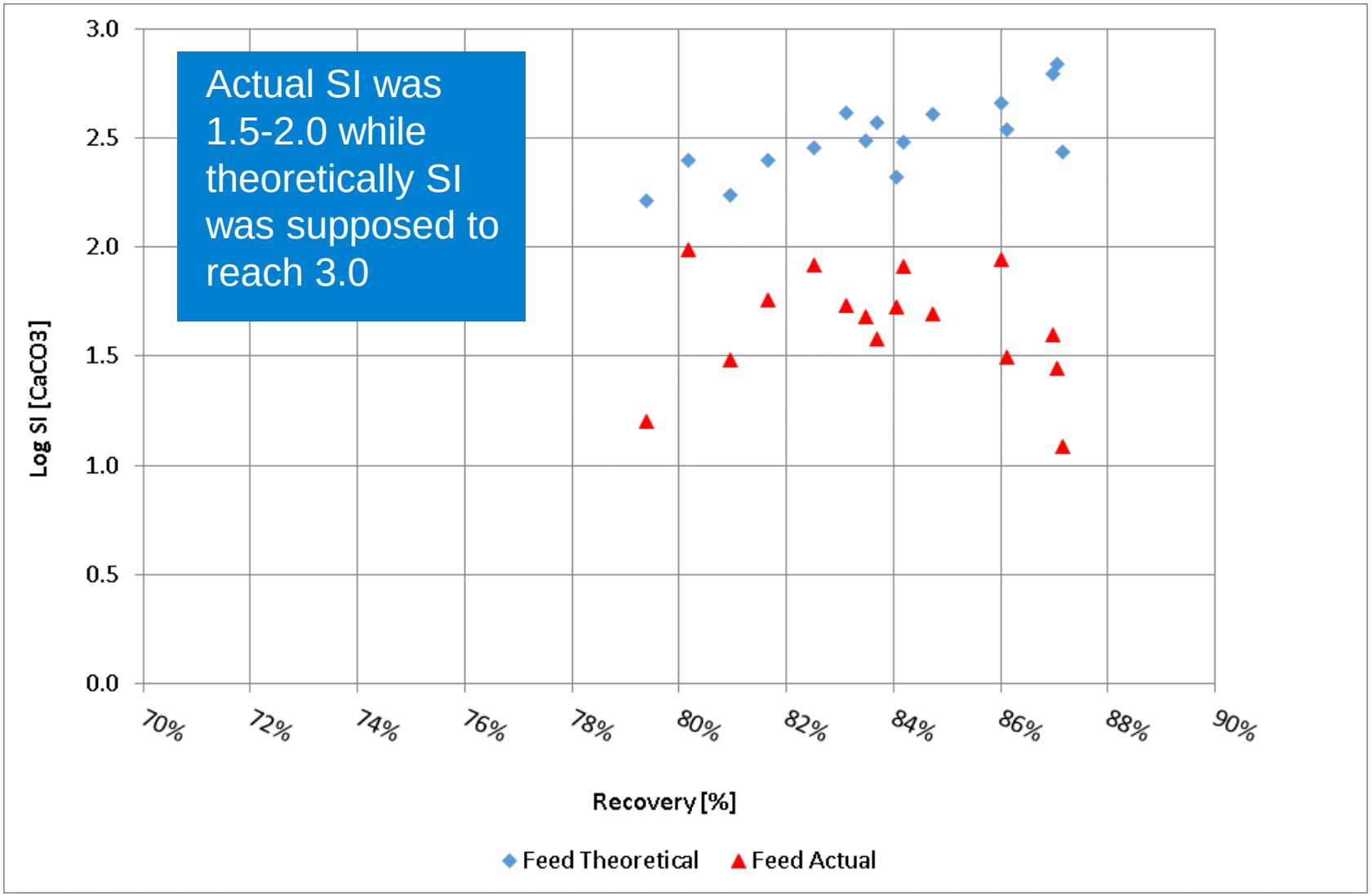
Case Study 2 – Solution pH



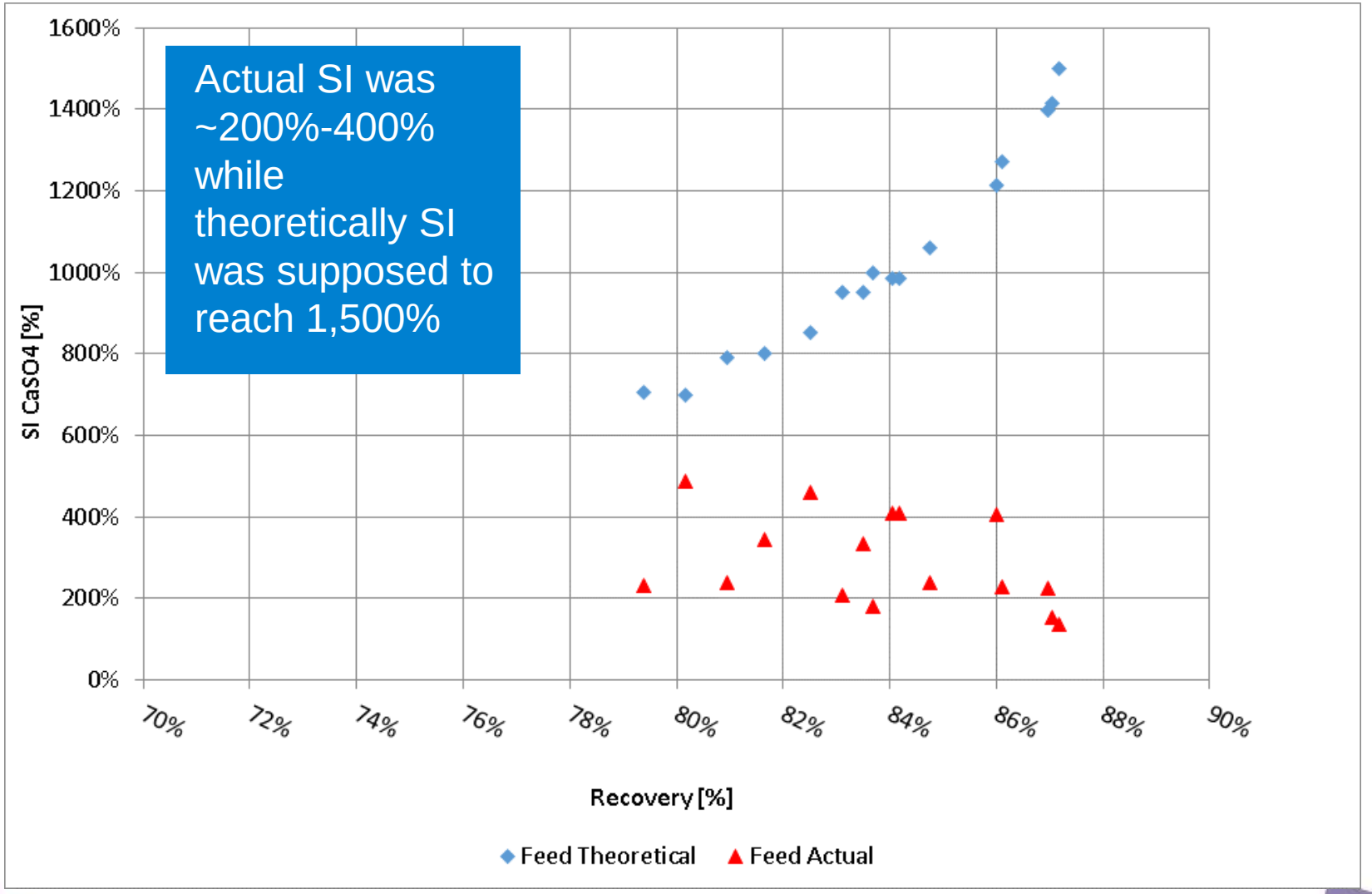
Case Study 2 – Salt Removal



Case Study 2 – Calcium Carbonate Saturation Index



Case Study 2 – Calcium Sulfate Saturation Index



Case Study 2 – Main Findings

The pilot operated continuously with mine affected wastewater, removing calcium, sulfate and alkalinity in the pellet reactor, without scaling on the RO membrane.

Recovery of 84% – 86% was reached.

During the entire operation, antiscalant was added to the recirculated solution. The antiscalant concentration was maintained at ~1 ppm as phosphate.

Thoughts to Take Home

Semi-batch RO system with an integrated salt precipitation cycle for continuous desaturation of industrial effluents

Applicable for RO brine, industrial effluents and mine affected wastewaters with high scaling tendency

High flexibility – operate with variable feed water qualities, concentrations, flows and recoveries

High recovery rates – limited only by osmotic pressure not by supersaturation of sparingly soluble salts

Low investment and operation costs

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