The Current State and Future Priorities of Brine Research in South Africa:

Workshop Proceedings

(This Workshop is an output of the Water Research Commission in collaboration with ESKOM)
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CSIR

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The publication of this report emanates from a WRC Short-Term Project (K8/1052) that resulted in a workshop on brine research in South Africa, held in January 2014.

Executive Summary

The Water Research Commission Brine Workshop on the state of brine research in South Africa was held on 22-23 January 2014 at the ESKOM Academy of Learning Midrand, Gauteng Province. The workshop was hosted by ESKOM in collaboration with the Water Research Commission (WRC), and was facilitated by the Council for Scientific and Industrial Research (CSIR). A variety of stakeholders participated in this workshop; including representatives from industry, academics and science councils and government departments.

The aim of the workshop was to provide, a sector perspective of the current state of brine research in South Africa and the gaps that will define the future research portfolio and the priorities that the partners can pursue over the next 10 years. This should enable the sector to consolidate, focus, support and drive relevant research initiatives with the aim of realising "real" solutions to the current and future brine challenges.

The structure of the workshop was designed to facilitate participation; interaction and networking between stakeholders to collectively discuss and formulate innovative solutions to the challenges associated with brine research in South Africa. Prior to the workshop a blog was created to enable participants to submit inputs to the topic under discussion.

The workshop was divided into different sessions; Session One of the workshop was on the future desired state of brine in South Africa. Session Two took the form of introductory presentations from different experts working with brine research. Workshop Session Three took the form of group discussions and feedback from the different groups in plenary.

Participants were continuously encouraged to continue engaging each other in the blog and to also submit additional inputs on the topics discussed during the day.

Day Two of the Workshop started off with reflections on Day 1 proceedings and proceeded to Session Four of the workshop which was setting out the research priorities in terms of probing what needs to be done. The last session of the workshop entailed crafting a road map on how should we do in the short- and long term. Dr Valerie Naidoo gave a parting message at the end of the workshop and thanked the participants for attending the workshop.

The proceedings outline the inputs from the participants in the following 3 main areas:

1. The Future Desired State and the gaps that need to be met to achieve a 5 to 10 year vision.

2. The Research priorities areas.

3. The practical steps that could be taken (roadmap).

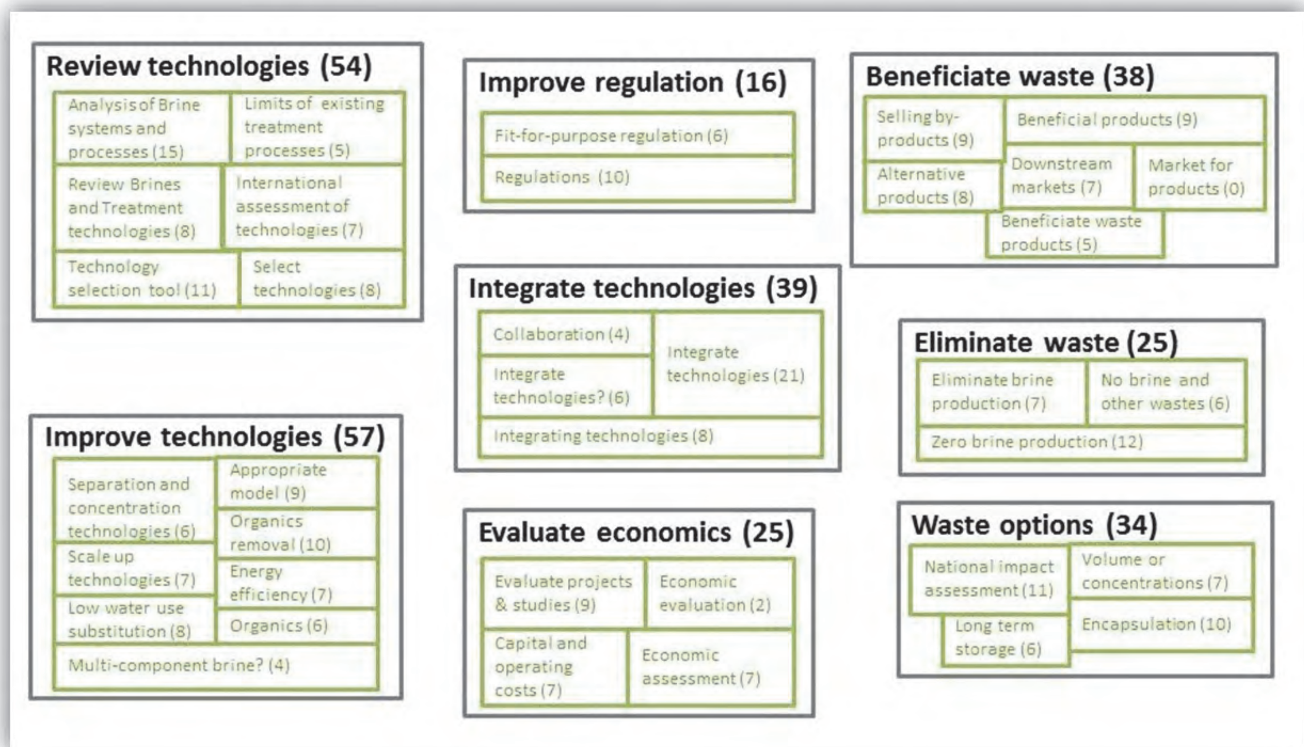
The gap analysis was framed within the 4 areas of Knowledge, Technology, Capability and Practice. Under the knowledge area there was a need to share, advance and benefit knowledge while the gaps in technology was largely focussed on implementation, integration, collaboration, co-ordination and funding. Capability gaps could be grouped into training, networking, regulation, markets and

innovation while practice was grouped into enable, measure and manage, learn and adopt and support.

The research priorities could be grouped into 8 sub-clusters and 4 clusters:

1. Technologies
    a. Review Technologies and Knowledge
    b. Improve Technologies
    c. Integrate Technologies
2. Waste
    a. Beneficiate Waste
    b. Waste Options
    c. Eliminate Waste
3. Economics
4. Regulation

Finally, a 6-12 month action plan was looked at from the perspective of different role players, the desired state topic areas, and a chronology of steps. The three perspectives are provided in the report.



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Introduction

The Minister of Water and Environmental Affairs highlighted the importance of research at the WRC Water Innovation Symposium, saying that we as a community of practice working in and for water should be extremely proud of the achievements we have made, but that we must also remain cognisant of the challenges that lie ahead. She further said that it requires continued dedication of water researchers and scientists to ensure that our new water strategy results in genuine improvement in the lives of South Africans and stressed that the growth of good and relevant water science and technology is critically important for us to be able to achieve this (Mrs. Edna Molewa, September 2013).

The Department of Water Affairs emphasises the centrality of water in the economy in its Strategic Plan for 2013/14-2017/18 (DWA, 2013), stating that water runs through various sectors as an enabler and bedrock for all future planning and development. The strategy makes specific reference to the need to develop water reuse and desalination options to meet local needs. Van der Merwe et al (2011) estimated that 534 739 kl of effluent is managed/discharged on a daily basis in the inland environment, with mining (27.1%), power generation (24.7%), paper & pulp (16.6%), petroleum (12.9%) and steel/metals processing (5.7%) discharging 87% of all effluent. The inland discharge translates to 1 058 t/d of salt being discharged at inland locations. While desalination technologies can contribute to local water security, it is also critically important to find sustainable solutions to dealing with associated brine as a waste product. Desalination is becoming increasingly important to sustain water quality in production processes and to protect the environment, therefore sustainable brine disposal strategies has become critical, which requires new, innovative approaches (Van der Merwe et al, 2011).

The 2-day workshop held on 22-23 January 2014 involved representatives from industry, academia, science councils and government departments and set out to establish the state of brine research and define research priorities. The complete participant list is attached as Appendix A. The workshop outcomes should enable the sector to consolidate, focus, support and drive relevant research initiatives with the aim of realising real solutions to the current and future brine challenges.

> *The objective of the workshop was to provide a sector-perspective of the state of brine research in South Africa and the gaps that will define the future research portfolio and the priorities that partners can pursue over the next 10 years.*

The Workshop programme hereunder included background presentations and participant inputs on the future desired state, identification of gaps, determination of research priorities and the development of a road map for the way forward. Although the workshop focussed on brine management in inland contexts, the output from the workshop also has the potential to benefit brine management in coastal contexts. It is also understood that the focus on research priorities does not preclude inputs on the regulatory/enabling environment and recommendations to improve coordination and networking in the sector.

BRINE RESEARCH WORKSHOP AGENDA

22-23 JANUARY 2014

VENUE: ESKOM ACADEMY OF LEARNING

Wednesday, 22 January 2014

Welcome

Future Desired State
(What do we want to achieve 5 and 10 years from now?)

Introductory Presentations

Lunch

Gap Analysis
(Quantification, technologies, management, beneficiation)

Closure

Thursday, 23 January 2014

Reflection on Day 1

Research Priorities
(What needs to be done?)

Lunch

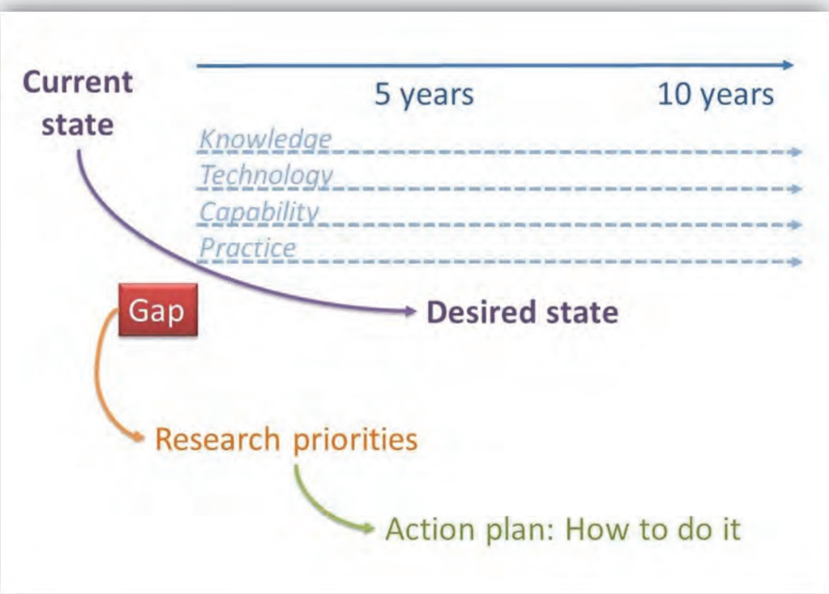
Road Map
(How should we do it in the short and long term?)

Closure

Facilitation: Dr Marius Claassen & Winile Masangane (CSIR)

Workshop Process

The workshop process followed the framework hereunder, with the difference between the current state and future desired state representing the research gap. The gap in the areas of knowledge, technology, capability and practice in five years and ten years translate to research priorities, which provides the basis for the action plan.



Workshop Session One: Future desired state of brine research in South Africa (what do they want to achieve in 5 to 10 years)

> Alice: "Would you tell me, please, which way I ought to go from here?"
> "That depends a good deal on where you want to go," said the Cat.
> "I don't much care where--" said Alice.
> "Then it doesn't much matter which way you go," said the Cat.
>
> *Alice's Adventures in Wonderland (Carroll, 1865)*

Session One of the workshop entailed participants responding to the following question by oral and written inputs as well as making submission on the blog (wrcbrinews.blogspot.com) .

What do we want to achieve?

- *In 5 years*
- *In 10 years*

The inputs were organised in thematic groups with the relationship between groups being indicated with arrows (Figure 1a and 1b).

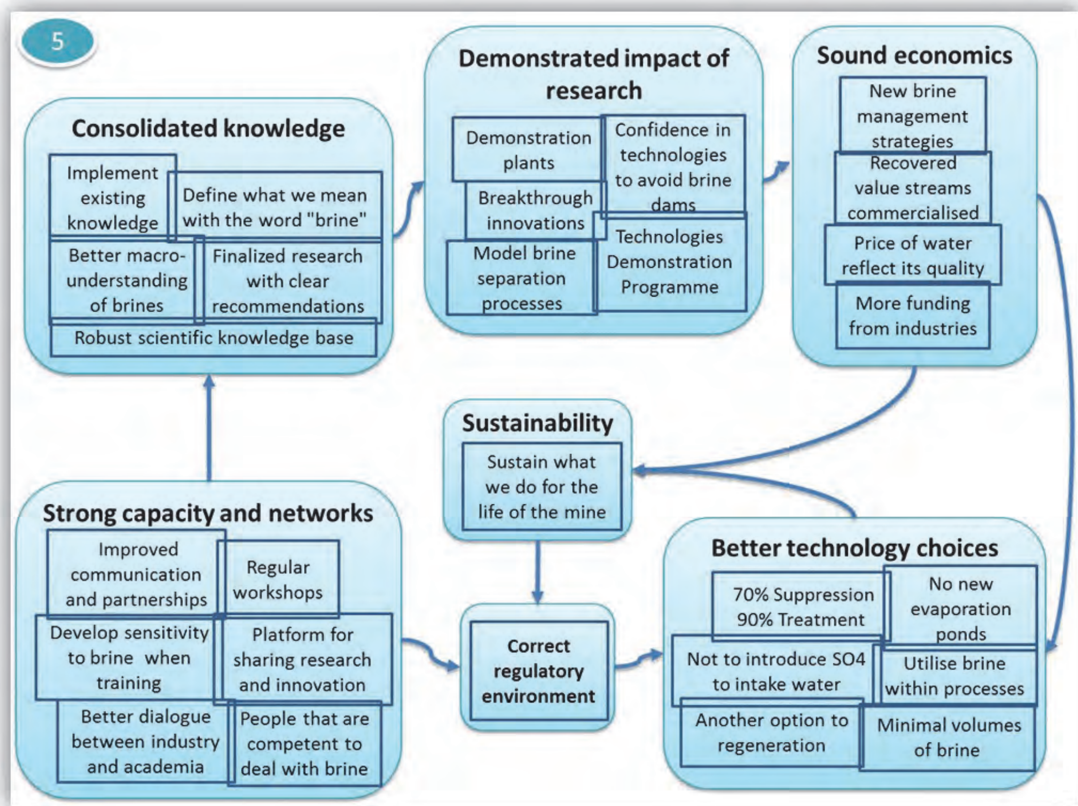


Figure 1a: Future desired state in 2019

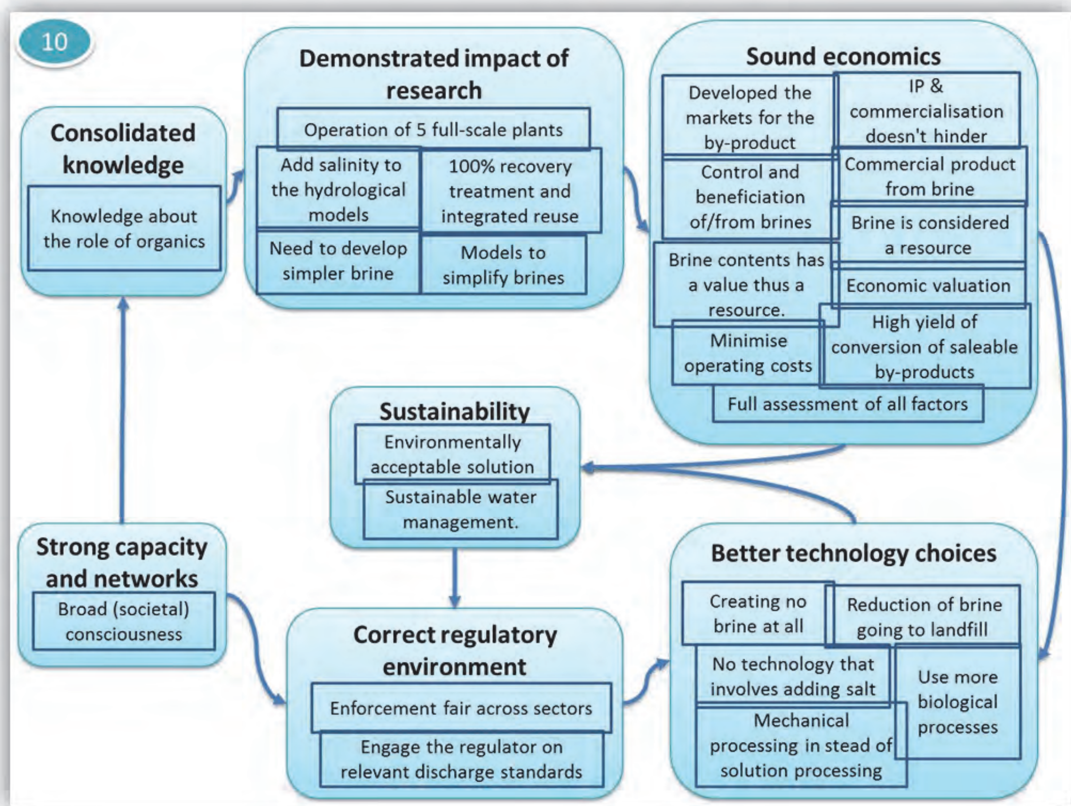


Figure 1b: Future desired state in 2024

Workshop Session Two: Introductory presentations

The slides used by the presenters are provided in Appendix B, with a headlines of each presentation provided hereunder.

Dr Jo Burgess: Brine Research and the WRC

- Trends
  - Brine volumes generated as a result of coal and gold mining probably represent the most important challenge over the medium term.
  - Cumulatively, it is possible that brine volumes could be around 4000 t/d within 5 years, and as much as 15 000 t/d of brine within 20 years.
  - Location: in the short term (depending on future strategies to manage the West and East Rand Basins) brine generation could be relatively evenly split between the Johannesburg area, and the Witbank area;
  - The greatest increase in brine generation is expected (in the longer term) to be in the area of the Witbank Coal Fields.
- Present strategies
  - Discharge to evaporation ponds;
  - Disposal to surface water bodies;
  - Disposal through pipelines to municipal sewers;
  - Deep-well injection;
  - Concentration into solid salts;
  - Land application and irrigation of plants tolerant to high salinity (halophytes).
- What problems do we face?
  - It's wasteful (solutes recovery);
  - It's temporary (ponds fill faster than brines evaporate);
  - It's wasteful again (water);
  - Sludges.
- What do we need to solve them?
  - Incremental improvements (enhanced evaporation rates);
  - Disruptive technologies (send it all to the moon for 1 c);
  - New mindset (what would make brine worth its weight in saffron?)

Dr Leslie Petrik (UWC)

- Dr Petrik gave an overview of brine research at UWC, which included:
  - Sulphate removal from neutral mine water using coal fly ash
  - Industrial Brine Minimization: Determining the Physical Chemical Parameters that Affect Evaporation Rates on Multi-Component Hyper-Saline Effluents
  - Application of mineral carbonation processes for brine remediation
  - Treatment of mine water using a combination of coal fly ash and flocculants in a jetloop reactor system

    - The Synthesis of Highly Selective Immobilized Ligands for Extraction of Toxic Metal Ions from Waste Water
    - Brine cleanup by carbonation with fly ash

Dr Marcos Rodriguez Pascual (UCT): State of the art of eutectic freeze crystallization

- The EFC process is in most cases still favorable from an energy point of view, with typically savings in energy costs of about 50% compared to triple stage evaporation.
- Additional advantages of the EFC process are; high purity salt and ice crystals are produced due to the highly selective crystallization reactions, no additional chemicals are required, low temperatures results in less corrosion and the process is safe and easily controlled.
- Process has been proven on Pilot Scale of 250 litres/hour.
- EFC Technology has less energy cost compared with existing technologies, such as 3 stage evaporation, or Freeze Crystallization for desalination.
- EFC is environmentally friendly as it does not use added chemicals, and reduce to minimum (or zero) the waste disposal
- Co-products increase the economic profit.
- Crystallizer designs have been developed and implemented
- So, why it has not been applied yet to industrial scale?

Eskom – Gerhard Gericke, Dheneshree Lalla, Ken Galt

- Impact of deteriorating raw water quality
    - Reduced runs on demin plant, increased regeneration, increased effluent production
    - Reduced cycles of concentration on CW system, increased blowdowns, increased effluent production
    - Outside the design base of dosing systems
    - Ageing plant struggling to cope with water within design base, aggravated by inferior feed water quality
- Water pinch strategy (process integration)
    - Study at 2 Eskom power stations
    - Aim: to determine whether water usage and process requirement (quality) is optimal
    - What water can be used for what purpose?
    - How much water is needed for what purpose?
    - To what extent can water be re-used?
    - What impact will this have on raw water intake and impurity concentration?
- Impact of legislation on the way forward
    - To what extent will co-disposal (water/salt) on ash be regulated?
    - At what point will industry be forced to employ re-use and treatment processes for re-use within its operations? What is the impact on waste generation?
    - Liner systems are already enforced, but what is the minimum requirement and at what cost to industry and consumer?

    - A change in operating and water management philosophies might be required to meet future regulatory and legislation requirements.

Ritva Muhlbauer (Anglo American): The brine challenge

- Selective integrated mine water remediation to produce valuable products with no waste disposal
    - JIA-Coaltech initiative: Laboratory scale and piloting work on
        - Eutectic Freeze crystallization – potential for pure salt production
        - HybridICE – mixed salt product
    - Demonstration plant planned at Optimum Colliery
        - 2.5ML/d New Vaal Colliery brine treatment plant under construction
            - NaSO4 product = ~10% of SA NaSO4 production
            - Mixed salt waste
    - Future Technology Development
        - Short to medium term
            - Implementation of current available brine treatment technologies
            - Incremental improvement in brine treatment technologies
            - Alternative product generation to increase sustainability
        - Long term
            - Zero waste approach to lower infrastructure and lifecycle costs
            - Socio-economic development opportunities
        - Implementation of DWA Hierarchy of Controls: "Pollution Prevention"

Workshop Sessions Three: Four corner discussions – Gap Analysis

In this session the participants were divided into four groups that were representative of the different affiliations present at the workshop.The participants discussed the following questions in break-away groups and provided feedback in plenary. The inputs were organised under the headings of **knowledge, technology, capability and practice**, labelled as "desired state" (blue boxes in Figures 2a-d) "gap" (red boxes in Figures 2a-d) and clustered.

What is the future desired state of knowledge, technology, capability and practice?

What is the gap compared to current state of knowledge, technology, capability and practice?

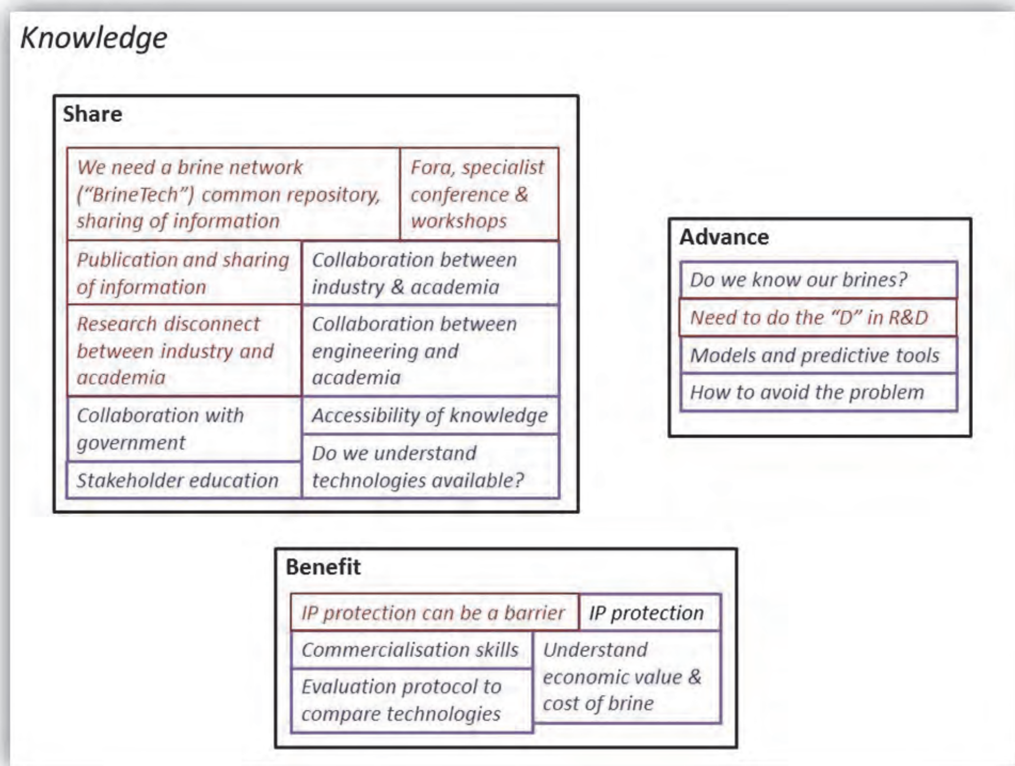


Figure 2a: Future desired state and gaps for Knowledge.

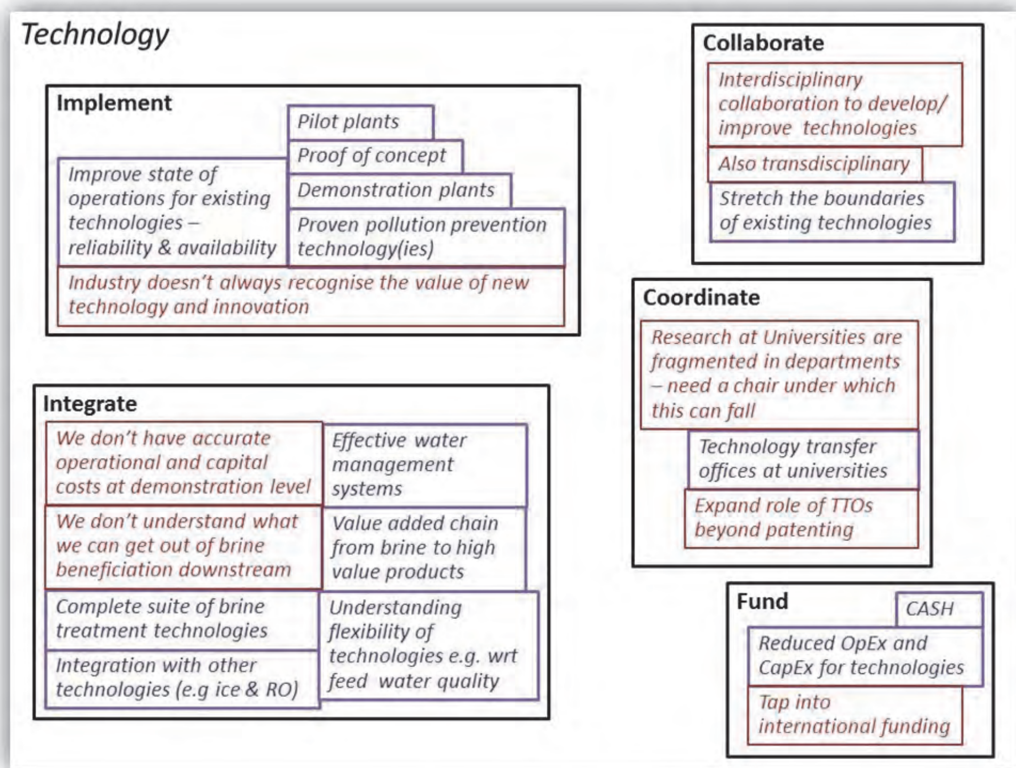


Figure 2b: Future desired state and gaps for Technology.

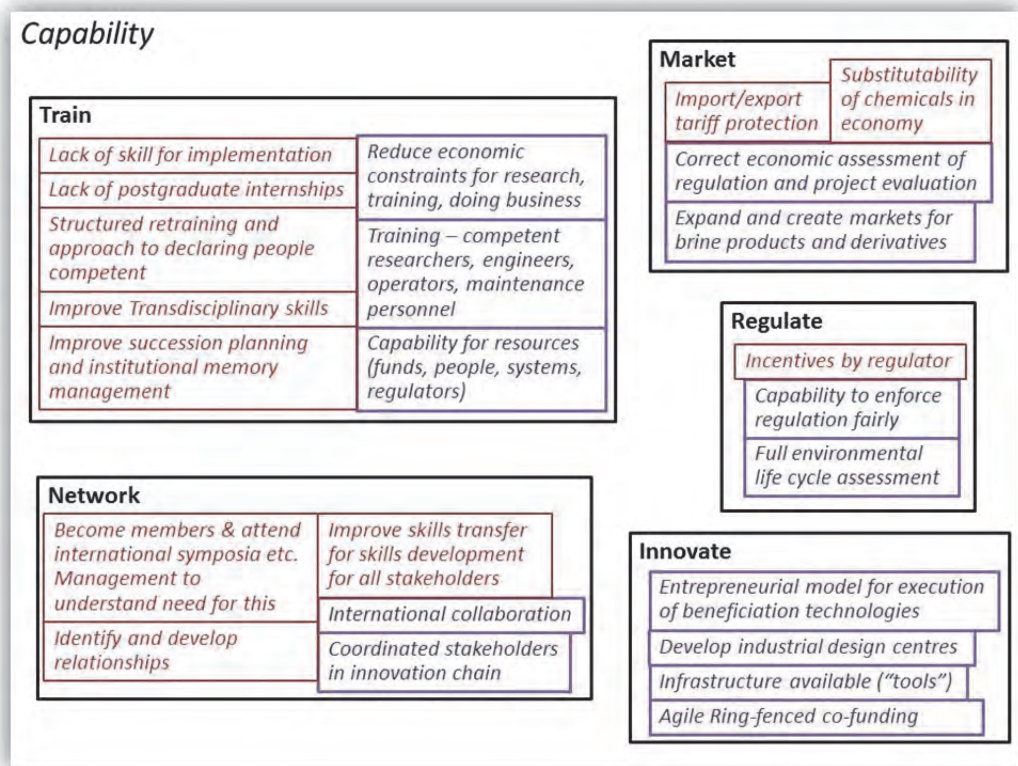


Figure 2c: Future desired state and gaps for Capability.

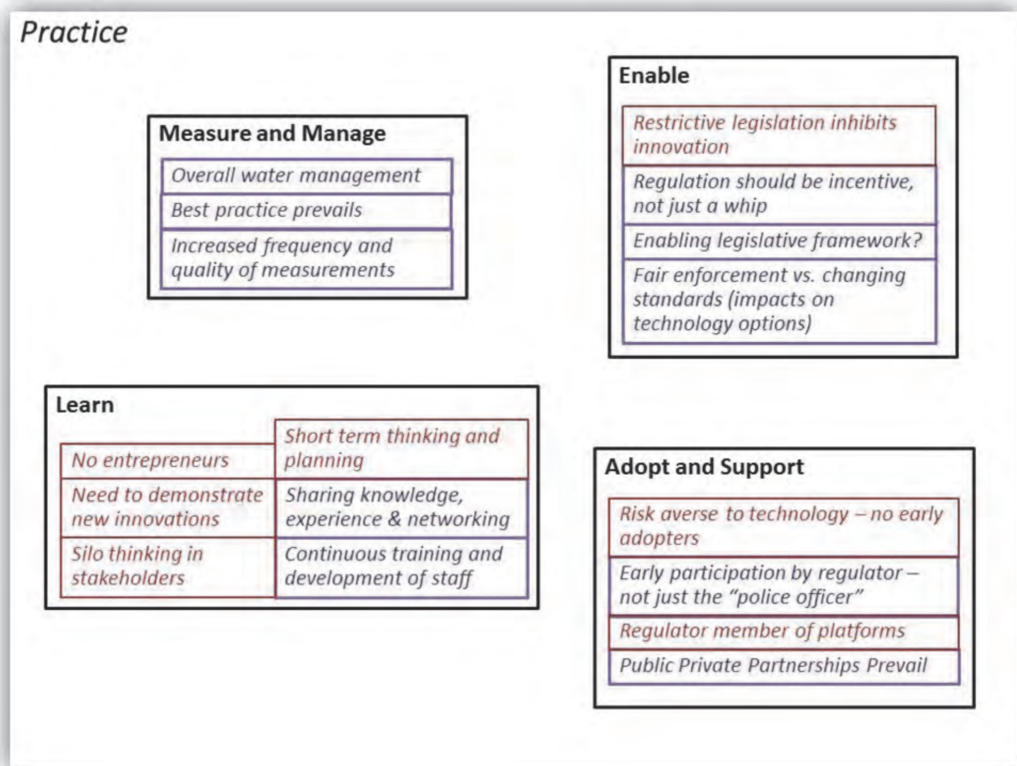


Figure 2d: Future desired state and gaps for Practice.

Day Two of the workshop

Workshop Session Four: Research priorities

Facilitator Marius Claassen

The participants discussed research priorities, based on the gaps above and gave feedback in plenary. Each group presented their top 10 priorities (listed hereunder), with additional priorities also listed. Weights were assigned to the research priorities by giving every participant a number of stickers. The numbers in brackets after each research priority are the number of votes each research priority received.

1.1 Thermodynamic analysis of Brine systems and potential processes (15)

1.2 Review of SA Brines (chemistry, mass, geo-location) and Treatment technologies (8)

1.3 Low water use substitution (linked to 1.1 & 1.2) e.g. cleaner production, dry cooling, etc. (8)

1.4 Beneficial product identification and process route development (9)

1.5 Development of appropriate model for salt flows (9)

1.6 Develop and refine separation and concentration technologies (6)

1.7 Organics source identification, chemistry & removal (10)

1.8 Economic assessment of TDS to the economy (7)

1.9 Framework for full evaluation of demonstration projects & baseline studies (9)

2.1 Extend "brine" classification to "saline" waters to map against appropriate technology and influence fit-for-purpose regulation (6)

2.2 How do we use existing mine voids and working for long term storage of water and brines with limited impact to the environment (6)

2.3 Determine the capital and operating costs of the available demonstration technologies (7)

2.4 Undertake research to determine the downstream markets for brine and its derivatives and their economic value (7)

2.5 Do we know how to integrate the different technologies available and develop an appropriate model (Energy/volume/cost)(21)

2.6 What are the drivers leading to the selection of appropriate brine technologies "Brine economy" (8)

2.7 How do we beneficiate waste products including saline, brine and gypsum to create economic value (5)

2.8 Is waste volume minimisation at high concentrations better or large volume with low concentrations (7)

2.9 Design a process (incl. management system) that leads to zero brine production (12)

2.10 If brine becomes encapsulated is it inert? (10)

3.1 What is the energy efficiency of brine treatment? How can it be improved? (7)

3.2 How do we scale up brine treatment technologies from lab scale? (7)

3.3 Full scale Economic evaluation (CapEx and OpEx)? (2)

3.4 Are there alternative products that can be derived from brine other than salts? (8)

3.5 Market assessment of products generated and NPV (0)

3.6 What is limiting interaction and collaboration between brine stakeholders? (4)

3.7 How do we address compliance with waste regulations in 2021? (10)

3.8 How do we treat multi-component brine? (4)

3.9 How do we integrate technologies effectively to achieve appropriate outcome? (6)

3.10 What is the effect of organics on brine treatment? (6)

4.1 Investigate practicality of selling by-products of brine treatment (size of market, price, etc.) (9)

4.2 Invent water and wastewater treatment and commodity production that didn't create brine and other wastes (6)

4.3 Undertake research to determine and document the limits within which our existing treatment processes work (5)

4.4 Compare existing processes ito effectiveness energy efficiency CapEx, OpEx, etc. to create a publically available impartial technology selection tool (11)

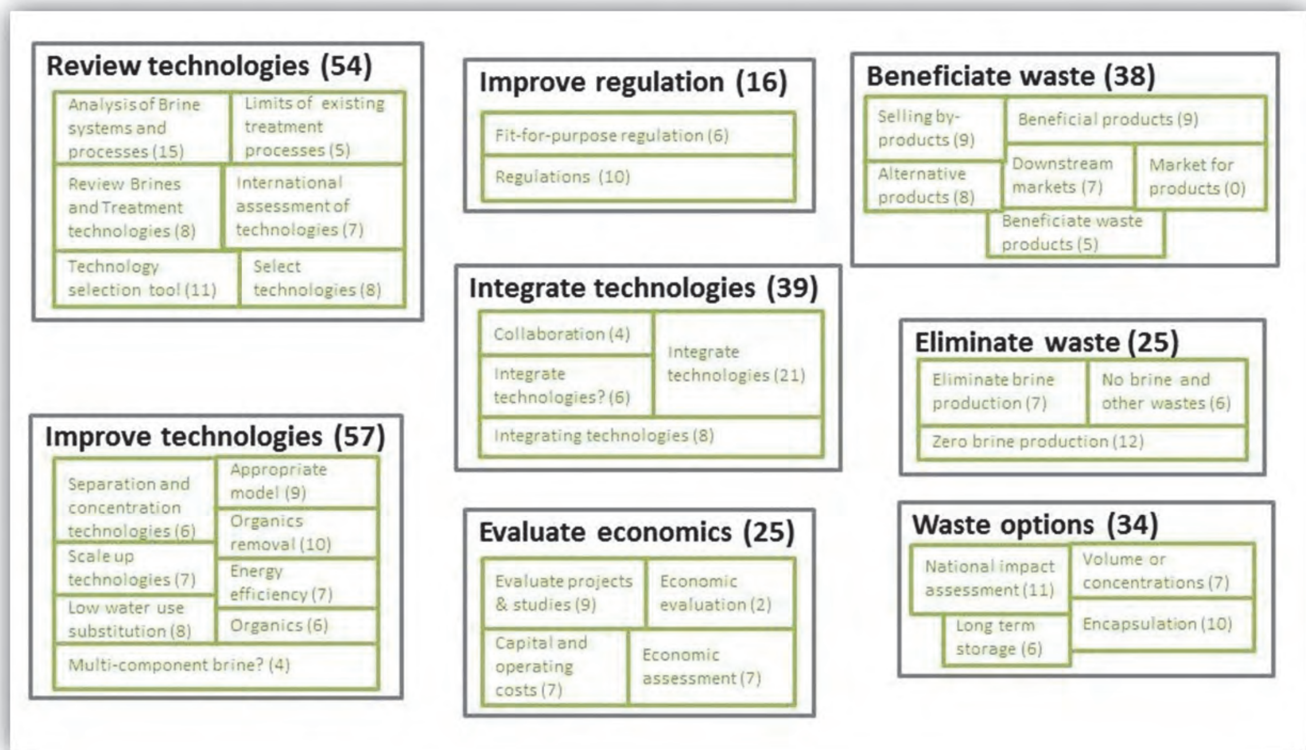
4.5 Independent international assessment of new technologies being produced, the technical requirements of industry and the difference between the two + a public catalogue of brine R&D (7)

4.6 Investigate how process trains that maximise resource efficiency and minimise waste can be constructed by integrating the technologies from different groups (8)

4.7 Using 1669/1/09 as starting point identify brine prevention opportunities in different industries to eliminate brine production (7)

4.8 Undertake a national total impact assessment/prediction of the consequences of using the brine disposal options available as a catchment/national community (not case-by-case) (11)

These priorities were clustered to identify key areas of future research. The clusters hereunder also indicate the combined weight (priority) of each area.



Workshop Session Five: Road Map

The first step in the road map process was to identify practical steps that could be taken. This was done in break-away groups and reported in plenary. The list of suggested steps is provided hereunder.

1. Group 1
   - 1.1. Linked-In group "Brine networks"
   - 1.2. International Brine conference in SA
   - 1.3. Formulation of a Brine-dedicated group within WISA & WRC (+ from group 3)
   - 1.4. Centre of Excellence in Brine at a University
   - 1.5. Collaboration between industry and research centres and government to develop and build business case to leverage funding
   - 1.6. International collaboration to source funding
   - 1.7. Levy (environmental) from government to fund demonstration scale (technology)
   - 1.8. Tolling the brine produced
   - 1.9. Private investors
   - 1.10. Social funds by incorporating the community
   - 1.11. Charity foundations, e.g. Gates Foundation
2. Group 2
   - 2.1. Create coordinated research plan
   - 2.2. Find and collate sources of funding on the WEB, with links

2.3. Companies to document their problems and advertise them to researchers
2.4. Annual progress report from each stakeholder to rest of Brine Division
2.5. Ministerial and Policy briefs on policies & best practice
2.6. Brine Division to write motivation statement, saying why funding brine research is good value for money
2.7. Brine Division to collate and provide links of publications to funding bodies (to see what is done or will be done)

3. Group 3
   3.1. (Vehicle possible through WISA) – Need to have agreement on continuation of interaction with Workshop participants (Blogspot, etc.)
   3.2. How to promote industry/academia partnerships
   3.3. Build collaborative network for large projects with ring-fenced co-funding and sharing of information
   3.4. International funding, e.g. H2020
   3.5. Dissemination of information through the Division but also through WIN-SA
   3.6. Ensure that networks are kept alive and grown (spread the word)
   3.7. DST/NRF conference budget
   3.8. WRC docs that currently exist needs to be fully Google-searchable
4. Group 4
   4.1. “Vehicle” is required
   4.2. Centre of Excellence model – since it is a global problem – allow one to concentrate funds (“don’t spread funds too thin”)
   4.3. Having a steering committee with people that are directly affected
   4.4. Should have dedicated project management function, incl finance (e.g. H2020)
   4.5. THRIP, but review terms and conditions of THRIP funding
   4.6. WRC funds in total should be increased so that they can be a central coordinator
   4.7. Look at Coaltech model
   4.8. Need high-profile champion
   4.9. Need to shorten concept to execution
   4.10. Bringing more engineering and commercial partners in at research question phase (e.g. “research by tender”
   4.11. Venture capital

The next step in the road map process was to record the learning from past experiences (implementation of similar programmes). The lessons learnt were as follows:

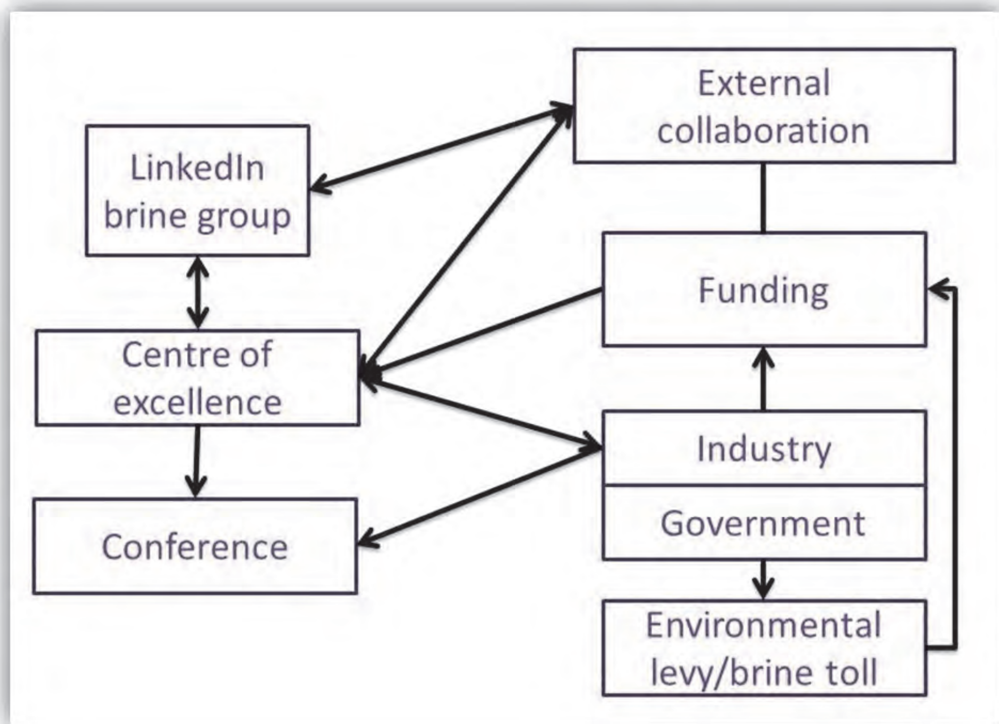
- Copy HISA/Biotech model
  - Champion/discipline
  - Against terms of reference
- No funding issue national – solved before ToR
- Steering committee comprising of stakeholders
- Dedicated project management, incl. financial (EU model FP7)
- Don’t spread funding too thin (Centres of excellence)
- More engineering/commercial in research (research by tender)

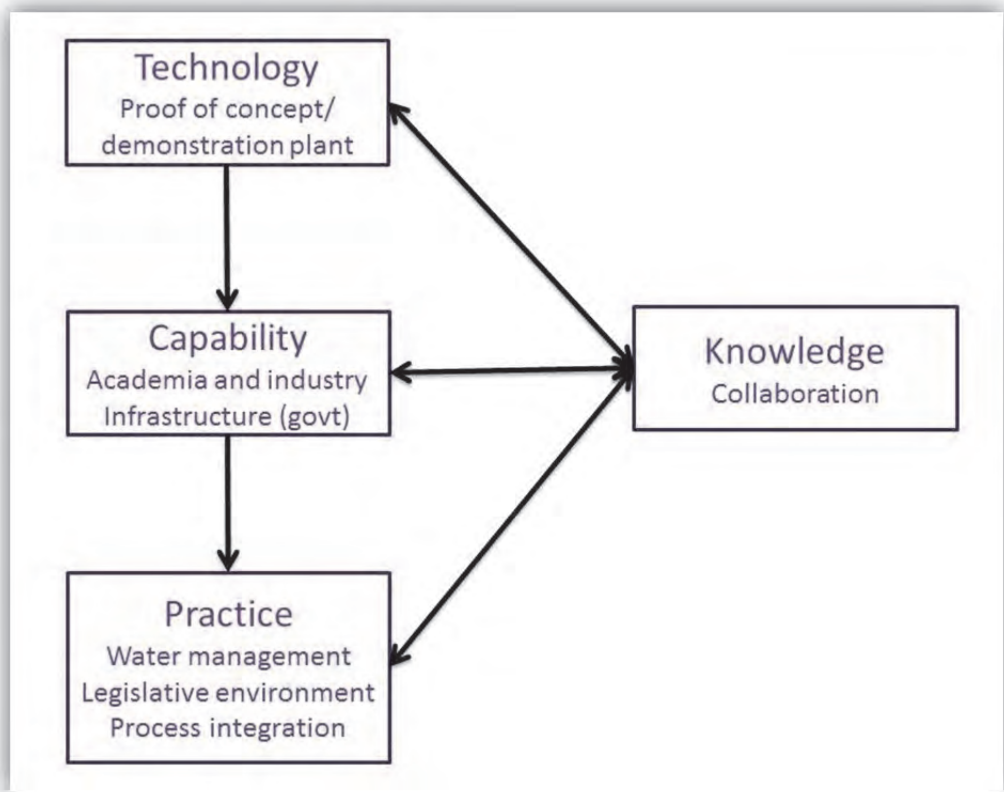
- Review terms and conditions of THRIP funding
- Increase WRC funding to be central facilitator
- Model for large vs. small research (Coaltech)
- Shorten time from concept to execution
- High profile champion

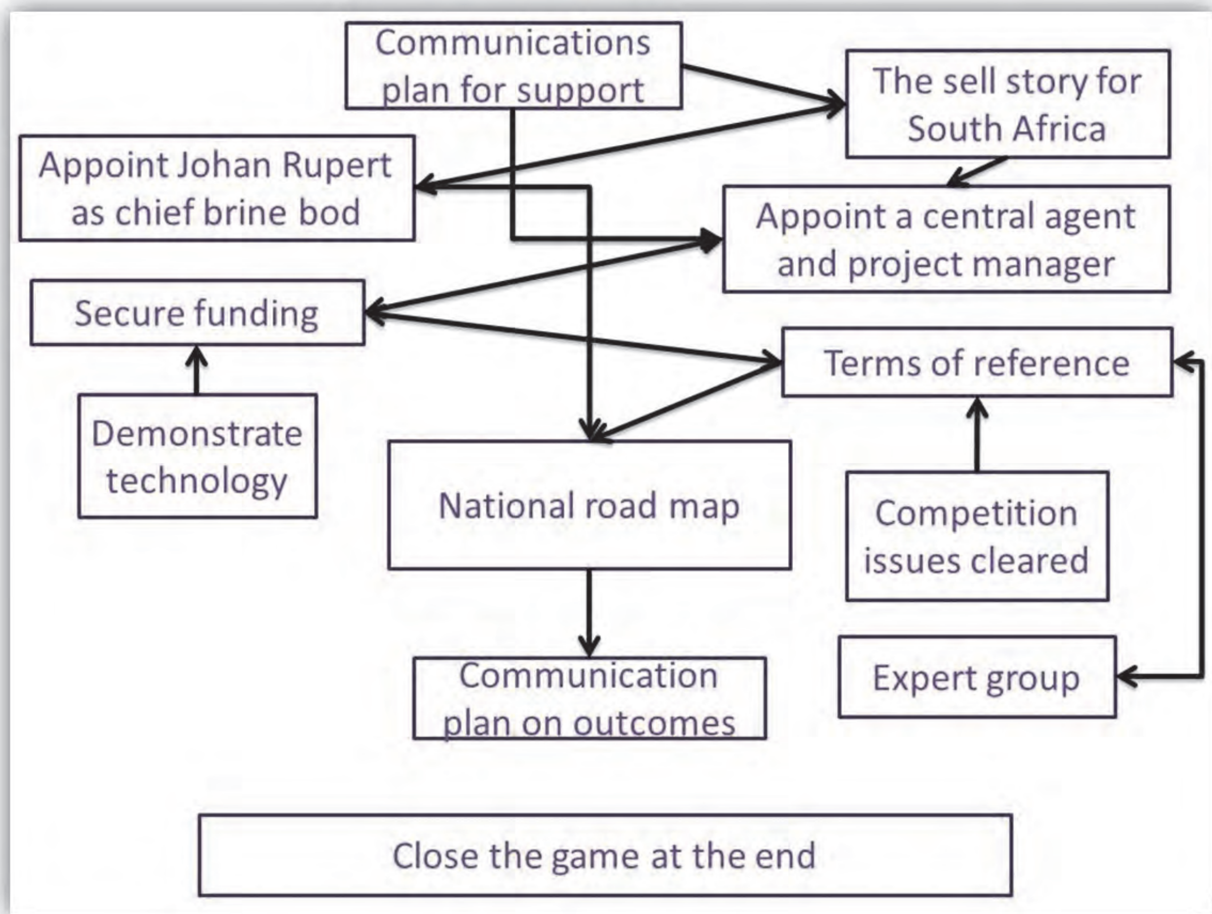
Some practical next steps were identified for short term action. These were:

- Set up community of practice
- Communicate outputs of the workshop
- Set up LinkedIn/Blogspot & Brine networks
- Set up coordination vehicle
  - WISA division: Brine
  - Evaluate potential for volunteers
- Annual workshop: Knowledge sharing
- Make info more easily accessible
- Match-making session: Funds and partnerships
- Water network optimisation seminar (PAMSA)
- Facilitate an aquatic chemistry training course for industry and students (UFS)
- International brine conference in South Africa
- Establish a Centre of Excellence for brine at a University
- Develop collaboration between industry, research and government
  - Build case to leverage funding
- International collaboration to source funding
- Environmental levy from government to fund demonstration scale technology
- “Tolling” the brine produced

The 6-12 month action plan was looked at from the perspective of different role players, the desired state topic areas, and a chronology of steps. The three perspectives are provided hereunder.


External collaboration
LinkedIn brine group
Funding
Centre of excellence
Industry
Government
Conference
Environmental levy/brine toll


Technology
Proof of concept/ demonstration plant
Capability
Academia and industry
Infrastructure (govt)
Knowledge
Collaboration
Practice
Water management
Legislative environment
Process integration


Communications plan for support
The sell story for South Africa
Appoint Johan Rupert as chief brine bod
Appoint a central agent and project manager
Secure funding
Terms of reference
Demonstrate technology
National road map
Competition issues cleared
Communication plan on outcomes
Expert group
Close the game at the end

References

Carroll Lewis (1865) Alice's Adventures in Wonderland. MacMillan and Co. London.

DWA (2013) Strategic Plan for the fiscal years 2013/14 to 2017/18. http://www.dwaf.gov.za/documents/Other/Strategic%20Plan/2013/Strategic%20plan%20draft%20-%2011%20Mar%202013.pdf.

Van der Merwe IW, Lourens A, Waygood C (2009) An Investigation of Innovative Approaches to Brine Handling. WRC Report No. 1669/1/09

Appendix A: Participant list

Attendance Register: Brine Workshop Workshop 22-23 January 2014			
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Appendix B: Introductory Presentations

WRC – Dr Jo Burgess

Brine Research and the WRC

WRC / Eskom Brine Workshop

January 2014

Dr Jo Burgess
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The WRC's mandate

- Promoting co-ordination, co-operation and communication in the area of water research and development.
- Establishing water research needs and priorities.
- Stimulating and funding water research according to priority.
- Promoting effective transfer of information and technology.
- Enhancing knowledge and capacity building within the water sector.

Research priorities

- To solve water-related problems which are critical to South Africa's sustainable development and economic growth.
- Fundamental research – it must be clear that it *might* lead to a solution and fit into the national research priorities
- Applied research - testing, prototypes
- Innovations and novel solutions - sensors, POU devices
- (Scale-up and implementation mainly via partners)

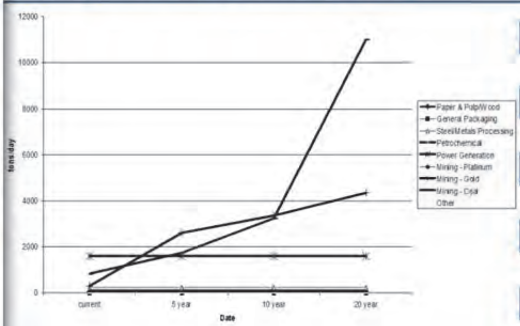
Drivers for generation of brines = water desalination (brackish, waste, sea)

- **Scarcity (availability)**
  - Water security
  - Water demand and supply challenges
  - Water allocation (competition for available sources)
- **Growth**
  - Population and migratory patterns
  - Growth of industrial sectors
- **Regulatory**
- **Pricing**
- **Water quality**
- **Location**
- **Climate (unreliability)**
- **Economics**
  - Economically unfeasible to transfer water from surplus to deficit areas
- **Availability of technologies**
- **Cost of technologies**

Current and Projected Sources of Brine and Sludge (2009)

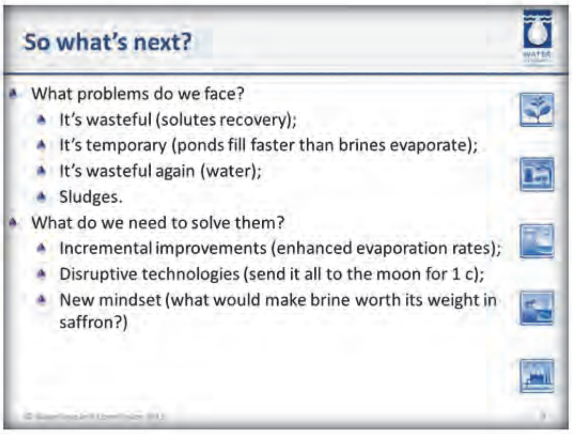
Sector	Total effluent			Salt load to environment		
	Total effluent	Total excl marine	Portion excl marine	Total salt	Total salt excl marine	Portion excl marine
	kl/day	kl/day	%	t/day	t/day	% of total excl marine
Paper & Pulp Wood	272001	89001	16.6	1440	80	7.6
General Packaging	1950	1950	0.4	2	2	0.2
Steel/metals processing	30500	30500	5.7	72	72	6.8
Petroleum	83900	69100	12.9	354	300	28.4
Chemical	13070	11070	2.1	51	44	4.2
Power Generation	132000	132000	24.7	159	159	15.0
Mines	145025	145025	27.1	350	350	33.1
Chemical suppliers	528	528	0.1	0	0	0.0
Dairy	2700	2700	0.5	4	4	0.4
Sugar	8100	3900	0.7	10	2	0.2
Canning	2200	2200	0.4	1	1	0.1
General food	13970	10970	2.1	11	5	0.5
Pharmaceutical & personal care	1430	1430	0.3	1	1	0.1
Animal Nutrition	1205	1205	0.2	1	1	0.1
Poultry & Meat	12100	12100	2.3	8	9	0.8
Beverage	14670	14670	2.7	11	11	1.0
Textile	6000	6000	1.1	13	13	1.2
Waste management	190	190	0.0	5	5	0.5
Fish Processing	220700	200	0.0	7921	1	0.1
Totals	**962239**	**534739**	**100**	**10413**	**1058**	**100**

Brine generation potential (2009)




Trends
Brine volumes generated as a result of coal and gold mining probably represent the most important challenge over the medium term.
Cumulatively, it is possible that brine volumes could be around 4000 t/d within 5 years, and as much as 15 000 t/d of brine within 20 years.
Location: in the short term (depending on future strategies to manage the West and East Rand Basins) brine generation could be relatively evenly split between the Johannesburg area, and the Witbank area;
The greatest increase in brine generation is expected (in the longer term) to be in the area of the Witbank Coal Fields.


Present brine strategies (we can do these)
To date, the most important disposal strategies employed in various regions of the world include:
Discharge to evaporation ponds;
Disposal to surface water bodies;
Disposal through pipelines to municipal sewers;
Deep-well injection;
Concentration into solid salts;
Land application and irrigation of plants tolerant to high salinity (halophytes).

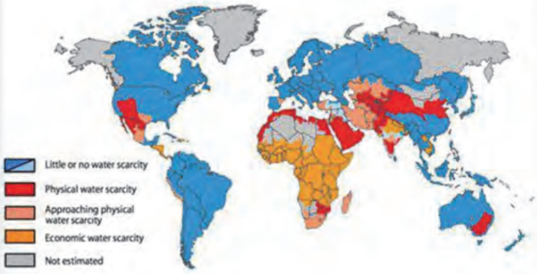

So what's next?
What problems do we face?
It's wasteful (solutes recovery);
It's temporary (ponds fill faster than brines evaporate);
It's wasteful again (water);
Sludges.
What do we need to solve them?
Incremental improvements (enhanced evaporation rates);
Disruptive technologies (send it all to the moon for 1 c);
New mindset (what would make brine worth its weight in saffron?)

UWC – Dr Leslie Petrik

ENS
Environmental Nano Sciences

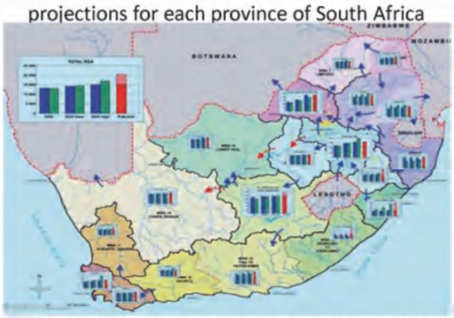
WRC/Eskom workshop
22-23 Jan 2014

L.Petrik (UWC)



World water scarcity map (Foreign Policy Magazine 2009)

Water demands and availability projections for 2025 projections for each province of South Africa



Water availability =blue bar; water use =green bar; water development potential = red bars (DWAF 2009)

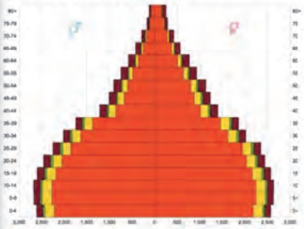
Stats SA

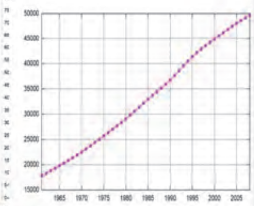
41,49% of South Africans are under 20 years of age

This is 20 987 716 people who need services

71% of all children under 18 years of age are on a grant

In the 2009/10 tax year, only 5 920 612 individual taxpayers, 1 878 856 companies and 685 523 VAT vendors were registered





Population increase in SA since 1960

Composition of sea water in mg/L from different regions showing the major ions

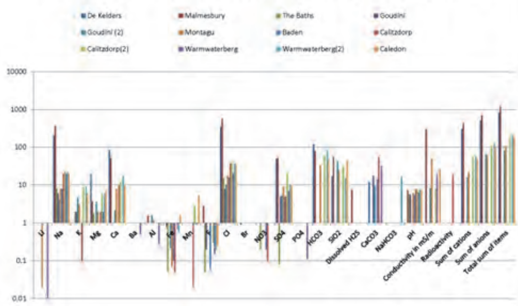
Source: Lenntech (2011)

mg/L	Typical sea water	Eastern Mediterranean	Arabian Gulf (Kuwait)	Red Sea (Jeddah)	Cape Town
Chloride (Cl^-)	18980	21200	23000	22219	19833
Sodium (Na^+)	10556	11800	15850	14255	10168
Sulphate (SO_4^{2-})	2649	2950	3200	3078	2733
Magnesium (Mg^{2+})	1262	1403	1765	742	1234
Calcium (Ca^{2+})	400	423	500	225	394
Potassium (K^+)	380	463	460	210	397
Bicarbonate (HCO^{3-})	140		142	146	
Strontium (Sr^{2+})	13				8
Bromide (Br^-)	65	155	80	72	
Borate (BO_3^{3-})	26	72			
Fluoride (F^-)	1				
Silicate (SiO_3^{2-})	1		1.5		
Iodide (I^-)	<1	2			
TDS	34483	38600	45000	41000	34800

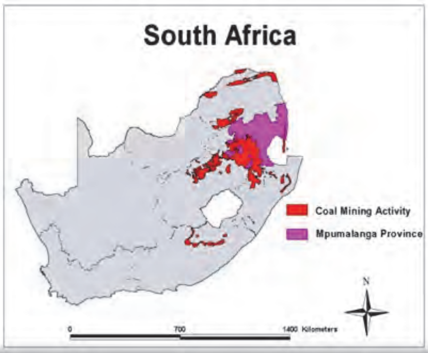
Water classification by salinity level

Water Class	Fresh Water	Brackish Water	Saline Water	Brine
Salinity (mg/L)	<500	500-35000	35000-50000	>50000

SA Natural spring waters (mg/L)



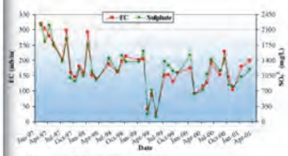
Coal mining areas



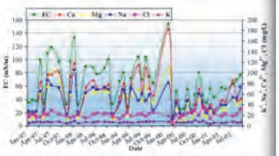
pH, EC and SO_4^{2-} concentration of a selection of coal mine drainages

Collieries	pH	EC mS/m	SO_4^{2-} mg/l
Goedhoop	6.20	160.8	1 234
Kleinkopje	5.76	136.8	799.6
Kriel	6.66	59.90	218.8
New Clydesdale	6.99	38.27	115.3
Sasol Secunda	8.09	544.7	1 094
TNC	7.79	135.3	558.2
Tweefontein	7.41	162.9	673.0
Arnot	8.10	0.87	221.0
Douglas	6.05	146.7	853.7
Greenside	6.44	156.4	763.6
Koornfontein	7.32	102.1	369.0
Middelburg South	6.67	161.6	1 234
Middelburg	6.62	147.9	825.4
Minaar	6.47	68.46	312.0
Rietspruit	7.70	142.5	907.9
South Witbank	3.75	126.5	733.6
Navigation	2.7	900.2	18 889
Brugspruit	2.4		11 890
Emalahleni intake	2.7	460	3090
Skoongesig	2.79	279	5700

Mine water: Seasonal variability



Monthly EC values and SO_4^{2-} concentrations for South Witbank colliery drainage water over 4 years.



Monthly EC values and some ion concentrations for TNC colliery drainage water over 4 years.

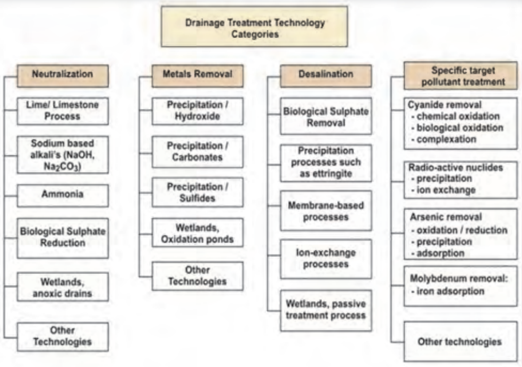
Does not always correspond to rainfall events

Many power stations also use mine water as a source of raw water which implies that the **high salt load in these waters report to any water treatment facility at the power station**

Overview of SA technologies developed to treat mine waste water

NO SHORTAGE OF OPTIONS!!!

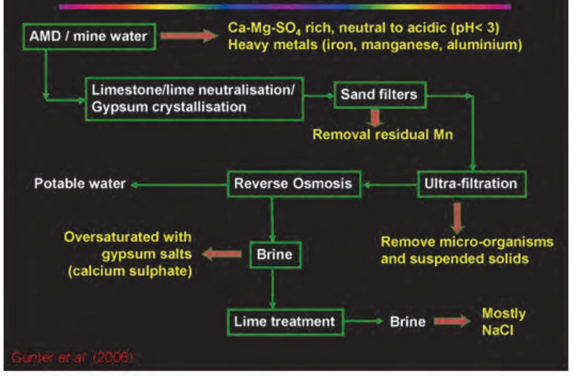
Process	Principle	Trace / Major element removed
Thiopak	Anaerobic biological conversion	Sulphate Major
Ecodose	Electrochemical process	Major
Savmin	Gypsum crystallisation	Sulphate Major
SPARRO	Precipitation and RO	Major
Ferrite process	Magnetite seeding	Major
Biosure	Biological treatment	Major
Petrik	Fly ash/Zeolite adsorption	Major/Minor/Trace



Conventional BRINE Treatment Methods

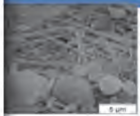
Pollutant	Removal Method(s)	Challenges
Monovalent ions (e.g. Na^+, Cl^-)	Reverse Osmosis	High costs, Low recovery rates
Hardness (Ca^{2+}, Mg^{2+})	Nanofiltration, ion-exchange	Nanofiltration, ion-exchange
Colloids (turbidity)	Coagulation, flocculation	Pretreatment procedure
Pathogens, bacteria, protozoa	Disinfection, Membrane process	High Energy process
Odour causing Organic Pollutants	Adsorption (Activated Carbon)	Not very effective
Harmful Organic Pollutants	Oxidation (UV-Irradiation, Chlorination, Ozone)	Not very effective, High cost. Chlorination-carcinogenic byproducts

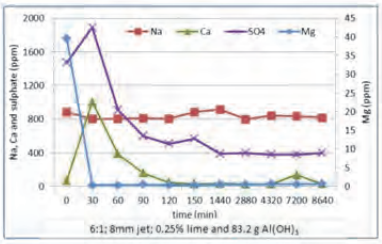
Emalahleni Mine Water Treatment



Sulphate removal from neutral mine water using coal fly ash

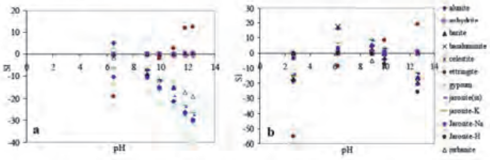
Godfrey Madzivire





Minerals Engineering 23 (2010) 252–257

Saturation indices obtained from PHREEQC model of sulphate minerals of NMD (a) and AMD mixtures (b) at various pH values



Presence of Fe and Al in AMD enhanced sulphate removal through precipitation of Fe and Al oxyhydroxysulphates.

The mineral phases that were responsible for sulphate removal were found to be alunite, anhydrite, barite, basaluminite, jurbanite, jarosite-ss, jarosite-K, jarosite-Na, jarosite-H, celestite and gypsum.

IMWA, 2010. Wolkersdorfer & Freund (Editors)

Characterization of brines

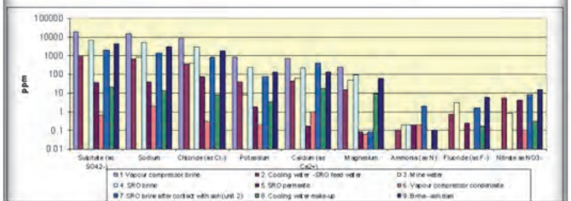
- (i) Low concentration (<20 ppm): Ammonium (NH4+), lithium (Li+), fluoride (F-), and nitrates (NO3-).
- (ii) Medium concentration (> 50 but <1000): Calcium (Ca 2+), magnesium (Mg2+), and potassium (K).
- (iii) High concentration (~8000): chloride (as Cl-).
- (iv) Very High concentration (>10,000ppm): Sodium (Na+), sulphate ($SO4^{2-}$).

Brine composition

Chemical composition of stage 3 reject brine from Emalahleni, pH =7.67, EC = 21.7 mS/cm, TDS = 8146 mg/L

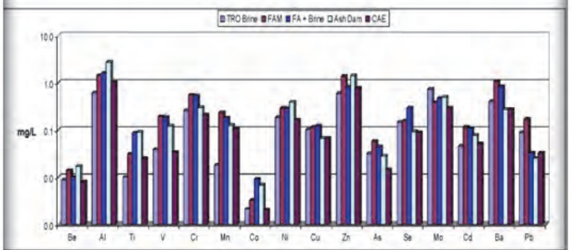
Major cations in Brine	Concentration (ppm)	Traces in brine	Concentration (ppm)
Sodium	3355±25.46	Strontium	11.06±0.18
Potassium	758± 2.06	Aluminium	0.07
Magnesium	111.85±0.07	Chromium	0.02
Calcium	610.2±10.47	Phosphorus	119±0.01
Anions		Vanadium	0.49
Sulphate	12704±143.54	Cobalt	0.01
Chloride	1065±7.78	Selenium	0.06
Nitrate	339±13.44	Iron	0.07
		Boron	0.01

Tutuka brines

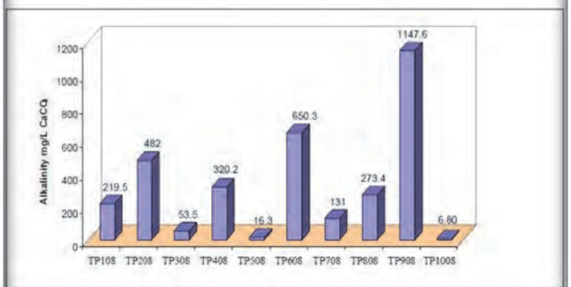


Tutuka levels of Na in brine much higher than Secunda and vary more

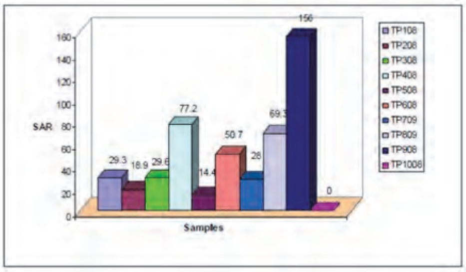
Trace elements in brine



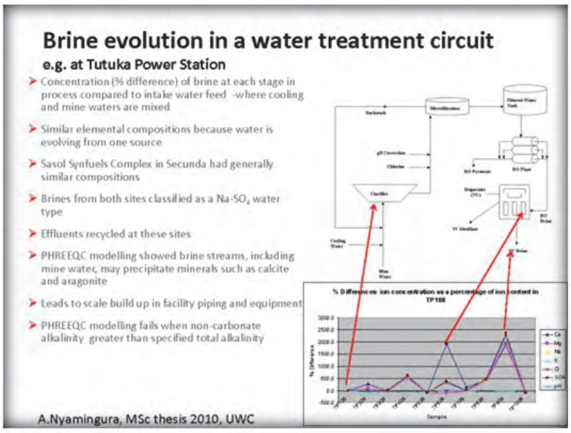
Alkalinity in Tutuka Power Station effluents

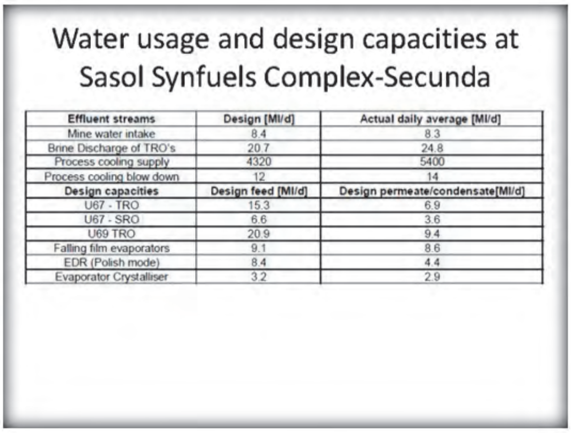


Sodium adsorption ratio (SAR) values of Tutuka Power Station samples

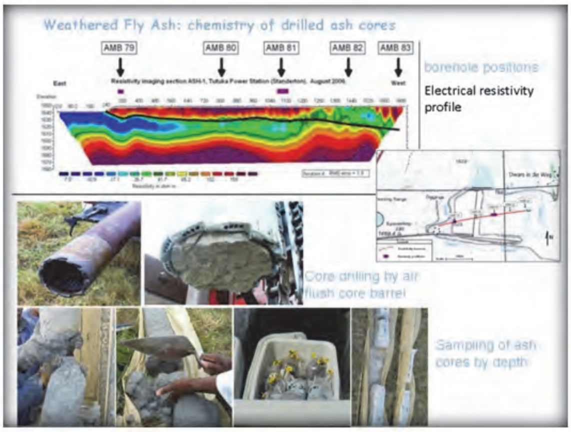


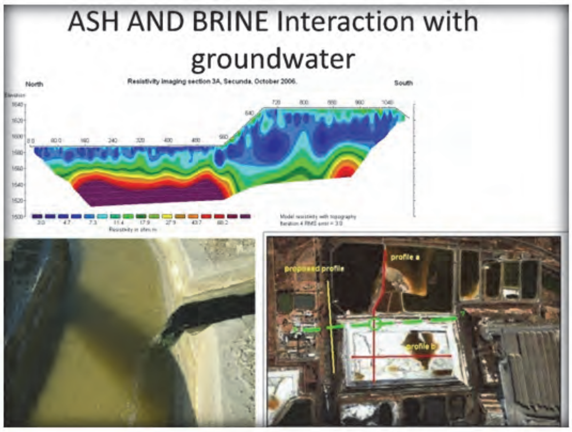
Only water with SAR values below 10 is permitted to be used as irrigation water

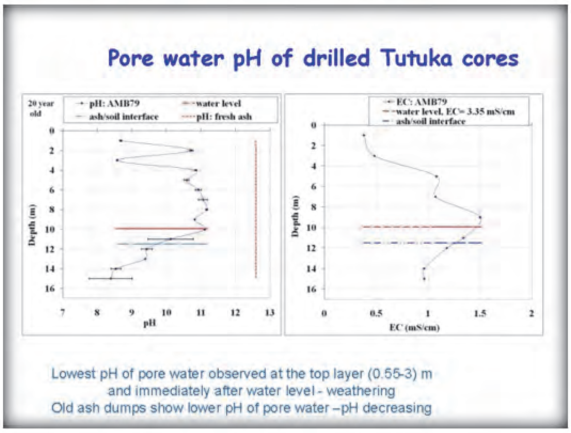


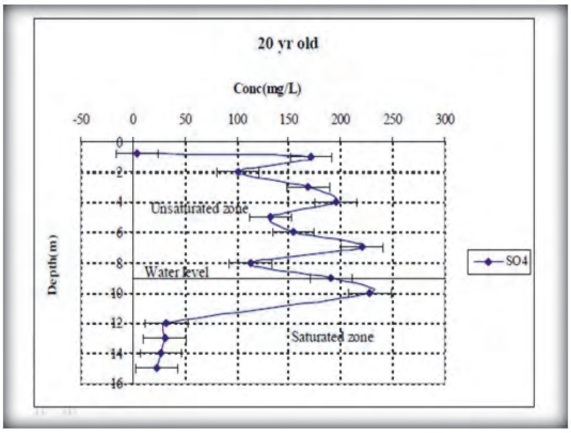


Effluent streams	Design [Ml/d]	Actual daily average [Ml/d]
Mine water intake	8.4	8.3
Brine Discharge of TRO's	20.7	24.8
Process cooling supply	4320	5400
Process cooling blow down	12	14
Design capacities	**Design feed [Ml/d]**	**Design permeate/condensate[Ml/d]**
U67 - TRO	15.3	6.9
U67 - SRO	6.6	3.6
U69 TRO	20.9	9.4
Falling film evaporators	9.1	8.6
EDR (Polish mode)	8.4	4.4
Evaporator Crystalliser	3.2	2.9

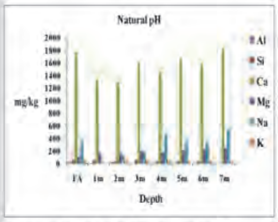




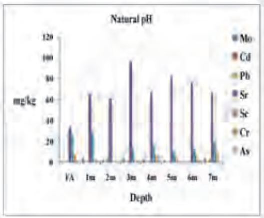




Salt accumulation???Leaching



Major elements in water soluble extract of fresh ash (FA) and unsaturated dry disposed ashes.

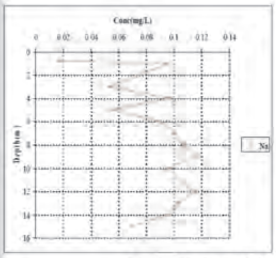


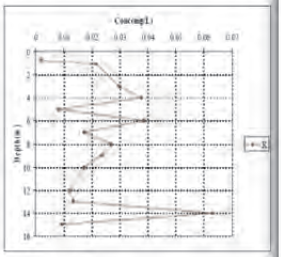
Trace elements in water soluble extract of fresh ash (FA) and unsaturated dry disposed ashes.

Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 2011, Volume 33 Issue 8, January: 768

Coal Combustion and Gasification Products 2011, 3, 28-40, doi: 10.4177/CCGP-D-11-00005.1

NOT a sustainable salt sink!





Energy Science and Technology, Volume 2, Number 2, November 30, 2011. ISSN 1923-8460

Current related projects

- 2100 Industrial Brine Minimization: Determining the Physical Chemical Parameters that Affect Evaporation Rates on Multi - Component Hyper - Saline Effluents 01/04/2011 31/03/2014
- 2128 Application of mineral carbonation processes for brine remediation 01/04/2012 31/07/2015
- 2129 Treatment of mine water using a combination of coal fly ash and flocculants in a jetloop reactor system 01/04/2012 31/03/2017
- 2391 The Synthesis of Highly Selective Immobilized Ligands for Extraction of Toxic Metal Ions from Waste Water 01/05/2014 30/09/2017

WRC PROJECT K5/2100

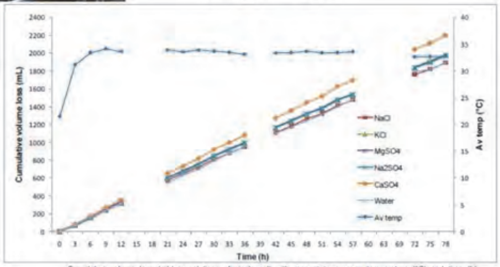
- Industrial Brine Minimization: Determining The Physical Chemical Parameters That Affect Evaporation Rates On Multi-component Hyper-saline Effluents
- Identify different types of brines generated at different sections of the desalination plant
- Characterize and understand hyper saline water chemistry
- Effect of climate on the rate of evaporation of water and brine
- Impacts of natural climatic conditions such as temperature, wind speed, humidity, irradiance, dew point, pressure, etc. of the desalination ponds

Type of salt
Water holding capacity

Water holding capacity of dried single salt samples when exposed to saturated conditions in a desiccator after 24 hour drying

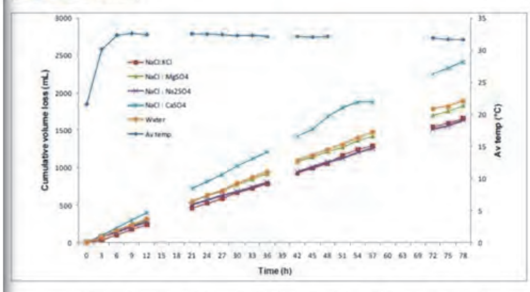
Salt	Actual weight of salt (g)	Weight of moist salt (g)	Moisture Content (%)
$MgSO_4$	4.20	5.86	39.5
KCl	4.54	5.16	13.6
Na_2SO_4	4.96	4.99	0.60
$CaSO_4$	4.19	4.54	8.4
NaCl	4.12	5.32	29.1

Rate of evaporation in 3L evaporation pans: Single salts



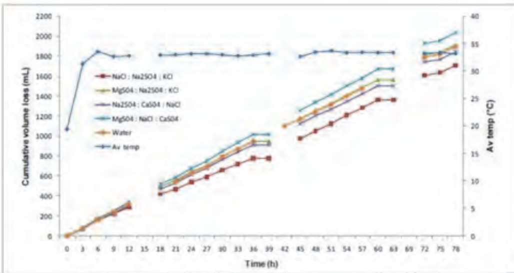
Cumulative volume loss (mL) in solutions of single salt with respect to average temperature (°C) and time (h)

Double salts



Cumulative volume loss (mL) in solutions of double salts with respect to average temperature (°C) and time (h)

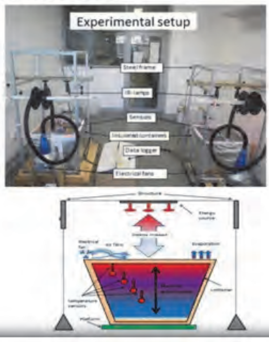
Triple salts



Cumulative volume loss (mL) in solution of triple salts with respect to average temperature (°C) and time (h)

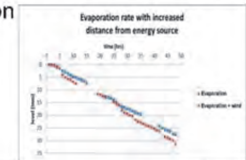
Evaporation under controlled parameters

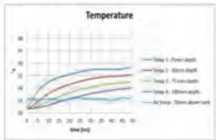
- Temperature
  - Thermal stratification
  - radiation
- Humidity
- Wind speed

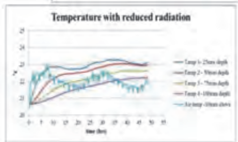


Temperature

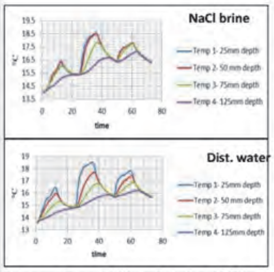
- The thermal stratification
- The evaporation rate changes
- Ambient temperature influence



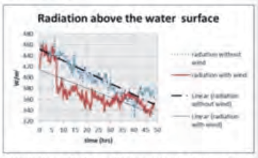




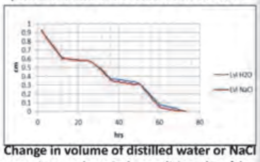
Effect of Wind



Temperatures at different depths with the wind blowing over the surface area at 2m/s



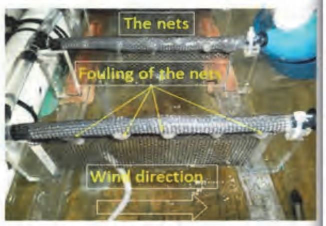
Variations of the radiation over a 48 hour time period with and without the wind assistance



Change in volume of distilled water or NaCl over time under windy conditions (2m/s)

Wind –aided evaporation (WAIV)

- Nets float above brine surface
- parallel to wind direction
- fibre strand with Polyvinyl Chloride (PVC) coating



Improving performance of evaporation ponds?

- Fabric evaporators
- Wetted boundary layer breakers
- Salt tolerant plants
- Droplet spraying
- Halophilic chromophoric bacteria
- Dunaliella high-rate algal pond for saline carbonate brines (Prof. Rose)

WRC Project Number: K5/2128

Application of Mineral Carbonation Processes for Brine Remediation

Approach to water reclamation from waste brine

Fly ash/brine/CO_2 interaction on fresh and weathered ash

Fresh ash was characterized and applied for ex-situ mineral carbonation in the laboratory

Weathered Secunda ash cores were investigated for their in-situ CO2 capture capacity

Brine from Emalahleni

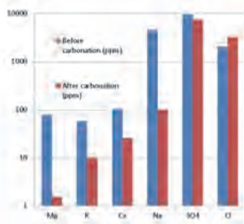
Variables explored: pressure, temperature, ash particle size, solid to liquid ratio, fresh and weathered ash

Initial conc., major conc. and range of removal of major elements from brine via carbonation

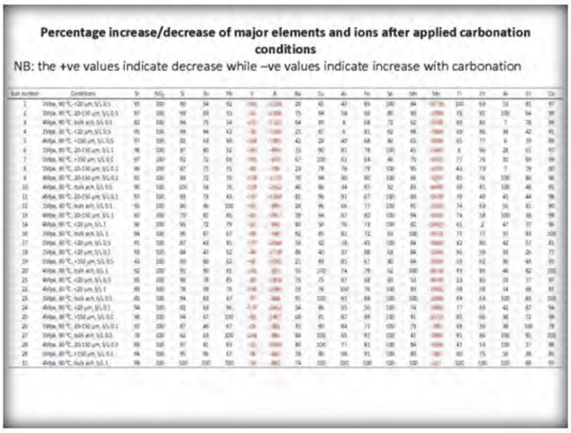
Element	Initial conc. (mg/L)	Highest conc. removal (mg/L)	Removal range (%)
SO_4	11 704	2 600	27
Na	3 355	2 201	29
Ca	210	27	73
Mg	111.85	111	87
K	79	8.2	88

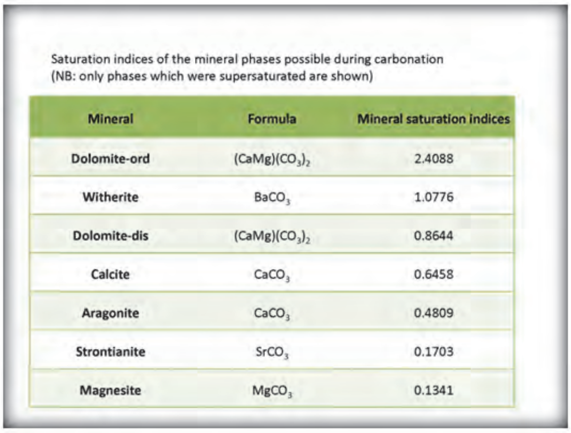
Brine cleanup by carbonation with fly ash

SEM micrographs of fresh fly ash (a) and carbonated fly ash (b)

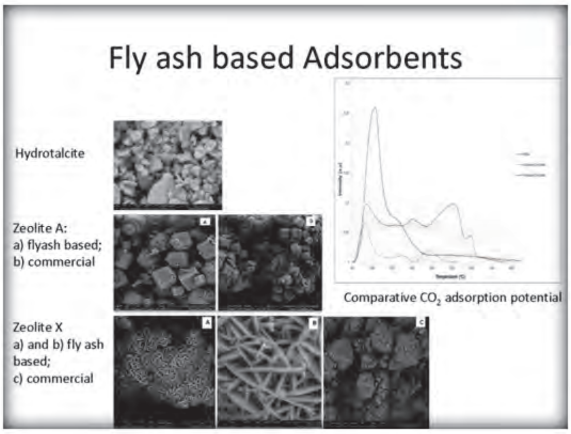


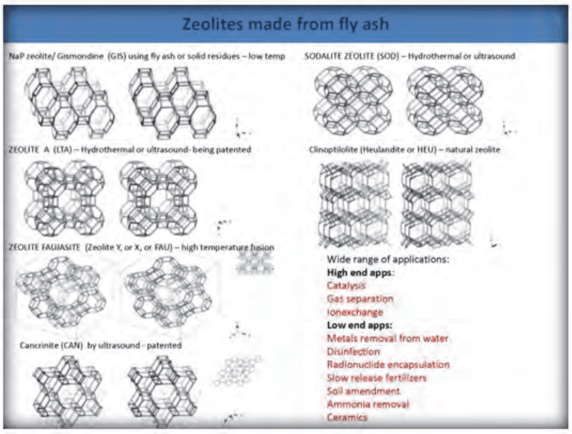
Comparison of raw brine and brine after carbonation

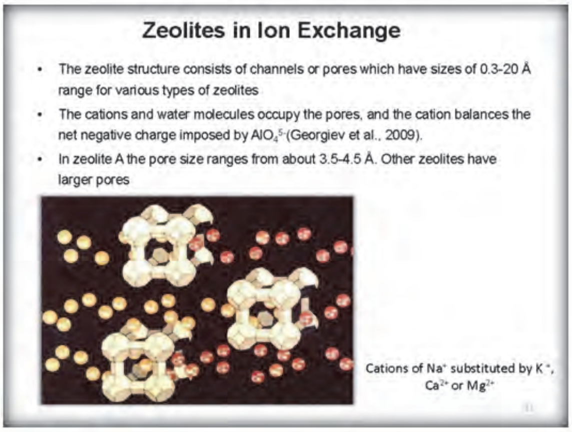


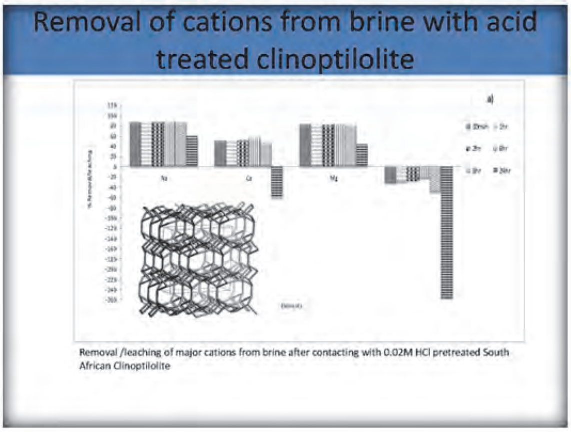


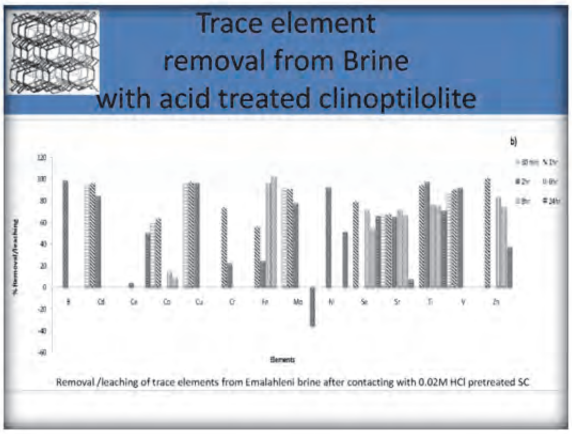
Mineral	Formula	Mineral saturation indices
Dolomite-ord	$(CaMg)(CO_3)_2$	2.4088
Witherite	$BaCO_3$	1.0776
Dolomite-dis	$(CaMg)(CO_3)_2$	0.8644
Calcite	$CaCO_3$	0.6458
Aragonite	$CaCO_3$	0.4809
Strontianite	$SrCO_3$	0.1703
Magnesite	$MgCO_3$	0.1341

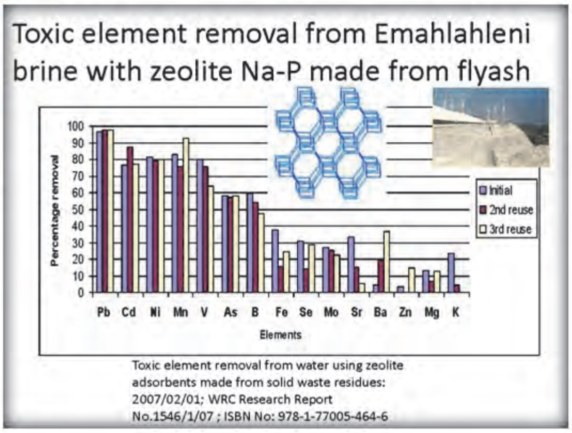


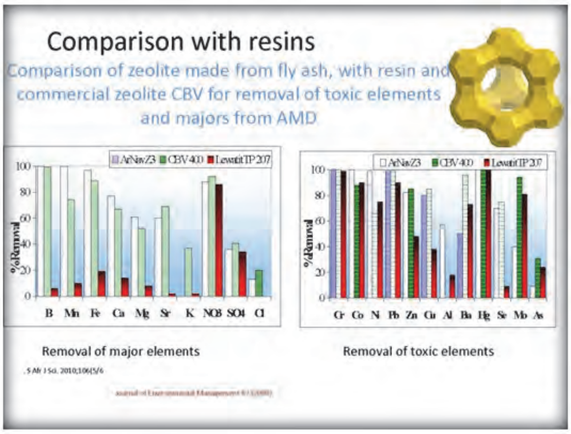




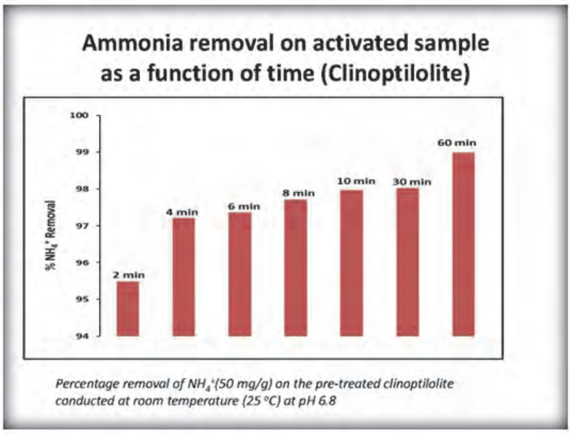








Comparison with resins
Comparison of zeolite made from fly ash, with resin and commercial zeolite CBV for removal of toxic elements and majors from AMD
ArNaZ3
CBV 400
Lewatit TP 207
%Removal
B Mn Fe Ca Mg Sr K NO3 SO4 Cl
Cr Co Ni Pb Zn Cu Al Ba Hg Se Mo As
Removal of major elements
Removal of toxic elements
S Afr J Sci. 2010;106(5/6

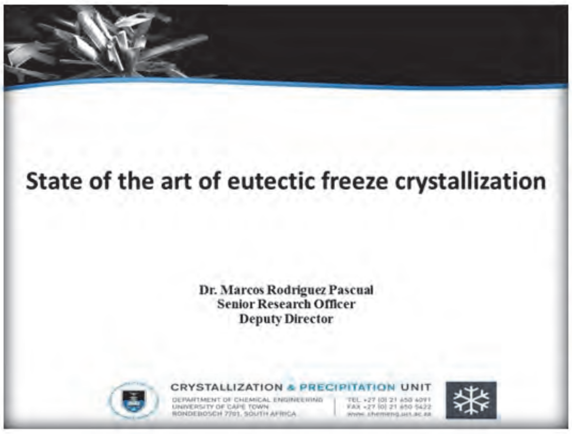


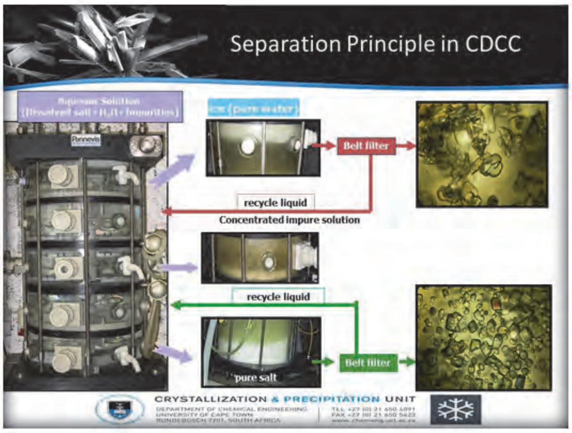
Ammonia removal on activated sample as a function of time (Clinoptilolite)
% NH4+ Removal
2 min
4 min
6 min
8 min
10 min
30 min
60 min
Percentage removal of NH4+(50 mg/g) on the pre-treated clinoptilolite conducted at room temperature (25 °C) at pH 6.8

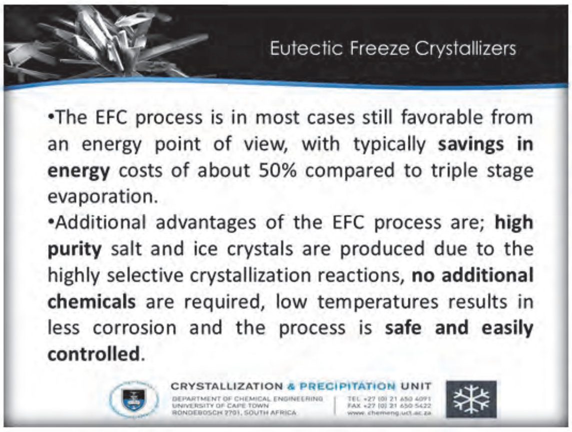
Students

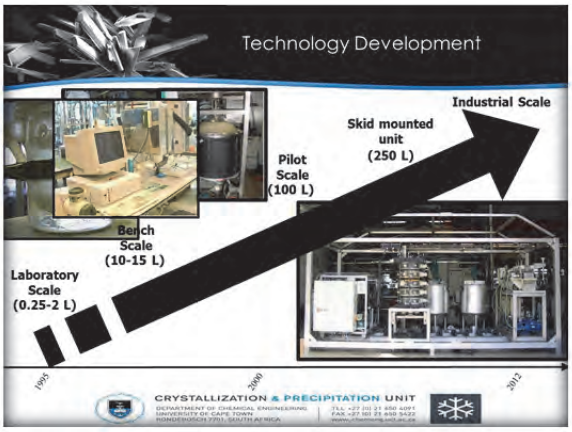
THANK YOU!

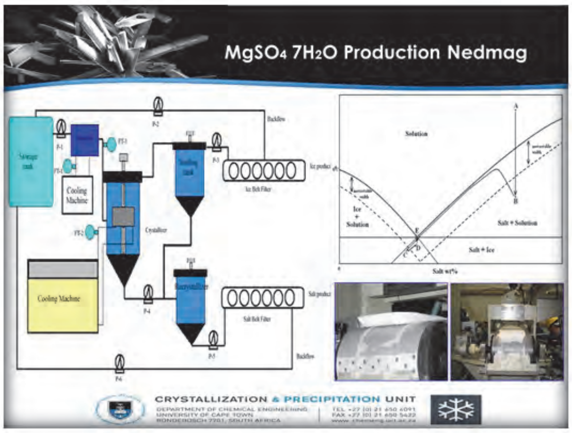
UCT – Dr Marcos Rodriguez Pascual

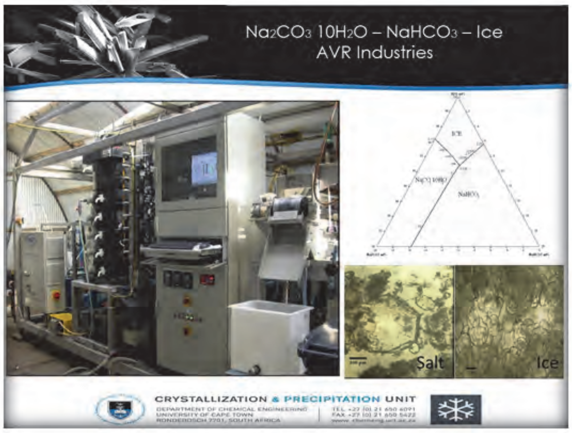












Previous and Existing Funding

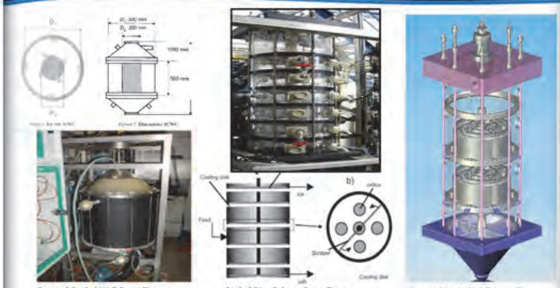
- Anglo Coal
- Sasol
- Eskom TESP
- Coaltech
- Lonmin
- Atl-Hydro (collaboration but no funding)
- Proxa (collaboration but no funding)

Interest

- AngloPlat
- Anglo Gold Ashanti
- Earth Metallurgical Solutions
- DRD Gold
- Water Care Mining
- ESKOM
- BASF (Germany)
- EcoWat (Norway)
- GE (USA)
- Eco Solutions (USA)
- Filterboxx (Canada)
- Vale (South America)
- Murrin Murrin (Australia)
- AMIRA

CRYSTALLIZATION & PRECIPITATION UNIT

Scraped Heat Exchanger Crystallizers



Scraped Cooled Wall Crystallizer — Cooled Disc Column Crystallizer — Scraped Cooled Wall Crystallizer

CRYSTALLIZATION & PRECIPITATION UNIT

Common Problem in Scraped Heat Exchanger Crystallizers

- Temperature Gradient from HE surface to middle area.
- Poor mixing due to the low turbulence.
- No control over the crystal suspension .

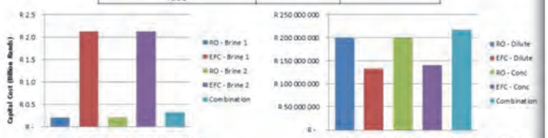
Solid Body Rotation

- Not even Supersaturation
- Higher scale formation on HE
- Broad CSD
- No control over residence time

CRYSTALLIZATION & PRECIPITATION UNIT

Capital Cost for treating dilute (0.15 wt %,2.5wt%) water stream of 20 ML/day

	250 litre Crystalliser	Large Volume Crystalliser
Crystalliser Volume (litres)	250	833333
Diameter of Crystalliser (m)	0.542	8.10
Height of Crystalliser (m)	1.08	16.2
Number of crystallisers required	3334	1
Cost of one crystalliser	R 383 722	R 2 348 515
Cost of all crystallisers required for feed	R 1 279 330 305	R 2 348 515



Comparison of Capital Costs based on Pilot scale crystallizers of 250 l

Comparison with optimal crystalliser volume of 25 000 litres (diameter 2.5m, height 5 m)

CRYSTALLIZATION & PRECIPITATION UNIT

Annual Operating Cost for treating dilute (0.15 wt%, 2.5 wt%) water stream of 20 ML/day

Operating costs	EFC
Electricity Cost per annum	R 118 million
Compressor Duty (MW)	31.3

Operating costs	RO
Cleaning (per annum)	R 4 113 550
Membrane replacement	R 4 113 550
Electricity (per annum)	R 4 483 402
Disposal	R 4 900 000

Operating costs	Combination Process
Membrane Cleaning	R 3.6 million
Electricity for RO	R 4.5 million
Electricity for EFC	R 5.6 million
Total Annual Operating Costs	**R 13.6 million**

CRYSTALLIZATION & PRECIPITATION UNIT

Conclusions

- Process has been proven on Pilot Scale of 250 liters/hour.
- EFC Technology has less energy cost compared with existing technologies, such as 3 stage evaporation, or Freeze Crystallization for desalination.
- EFC is environmentally friendly as it does not use added chemicals, and reduce to minimum (or zero) the waste disposal
- Co-products increases the economic profit.
- Crystallizer designs have been developed and implemented
- So, Why it has not been applied yet to industrial scale?

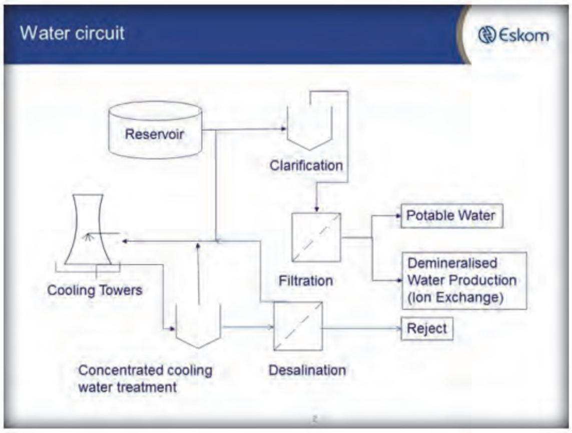
CRYSTALLIZATION & PRECIPITATION UNIT

Industrialprocesssolutions.ac.za

Thanks for your attention

CRYSTALLIZATION & PRECIPITATION UNIT

Eskom – Gerhard Gericke, Dheneshree Lalla, Ken Galt

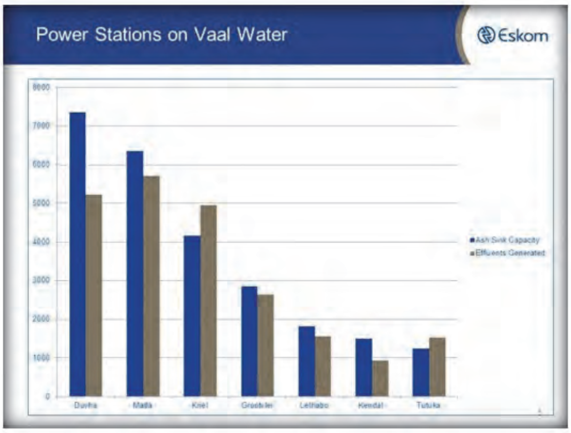


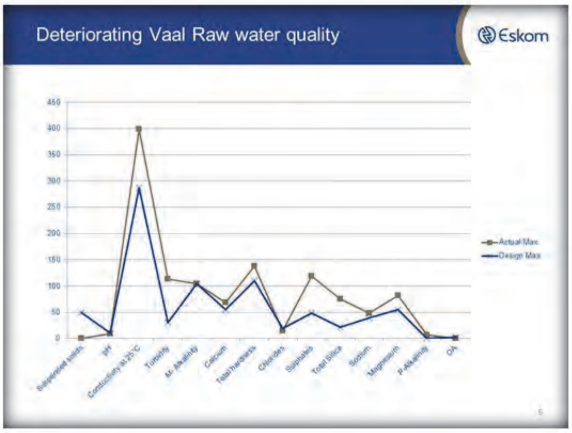
Effluent Generated (per station)

Effluent	Volume	Conductivity
Concentrated Cooling Water Blowdown	+/- 1500 Ml/year	< 4 mS/cm
Ion Exchange Regeneration Effluent	+/- 300 Ml/year	40 mS/cm
Clarifier Sludge Blowdown	+/- 100 Ml/year	Low salinity – not measured
Desalination Plant Reject	+/- 500 Ml/year	12 – 50 mS/cm

Reuse of Effluent

- Ash conditioning / sluicing
- Ash box make-up
- Dust suppression on dry ash dumps

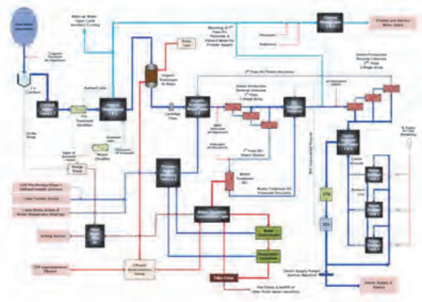




Impact of deteriorating raw water quality

- Reduced runs on demin plant, increased regeneration, increased effluent production
- Reduced cycles of concentration on CW system, increased blowdowns, increased effluent production
- Outside the design base of dosing systems
- Ageing plant struggling to cope with water within design base, aggravated by inferior feed water quality

Medupi Water Treatment Plant



WATER PINCH STRATEGY (PROCESS INTEGRATION)

- Study at 2 Eskom power stations
- Aim: to determine whether water usage and process requirement (quality) is optimal
- What water can be used for what purpose?
- How much water is needed for what purpose?
- To what extent can water be re-used?
- What impact will this have on raw water intake and impurity concentration?

IMPACT OF LEGISLATION ON THE WAY FORWARD

- To what extent will co-disposal (water/salt) on ash be regulated?
- At what point will industry be forced to employ re-use and treatment processes for re-use within its operations? What is the impact on waste generation?
- Liner systems are already enforced, but what is the minimum requirement and at what cost to industry and consumer?
- A change in operating and water management philosophies might be required to meet future regulatory and legislation requirements.

Thank you

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Anglo American – Ritva Muhlbauer