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Post Doctoral Research Fellowship

Research Group Workshop

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DUT, Steve Biko Campus

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Four point plan for the AMD problem

J P Maree

Effluent treatment needs

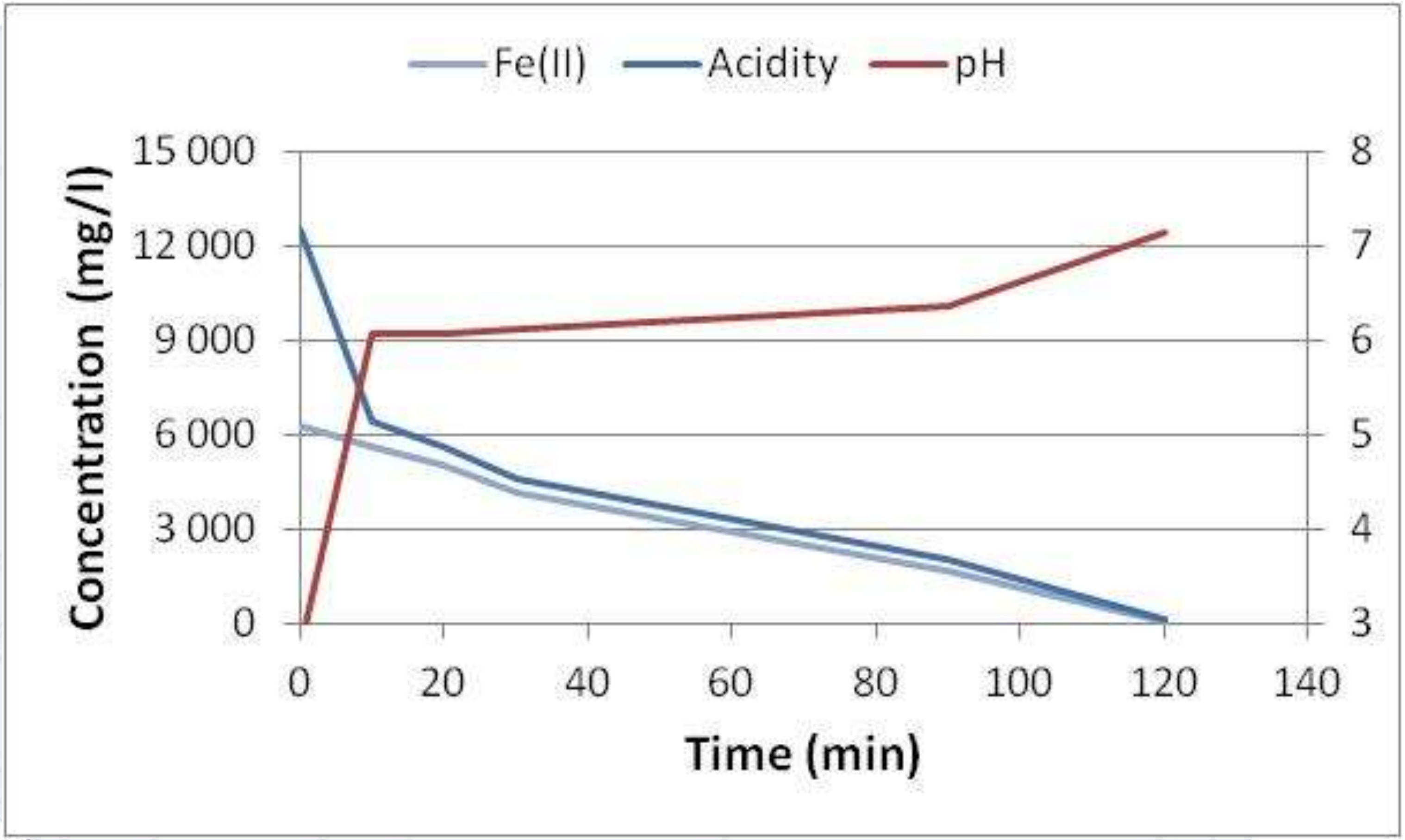
- Neutralisation
- Desalination
  - Membranes
  - Chemical
- Brine treatment
- Sludge processing

Neutralisation

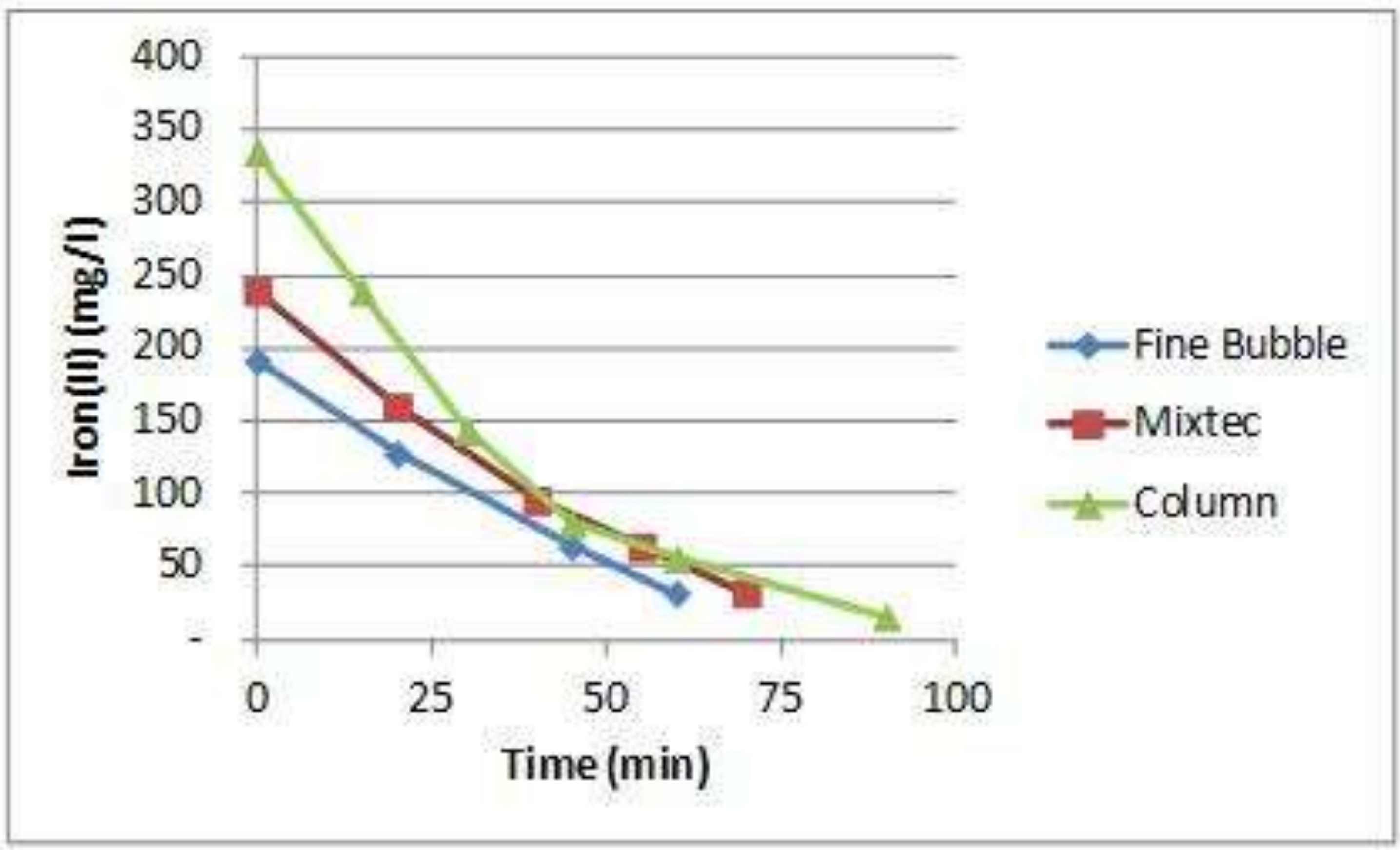
AMD

- Short term solution – R924 million
- Environmental risk
- Health risk

Limestone neutralisation – Water A



Limestone neutralisation – Water B



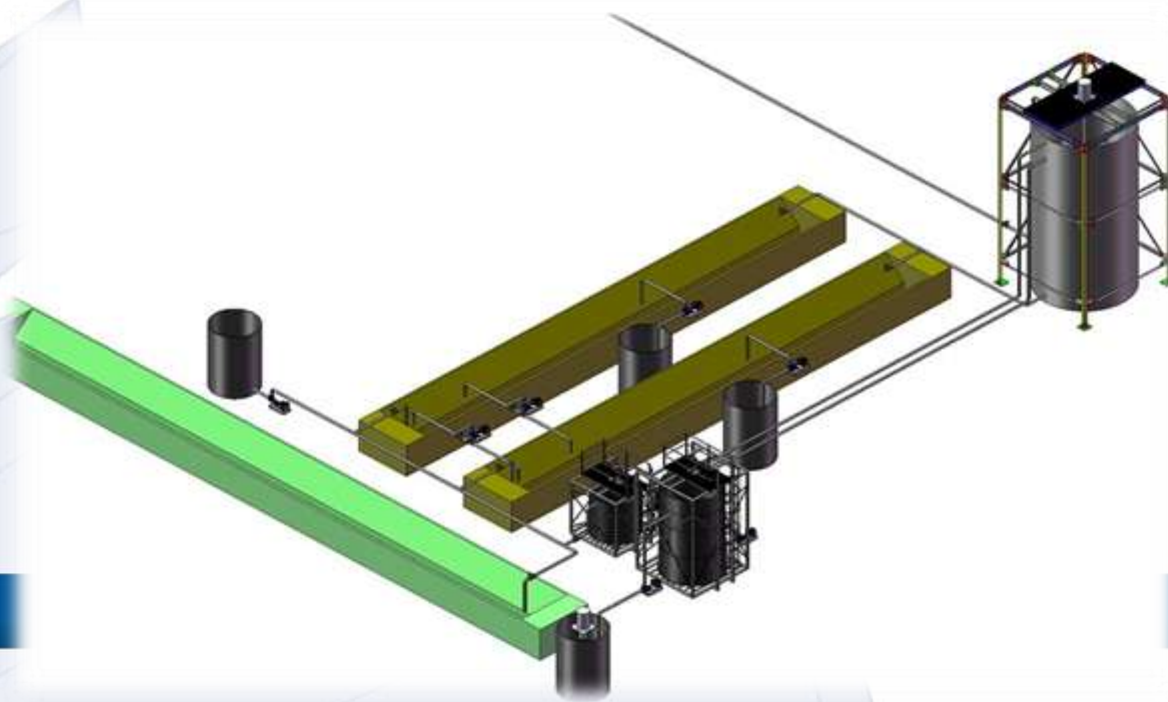
Chemical composition of feed and treated water and alkali cost.

Parameter	Western Basin			
	Feed	Treated		
		Option 1 (CaCO3 for Free acid and Fe(II); Lime for metals)		Option 2 (Only lime)
		$CaCO_3$	Lime	Lime
Flow (Ml/d)			25	25
Dosage (mg/l)		3 940	515	2 917
Price (R/t)		449	2 000	2 000
Cost (R/m3)		1.77	1.03	5.83
Cost (R/m3)			2.80	5.83
Cost (R/year)			25 550 002	53 226 517
Cost ratio			0.48	1.00
pH	2.9	6.6	9.2	9.2
Alkalinity (mg/l as CaCO3)		100	200	200
Sulphate (mg/l as SO4)	4800	2 701	2 285	2 285
Chloride (mg/l as Cl)	37	37	37	37
Sodium (mg/l as Na)	50	50	50	50
Magnesium (mg/l as Mg)	147	147	147	147
Free acidity (mg/l as CaCO3)	979	0	0	0
Aluminium (mg/l as Al)	6	0.0	0.0	0.0
Iron(II) (mg/l as Fe)	625	10.0	0.0	0.0
Iron(III) (mg/l as Fe)	100	0.0	0.0	0.0
Manganese (mg/l as Mn)	228	228.0	0.0	0.0
Calcium calc (mg/l as Ca)	602	720	760	760
TDS (calc) (mg/l)	5 995	3 954	3 410	3 410

Recommended solutions by CSIR/TUT

Short term

- Use $CaCO_3$ for removal of free acid, iron(II), iron(III) and aluminium(III)
- Use lime for removal of other metals



Desalination

Desalination(1)

- Ultra Filtration/Reverse Osmosis + Freeze Desalination for brines

- Chemical desalination (water treatment + processing of sludges to valuable products)
  - CSIR ABC (alkali-barium-calcium) process
  - TUT MBA (magnesium-barium-alkali) process
  - TUT NB (ammonium hydroxide-barium hydroxide) process
  - MINTEK SAVMIN process (Ettringite)

Desalination (2)

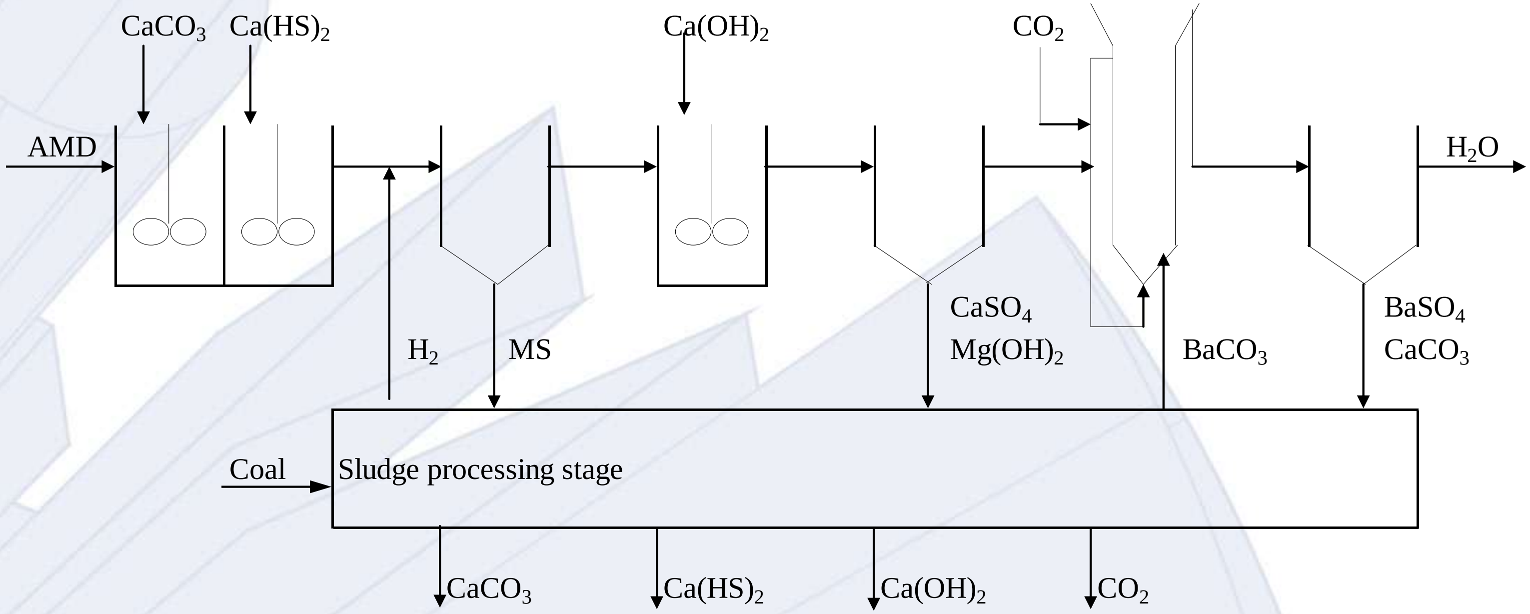
- Resin processes
  - GypCIX
  - EARTH
- Electrolytic
  - Ecodose
  - P2W

Cost of desalination technologies

Technology	Running cost	Income	Difference
	R/m^3	R/m^3	R/m^3
CSIR ABC (Alkali-Barium-Calcium) Process	4.04	3.56	-0.49
KeyPlan HiPRO Process	9.12	3.35	-5.78
AR Technologies Sodium Carbonate Reverse Osmosis Process (ARRO)	12.79	4.29	-8.51
Mintek SAVMIN	11.3	3.84	-7.46
EARH Ion Exchange	12.95	10.7	-2.25
Paques Thiopaq Process/CSIRosure	8.73	5.7	-3.03
Biosure	8.73	6.12	-2.61
TUT/CSIR MBA (Magnesium-Barium-Alkali) Process (laboratory stage)	2.22	5.58	3.36
Lime treatment for Industrial water	5.5	0.7	-4.8

CSIR ABC Desalination process (Alkali-Barium-Calcium)

- Lime and/or CaS pre-treatment
- Barium treatment for SO4 removal
- Sludge processing



Western Utilities Corporation pilot plant to evaluate ABC process

Water quality of decant water

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Parameter	**Feed** *(mg/ℓ)*	**Treated** *(mg/ℓ)*	**Recommended**
pH	**3.1**	7.5	
Sulphate	**4510**	250	500
Chloride	**37**	37	200
Free acid	**500**	0	
Sodium	**96**	95	150
Potassium	**3**	4	
Magnesium	**113**	2	
Calcium	**559**	30	
Silica	**36**	6	
Manganese	**174**	1	1
Iron(II)	**1100**	0	1
Iron(III)	**200**	0	0
Aluminium	**6**	0	1
Zinc	**11**	0	0.05
Nickel	**18**	0	0.01
Cobalt	**7**	0	0.01

Sludge processing

Gypsum from fertilizer industry

Sulphur import	1 000 000	t/a
Price	2 000	R/t
Cost of sulphur for SA	2 000 000 000	R/a
SA Total imports	70 800 000 000	
Precentage	2.8	

SO_2 from power stations

- 2 360 000 t/a SO2
- 1 180 000 t/a S

South Africa Power Stations:

Arnot - 2100 MWe
Duvha - 3600 MWe
Hendrina - 2000 MWe
Kendal - 4116 MWe
Kriel - 3000 MWe
Lethabo - 3708 MWe
Majuba - 4110 MWe
Matimba - 3990 MWe
Matla - 3600 MWe
Tutuka - 3654 MWe

Brine treatment

Hybrid ICE Freeze Crystallization

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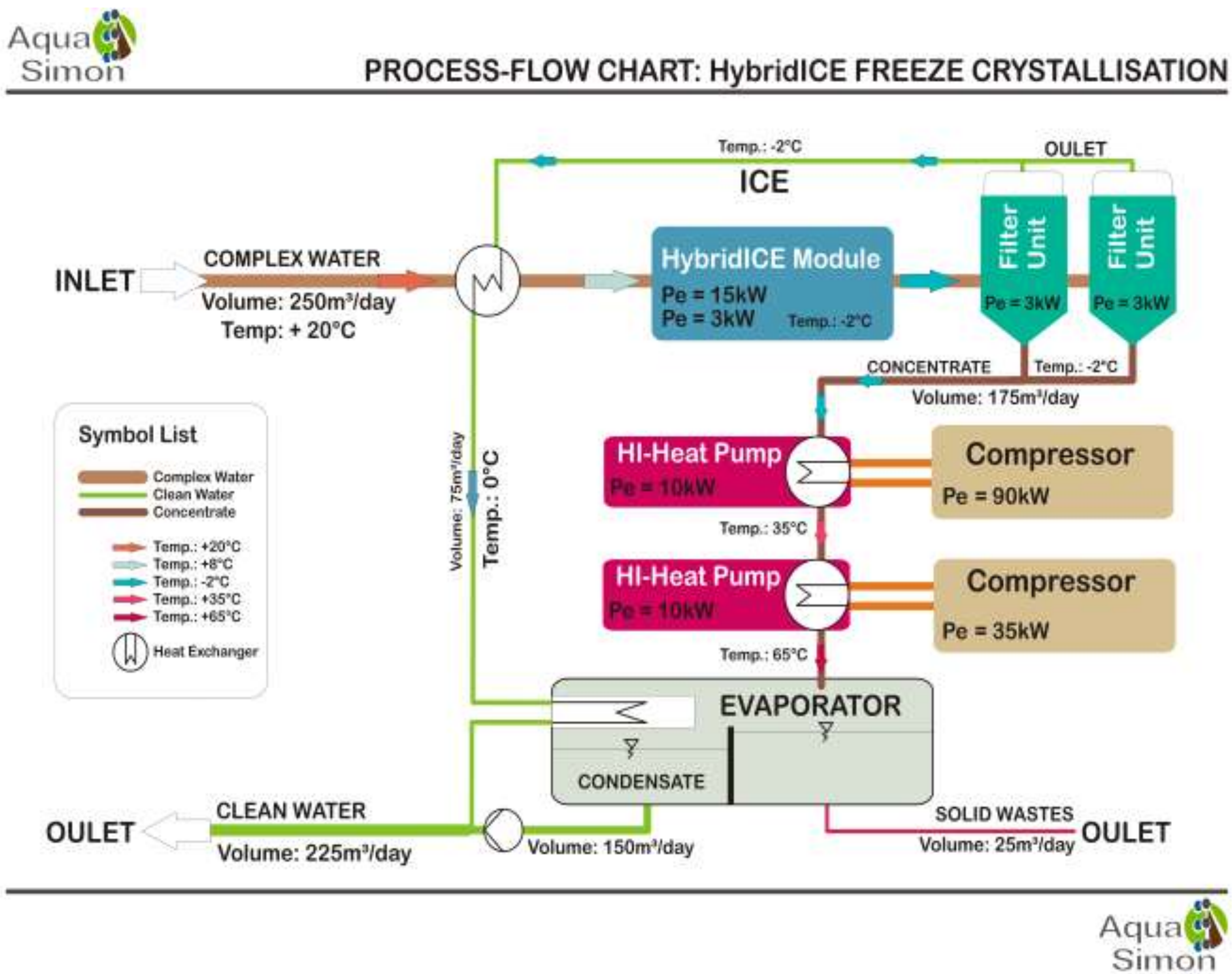
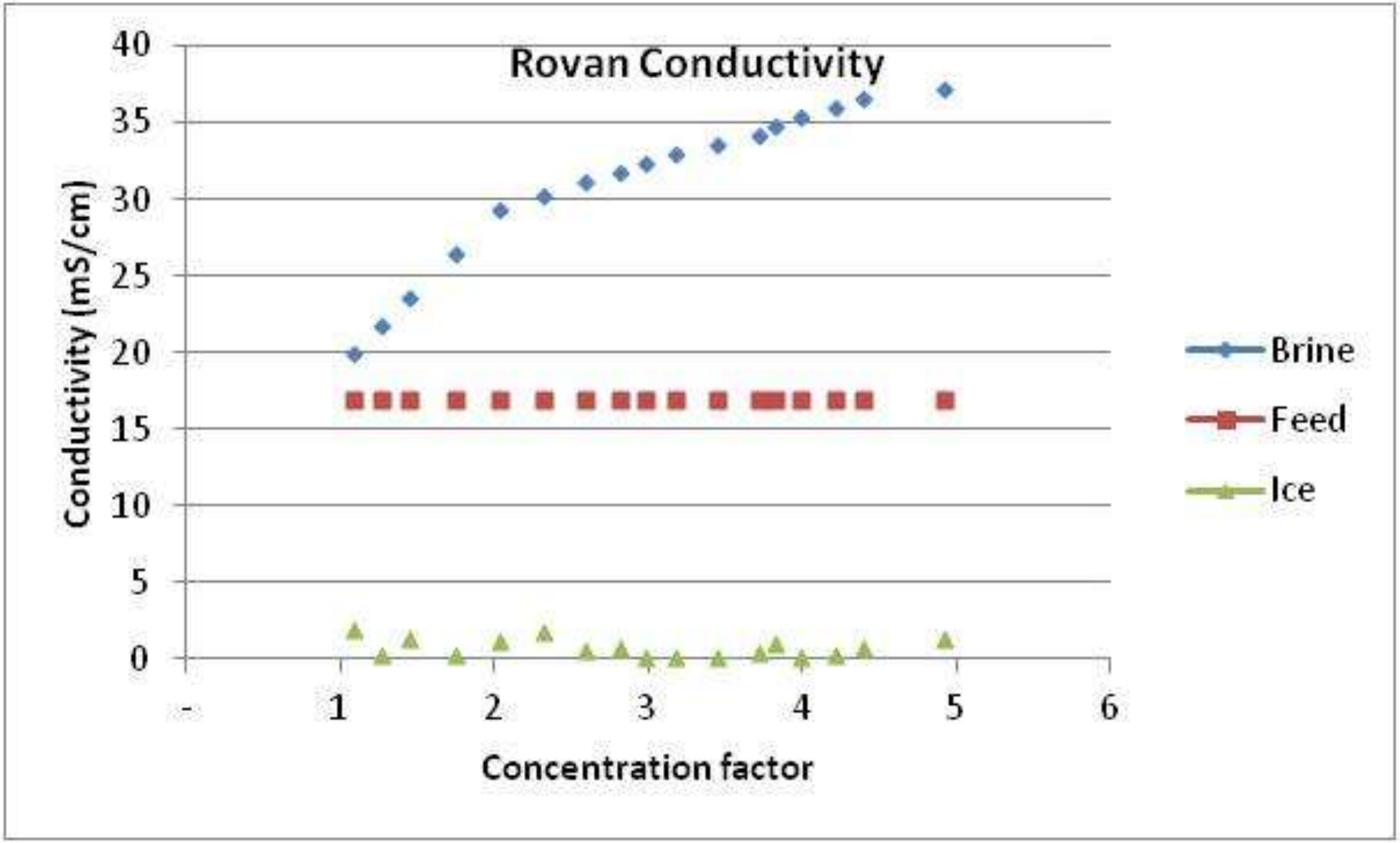
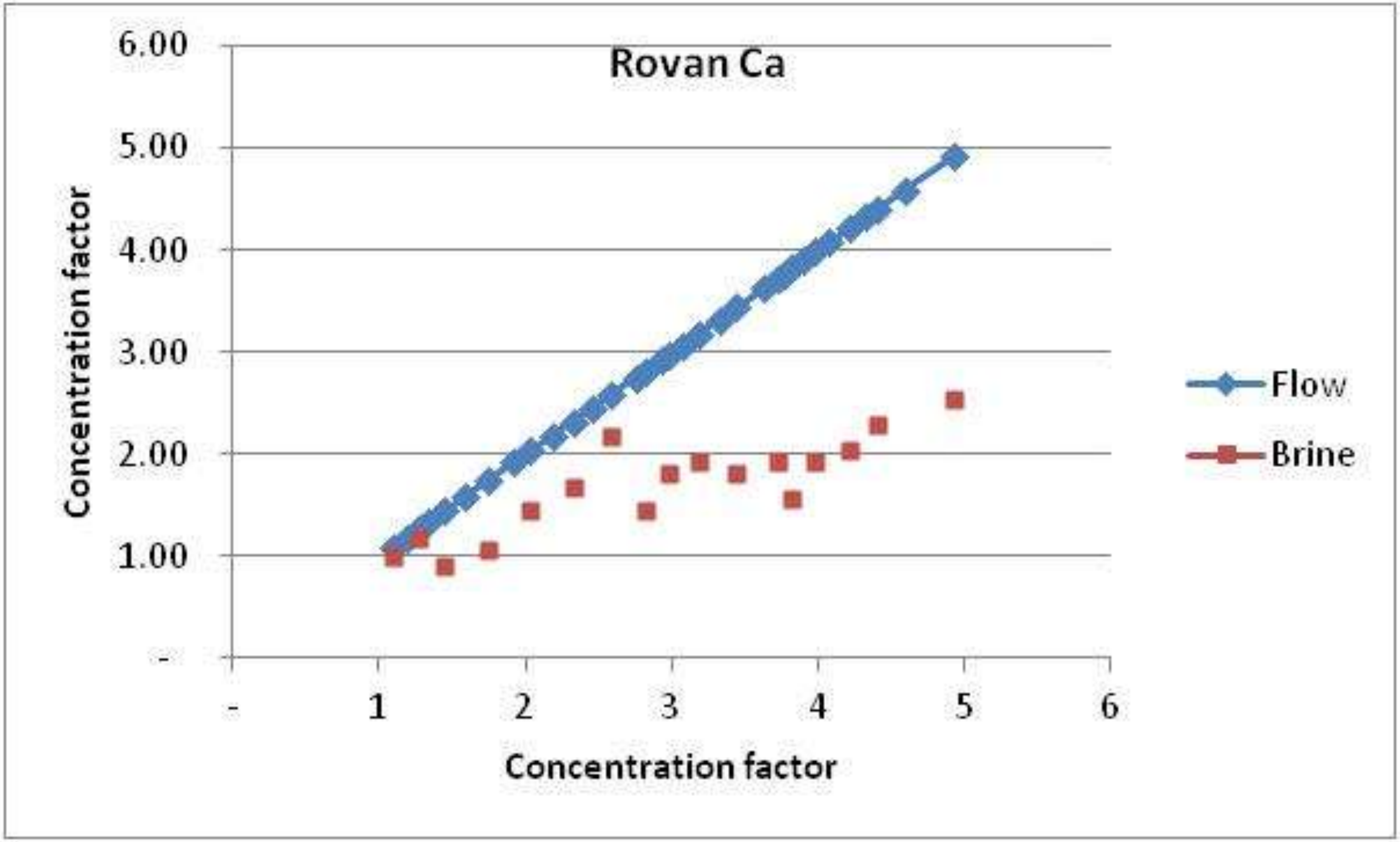



HybridICE


Rovan Conductivity
Conductivity (mS/cm)
40
35
30
25
20
15
10
5
0
-
1
2
3
4
5
6
Concentration factor
Brine
Feed
Ice


Rovan Ca
Concentration factor
6.00
5.00
4.00
3.00
2.00
1.00
-
-
1
2
3
4
5
6
Concentration factor
Flow
Brine

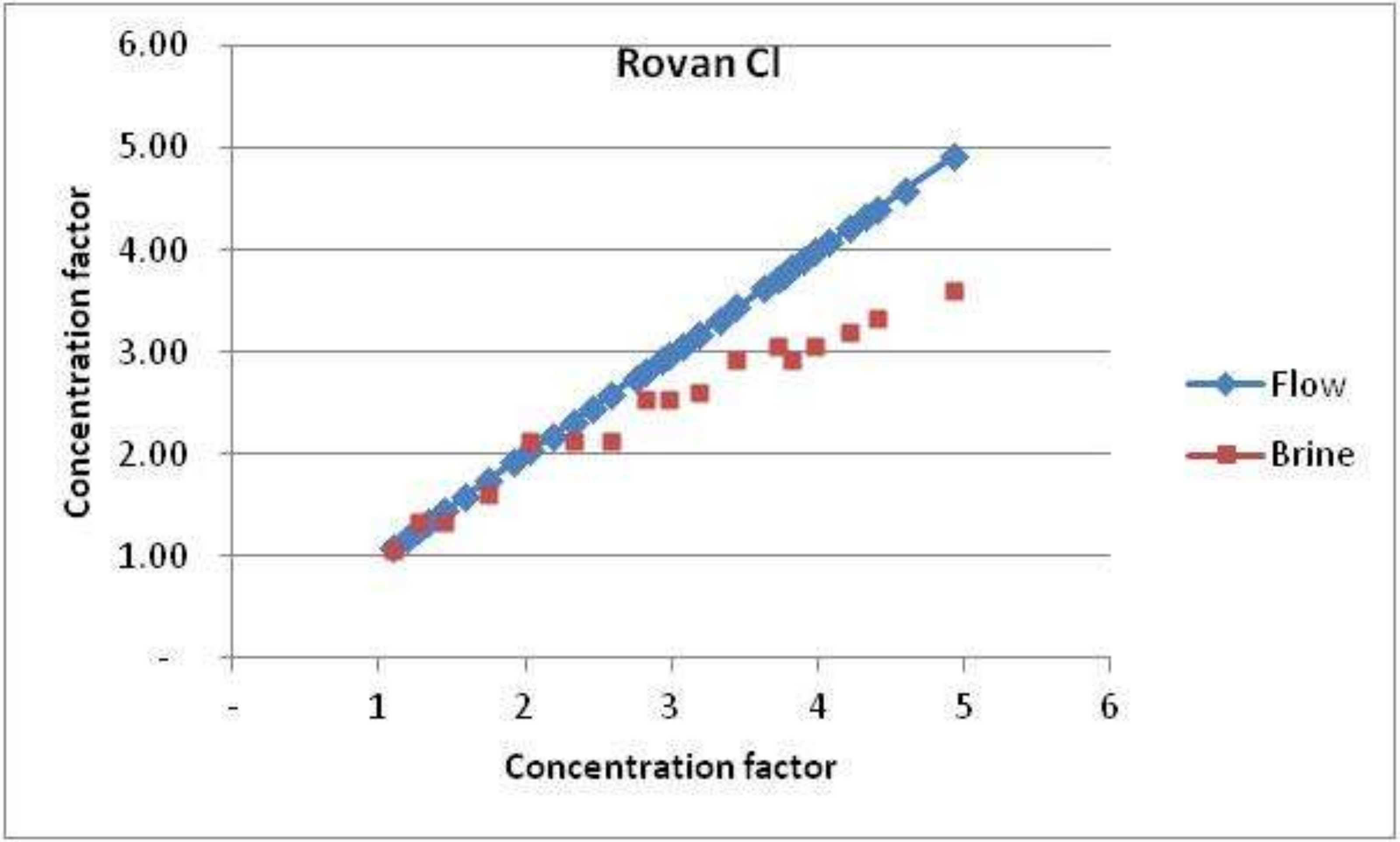

Rovan Cl
6.00
5.00
4.00
3.00
2.00
1.00
-
Concentration factor
-
1
2
3
4
5
6
Concentration factor
Flow
Brine

Table 2: Energy utilization

Parameter	**Value**
Energy to cool water from 25 to -2degC (kJ/kg)	113.4
Energy to freeze water (kJ/kg)	333.0
Total energy (kJ/kg)	446.4
Total energy (kWh/t ice)	124.0

Game Reserve put at risk

Neutralised mine water

Required solution

- Stimulate mining industry and protect the environment
- Neutralise AMD at 50% the cost of HDS treatment – Short term
- Desalinate AMD when needed for drinking water – Long term
- Minimise pumping cost

Approach to solution

- Understand the problem – segments
- Cost alternative options

Water quality from gold mines in Gauteng

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Parameter		Western basin	Eastern basin	Central basin
		Rand Uranium	Grootvlei	ERPM
		IRB		
Flow	(Ml/d)	20	108	60
Flow	(m3/h)	833	4500	2500
pH			8	3.5
Free acidity	(mg/l as CaCO3)	700	0	300
Iron(III)	(mg/l as Fe)	100	0	
Aluminium	(mg/l as Al)	6.4	0	3
Total acidity	(mg/l as CaCO3)	2 437	183	1 749
Iron(II)	(mg/l as Fe)	800	102	800
Total/Free acidity		0.29	0.00	0.17
Alkalinity	(mg/l as CaCO3)	0	350	
Sulphate	(mg/l as SO4)	4800	1075	4096
Calcium	(mg/l as Ca)	528	216	582
Magnesium	(mg/l as Mg)	147	128	250
Manganese	(mg/l as Mn)	228	2	15
Zinc	(mg/l as Zn)	11.9		4
Cobalt	(mg/l as Co)	4.55		1.5
Nickel	(mg/l as Ni)	18		5
Copper	(mg/l Cu)	21		
Uranium	(mg/l U)	0.465		
Silicon	(mg/l Si)	11		
Barium	(mg/l Ba)	0.2		
Chloride	(mg/l as Cl)	37.03	157	180
Sodium	(mg/l as Na)	50	202	104
Potassium	(mg/l as K)			14
TDS	(mg/l)	6 777.1	2 092.0	6 060.6

Components of AMD

$4FeS_2 + 14O_2 + 4H_2O \rightarrow 4FeSO_4 + 4H_2SO_4$

1. Free acid: H_2SO_4 already partially neutralised

   Can be neutralised with $CaCO_3$ (R300/t)

2. Fe(II) acid: Cannot react with limestone/dolomite; No sinkholes from Fe(II): Can be neutralised with $CaCO_3$ (R300/t)

3. Low concentrations of heavy metals

   Lime treatment only needed for removal of heavy metals (lime; R2100/t)

4. Salt (Ca, SO_4)

   Desalination only needed when water demand > water supply

Decant water from gold mines in Gauteng

Basin	**Flow rate (Ml/day)**
Far Western	65
Western	60
Central	100
Eastern	120+
Total for Gauteng gold mines	**345+**
Mpumalanga coal mines	**80+**

PUMPING OR NOT

Views on Pumping

View 1 – Pump to below ECL level

- Allow future mining and protect tourist sites (Gold Reef City)
- No ground water pollution
- No damage to foundations
- Storage capacity/Flow equalization for treatment plant

View 2 – Allow water to decant

- Reduced dissolution of CaCO3 in ingress water
- Reduced pyrites oxidation

Pumping cost

	Total	Equalization pond
Flow (Ml/d)	188	188
Head, h (m)	310	0
Electricity cost:		
Electricity cost (R/m^3)	0.84	
Electricity cost (R/a)	57 887 175	
Capital cost:		
Pump capital cost (R)	211 460 000	290 482 666

$P_h = q\ \rho\ g\ h / (3.6 \times 10^6)$ where

P_h = power (kW); q = flow capacity (m^3/h); ρ = density of fluid (kg/m^3); g = gravity (9.81 m/s^2); h = differential head (m)

Recommendation: Determine whether ECL levels can be moved to higher levels

Revisit the importance of the ECL level

- Iron(II), main compound in AMD, des not react with $CaCO_3$
- Free acid in AMD is already partially neutralized
  - Western basin – 58%
  - Central basin - 79%
  - Eastern basin – 99%
- Less $CaCO_3$ will dissolve in Ingress water when mine water is just below the decant point.

Pumping cost

	Total	Decant	Equalization pond
Flow (Ml/d)	188	188	188
Head, h (m)	310	30	0
Electricity cost:			
Electricity cost (R/m^3)	0.84	0.08	
Electricity cost (R/a)	57 887 175	5 609 685	
Capital cost:			
Pump capital cost (R)	211 460 000	20 492 000	290 482 666

$P_h = q\ \rho\ g\ h\ /\ (3.6 \times 10^6)$ where

P_h = power (kW); q = flow capacity (m^3/h); ρ = density of fluid (kg/m^3); g = gravity ($9.81\ m/s^2$); h = differential head (m)

Recommendation: Determine whether ECL levels can be moved to higher levels

Problems/Solutions to rising levels of acid mine water

Problem	Solution
Ground water pollution	Supply owners with water from the Rand water distribution network
Damage to foundations	Injection of clean water

Lake Cospuden

Lake Cospuden is a completely rehabilitated, open-cast, lignite mine. The lake is now popular for cycling (circumference: 13 km), sailing and has a restaurant. As the water in the lake has a higher level than that of the groundwater, it is not polluted by acid mine drainage.

	
Photo 13. Lake Cospuden	Photo 14. Lake Cospuden

Proposed solution

- Stimulate mining industry and protect the environment
- Neutralise AMD at 50% the cost of HDS treatment – Short term
- Desalinate AMD when needed for drinking water – Long term
- Minimize pumping cost

Other tasks

- Natural organic matter
- Alternative technologies
- Global warming
- Legal studies

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- Tshwane University of Technology (TUT)
- Key Structure Holdings

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