Improving gold mining economics through the use of membrane technology- A study into the reduction of lime and cyanide consumption at WA gold mines

Presenter

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eco technol

MetFest 2017

Kalgoorlie

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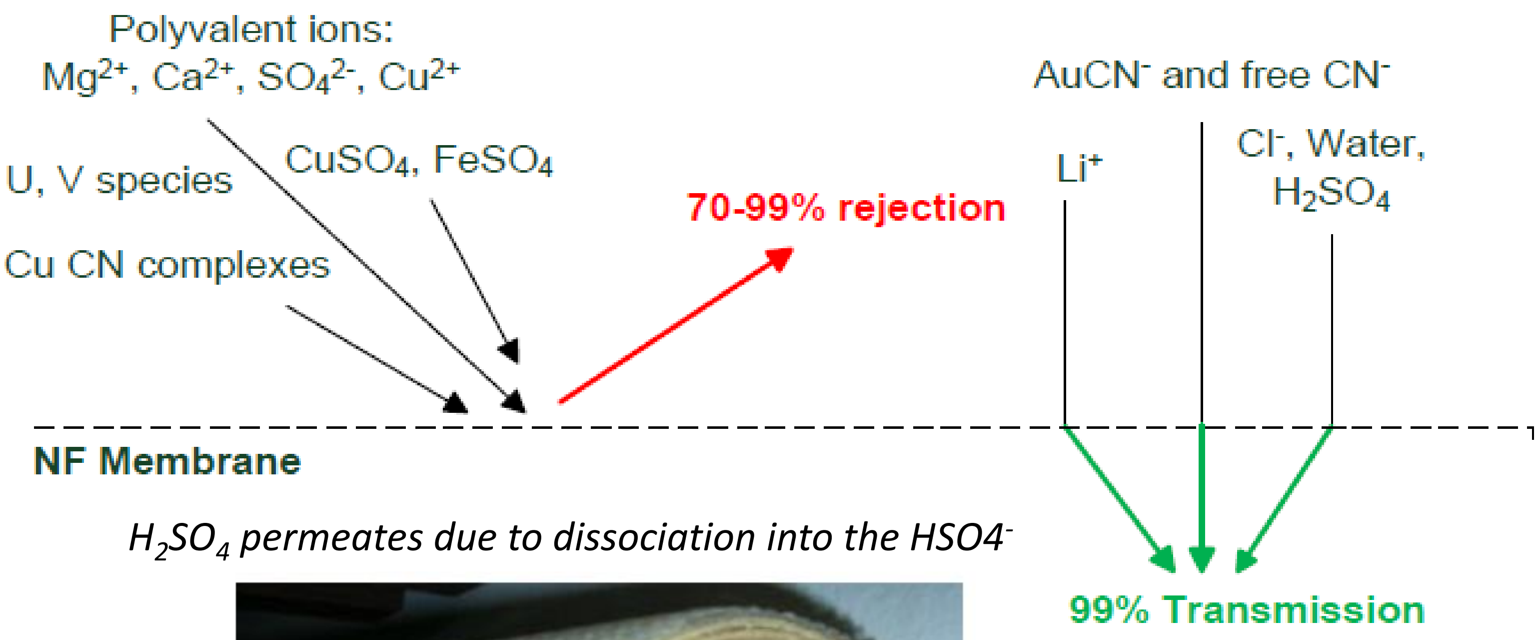
Overview

- Membrane Overview & Current Applications
- Gold Mining in Hypersaline Waters
- Test work
- Summary and Moving Forward

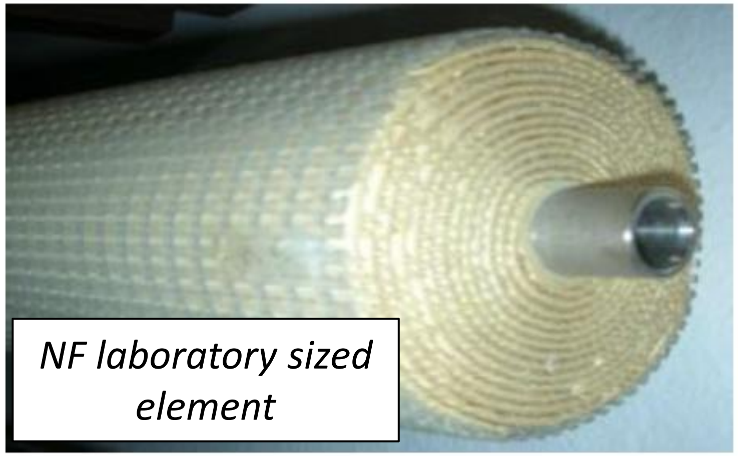
Ecotechnol membranes removes the ions in hypersaline water responsible for high reagent consumption

Nanofiltration- separation mechanism

1. Rejection by Size
2. Rejection due to ionic charge
   - Multivalent anions are strongly rejected (SO_4^{2-}, CO_3^{2-})
   - Cations associated with rejected anions are subsequently rejected also
   - Monovalent anions report to the permeate



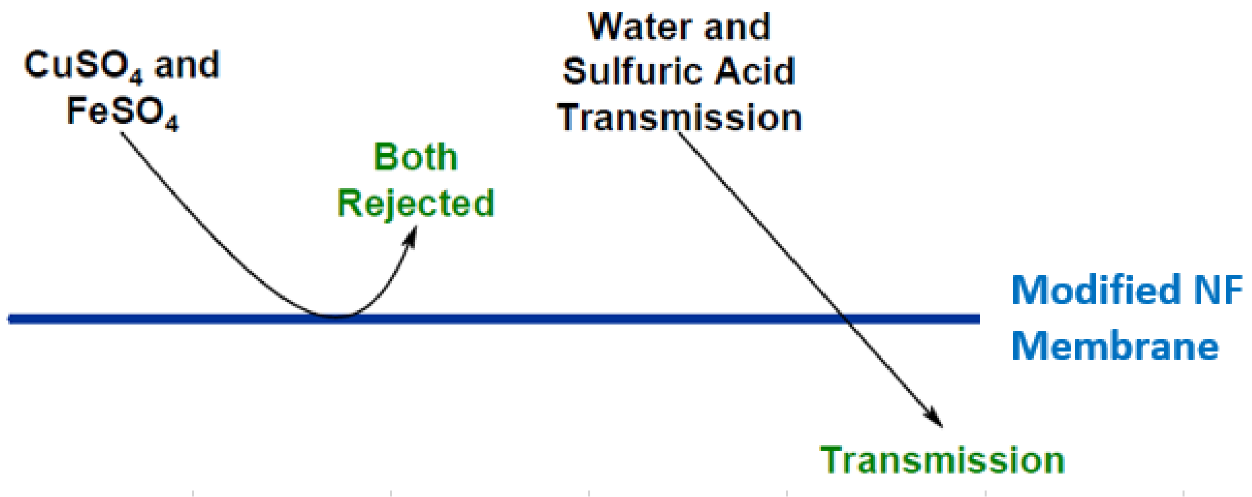
H_2SO_4 permeates due to dissociation into the $HSO4^-$

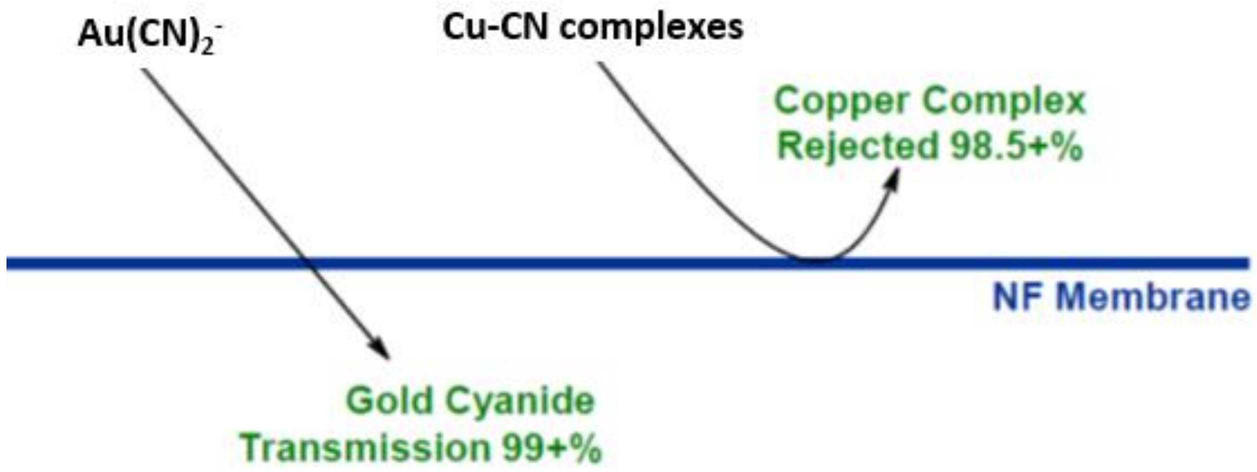


NF laboratory sized element

Nanofiltration- current applications

- Acid/Caustic purification and Environmental Applications (AMD, metals)
- Replace SX prior to Electrowinning OR pretreatment prior to SART-Copper



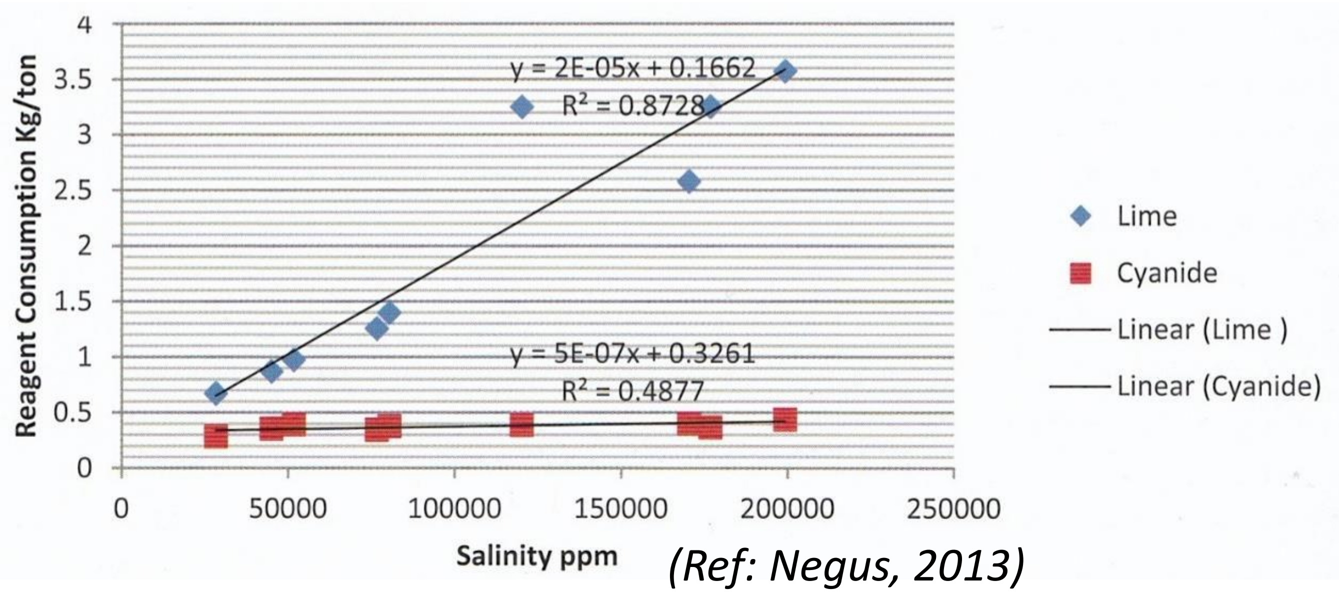


Separation of Graphite (L) & Graphene (R) at pH 2

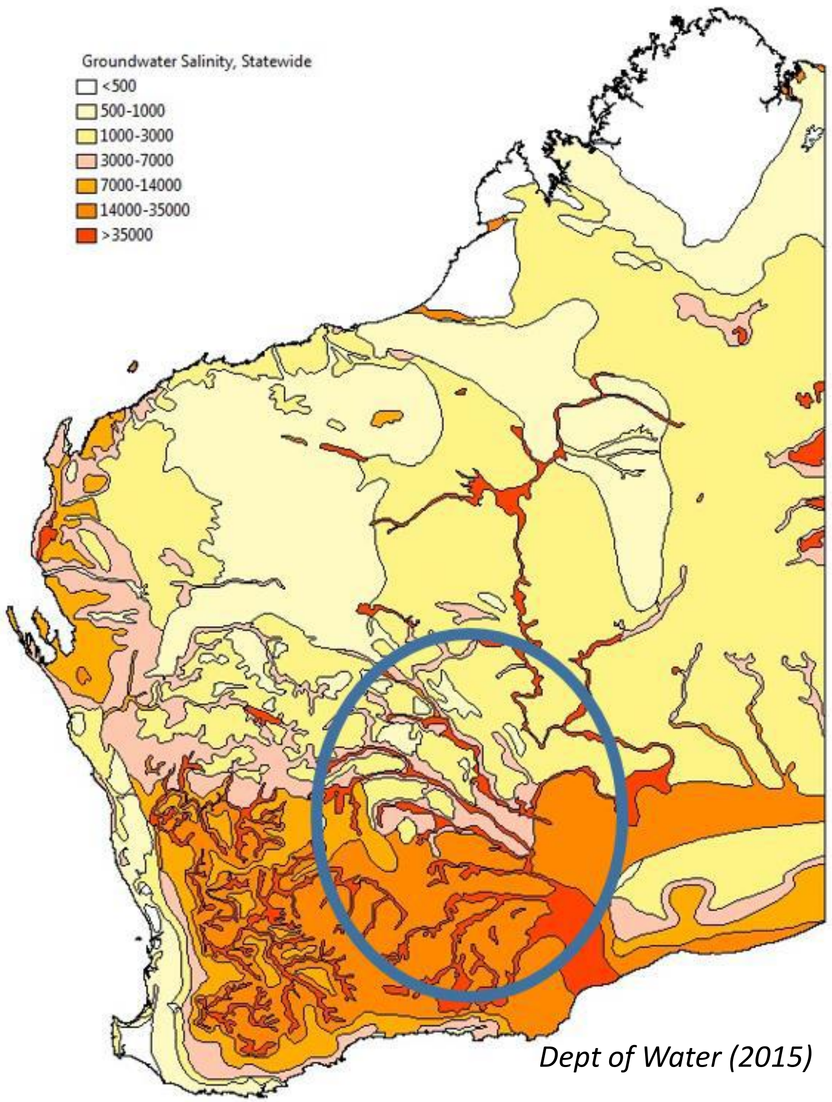
Gold Mining in Hypersaline Water

Impact of Hypersaline Water on Gold Mining:

1. Increased Lime consumption
2. Increased Cyanide consumption due to lower operating pH's
3. Scaling issues (mainly gypsum)
4. Carbon fouling
5. Solubility of Oxygen decreases with increasing salinity



(Ref: Negus, 2013)



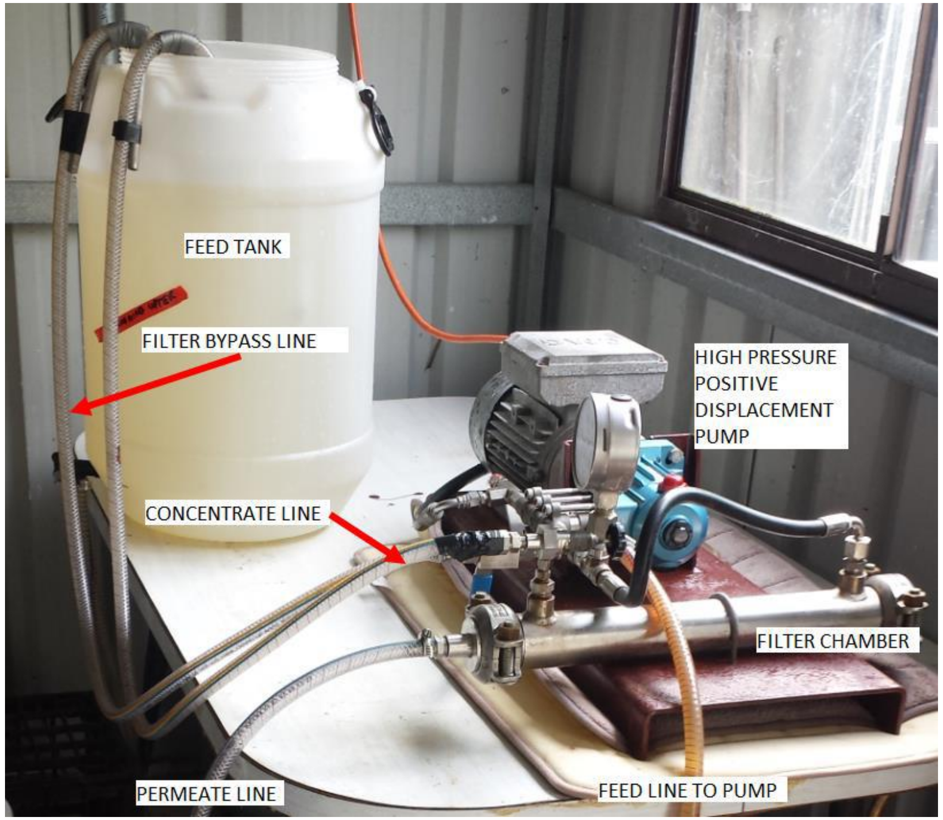
Dept of Water (2015)

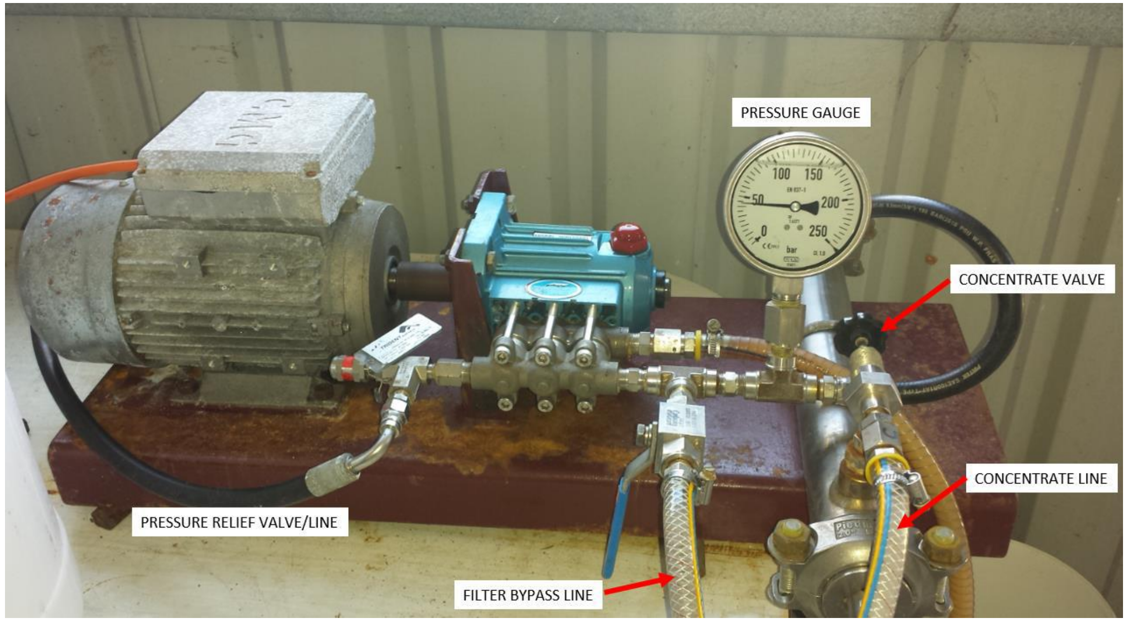
The presence of hypersaline water is strongly associated with greenstone belts and palaeochannels (so is gold!)

ecotechnol technology for the future

Hypersaline Water Testwork

Aim: To investigate the removal of mainly Magnesium, Calcium and Sulphate using UF/NF then assess its impact upon lime and cyanide consumption and Gold leaching Kinetics





Key measured parameters:

- Pressure (UF ~5 bar, NF ~30-50 bar)
- Flowrate (UF 65 mL/m^2/min, NF 20-40 mL/m^2/min)
- Volumetric recovery to permeate (50-90%)
- Analysis of Feed, Concentrate and Permeate

Ecotechnol lab scale unit now located at Curtin University

Previous Testwork Results

Results:

Borefields Water (Site)	TDS (mg/L)	Ion Rejection (%)			% Water to Permeate	Pressure (bar)
		Mg	Ca	Sulfate		
Bullabulling	49,000	96	94	97	90%**	27
Carosue Dam	100,000	87	67	98	80%	50
3	280,000	81	65	99.7	64%	55
4	56,000	98	94	99	90%	30
5*	39,000	93	93	97	50%**	38
6	98,000	92	82	99	50%**	48
7	250,000	84	64	96	50%	55
8	230,000	76	46	92	60%	48
9	72,000	85	85	95	73%	40

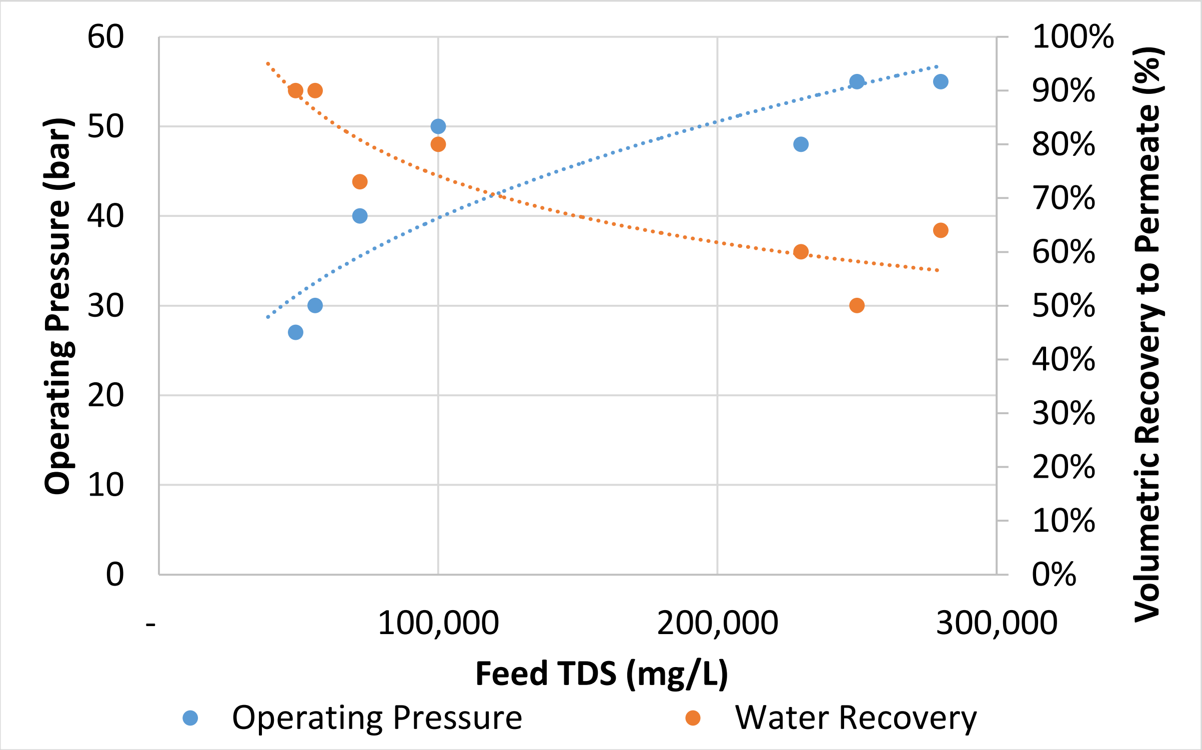
** Process Water ** No Antiscalent added*

High rejection of Mg, Ca and Sulphate

Ecotechnol Testwork cont'd

Observations:

1. Strong rejection of the targeted ions (Mg^{2+}, Ca^{2+}, SO_4^{2-})
2. TDS has a strong influence upon operating pressure and single stage volumetric recovery to permeate
3. Antiscalent has a positive impact upon volumetric recovery to permeate
4. The use of UF prior to NF is critical to success



Pre and Post UF treatment

Ideal Application- A Low TDS (<100k) and high Magnesium Water (>2k mg/L)

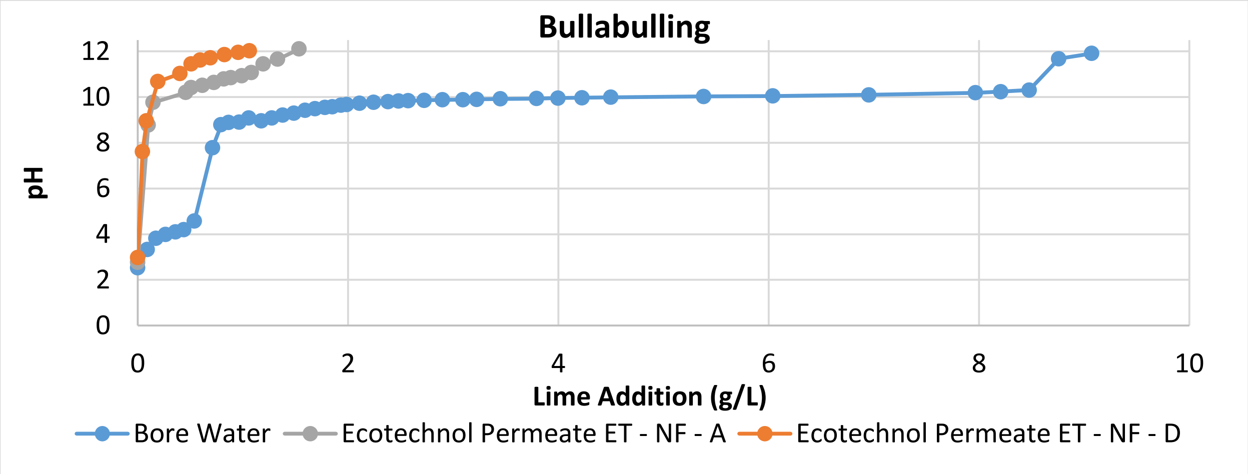
Gold Mining in Hypersaline Water

Site- Locality	pH	TDS mg/L	Cl mg/L	Ca mg/L	Mg mg/L	Na mg/L	Sulphate mg/L
Southern Cross	6.76	249,500	144,630	820	10,020	79,900	13,244
Norseman	7.3	280,000	130,000	780	9,100	82,000	18,000
Kalgoorlie- East	6.54	260,000	150,000	665	8,150	76,000	17,500
Kalgoorlie- East	6.4	124,000	143,400	584	7,940	78,100	-
Kalgoorlie- North East		88,000	69,000	101	7,210	36,300	-
Laverton- South	7.07	100,000	82,000	970	5,300	47,000	11,000
Laverton- South	7.4	230,000	130,000	840	5,000	78,000	15,000
Southern Cross	6.76	109,450	62,950	307	4,327	33,200	6,513
Kalgoorlie- South	5.9	104,600	58,700		4,300	34,800	6,100
Laverton- South		98,000	70,000	1,300	4,100	41,000	8,200
Wiluna- South East	7.6	42,528	65,518	739	4,073	35,610	12,563
Southern Cross	6.65	86,800	49,500	314	4,000	24,900	5,700
Menzies- West	7.72			3,000	4,000		800
Coolgardie	7.7	90,200	47,000	1,500	3,800	28,000	-
Southern Cross	6.9	83,200	48,000	254	3,800	24,600	5,400
Southern Cross	7.1	78,900	45,500	244	3,650	23,400	5,500
Southern Cross	6.6	73,100	41,000	239	3,550	20,900	4,950
Southern Cross	7.1	77,700	44,500	244	3,450	23,400	5,550
Kambalda	3.8	-	49,000	500	3,272		2,060
Kalgoorlie- North East	6.6	91,000	49,000	320	3,100	28,000	7,300
Southern Cross	4.5	70,000	37,000	300	3,000	19,000	4,900
Meekatharra- North West		39,300	23,000	510	2,600	14,100	
Coolgardie	-	66,300	36,750	635	2,570	20,300	1,900
Kalgoorlie- South East	5.85	57,950	11,800	475	2,490	25,000	4,365
Southern Cross	6.97	63,726	35,900	681	2,264	20,100	4,210
Coolgardie- West		47,000	30,000	210	2,100	17,000	
Southern Cross	7.2	37,000	19,000	610	1,900	7,100	2,400
Kalgoorlie- East	7.7	45,100	24,645		1,795	13,450	
Southern Cross	3.9	72,000	43,000	2,200	1,200	20,000	3,000
Southern Cross	5.6	51,000	28,000	1,300	1,200	15,000	1,500
Murchinson	8.3	24,000	-	150	850	7,000	2,900
Murchinson	8.5	6,200	2,900	98	240	1,900	730
Wiluna	7.7	4,525	1,600	143	215	945	985
Murchinson	7.8	4,500	1,800	285	138	1,300	
Meekatharra- North West		2,380	970	16	120	680	-
Wiluna- East	7.8	1,200	300	80	62	190	252
Wiluna- South West	7.69	740	170	102	40	59	120

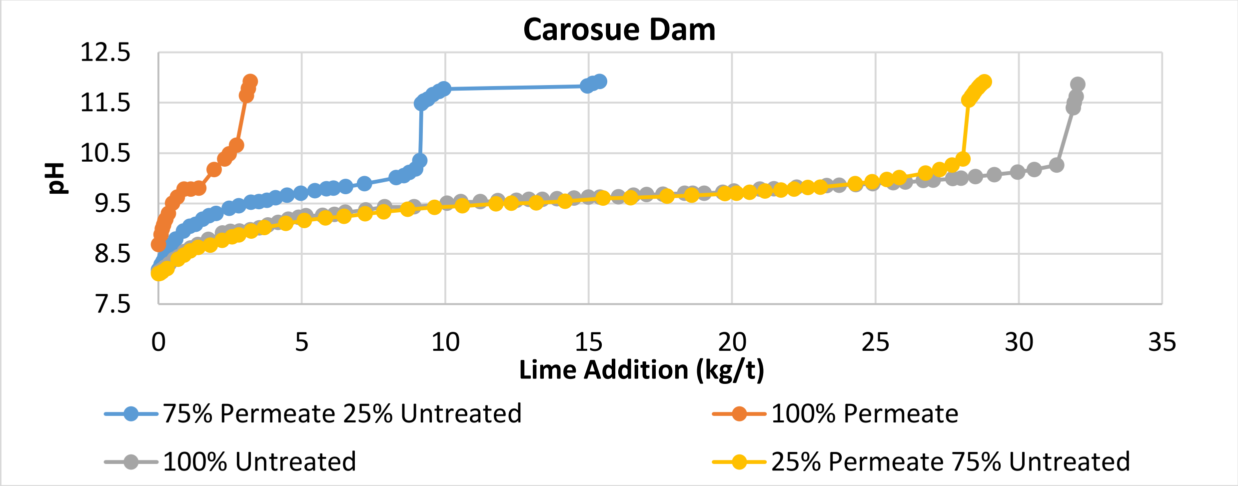
Seawater
35k TDS

Ecotechnol Testwork cont'd

Impact on Lime Consumption (Lime Demand Tests)



pH	Bore water (kg/t)	NF-D Permeate (kg/t)	Reduction in Lime (%)
9	1.01	0.08	**92.1%**
10	4.5	0.13	**97.1%**
11	8.3	0.40	**95.2%**
12	9.07	1.06	**88.3%**



pH	Bore water (kg/t)	100% Permeate (kg/t)	Reduction in Lime (%)
9.3	6.5	0.35	**95%**
10	28	1.68	**94%**
10.5	31.5	2.5	**92%**

Slightly positive impact on gold extraction

Ability to operate the leach circuit at higher leach pH's

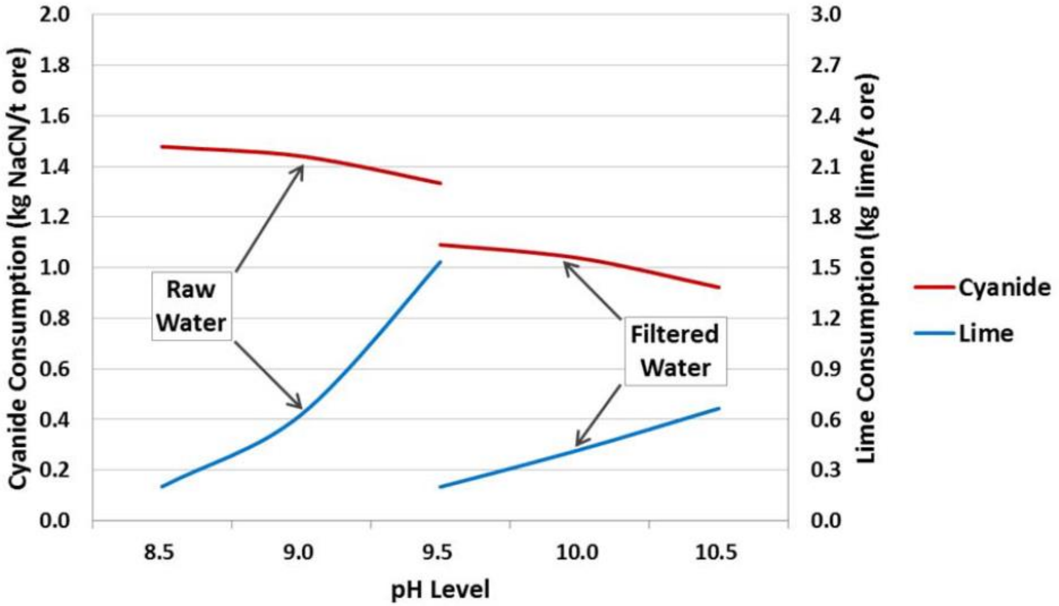
Ecotechnol Testwork cont'd

Bottle Roll Testwork- Bullabulling Gold Project

Phase 1: Comparative Bottle Rolls in Oxide and Fresh Ore

	Oxide Ore			Fresh Ore		
	ET-NF-D Permeate pH 10.2	Bore Water pH 9.5	Reduction (%)	ET-NF-D Permeate pH 10.2	Bore Water pH 9.5	Reduction (%)
Lime Consumption (kg/t)	5.8	12.4	53%	1.6	8.3	81%
Cyanide Consumption (kg/t)	1.21	1.39	13%	0.9	1.45	38%

Phase 2: Client managed testwork for verification (18 bottle roll tests in total)



ASX Code: BAB 12th June 2014 Release

- Lime consumption 87.2% lower with treated water
- Average cyanide consumption was 28.0% lower

No observable impact on Gold Extraction

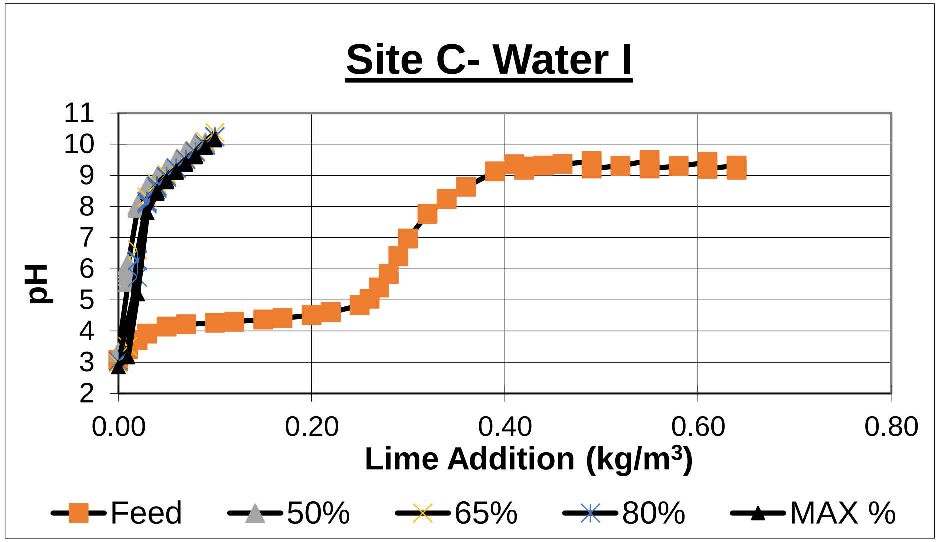
2017 Testwork

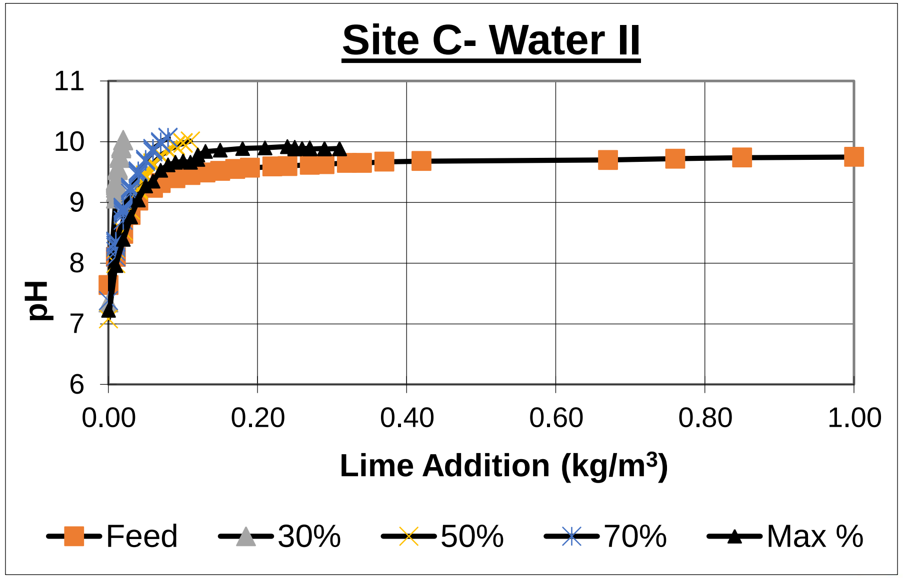
Site	Water	Feed		Permeate	Mg Rejection	Permeate Recovery
		TDS	Mg	mg/L	%	%
A	i	87,000	3,500	84	**99**	40
	ii	110,000	4,900	380	**95**	67
B	i	46,000	2,100	56	**97**	75
C	i	38,000	1,100	9-35	**97-99**	50-96*
	ii	170,000	6,500	830-1,900	**71-87**	30-83*
	ii*			28	**99**	

**Tested a range of permeate recoveries to Maximum ** 2 stage NF*

Site B- Lime Demand Tests

pH	Untreated g/L	Treated g/L	% Reduction
9	0.13	0.02	85%
10	3.08	0.07	98%
11	7.79	0.14	98%





Magnesium and Sulphate strongly rejected

Site A Bottle Rolls

Bottle Rolls- conducted on two composites at plant specified conditions & elevated pH

Lime Consumption

Sample	Plant pH (set point)	Process Water			Raw Water			Tap Water
		Untreated	Treated	Reduction	Untreated	Treated	Reduction	
		kg/t	kg/t	%	kg/t	kg/t	%	kg/t
CIL #1 Feed	12	156	44	72%	237	88	63%	33
CIL #3 Feed	9	6	0.5	92%	2.9	0.7	76%	0.3
CIL #3 Feed	10.5		3.8	37%		7.22	-149%	-

Exceeded Buffer Point

Cyanide Consumption

Sample	Plant pH (set point)	Process Water			Raw Water			Tap Water
		Untreated	Treated	Reduction	Untreated	Treated	Reduction	
		kg/t	kg/t	%	kg/t	kg/t	%	kg/t
CIL #1 Feed	12	1.23	1.19	3%	1.39	0.9	35%	1.86
CIL #3 Feed	9	0.15	0.13	13%	0.2	0.28	-40%	0.14
CIL #3 Feed	10.5		0.09	40%		0.08	60%	-

Significant Reduction in Lime Consumption & ability to increase pH reducing Cyanide consumption

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technology for the future

Cost and Brine Discharge Consideration

Cost:

OPEX: Dependent on TDS & Power cost, ranging from \$0.30/m^3 to \$0.70/m^3

CAPEX: Dependent on Treatment rate eg 250m^3/hr Permeate ~ \$5M

Lined Evaporation pond

Disposal Options of the Brine Concentrate:

1. In-pit disposal
2. Evaporation ponds
3. Reinjection into saline groundwater eg Bellevue and Bounty gold projects

NF Module

Value Added by-products

1. Production of >99% $CaSO_4$ through seeded reactors (Gypsum)
2. Generation of high $MgSO_4$ stream for Epsom Salt production
- Fertilizer, Mg supplement to Livestock, soil improver, building products

Zero Discharge Solutions possible

Disposal options are site specific

Summary

- Not new technology- only new application!
- UF/NF effectively removes Mg, Ca and Sulphate ions into a brine concentrate
- Reduces lime and cyanide consumption by 80-90% and 20-30% respectively
- Additional benefits to gold processing probable
- Other applications for Nanofiltration in Mineral Processing

Thank you

UF Module

NF Module

Containerised NF Module

Additional Reading:

Tapley, B. Stoitis, N. Lien, L. *“Modified Nano-Filtration Membrane Treatment of Hyper-saline Goldfields Water- an Overview and Benefits to Gold Plant Operation and Economics”* MetPlant 2015