

Produced water treatment by nanofiltration

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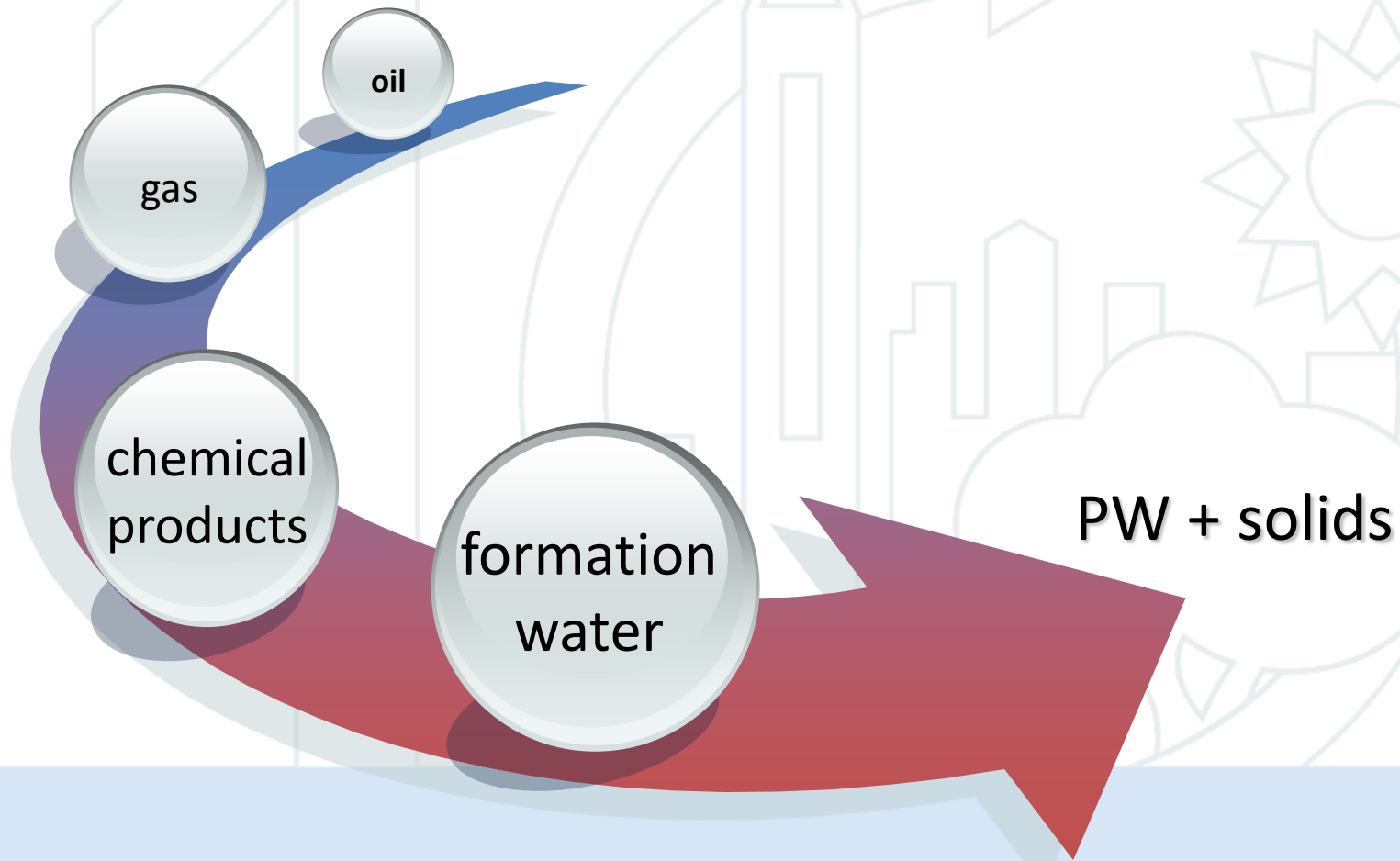
Introduction

1:3
oil : PW

83 mbpd : 260 mbpd 2013

107 mbpd : 321 mbpd 2033

Introduction



Introduction

Problems

toxicity

corrosion

deposition

Introduction

Water
scarcity

Correct
disposal

Low cost
+
High
performance

NF as alternative
treatment

Materials and Methods

- **Membrane Characterization** - Filmtec NF90 flat sheet membrane – Dow Chemical Company

pH	Operating	2 – 11
	Cleaning	1 – 13
Temperature	Operating	Up to 25 °C
	Cleaning	Up to 45 °C
Maximum Operating Pressure	Bars	41
	Psi	600
Permeate flow	L.h ⁻¹	83 – 1,620
	GPD*	525 – 10,300

*Gallons Per Day

Materials and Methods

- **Membrane Characterization** - Filmtec NF90 flat sheet membrane – Dow Chemical Company
 - compactation – DI water – 7 bars – 3.5h – 192 L.h⁻¹
 - hydraulic permeability (L_p)
 - rejection coefficient (f) – NaCl, CaCl₂, Na₂SO₄

$$f = \left(1 - \frac{C_{permeate}}{C_{feed}} \right) \times 100$$

Materials and Methods

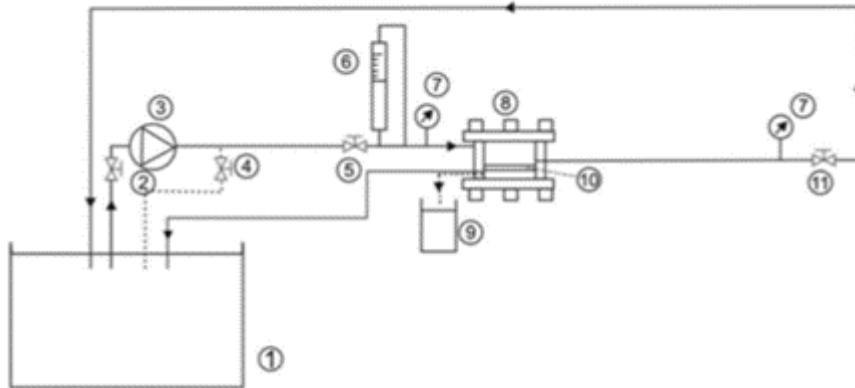
- **Onshore Synthetic PW***

Salts	Concentration (mg.L ⁻¹)	Salts	Concentration (mg.L ⁻¹)
NaCl	933.00	NaF	2.00
CaCl ₂ .H ₂ O	618.00	FeCl ₃ .6H ₂ O	1.00
MgCl ₂ .6H ₂ O	549.00	BaCl ₂ .2H ₂ O	1.00
KCl	89.50	MnCl ₂ .4H ₂ O	1.00
Na ₂ B ₄ O ₇ .10H ₂ O	26.70	NaBr	1.00
AlCl ₃ .6H ₂ O	3.00		

*Data from Potiguar Basin onshore platform

Materials and Methods

- **Permeation Experiments**



1–Feed tank; 2–Two-way valve; 3–Pump; 4 and 5–Two-way valve; 6–Rotameter; 7–Manometer; 8–Permeation cell; 9–Permeate sample; 10–Membrane; 11–Pressure-regulation valve

- ✓ 14.5 cm²
- ✓ Feed temperature 28±2 °C
- ✓ Total recirculate mode
- ✓ 2 – 6 bars
- ✓ 96 L.h⁻¹, 192 L.h⁻¹, 240 L.h⁻¹
- ✓ pH ≈ 7,0
- ✓ ionic chromatography
- ✓ Washing between each run

Materials and Methods



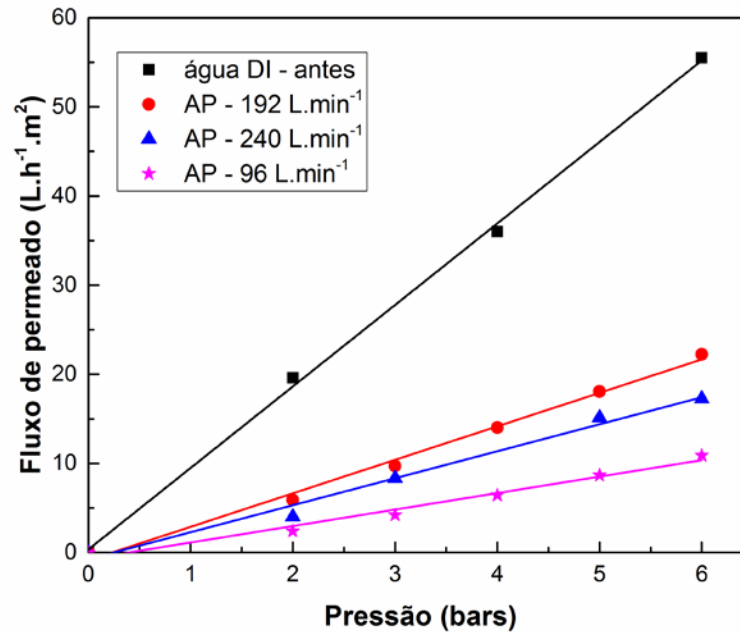
Results and Discussion

- **Membrane Characterization**

L_p (L.h ⁻¹ .m ⁻² .bar ⁻¹)	f_{NaCl}	f_{CaCl_2}	$f_{\text{Na}_2\text{SO}_4}$
9.19	95.79%	97.94%	99.07%

Results and Discussion

- **Permeation Experiments**



Results and Discussion

- **Separation Process**

192 L.h⁻¹

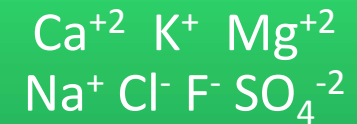
- 2, 3, 4, 5, 6 bars

240 L.h⁻¹

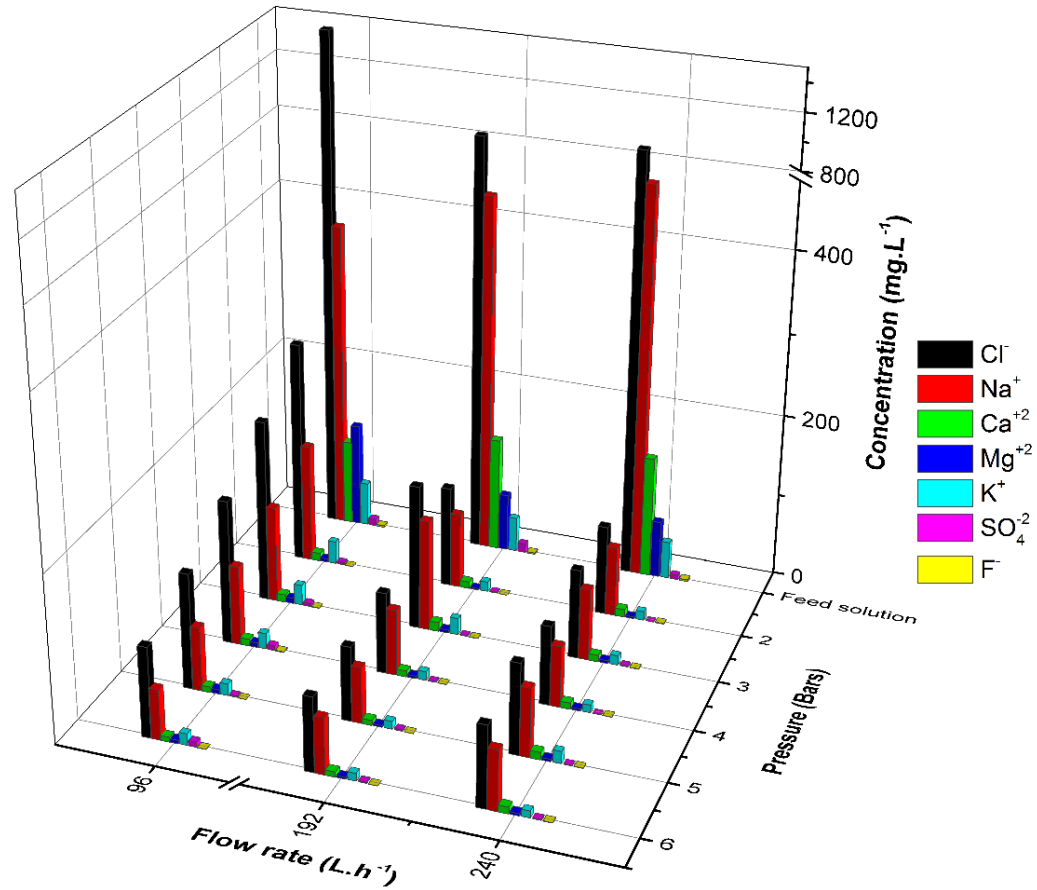
- 2, 3, 4, 5, 6 bars

96 L.h⁻¹

- 2, 3, 4, 5, 6 bars



Results and Discussion



Results and Discussion

	Regime/lons	Cl ⁻	Na ⁺	Ca ⁺²	Mg ⁺²	K ⁺	SO ₄ ⁻²	F ⁻
	96 L.h ⁻¹ 6 bars	92.72	83.89	94.42	96.95	74.19	99.87	88.39
<i>f (%)</i>	192 L.h ⁻¹ 6 bars	91.15	86.52	96.63	98.58	81.55	93.73	> 98
	240 L.h ⁻¹ 4 bars	89.85	84.55	94.94	96.76	79.39	> 99	91.25

Conclusions

- Rejection coefficient > 81%
- Reduction of permeability – fouling
- Best work regime – 192 L.h⁻¹ + 6 bars
- Next steps:
 - Real effluent treatment
 - Electrodialysis

Aknowledgements



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6th International Workshop - Advances in Cleaner Production

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Academic Work