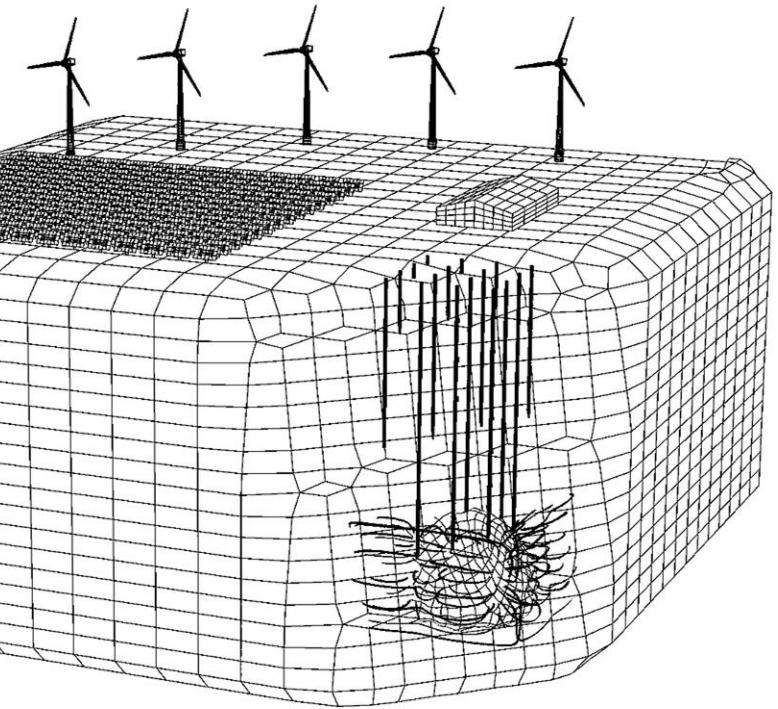


Next-Generation Metal Mining using Electrokinetic In Situ Recovery

Prof. Henning Prommer

University of Western Australia, School of Earth Sciences

Ekion Pty Ltd

OUTLINE

The grand challenge

Alternatives to “conventional mining”

EK-ISR: From “Eureka moment” to proof-of-concept

Ekion: Further tech development and commercialisation

Next Steps

THE GRAND CHALLENGE

The energy transition

- Decarbonisation requires unprecedented amounts of critical metals and there is a known gap between future demand and supply with conventional mining methods

Sustainable mining

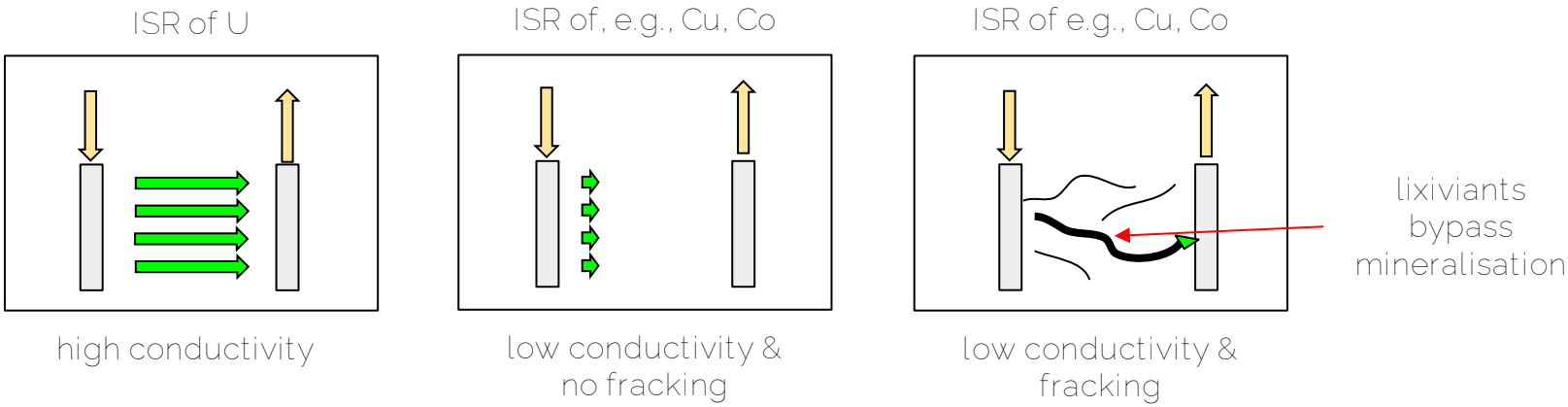
- Conventional mining methods have a high impact on the environment and surrounding communities, generating dust and large amounts of long-lasting waste products

Declining ore grades

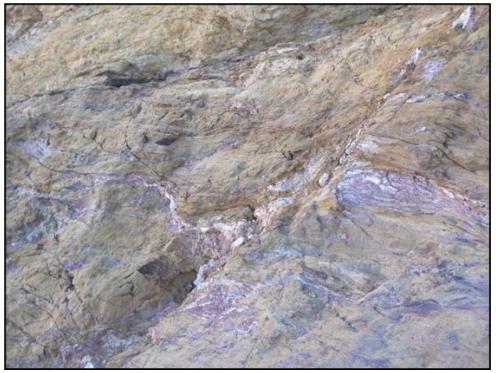
- New mines are targeting lower and lower ore grades, which require more resources to operate and exacerbate the effects on the environment

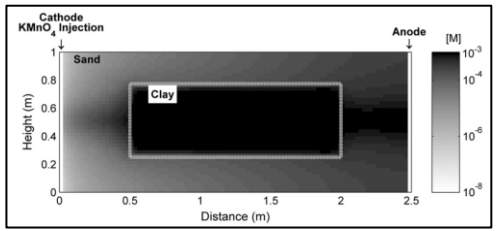
BEYOND DIGGING

- In Situ Recovery: Currently the only true alternative to conventional mining
- ISR, where applicable, reduces environmental impacts (no tailings, reduced land use)
- However, currently ISR applications are effectively limited to uranium



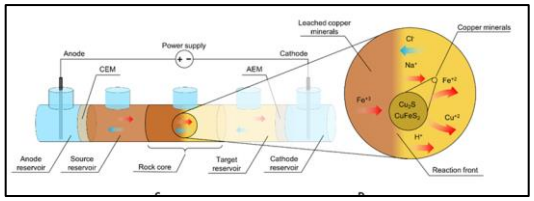
OUR EUREKA MOMENT

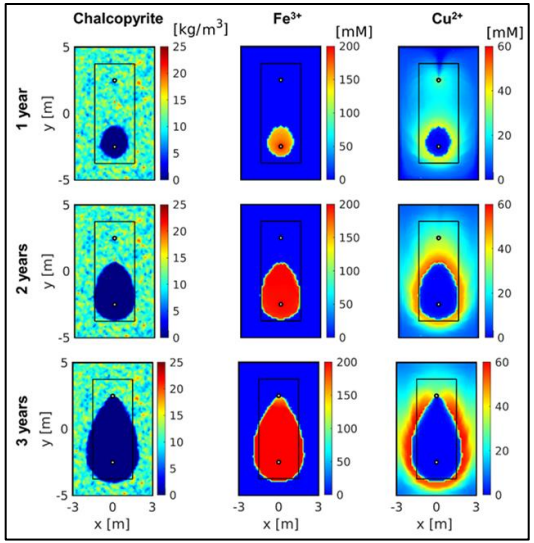




- Various attempts to expand application envelope of ISR beyond U
- MERIWA M409 In-Place Leaching of Oxidised Gold Ores: Recovery of gold from WA oxidised gold ores challenged by low hydraulic conductivities and subsurface heterogeneity
- ARC Linkage on Electrokinetics for groundwater remediation.
  "Rapid" transport of potassium permanganate into clays to destroy chlorinated hydrocarbons

MRIWA M0450





- Feasibility of Electrokinetic In Situ Leaching
- MRIWA Director's PhD Scholarship Evelien Martens
- First proof-of-concept for EK-ISR of Au and Cu from intact ore at the cm-scale
- Up-scaled, process-based numerical modelling

Feasibility of electrokinetic in situ leaching of gold

Evelien Martens[a,b,c], Henning Prommer[a,c,*], Xianwen Dai[d], Ming Zhi Wu[e], Jing Sun[a,c], Paul Breuer[d], Andy Fourie[b]

[a] School of Eart
[b] School of Civi
[c] CSIRO Land a
[d] CSIRO Minera
[e] University of

ARTIC

Keywords:
Electrokinetics
Electromigratio
In situ leaching
Gold
Iodide
Lixiviant

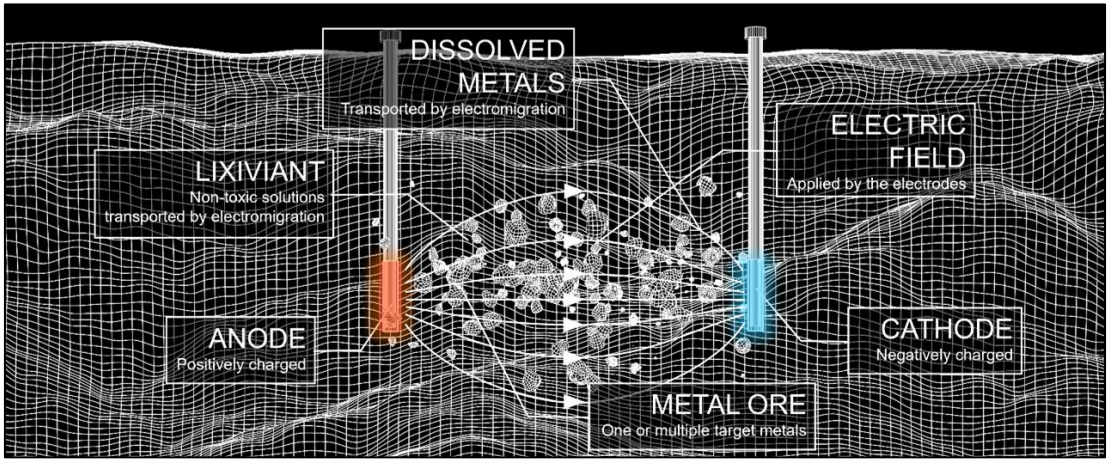
SCIENCE ADVANCES | RESEARCH ARTICLE

ENGINEERING

Toward a more sustainable mining future with electrokinetic in situ leaching

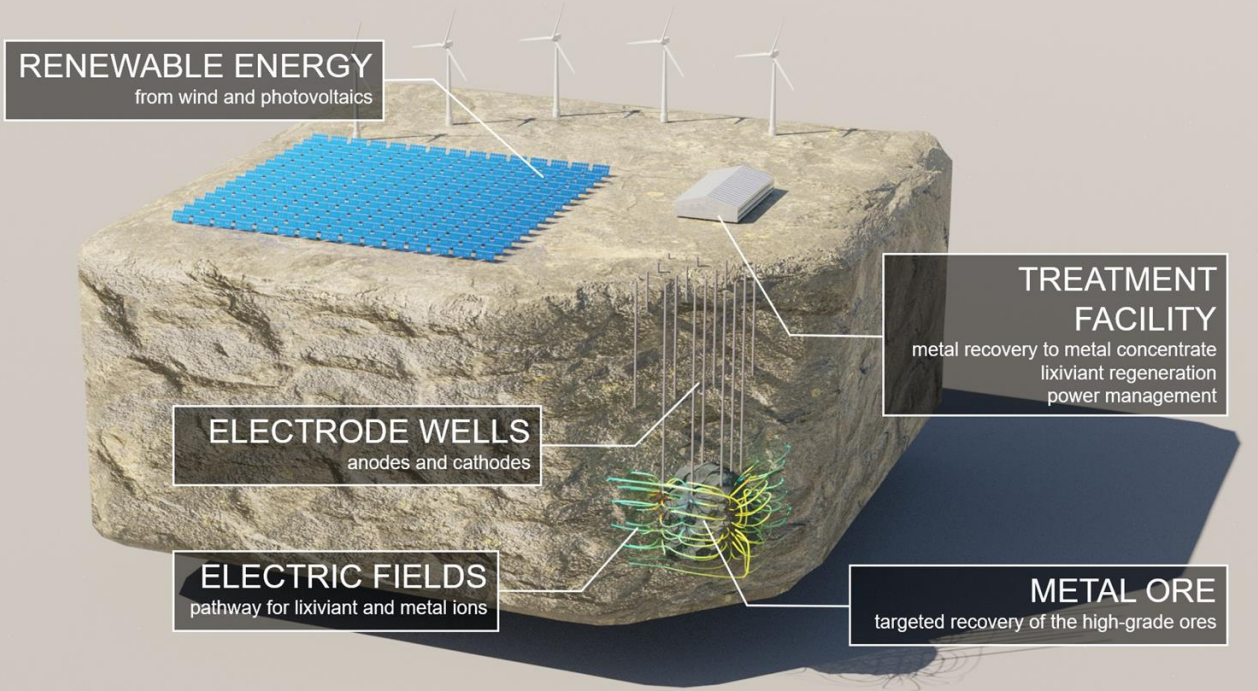
Evelien Martens[1,2], Henning Prommer[1,3]*, Riccardo Sprocati[4], Jing Sun[1,3,5], Xianwen Dai[6], Rich Crane[7], James Jamieson[1,3], Pablo Ortega Tong[1,3], Massimo Rolle[4], Andy Fourie[2]

EK-ISR PROCESS



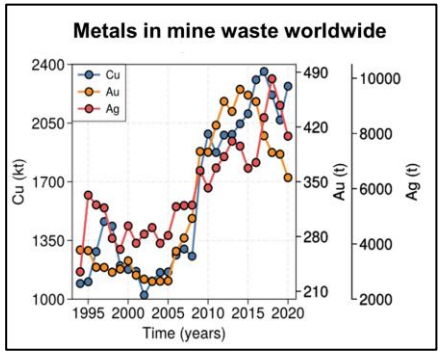
- EK-ISR uses electric fields to stimulate the transport of ions in low-permeability strata
- Electrodes of opposite polarity (anodes and cathodes) replace injection and recovery wells used for ISR. Power supply can be variable, e.g., from solar.
- Lixiviant is transported across the ore body while dissolving the metals. They are then transported towards the cathode and collected for further processing

EK-ISR FOR INTACT ORE



- Metal extraction from hard rock stranded deposits
- Valorization of existing mines - accessing what is left behind

EK-ISR FOR TAILINGS: OPPORTUNITIES

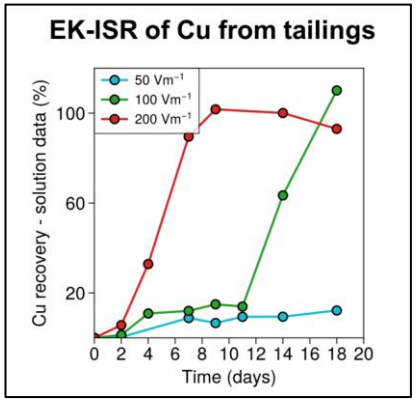


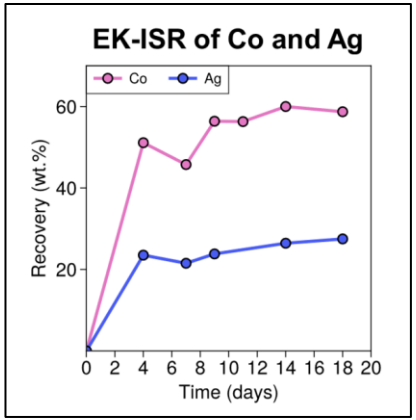
*[Mahaulpatha et al., in prep.]

- Enormous metal values are locked up in tailings dams in WA alone. Worldwide: $427B (Cu)*, $655B (Au)*, $152B (Ag)*
- Metal value in a single tailings dam can easily exceed $100M AUD, up to >$5B AUD
- Currently, access to metal values requires excavation, re-processing and re-deposition
- EK-ISR can target specific high-grade zones
- Additional value from:

  EK-induced dewatering after metal extraction
  enhanced geotechnical stability
  acceleration of mine closure

EK-ISR FOR TAILINGS: PROOF-OF-CONCEPT





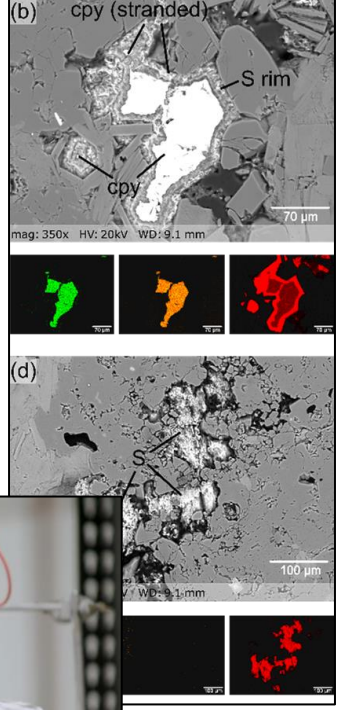
- MRIWA PhD Scholarship Bishenka Mahaulpatha
- Initial proof-of-concept for EK-ISR application to tailings

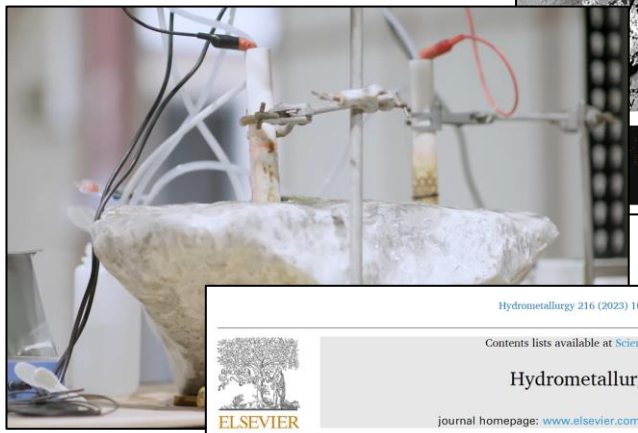
  Sample from tailings dam containing >1B AUD metal value
  Acidic leaching with ferric chloride as lixiviant
- Key results so far:

  Successful recovery of Cu, Co and Ag at cm-scale
  Carbonates (3% Ankerite) cause increased reagent and electricity consumption
  Hematite causes retardation of Cu migration

M0544: TOWARDS A MECHANISTIC UNDERSTANDING OF EK-ISR

- Aimed at improving our mechanistic understanding of the coupled ionic transport and geochemical reaction processes
- Detailed mineralogical characterisation pre-/post-leaching: Does EK help to overcome passivation?
- Numerical modelling + LCA of EK-ISR vs conventional mining vs electrified version of conventional mining





Hydrometallurgy 216 (2023) 105993

Contents lists available at ScienceDirect

Hydrometallurgy

journal homepage: www.elsevier.com/locate/hydromet

Secondary phase formation during electrokinetic in situ leaching of intact copper sulphide ore

Pablo Ortega-Tong [a], James Jamieson [a], Benjamin C. Bostick [b], Andy Fourie [c], Henning Prommer [a,d,*]

NEXT CHAPTER: EKION Pty Ltd

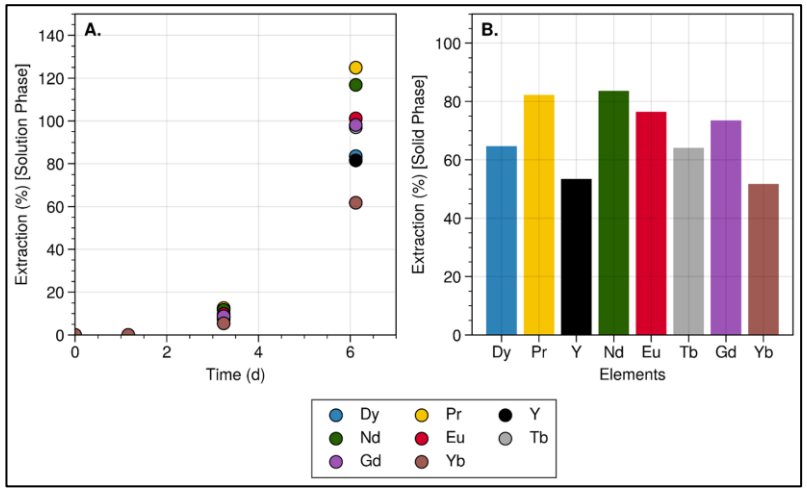
- Started Ekion Laboratory in Osborne Park 2023/Q4 (3 co-founders)
- Initial support from Think and Act Differently via ISR JV (BHP, Rio Tinto, IGO)
- Primary goals, Phase 1:

  De-risking field experiments via up-scaling to dm-scale (tailings in IBC containers)

  Further testing of EK-ISR application envelope (e.g., Ni-tailings)

NEXT CHAPTER: EKION Pty Ltd

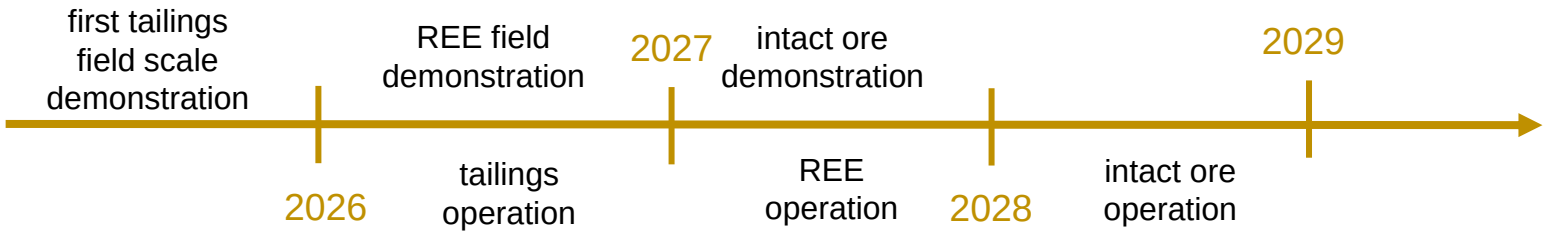
- Feasibility of EK-ISR for REE extraction
- Potential application to clay-hosted REEs in WA. First experiment with WA clay sample ready to go.
- Initial EK-ISR experiment with sample from SA shows 83% recovery of HREEs
- EK-ISR could recover REEs under farmland or environmentally sensitive areas



WHAT'S NEXT

- Initial focus on up-scaling EK-ISR application to tailings material
- Proof-of-concept for alkaline, more selective lixiviant system

  Degradable and fully recyclable
  Improved economics more environmentally friendly
- Secondary focus on REEs from IADs, long-term focus on intact ore
- Joined the ARC Training Centre in Critical Resources



TAKE HOME MESSAGES

- ISR is currently the only alternative to conventional mining - but the low hydraulic conductivity of non-U ore bodies is a tough challenge
- At the laboratory-scale EK-ISR has shown to work for low-k intact rocks, tailings and clays, but validation at the field-scale is still required
- MRIWA's early-stage support was crucial to get this research off the ground

ACKNOWLEDGEMENTS

- MRIWA
- BHP, Newmont, Newcrest, Evolution Mining
- TAD ISR JV: BHP, IGO, Rio Tinto
- Prof. Andy Fourie (UWA)
- Postgraduate Students and Postdocs:

  Evelien Martens (UWA)
  Pablo Ortega-Tong (UWA)
  Riccardo Sprocati (DTU) → Co-founder Ekion
  Bishenka Mahaulpatha (UWA)
  James Jamieson (UWA) → Co-founder Ekion

- Many colleagues at CSIRO Environment and Minerals