

Electrokinetic dewatering, consolidation and strengthening of fine tailings: a large tank test using ePVD electrodes to inform a field trial

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Abstract

Tailings storage facilities (TSFs) for fine-grained mine waste often take decades to self-consolidate and gain enough strength after closure to allow safe rehabilitation and spread of growth media. Often, large volumes of imported granular fill to construct access roads are required. While electrokinetic dewatering offers a means to accelerate dewatering and strength gain, this was historically cost prohibitive due to use of metal electrodes. Development of low-cost polymer electrodes has made electrokinetic dewatering a potential economic option. Central Alliance was engaged by a tier 1 mining company to develop a techno-economic model for electrokinetic treatment, including the design and implementation of a full-scale trial. The results of the second stage of development are presented here.

A large outdoor tank test was undertaken on iron ore tailings to validate bench-scale test findings under realistic climatic conditions and at a 1:1 scale in plan, with the results and practical experience feeding into the design of a full-scale in situ electrokinetic treatment trial. The set-up comprised a 3 m diameter tank filled to 0.9 m depth with fine iron ore tailings. Six polymer electrokinetic geosynthetic (EKG) anodes were arranged in a hexagon around a central polymer EKG cathode drainage conduit. During an initial 7-day settling period, the water content (wet basis) reduced from 44.0% to 41.2%. On application of direct current at 50 V, drainage at the cathode peaked, then dropped to zero after 37 days of near-continuous treatment, when a water content of 25.5% was determined. Electrokinetic treatment continued until day 60, with no further drainage at the cathode. Water content continued to fall, reaching 17.6% at completion. Over the treatment period, the average hand vane shear strength increased from 2.7 kPa at the start to 37 kPa at day 48, after which the material became too stiff to test. Average tailings thickness reduced from 889 mm to 671 mm over the test period. Total energy consumption was 39.1 kWh, equivalent to 6.2 kWh/m³.

A key observation was the development of large desiccation cracks that disrupted electric field pathways and reduced the electrode–soil contact, decreasing electroosmotic efficiency. However, the surface area available for evaporation was increased significantly, likely contributing to increased moisture loss.

The test demonstrated substantial moisture loss and strength gains, providing essential data and practical experience for the next steps of design and implementation of a full-scale field trial over a proposed treatment area of 30 × 30 m and depth of 5–10 m. The polymer EKG electrodes were shown to perform as required, with no signs of degradation, offering a low-cost alternative to metal electrodes, opening the possibility of economic widespread implementation of electrokinetic treatment and accelerating TSF closure programs.

Keywords: electroosmosis, EKG, electrokinetic, dewatering, mine tailings

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1 Introduction

Metallurgical processing of the great majority of metallic ores uses water as both the processing and transportation medium. The process typically involves crushing and milling the ore rock to produce smaller particles which can then be separated and concentrated using a variety of water-based methods, yielding metallic concentrate and tailings. Tailings is usually characterised into coarse fractions and fine material (paste and thickened tailings). Fine-grained tailings is traditionally managed within a tailings storage facility (TSF), whereby the waste material is maintained in a liquid, pumpable condition and deposited for long-term disposal. The ease of management of fine-grained tailings in this manner is strongly influenced by the low strength and low permeability of deposited fine-grained tailings: the consistency of the tailings needs to be such that the tailings can be pumped, which also means that the deposited material will be of low strength and may require several years of self-weight consolidation to increase in strength. The speed of consolidation and strengthening can be increased by removing water, for example by using a conventional well-point approach. However, the low hydraulic permeability of the tailings places significant economic and practical limits when applied to fine-grained tailings.

In terms of mine closure, one important aspect is to improve the strength of the material at and near the surface to a sufficient depth to facilitate access by earthmoving equipment that is required for closure operations such as the development of haul roads across the surface of the TSF from which to deposit and spread growth media as part of the remediation works. However, the material's low permeability means that there are few (if any) methods to reduce the time required to achieve acceptable surface stability of TSFs that are both practicable and economically feasible.

This paper describes the set-up and results of a test using electroosmosis on iron ore tailings implemented with electrokinetic geosynthetic (EKG) materials to improve the strength of fine-grained tailings, with the results to contribute to an evaluation of the use of the technique as part of closure works.

Note: unless otherwise stated, where water content is referred to in this paper, water content on a wet basis by mass determination is reported.

2 Electroosmotic dewatering

2.1 Controls

Water normally flows in response to a difference in pressure and the rate of water flow is determined by the hydraulic permeability of the material and the pressure gradient – a relationship described by Darcy's Law. Fine-grained materials can present an effective barrier to, or severe limitation on, pressure-driven flow because the very low permeabilities mean that it is impractical or impossible to apply or achieve pressure gradients that can result in meaningful flow rates. The practical consequence of this is that it is usually very difficult, and/or slow, to move water in, out, or through materials such as silts, clays and fine tailings.

Electroosmosis is the phenomenon of water flow through a particulate solid framework in response to the application of a voltage. It was first observed by Reuss (1809) and first used in 1939 for practical engineering purposes by Casagrande (1949) for dewatering and improving the strength of fine-grained soils. Electroosmotic (EO) flow is directly analogous to conventional hydraulic or Darcian except that flow rate is determined by the coefficient of electroosmotic permeability and the voltage gradient. Unlike Darcian flow, EO flow is – to a significant extent – independent of grain size and is potentially a very useful phenomenon to create water flow in fine-grained materials. However, EO flow is usually coupled with other fluxes which develop in response to thermal, chemical and pressure gradients, related respectively to electrical resistive heating, electrochemical reactions at the soil–electrode interfaces and geomechanical responses conditional upon boundary condition control. These coupled fluxes introduce significant additional complexity, the sources of which are dominated by the electrode–soil interfaces, i.e. the electrodes and the control of the boundary conditions.

To be effective, efficient and economical, the set-up (including the electrodes) need to meet several demands which may be grouped into composition, form and operation:

- **Composition**
 - Minimise electrical resistance between the electrode surface and the substrate.
 - Achieve electrochemical stability to minimise or manage oxidative corrosion and maintain tolerance of high/low pH environments.
 - Maintain good mechanical contact between electrode surface and the substrate (soil/slurry/tailings, etc.).
- **Form**
 - Aim to achieve form and characteristics that permit efficient installation.
 - Adopt a surface area that controls operational current densities to minimise or manage localised resistive heating of the substrate and manage electrochemical stress on the electrode.
 - Ensure the internal structure enables and manages effective fluid fluxes, including water accumulating at the cathode boundary and electrolytically produced gases, the accumulation of which would impair electro-mechanical contact.
- **Operation**
 - For applications that benefit from polarity reversal, ensure the electrodes can operate as both anodes and cathodes.
 - Ensure the treatment methodology is safe to install and run.
 - Ensure the environmental impact is acceptable.
 - Achieve low cost.

2.2 Electrokinetic geosynthetic electrodes

Electrokinetic geosynthetic (EKG) electrodes were invented and developed at the University of Newcastle (Jones et al. 1996) and pioneered commercially by Electrokinetic Ltd (Jones et al. 2011; Lamont-Black et al. 2012; Jones et al. 2017). Commercially available EKG electrodes achieve electrical conductivity using carbon-doped polymer (Pugh 2002), which reduces the corrosion rates compared to common metals (steel, copper, aluminium) without invoking the high cost of corrosion-resistant materials such as platinum group metals. Conductive polymer can be extruded into a variety of shapes and forms, thus permitting the EKG polymer to adopt conventional functions of geosynthetics such as drainage, filtration and reinforcement.

By applying electroosmosis via EKG electrodes, geosynthetic materials become active agents in the ground, principally creating directed matrix flow in fine-grained materials and managing electrode boundary conditions to minimise electrical resistance and manage water flow. The EKG electrodes in this study took the form of conventional prefabricated vertical drains (PVDs) and are termed electrokinetic prefabricated vertical drains (ePVDs). They comprised high-density polyethylene (HDPE) doped with carbon formed into a flexible strip 100 mm wide, with axial fins which, when installed perpendicular to the ground surface, form vertical channels to encourage the transmission of water and gases (Figure 1).

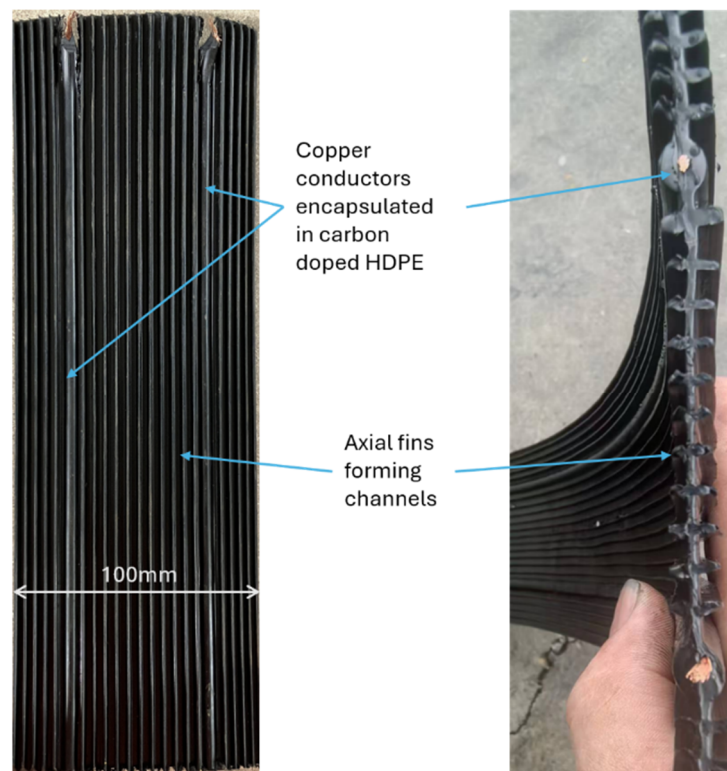


Figure 1 ePVD sample strip showing channels for vertical water and gas transmission

2.3 Electroosmotic dewatering design

There are no published industry guidelines for applying electroosmotic dewatering in the manner for example of consolidation by pre-loading. The discussion below outlines the selection of design parameters used in the trial.

The fixed or given material characteristics in guiding and developing a dewatering design are electroosmotic permeability (k_e), hydraulic conductivity (k_h), water content (w), electrical conductivity (σ), volume compressibility (m_v), maximum master voltage (V_{max}) that can be safely applied on a site and maximum permissible current density that avoids excessive desiccation of the anode-proximal material and/or damage to EKG electrodes (J_{max}). The independent variables or design parameters are chiefly electrode pattern, electrode spacing and voltage control during treatment. The dependent variables are chiefly the resulting flows of electroosmosis, electrical current and treatment duration to achieve target results of consolidation, water content and material strength. Optimal integration of the variables helps minimise the treatment cost. In addition to the process-based fixed parameters and independent variables, factors such as cost, treatment duration and socio-environmental impact must be considered in comparison with alternative methods.

Numerous authors have approached characterising quantitative ranges of acceptability for these parameters and variables, but consensus has not been reached and each application needs must be evaluated on its merits. The multiple gradients set up by electroosmotic dewatering (voltage, pressure, thermal, chemical) can lead to great complexity in flows and subsequent material responses to the extent that prediction and modelling must always be a simplification and often over-simplification, leading some authors [e.g. Zhang (2015)] to note that at the present level of understanding, design by the empirical method is the most reliable approach.

In developing a treatment design at full scale, there is a trade-off between the dependent and independent variables. In the great majority of cases, cost is most sensitive to electrode spacing owing to EKG material and installation metreage, cabling and dewatering costs, all of which increase approximately to an inverse square of the electrode spacing. Thus, with a relatively narrow range of minimum electrode spacing and a

fixed upper maximum applicable voltage (e.g. 50–80 V), the maximum voltage gradient is similarly confined to a small range. Electrical current and EO flow develop in response to the voltage gradient.

The electrical current developed under the applied voltage gradient is defined by the electrical conductivity of the tailings, which can vary by an order of magnitude, depending on the mining operation. The salinity of the process water used in mining operates is therefore one of the most important limiting factors in the applicability of electroosmotic dewatering. The current density at the electrode surface is a limiting factor from the perspectives of both the operation of the electrode and the effect on the adjacent material. The anode is the most critically affected because of the oxidative electrochemical reactions which affect the electrode (this includes EKG electrodes though to a lesser extent than metal electrodes), and desiccation of the anode–proximal soil/tailings because water moves away from the anodes under EO flow.

The EO flow that develops in response to this applied voltage gradient is defined by the coefficient of electroosmotic permeability and defines the EO flow rate. The persistence of EO flow is partly controlled by the material compressibility such that in stiff materials, porewater suction develops in response to EO dewatering and effectively grows to counter EO flow, which effectively ceases.

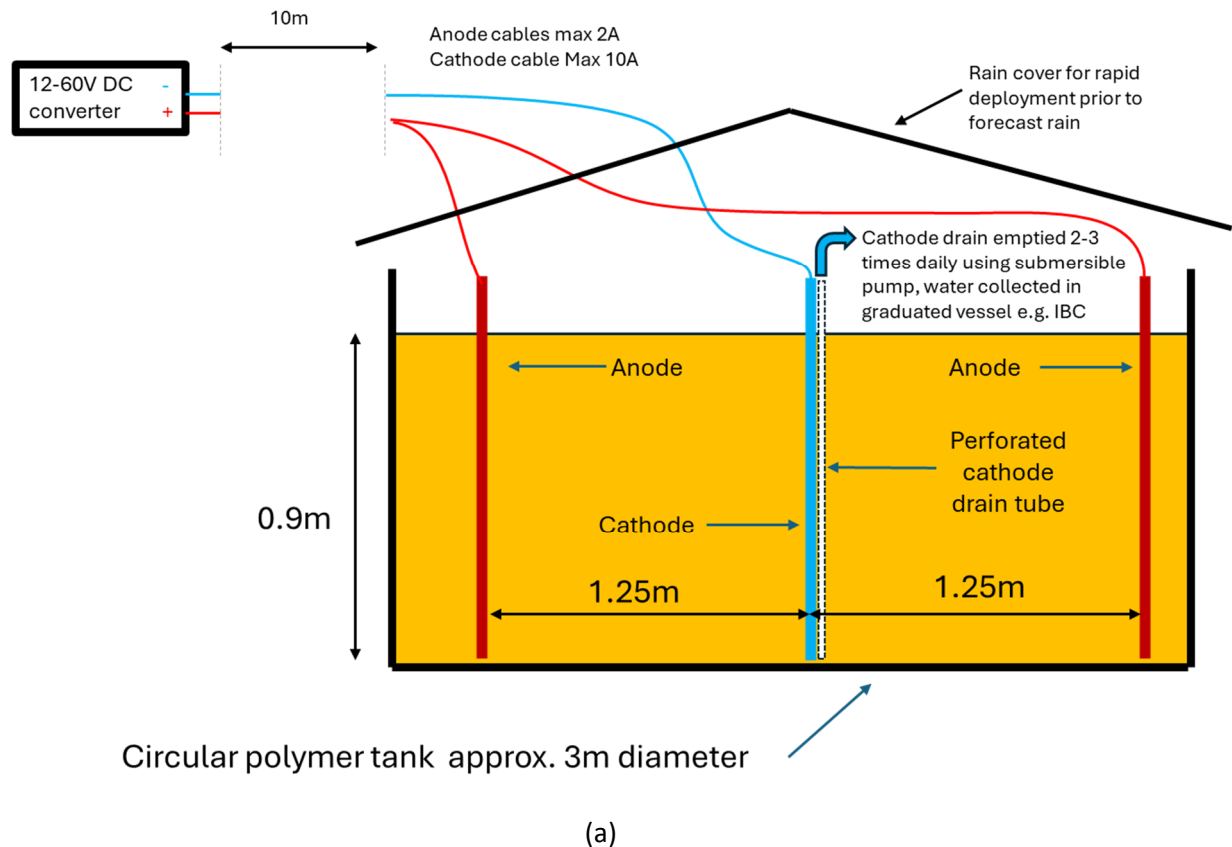
In summary, $V_{\max}$ is defined by safety and $J_{\max}$ is defined by ground resistivity/conductivity and electrode characteristics. The electrode array pattern used (e.g. square, hexagonal, triangular, rectangular.) should attempt to optimise the maximum distribution of a maximal electric field with electrode spacing and thus cost. In the case developed here, a hexagonal array was adopted because deployment in the ground would mean a series of tessellating cathode-centred hexagonal treatment cells with the effect that each cathode is served by 6 anodes and each anode serves 3 cathodes, thus the anode: cathode ratio would be 2: 1 and the anode current density would therefore be half that of the cathode.

3 Test set-up

3.1 Pre-activation

The test tank set-up comprised 4 distinct stages: preparing the tank, filling the tank, setting up and filling the control tank, and setting up the process equipment, including support framework, electrical supply, dewatering equipment and rain cover.

The tank comprised a 3 m diameter × 1.25 m deep polypropylene tank (Figure 2). Six ePVD anodes were arranged in a hexagonal pattern with a spacing of 1.25 m around a central cathode ePVD to create a radial electric field (Figure 2). A perforated tube, covered with a geotextile filter, was placed immediately adjacent to the central cathode to act as a locus for the drainage of electroosmotically transported water. The electrodes were installed and fixed to the floor of the tank prior to filling with iron ore tailings and connected to a 12–60 V direct current (DC) supply located under cover.



(b)



(c)



(d)

Figure 2 Set-up of the tank; (a) Schematic section through filled tank; (b) Tank with cover; (c) Filling operation; (d) Filled tank after 1-week rest period

The tailings fill was left to settle for 1 week, then excess topwater was removed and the tailings bed sampled for material testing prior to the commencement of active treatment. Initial testing to characterise the tailings starting condition comprised water content, Atterberg limits, particle size distribution, particle density and electrical conductivity.

A control tank was included as part of the testing scope to assess the effects of settlement and surface evaporation. Initially, the intention was to use a single 1 m³ intermediate bulk container with the top cut off to provide a similar depth of material as the main tank. In practice, the tailings material sampled from the thickener underflow and received at the test site had a higher than anticipated water content, with the result that settlement of the tailings was more than expected. This meant that to achieve a minimum acceptable bed depth for the start of the test, the tailings set aside for the control was also used in the main tank.

The overall result was that the control test comprised a single barrel of approximately 200 L, i.e. approximately $1/32^{\text{nd}}$ of the volume of the main tank, which therefore did not offer a reliable comparison.

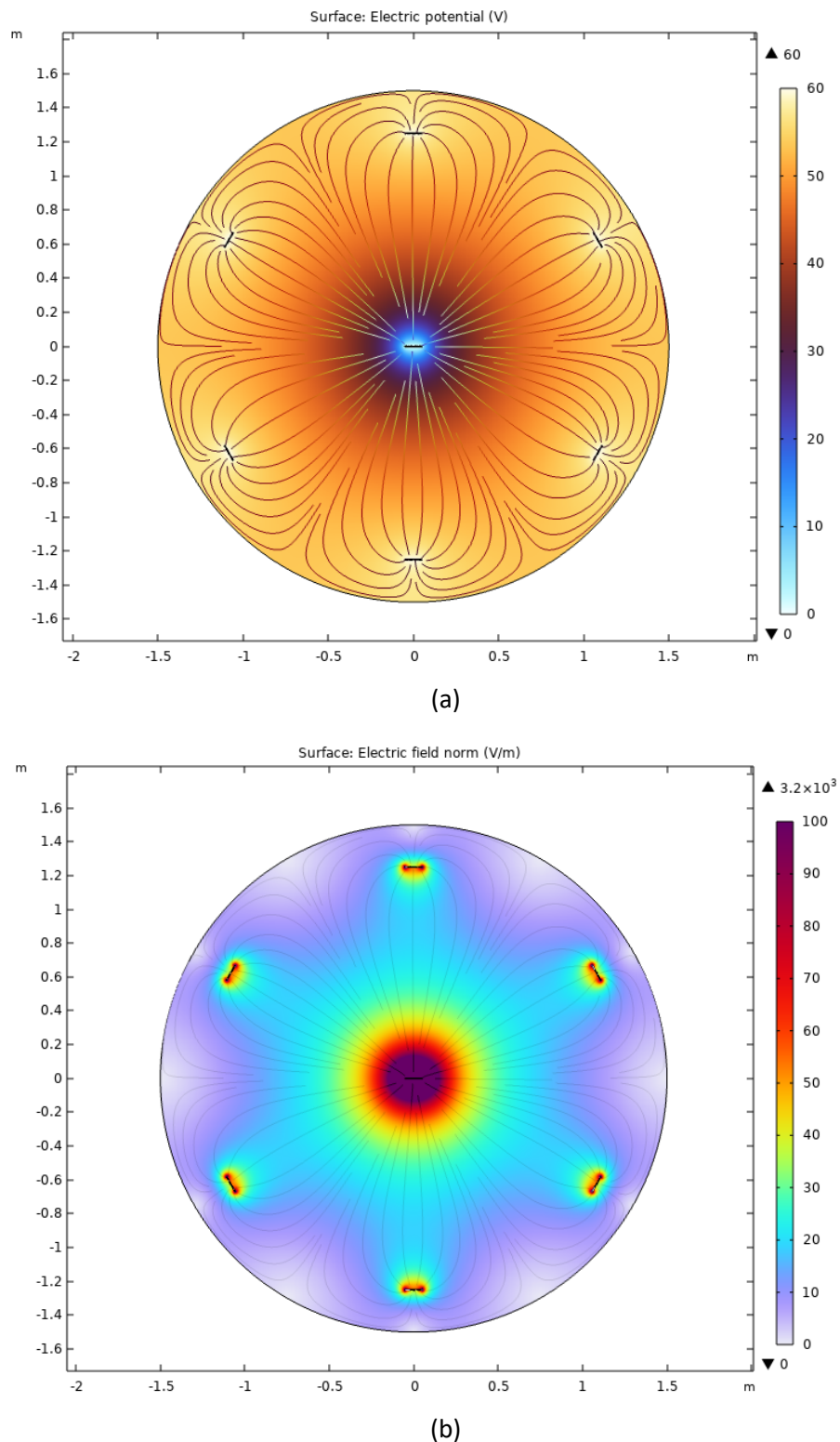


Figure 3 2D finite element model; (a) Electric potential; (b) Electric field strength

3.2 Activation

During the initial rest period, water was pumped daily from the central drainage tube using a 12 V submersible pump. Activation of electrokinetic treatment was commenced when this flow was judged to

have diminished significantly. The test was attended to every day during the test, to monitor voltage, currents, water flow, surface level, tailings condition and crack development, and undertake in situ testing (hand shear vane) and sampling of materials.

A voltage of 50 V was applied on a continuous basis. Voltage, current and cathode pump discharge measurements were taken 3 times per day. Towards the end of the test, short periods of system rest (zero applied voltage) and polarity reversal were instigated to revive both the dwindling system current and water abstraction. The system was run for a total of 60 days (Table 1): 41 days of normal polarity, 8 days of reverse polarity and 11 days of system rest (current off).

Table 1 Summary of treatment activation control

Treatment day count			Polarity	Applied voltage (V)
Start	Stop	Duration (days)		
0	19	19	Normal	50
19	22	3	Reverse	-50
22	25	3	Off	0
25	36	11	Normal	50
36	39	3	Off	0
39	42	3	Normal	50
42	45	3	Off	0
45	50	5	Reverse	-50
50	52	2	Off	0
52	60	8	Normal	60
Total		60		

3.3 Monitoring

Monitoring was periodic, comprising a combination of measurement of applied voltage, electrode currents, water discharge volume, surface levels, crack development, shear strength and material index properties (water content, Atterberg limits, particle size distribution and density). The data collected comprised process and material data.

3.3.1 Process data

The process data comprised the following:

- Current (amps) and voltage (volts), 3 times daily (07:00 h, 12:00 h, 16:00 h). Data were read directly from the DC power supply.
- Water discharge (L): 3 times daily (07:00 h, 12:00 h, 16:00 h). Data were collected by pumping the water from the central cathode and collecting it in a measuring cylinder.
- Surface level: once daily (average of 6 measurement stations on the surface).
- Water discharge pH: approximately once every 2 weeks.
- Crack measurements: measurement of width and depth approximately twice per week (starting on day 14), together with vertical photographs to map crack length.

4 Results

4.1 Summary

For the purpose of analysing the test data, 4 key stages are recognised: the as-received condition of the tailings fill, the end of the initial rest period (taken as time, $t = 0$ in the test timeline, at the point of electrokinetic treatment activation), the end of drainage and the end of the electrokinetic treatment stage. Table 2 summarises the results of the key performance indicators and Figure 4 illustrates the changing visual condition of the tailings over the test period. Figure 4 includes the cessation of cathode drainage during electrokinetic treatment as an additional stage.

Table 2 Key results of the dewatering process

Measurement index	Initial	End of rest period	End of electrokinetic drainage (day 36)	End of electrokinetic stage (day 61)	End of gravity stage $\Delta\%$	End of electrokinetic drainage stage $\Delta\%$	Total change $\Delta\%$
Water content (% dry basis)	78.65	58.84	35.54	21.35	19.81	43.11	57.3
Water content (% wet basis)	44.02	37.04	26.22	17.59	6.98	17.8	26.43
Total volume (m^3)	6.78	6.28	5.01	4.74	7.37	26.11	30.09
Total crack volume (m^3)	6.78	6.28	4.89	4.56	7.37	27.88	32.74
Cathode drainage (m^3)	0	0.303	0.489	0.489	–	–	–
Energy consumption (MJ)	–	–	135.58	141.22	–	–	–
Unit energy consumption (MJ/m^3)	–	–	20.00	21.1	–	–	–
Surface area (including cracks): volume ratio	1.04	–	–	3.98	–	–	–



Figure 4 Changing visual condition of the tailings throughout the test period (numbers shown are anode identifiers); (a) After initial filling; (b) End of initial rest period; (c) Cessation of electrokinetic cathode drainage; (d) End of test

4.2 In-process water content and volume and pH

The volume of the tailings and the water content is shown in Figure 5 and includes the laboratory-determined water content, together with the volume determined from surface level change. Crack volume was estimated by using the crack width and depth (measured for the major and intermediate cracks) and determining an average crack opening angle, which was applied to all major and intermediate cracks as mapped in vertical photographs. Minor cracks (defined as having a surface width of less than approximately 10 mm) were not included and thus the crack volume estimate likely represents an underestimate of the actual crack volume. The data indicate that over the duration of the test, the water content (wet basis), determined by laboratory measurement on recovered samples, reduced from 44.0% to 17.3%, which was accompanied by a 32.6% reduction in total volume (with crack volume accounting for 2.5% of the total volume loss). The pH of cathode

discharge water was measured every 12–14 days. During activation the pH showed very little variation across the period of the active dewatering, ranging from 11.8 to 12.1.

A time-series of cathode drainage discharge volume together with normalised volume change is shown in Figure 6. This indicates that after day 36 of the electrokinetic treatment, cathode drainage discharge had reduced to zero. However, volume change continued to accumulate, suggesting that evaporation may have had a significant influence on volume loss. Moreover, volume change continues to accumulate after day 36. There is also some indication that after day 36 when the voltage was turned off (days 36–39 and days 50–51), that volume change stopped, suggesting that even though no water accumulated in the cathode drain, EO flow may have stimulated flow towards crack surfaces thus assisting evaporation and volume loss. Thus, the mechanism of EO dewatering in the near-surface environment may be even more complex than initially anticipated.

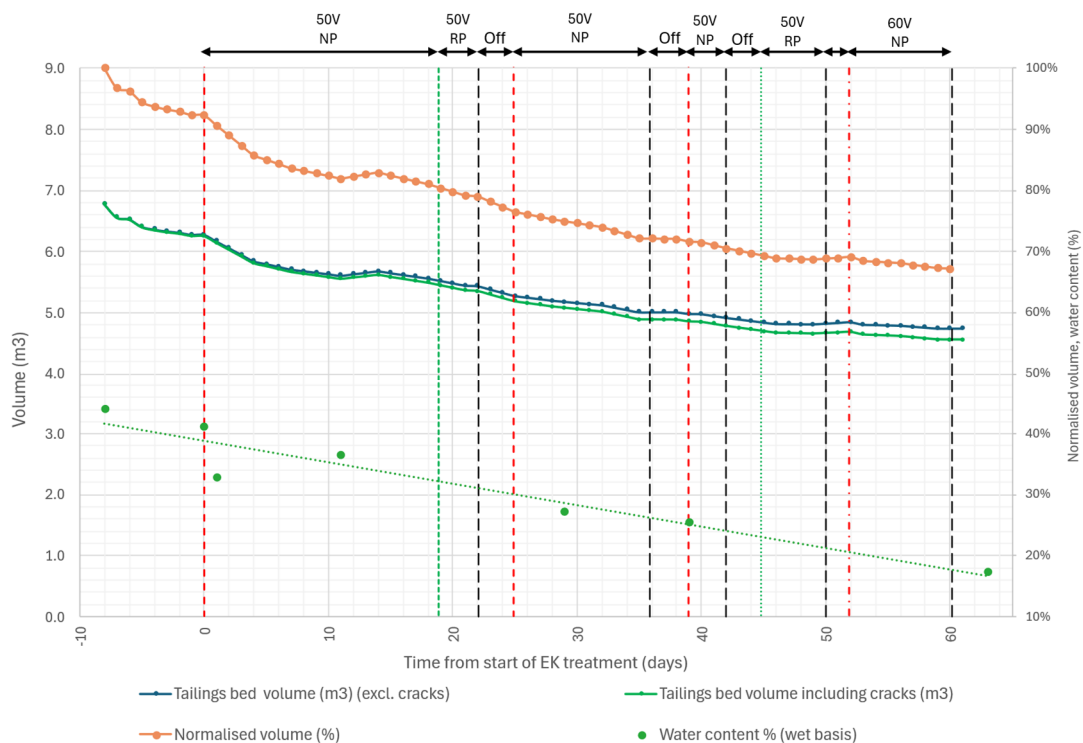


Figure 5 Time-series of water content and tailings volume (excluding and including crack volume, and as a percentage of original volume including crack volume). Date of electrokinetic treatment activation taken as $t = 0$ days

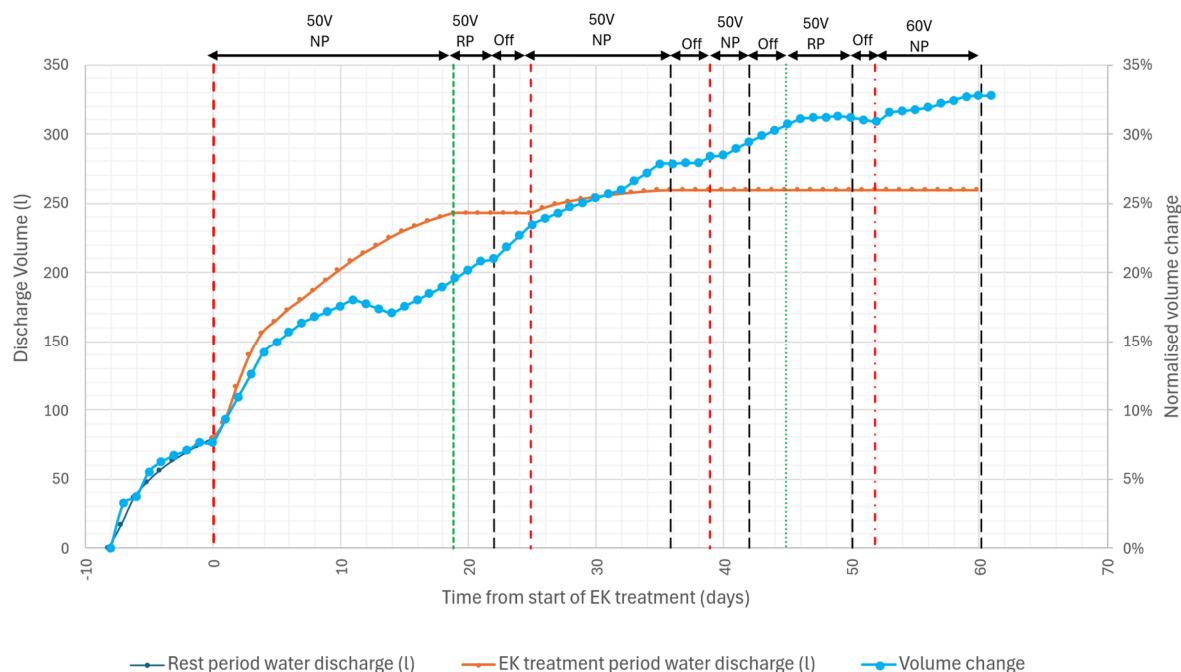


Figure 6 Time-series of cathode drainage discharge and total volume change (including cracks). Date of electrokinetic treatment activation taken as t= 0 days

4.3 In-process electrical energy

Figure 7 shows a time-series of the daily electrical consumption and cathode drainage volumes. The data indicate that the 2 main periods of normal polarity (NP) from electrokinetic treatment day 0 to day 19 and day 22 to day 36 account for the bulk of the EO dewatering. The purpose of the reverse polarity stages was to attempt to rejuvenate the anode surfaces which gradually become desiccated and/or detached from contact with the tailings, owing to progressive dewatering. It therefore anticipated that drainage from the central cathode reduced dramatically during the periods of reverse polarity. During the first and second periods of NP, both the electrical energy and the cathode drainage rates decreased but the drainage reduced more rapidly, as reflected in the changing EO flow efficiency over time. Tracking an index such as EO efficiency could provide a guide to prescriptive application of periods of reverse polarity in field applications.

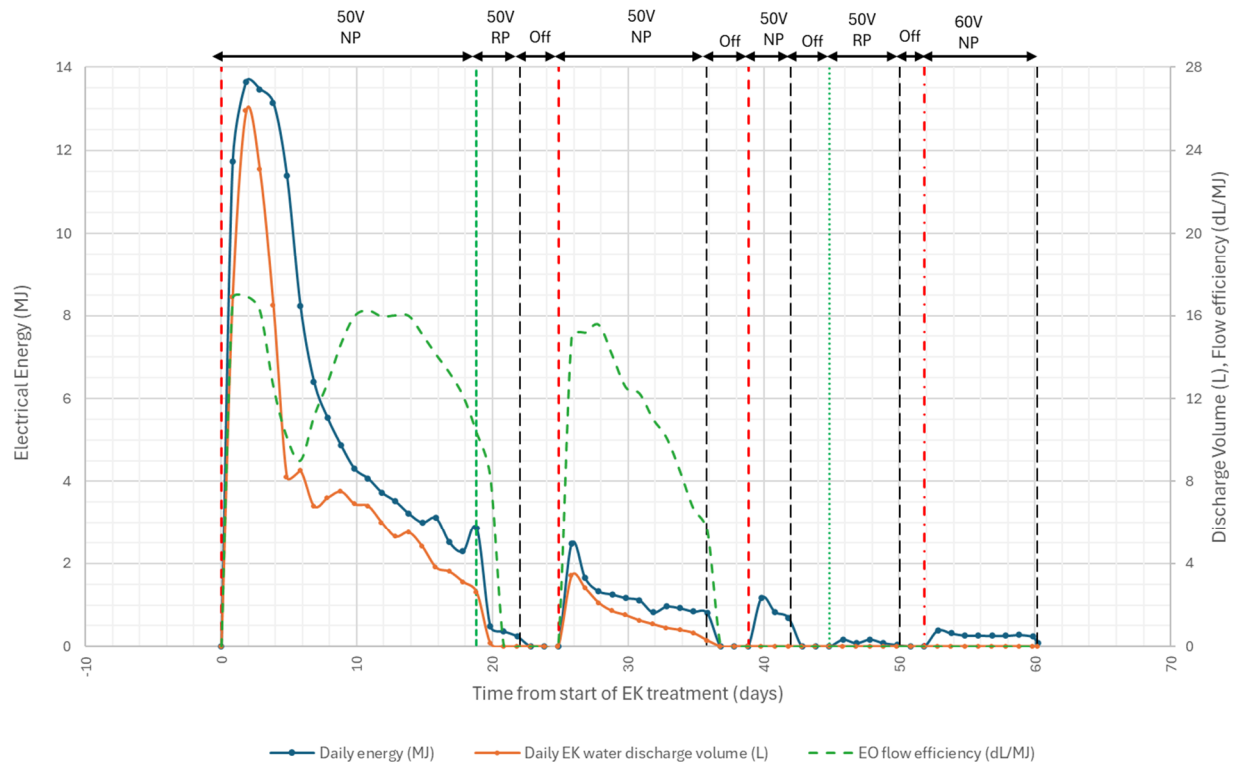


Figure 7 Time-series of daily electrical energy consumption, daily cathode drainage and 3-day average electroosmotic efficiency

4.4 In-process mechanical strength

The plan for treatment had been to characterise the undrained shear strength of the tailings by undertaking a series of tests using a hand shear vane fitted with extension rods to test at a variety of depths below the surface. Depths of 100, 350, 600 and 850 mm were selected. The measurements shown in Figure 8 indicate trends of increasing shear strength with treatment time and decreasing shear strength with depth below surface. There are no data beyond day 38 because it was no longer possible to insert the vane due to the stiffness of the material, and the undrained shear strength at the end of treatment would therefore likely be significantly higher. The mean shear strength across the depth of the tank was 37 kPa on day 38, but this is affected by the final strength value of 20 kPa for the 100 mm depth, which appeared anomalously low, especially compared to a value of 104 Pa measured the previous day, i.e. a potential outlier.

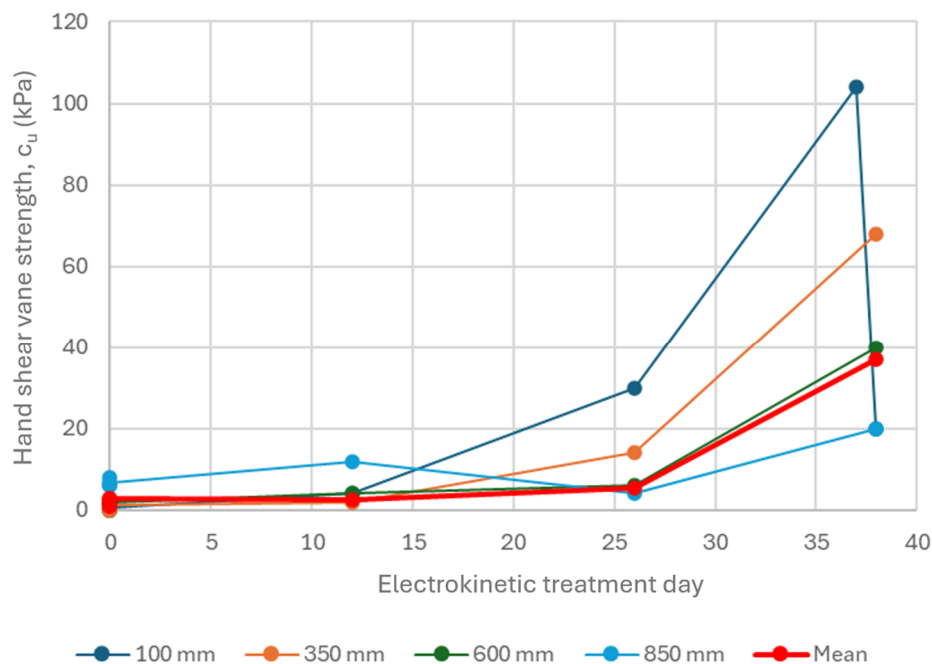


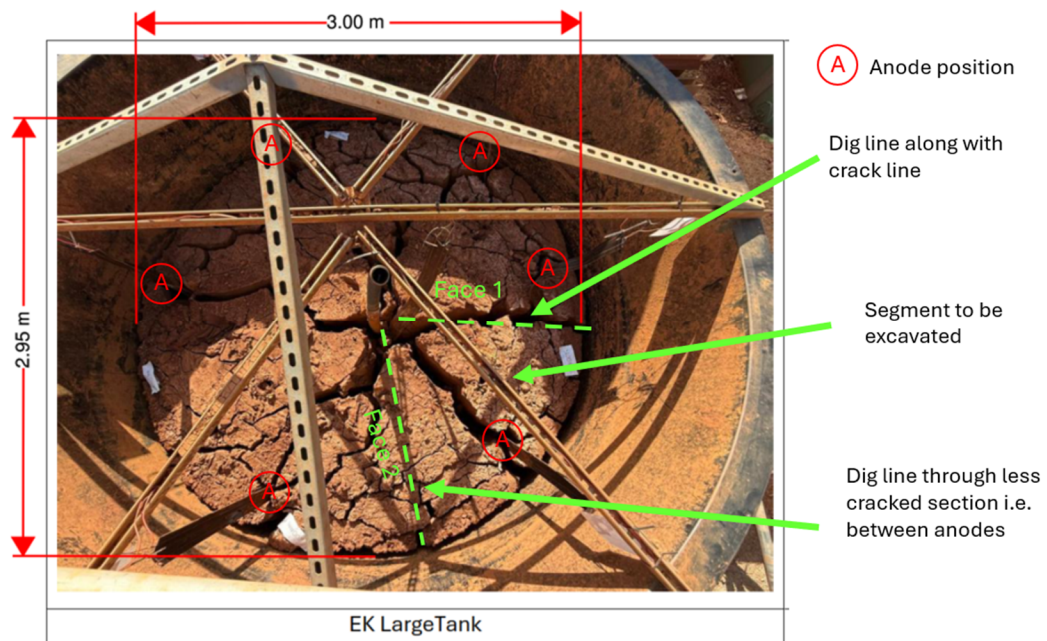
Figure 8 Time-series of undrained shear strength at different depths below the surface

4.4.1 Decommissioning monitoring

At the end of the test, the large tank test was deconstructed in order to characterise the material changes that had developed from the surface downwards and from the peripheral anodes towards the central cathode. During the progression of the treatment, major desiccation cracks developed in the tailings, adopting a roughly radial pattern that spread out from the central electrode towards the periphery, forming almost equal segments (Figure 4). The decommissioning plan was developed to sample the solidified tailings from 2 vertical surfaces. The first surface was the surface defined by the wall of one of the radial cracks that formed the segment edge, and the second was a vertical surface formed by excavating down through the centreline of one of the 'segments' [Face 1 and Face 2, respectively, in Figure 9(a)].

Bulk and lump samples were recovered for index testing. The material proved too stiff to permit any testing by hand shear vane. Coring was also attempted to recover linear transect samples behind an excavation face, but this also proved unsuccessful.

Figure 10 shows the distribution of water content determinations on Faces 1 and 2 from the decommissioning excavation. The values ranged from 7.9% to 24.4% (wet basis) and included trends of drier material towards the surface and the anodes. The mean of all the data was 17.6%.



(a)



(b)



(c)



(d)



(e)

Figure 9 Decommissioning excavation; (a) Excavation plan; (b) – (e) Excavation and sampling

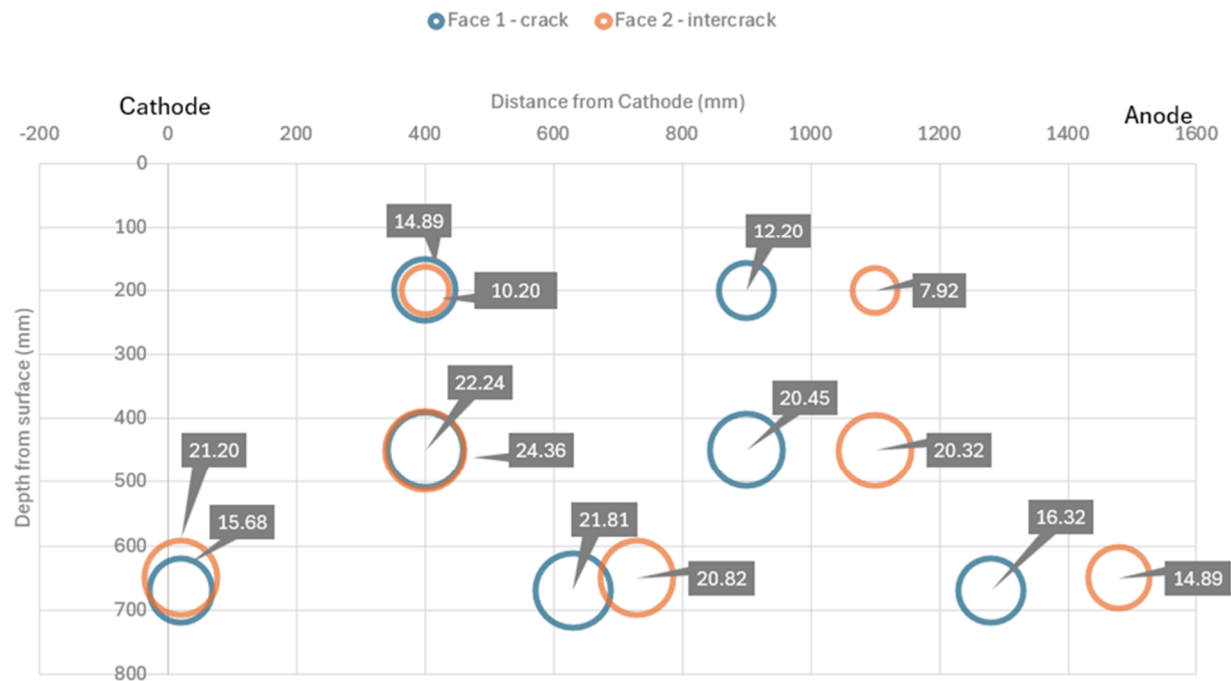


Figure 10 End of treatment tailings water content (wet basis)

4.4.2 Condition of electrokinetic geosynthetic material

After sampling the tailings, the EKG material was recovered and cleaned lightly. The material remained in good condition. The very few indications of damage are related to slight deformations caused during excavation. The polymer was generally shiny, preserving the slick extrusion texture of the surface from the manufacturing process, which indicates minimal electrochemical damage or sintering of the conducting graphite filler.

5 Discussion

The trial was designed to simulate EO dewatering of a single cathode-centred hexagonal treatment cell replicating all the elements of a full-scale treatment cell except for depth.

The spacing of 1.25 m was selected to provide a suitable voltage gradient of approximately 50 V/m, when considering the following:

- an upper safe master voltage limit (80 V)
- geometry options of installation rigs (minimum of 1.25 m for small, tracked-rigs)
- maintaining EKG electrode surface current densities below an upper limit of 5 A/m² (particularly anode)
- the anticipated tailings conductivity.

The trial indicated that dewatering continued throughout the treatment period, with the tailings water content (wet basis) starting at 44%, reducing to approximately 26% by day 36 (end of cathodic drainage) and continuing to 18% by the end of treatment on day 60. The reduction of water content and volume in the final two-fifths of the treatment period is attributed to the action of evaporation alone and is not attributable to electroosmotic-induced flow to the cathode drain. However, it is possible that after day 36 when cathodic drainage ceased, water flow to major crack surfaces could have been enhanced by electroosmotic flow.

Very deep cracks developed during the treatment period. Mapping and measuring the cracks indicated that 2.5% of the total 32.6% volume change in the tailings bed could be attributed to crack development, and that

this is likely to be an underestimate because not all cracks were mapped in this exercise. The extent to which crack development was influenced by the application of an electric field and the development of electroosmotic flow is not known, but the effect appeared to be significant and warrants further investigation.

The total treatment period comprised 60 days and volume change continued throughout the period, but the active drainage had ceased by day 36 and energy consumption had decayed to a residual level. Extensive crack development, which included cracks at the contact between electrodes and tailings, will have resulted in large disruptions to the electric field.

5.1 Implications for tailings storage facility surface stabilisation

Geotechnical analysis for surface stability under loading from construction equipment indicated that EKG treatment to a depth of 5 m would be required, based on a conservative assessment of achievable increases in undrained shear strength and application of a suitable Factor of Safety. The trial indicated that the shear strength of the material increased from approximately 1 kPa for the soft tailings to approximately 37 kPa by the end of effective treatment at day 36. However, these results are valid only for a tailings bed depth of 900 mm as used in this trial. At greater depths it is considered likely that lateral ground pressures would contribute to maintaining better contact between the tailings and the electrode surfaces, extending the period of active electrokinetic drainage, and this is an issue for further consideration and investigation.

The consolidation produced by electroosmosis is a permanent effect and closely analogous to consolidation by pre-loading.

6 Conclusion

This field trial was performed using iron ore tailings, and a key conclusion is that electroosmotic dewatering was supported by the material substrate. This corroborates the findings of Yüksek (2022). The investigation also demonstrated that EKG electrodes selected can be used successfully to dewater iron ore tailings, thus building on previous laboratory studies (Jayasiri et al. 2025).

At the relatively shallow depth investigated, the effective dewatering of the test materials required just over 5 weeks and resulted in:

- total volume reduction of 32.7%
- reduction of water content (wet basis) of 26.4%
- unit volume energy consumption of 20.0 MJ/m³ or 5.55 kWh/m³, which is equivalent to 6.0 kWh/dry tonne for this tailings
- increase in undrained shear strength to a level which would permit staged access to and remediation of a TSF surface
- no signs of degradation of carbon-doped polymer EKG electrodes.

The investigation highlighted the possibility of a significant role of crack development and evaporation and a potential link with electroosmotic treatment.

Acknowledgement

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