Annual Report

2024/25

Advancing the future of sustainable coal

CONTENTS

CHAIRPERSON'S STATEMENT

Phillip Mulder
Chairperson

The rejoining of Exxaro as a principal member and a notable increase in member contributions, saw significant growth for Coaltech in the 2024/25 financial year.

In addition, Coaltech secured several new funding streams through partnerships with stakeholders in the coal industry.

These collaborations have not only provided financial support but also facilitated new avenues for research and development projects.

However, Coaltech continues to encounter challenges in maintaining a steady flow of funds.

As such it is actively developing strategies to diversify its funding sources and ensure long-term financial stability.

Over the past year, the coal industry has experienced significant fluctuations.

While the demand for coal has resurged in certain regions due to increased industrial activity and energy needs, this has been tempered by a global emphasis on renewable energy sources and stricter environmental regulations.

Consequently, coal producers are under pressure to innovate and adapt.

In response to these market dynamics, Coaltech established the Future Technologies Research Focus Area that is focused on developing cleaner coal technologies and exploring alternative uses for coal by-products.

This initiative aims to ensure the long-term sustainability of the coal industry while complying with environmental standards.

Furthermore, Coaltech has strengthened its collaborations with key industry stakeholders, including mining companies, research institutions, and government agencies.

These partnerships are instrumental in advancing research and development efforts, and the creation of new technologies and processes to enhance the efficiency and environmental performance of coal operations.

Despite ongoing challenges, the coal market remains a critical component of the global energy mix.

Coaltech is committed to supporting its members and the broader industry in navigating this complex landscape and capitalising on emerging opportunities.

The following technical subcommittees have been active during the year:

- Mining (underground mining, open cast mining, ventilation, asset management & geoscience disciplines) – led by Gavin Silver (Seriti Power)
- Coal Processing – led by Maynard Lombard (Thungela)

CHAIRPERSON'S STATEMENT

- Rehabilitation and Surface Environment – led by Martinus van Wyk (Thungela)
- Future Technologies – led by Festus Leteane (Seriti Power)

The following projects were completed during the year:

Mining

- Development of a guideline for bulking and settling factors for opencast mine planning and rehabilitation.
- Life sustainability of refuge bays in underground coal mines.
- UAV-GPR
- Guideline for best practice for dust sample processes
- Development of spontaneous combustion guidelines

Coal Processing

- Upgrading of coal with a Knelson concentrator
- Pilot scale testing of the SepAir on the Witbank coal
- The effectiveness of emulsion binder for the recovery of rare earth elements (REEs).
- Flammability, corrosion, and environmental friendliness of fine coal composites
- Development of a wind sifter separator

Surface Environment

- Growth potential of flax on coal tailings in South Africa
- A technology to condition plants with adapted
- Rhizospheric soil/substrate bacterial species to improve vegetation resilience and growth on rehabilitated land
- Phyto mining and hyper accumulation of metals
- Carbon capture, footprint reduction and offsetting through post closure land use
- Vegetation resilience on rehabilitated land
- Soil cover guideline in consultation with authorities
- Absorption capability of different bamboo species

This year the corporate rebranding of Coaltech and extensive enhancements to its website were completed.

The following projects will be running in the 2024/25 financial year:

Mining

- Guideline for best practice for dust sample processes
- Stress Measurements to Confirm Stress Field Components for FOG Prevention in Complex Geological Areas
- Safe Criteria Limits of Blast Induced Ground Vibration and Air Overpressure for Typical South African Residential Structures in Mining Communities
- Evaluation and development of coal dust explosibility test equipment

Processing

- Circular Transformation of Carbon Ore Residue into Building Components - Technical Performance and Lifecycle Assessment.
- Coal-based circular innovation for asphalt application
- Characterization of Coal Downstream Materials for Resource Recovery and Conservation
- Repurposing coal waste – use of coal waste in concrete and segmental block pavements
- Coal stockyard management

Surface Environment

- Novel materials for continuous EFC application
- Carbon capture & energy recovery with algae
- Biological treatment of brine wastes
- Irrigation of natrophile grass species
- Rehabilitation of dumps using industrial plant material
- Integrated cropping and livestock business case model

CHAIRPERSON'S STATEMENT

- Investigating Local Brines for Battery Metals
- Facilitating irrigation as a mine water management strategy in the Mpumalanga Coalfields
- Soil Handbook
- Diatom based pan index for AMD impacted wetlands

FUTURE TECHNOLOGIES

- The application of agrivoltaics in improving the regenerative agricultural value of rehabilitated mine soils, and spoils without topsoil
- Using ion exchange to recover rare earth elements (REEs) from coal discards
- Enhancing scope 1 and 2 emissions management in the South African coal mining industry
- Communications strategy for scope 1 and 2 emissions management in South African coal Mining industry
- Circulating Fluidised Bed Clean Coal Technology Localisation Initiative

CHIEF EXECUTIVE OFFICER'S STATEMENT

Avhurengwi Nengovhela
Chief Executive Officer

Dear Stakeholders and Partners,

The 2024/25 reporting period was a defining moment for Coaltech, marked by strategic renewal, deeper collaboration, and a focused response to the evolving challenges facing the coal industry.

Our progress reflects a deliberate shift toward building an agile, future-ready organisation that continues to support industry transformation while maintaining our commitment to environmental and social responsibility.

A key highlight of the year was the launch of our inaugural Mine Closure Seminar in April 2025. This convened a diverse community of industry leaders, researchers, and regulators to shape a unified approach to mine closure. The level of engagement reinforced the value of a shared platform for dialogue and solutions, and the seminar has laid the foundation for the development of a dedicated mine closure framework for the coal sector.

Our membership base expanded, bringing in over ten new organisations across the coal value chain. Their inclusion has not only broadened our research capabilities but has also enriched the perspectives that inform our collaborative problem-solving.

Our Coal Colloquium, brought together over 350 participants and reaffirmed Coaltech's role as a trusted convener of stakeholders across science, industry, and policy all aimed at advancing the future of sustainable coal.

Over the past year, we have also taken steps to extend our reach beyond traditional research outputs. Our technical masterclasses, now accessible via our YouTube platform, reflect our commitment to knowledge dissemination and capacity building across the industry. This aligns with our broader strategy of ensuring that innovation is both inclusive and practical in its impact.

In support of a just energy transition, we strengthened strategic partnerships with organisations such as the Mpumalanga Green Cluster Agency. These collaborations will be critical in driving integrated solutions, from emissions management to land rehabilitation, and from circular economy innovation to community resilience.

Looking ahead, our focus is clear. We will continue to advance research excellence with practical outcomes, strengthen industry engagement, grow our organizational capabilities, and support the coal industry in adapting to South Africa's evolving energy landscape. Through consistent delivery and collaborative leadership, Coaltech remains committed to enabling a more sustainable and innovative coal sector.

I extend my sincere appreciation to our Board, members, project teams, and partners for their support and shared vision. Together, we are building the future of sustainable coal research, one project and one partnership at a time.

Avhurengwi Nengovhela
Chief Executive Officer

STEERING COMMITTEES COMPOSITION

Processing

Thungela Resources Limited (CHAIR)
Glencore Coal (VICE CHAIR)
Seriti Power
Sasol Limited
Eskom Holdings SOC Limited
Exxaro Resources Ltd
Council for Scientific and Industrial Research
Mintek
CI Group
Gravitas Minerals
Minopex
Acrux Sorting Technology
Fraser Alexander (Pty) Ltd
Genet Mineral Processing
Academic Institutions

Mining

Seriti Power (CHAIR)
Exxaro Resources Ltd (VICE CHAIR)
Glencore Coal
Sasol Limited
Eskom Holdings SOC Limited
Minerals Council South Africa
Thungela Resources Limited
Latona Consulting (Pty) Ltd
Vuna Group
FlowCentric Mining Technology
Maptek (Pty) Limited
Timrite
CEM Mining
BizAfrika 925 Limited
Anker Projects
Namane Resources (Pty) Ltd
Blugrey Occupational Hygiene Consultants (Pty) Ltd
Mandela Mining Precinct
Council for Scientific and Industrial Research
AECI Limited
Razor Labs
Academic Institutions

Environment

Thungela Resources Limited (CHAIR)
Eskom Holdings SOC Limited (VICE CHAIR)
Seriti Power
Sasol Limited
Glencore Coal
Exxaro Resources Ltd
Council for Scientific and Industrial Research
Minerals Council South Africa
Agreenco Environmental Projects
Terrasim Inc.
Agricultural Research Council
GCS Water and Environment Consultants
Nafasi Water (Pty) Ltd
FlowCentric Mining Technology
DMT Group
EXM Environmental Advisory
KLE Advance
Mintek
Water Research Commission
Department of Minerals and Energy
Department of Water & Sanitation
Mandela Mining Precinct
Academic Institutions

Future Technologies

Seriti Power (CHAIR)
Eskom Holdings SOC Limited (VICE CHAIR)
Thungela Resources Limited
Minerals Council South Africa
Sasol Limited
Eskom Holdings SOC Limited
Glencore Coal
Exxaro Resources Ltd
DMT Kai Batla
GCS Water and Environment Consultants
Timrite
EXM Environmental Advisory
South African National Energy Development Institute
Promethium Carbon
Blugrey Occupational Hygiene Consultants Pty Ltd
Council for Scientific and Industrial Research
Razor Labs
Acrux Sorting Technology
Academic Institutions

LEADERSHIP TEAM

Phillip Mulder
Chairperson

Naadira Haniff
Board Member

Veli Sibiya
Vice Chairperson

Maynard Lombard
Processing Chairperson

Avhurengwi Nengovhela
Chief Executive Officer

Carmen Bergman-Ally
Project Co-ordinator

Daniel Thenga
Board Member

Gavin Silver
Mining Chairperson

Marthinus W. van Wyk
Surface Environment Chairperson

Festus Leteane
Future Technologies Chairperson

Christian Teffo
Board Member

Lerato Saolose
Board Member

Londolani Rampfumedzi
SACMA Representative

OUR MEMBERS AND PARTNERS

OUR MEMBERS AND PARTNERS

RESEARCH REPORTS

SURFACE ENVIRONMENT

COAL DISCARD DUMP REHABILITATION USING INDUSTRIAL PLANTS

Bianca Boshoff, J Berner, and M Le Roux, North-West University

Introduction

Coal mining in South Africa generates large volumes of tailings, which pose significant environmental and socio-economic challenges. These tailings are characterised by high concentrations of heavy metals, low pH, and nutrient deficiencies, which severely limit its suitability for revegetation. The lack of sustainable reclamation strategies for coal tailings has resulted in widespread land degradation, contamination of water resources, and long-term negative impacts on local communities. Despite legislative requirements for mine rehabilitation, the development of effective and economically viable solutions remains inadequate.

Phytoremediation is a promising solution for the environmental and socio-economic issues about coal mining in South Africa. It entails the utilisation of solar energy used by plants to extract toxic metals from polluted soils.

However , this method poses ots own challenges, such as the time-consuming cultivation of the plants and that the adsorbed heavy metals can spread to humans if they consume the plant

Thus, non-edible fast-growing plants with economic value show the most promise as candidates for phytoremediation.

Kenaf (*Hibiscus cannabinus*) and Flax (*Linum usitatissium)*, fast-growing, multipurpose fibre crops, demonstrate potential for cultivation on degraded and metal-polluted soils due to its tolerance to abiotic stresses and its economic value. Its fibres are widely used in industries such as construction, paper, and automotive manufacturing, offering an opportunity to combine environmental restoration with economic benefits.

However, little is known about these crops' physiological responses to coal tailings, particularly the effects of heavy metal stress on its photosynthetic and photochemical processes.

The findings serve as a contribution to the development of sustainable solutions for mitigating the environmental and socio-economic impacts of coal mining.

Methods

Experimental setup and plant treatments

The experiment was carried out in a greenhouse with a day/night air temperature of 26/18°C and a 13 hour day photoperiod and a dark period of 11 hours.

Coal tailings of different sizes were collected from two mining sites in Witbank, South Africa. Commercial flax and kenaf seeds were manually seeded in 30cm diameter pots containing one of five treatments: potting soil alone (control), Coal A, Coal B, Coal A + Soil (1:1), or Coal B + Soil (1:1).

Each treatment consisted of three replicates arranged in a complete randomised block design. The pots were manually watered every two to three days throughout the eight-week experimental period to ensure adequate soil moisture. After seedling establishment, half of the flax plants were treated with organic fertiliser, Agriboost (1:1000 dilution) once a week. Kenaf plants were not treated with any fertiliser during the experiment.

Chlorophyll a fluorescence measurement and OJIP curves analysis

In vivo analysis of the fluorescence kinetics of polyphasic chlorophyll a, indicative of reduction in Q_A in photosystem II (PSII), was performed using an M-PEA fluorimeter (Hansatech Instrument Ltd., King's Lynn). '

Weekly photochemical readings were taken with a Multi- Function Plant Efficiency Analyzer (M-PEA) fluorimeter (Hansatech Instruments, King's Lynn, Norfolk, UK) to retrieve information about the prompt chlorophyll *a* fluorescence and modulated 820nm reflection. This device uses a far-red modulated 820nm LED, which is optically filtered to measure the P_{700} absorbance. Each reading is recorded after one second of light emission. After one hour of dark adaptation, eight readings per plant were taken on different leaves of the plants. Specific physiological parameters, derived from this data by the M-PEA, were analysed to determine the vitality of flax and kenaf when cultivated in coal tailings. The M-PEA Plus V1.10 software was used to determine the different parameters. The M-PEA records data regarding prompt fluorescence and modulated 820nm reflection simultaneously. An OJIP transient results from the data from which other vital parameters are calculated.

Also, chlorophyll content was quantified using a Chlorophyll Content Meter (CCM-300, Opti-Sciences, USA), which accurately measures the

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Bianca Boshoff, J Berner, and M Le Roux, North-West University

chlorophyll fluorescence ratio between 735nm and 700-710nm. This ratio is linearly proportional to chlorophyll concentration (mg/m²).

Furthermore, to evaluate the potential of kenaf to absorb heavy metals and rare earth elements (REEs), soil and plant samples were pooled and sent to Nvirotek Labs for analysis. After each experimental repetition, the plant material was dried and stored in paper bags until all repetitions were completed. Following this, initial and final soil samples from each treatment were collected and analysed. Additionally, plant material, which included roots, stems, and leaves of kenaf, was collected and analysed separately. A standard soil and plant analysis was conducted by Nvirotek for all samples. However, the analysis for heavy metals and rare earth elements (REEs) was outsourced to a specialised laboratory. The concentration of the following elements was determined by the outsourced lab.

All the raw data were first processed in Microsoft Excel, after which it was analysed with statistical software, SigmaPlot (Grafiti LLC, v12.0). Shapiro-Wilk test was used to determine the normality of the data, followed by a One-way Repeated Measures Analysis of Variance

(ANOVA) to determine variance. Some of the data were subject to a Two-way Repeated Measures Analysis of Variance (ANOVA). In the case that the variance test showed $p<0.05$, a Holm-Sidak post-hoc test was applied to determine the specific variance in the data. The data were analysed against a confidence level of 95%, which means statistical significance was considered for p-values <0.05. Furthermore, all the graphs depicted in the results chapter were drawn in SigmaPlot.

Results & discussion

The effect of coal tailings on photosynthesis of kenaf and flax – OJIP curve

The OJIP curve is a representation of the electron transport chain, which is the first phase of photosynthesis, known as the light dependent phase. If this process is inhibited or compromised for any reason, the plant experiences stress. This could lead to limited establishment, growth, biomass, or even death of the plant

Figure 2 illustrates that fertilised flax had a higher efficiency than the non-fertilised group. Also, the OJIP curve represented by both plants was normal, according to Figure 1. This indicates that both kenaf and flax maintained healthy electron transport, indicating the Photosystems (PSII) function remained intact in all treatments.

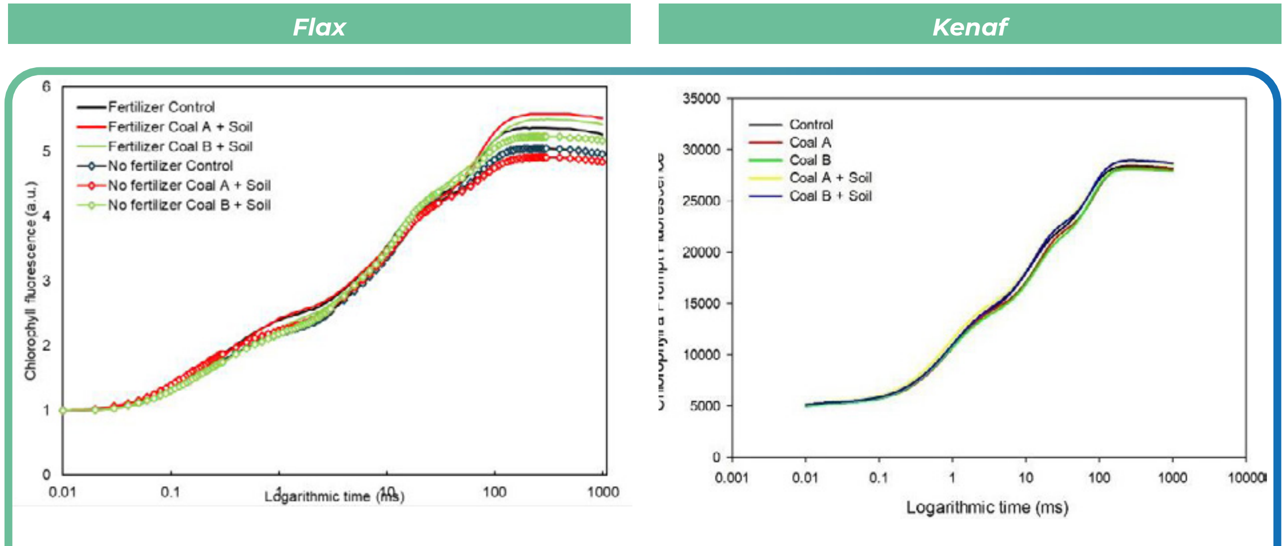

Figure 1: The normalised OJIP curve of flax and kenaf planted in soil, Coal A + Soil, and Coal B + Soil. Flax, where one group received organic fertilisers and the other group did not, and kenaf, planted in the respective soil treatments

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Flax	*Kenaf*

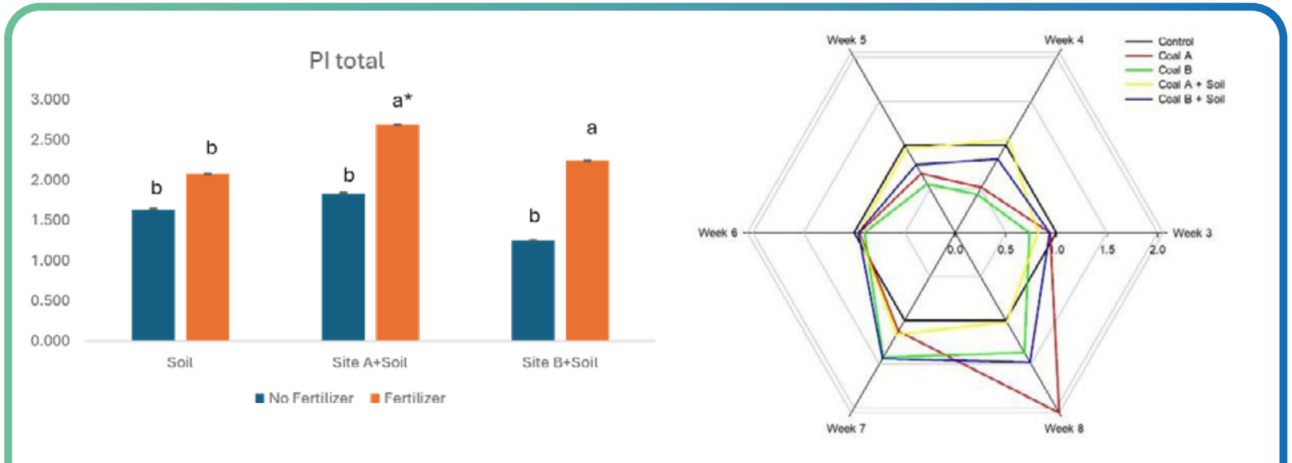

Figure 2: The Total Performance Index of flax planted in soil, Coal A + Soil, and Coal B + Soil. Flax, where one group received organic fertilisers and the other group did not. Different alphabet letters indicate significant differences within treatments. Asterisk indicates significant differences across treatments. Kenaf, where the Total Performance Index were measured and recorded weekly

The effect of coal tailings on photosynthesis of kenaf and flax – PItotal

The Total Performance Index refers to the overall photochemical health of the plant, considering Photosystems (PSI) and (PSII) health.

Flax

When looking at the total performance of flax after the eight-week period (Figure 3), there were some statistical differences. No significant differences were seen in both fertilised and non- fertilised flaz planted in soil.

However, with coal tailings and soil mixtures, fertilised flax showed better performance than nonfertilised plants. When considering the results across all treatments, the coal tailings and soil mixtures that received fertilisation performed significantly better than the nonfertilised treatments.

The performance of flax in the soil showed only a lower overall performance. Meaning that the flax planted in the three treatments not fertilised did not show significant differences. However, the coal + soil mixtures that were fertilised showed significantly higher performance in flax.

Kenaf

The radar plot in Figure 3 shows the total performance of kenaf over the eight-week period.

Although some variations over the weeks can be observed, statistical analysis showed no significant differences, indicating that the overall photochemical performance of kenaf was not affected by being planted in the coal tailings.

Absorption potential of heavy metals in kenaf

There is evidence (Figure 4) that kenaf absorbs and stores heavy metals in the different parts of the plant. Especially high levels of Cd, Pb, and As are present in the soil. Cd concentrations in the plant material were not very high, where Pb showed high concentrations in the roots. As, on the other hand, was mainly absorbed in the leaves, which had the biggest effect on the photochemistry of kenaf.

COAL DISCARD DUMP REHABILITATION USING INDUSTRIAL PLANTS

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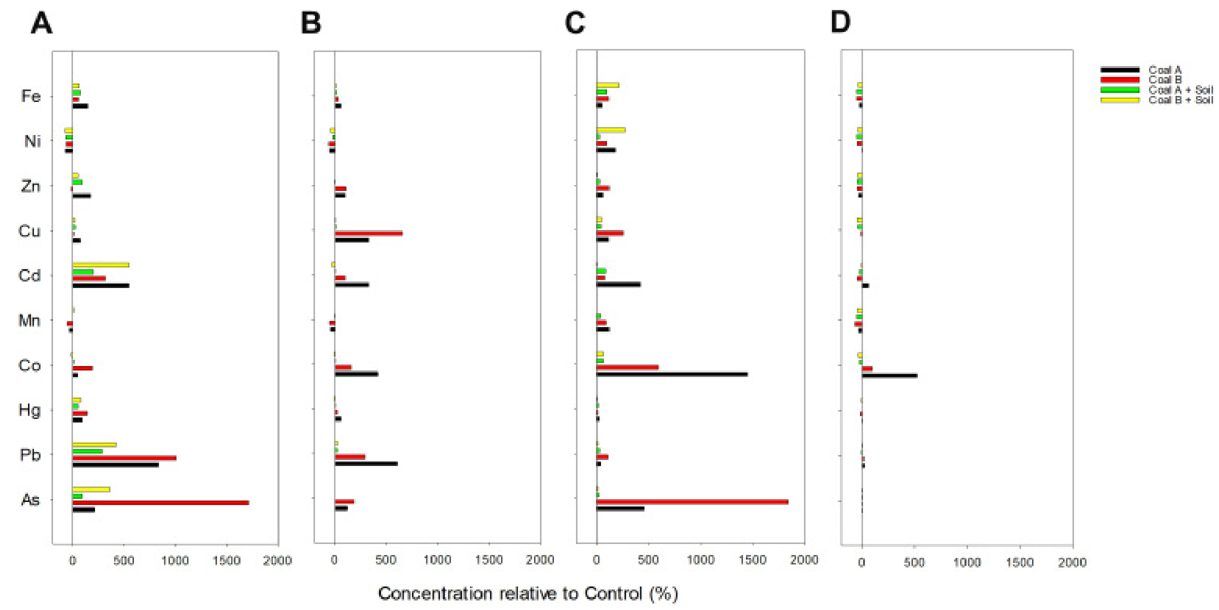

Figure 3: Bar graphs showing the normalised concentration (%) of the heavy metals in the (A) soil, (B) roots, (C) leaves, and (D) stems

Figure 4: Photos of flax grown in soil and coal tailings in the greenhouse at North-West University Potchefstroom

Conclusion

Although flax seeds could not germinate and grow in the raw coal tailing samples, they seem to be established in a mixture of coal tailings and soil. Establishment was challenging and limited, so fertilisation was applied to evaluate its effect. After establishing, the flax maintained acceptable health in the soil, coal A mixed with the soil, and coal B mixed with the soil. However, coal tailings and soil mixtures showed better health and performance relative to physiology and biomass yield. Flax planted in the typical potting soil showed no difference between the fertilised and nonfertilised groups. On the other hand, flax planted in the tailing- soil mixtures showed better performance when fertilisers were applied. Ultimately, the flax struggled to germinate and establish itself but eventually adapted and outperformed the flax in the control group.

COAL DISCARD DUMP REHABILITATION USING INDUSTRIAL PLANTS

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On the other hand, kenaf was able to germinate and grow successfully in all five treatments. It also showed the potential to absorb various heavy metals, which affected the photochemistry to an extent, but it could still adapt and grow.

Figure 5: Photos of kenaf growing in soil and coal tailings in the greenhouse at North-West University Potchefstroom

POTENTIAL ON CARBON CAPTURE, EMISSIONS AND FOOTPRINT REDUCTION OF REGENERATIVE POST-CLOSURE AGRICULTURAL LAND USE OF COAL MINES

Albert van Zyl, Terrasim Inc., Dr Stuart Christie and Dr Tony Knowles, Cirrus Group

1. Introduction

Reducing carbon footprints (C-footprint), enhancing carbon capture (C-capture), and developing carbon offset (C-offsetting) opportunities are increasingly important environmental management functions of mines. Coal mines often have significant areas of land that provide opportunities to capture atmospheric carbon (CO_2) and reduce the C-footprint of mines.

The aim of the study was to:

(i) Explore agricultural and agroforestry land management options to identify opportunities for C-capture and reduce C-footprint for agricultural mine land use.

(ii) Provide planning and management information that might be needed to develop these potential opportunities.

The C-capture, emissions and footprint of this study are for comparison purposes for agricultural and agroforestry land uses and associated management practices, and to be informative to identify strategies to optimise C-capturing potential and reduce C-emissions and footprint.

2. Study Approach and Methodology

Carbon capture opportunities include carbon sequestration by woody plant species and soil organic carbon (SOC) sequestration through improved land management. Numerical modelling was conducted to quantify the effects of agronomic, tillage and grazing practices on SOC sequestration for crops, pastures and integrated crop and pasture-based livestock systems for typical climate, soils and farming practices of the Mpumalanga Highveld coalfield.

Carbon emissions generated by various farming- and agroforestry practices were determined from fuel consumption, application rates of fertilisers, lime, herbicides and pesticides, and livestock type and stocking rates. Analysis of the balance between sequestered carbon and emissions was used to then identify potential C-offset opportunities.

Appropriate farming systems and potential future scenarios were explored during an interactive workshop that articulated improved C-capture and potential reductions in C-emissions and footprint. Planning and management information was then captured to sequester carbon and reduce C-emissions.

3. Carbon capturing potential and carbon emissions and footprint

3.1. Cropland

Conventional- and minimum till farming systems lead to a nett emission of CO_2 (Figure 1). SOC sequestration was predicted only for the no till system with 50% of crop rests retained after grazing of farmland (old lands). However, meaningful capturing of CO_2 over time is not expected due to low SOC sequestration rates. The main focus should, therefore, be to reduce emissions by reducing fuel consumption and (N) fertiliser application rates.

Conventional till system with no crop rests on the surface[1]

Minimum/no till systems that leaves crop rests for a soil mulch[1]

Note:[1] Photos provided by Asset Research

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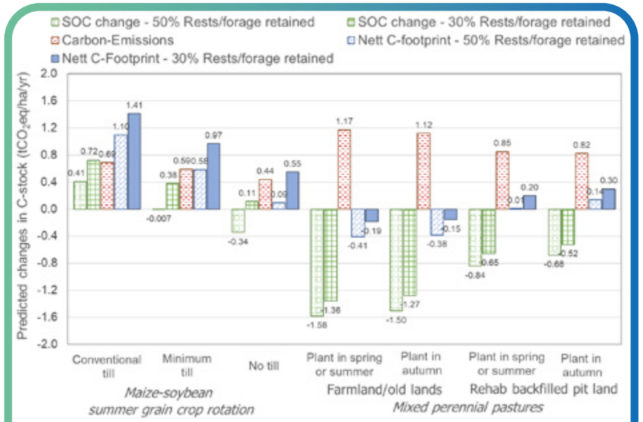

Figure 1: Carbon capture, emissions and footprint for crops and pasture[1,2]

Note: [1.] Loss in SOC stock is reported as positive values (+) since it represents CO_2 emission into the atmosphere. SOC sequestration is reported as negative values (-) as it removes CO_2.

[2.] SOC contained in the upper 30 cm of soil.

3.2. Pastures

Higher SOC sequestration rates were predicted due to the no till activities, live root mass that is maintained throughout the year, and controlled grazing to provide sufficient time between grazing for pasture to recover. This results in a sink for atmospheric CO_2 (Figure 1) for farmland where SOC sequestration rates are high enough to mitigate C-emissions. Higher C-emission rates were predicted due to the effect of enteric fermentation of livestock.

The lower biomass production that is typically observed at rehabilitated land may result in too low sequestration rates to effectively mitigate the C-emissions.

3.3. Integrated Crop and Pasture-based Livestock System

The combination of a no till, double cropping system with the inclusion of cover crops, and improved grazing practices of the Regenerative Agriculture (RA) system clearly emerged as the most important element in facilitating SOC sequestration for agricultural land use (Figure 2). This can mainly be ascribed to a considerable increase in the needed higher annual biomass production, root mass and carbon input of double cropping farming systems.

The substantial higher SOC sequestration translates to an adequate sink for CO_2 to effectively offset C-footprint sources.

Forage sorghum as summer cover crop or bioenergy crop

High density grazing of summer cover crop

Note:[1.] Photos provided by Asset Research

POTENTIAL ON CARBON CAPTURE, EMISSIONS AND FOOTPRINT REDUCTION OF REGENERATIVE POST-CLOSURE AGRICULTURAL LAND USE OF COAL MINES

Albert van Zyl, Terrasim Inc., Dr Stuart Christie and Dr Tony Knowles, Cirrus Group

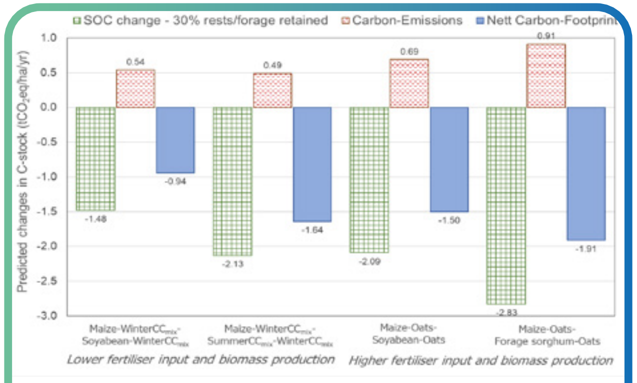

Figure 2: Carbon capture, emissions and footprint for Regenerative Agriculture[1,2]

Note: [1] Loss in SOC stock is reported as positive values (+) since it represents CO_2 emission into the atmosphere. SOC sequestration is reported as negative values (-) as it removes CO_2.

[2] SOC contained in the upper 30 cm of soil.

[3] CC: Cover crop

3.4. Irrigation

Irrigation has the potential to considerably increase biomass production, which can meaningfully increase SOC sequestration rates to effectively offset the C-footprint. It is important that only land suitable for irrigation is utilised and that irrigation scheduling is implemented. This is to ensure that the irrigation of land can produce the necessary higher biomass required to increase C-capturing to offset the higher C-emissions and footprint of energy (electricity) used for pumping and operating an irrigation system (Table 1).

		1.25 times[2]	***Increase in C-capture with higher biomass[1]***		
			1.5 times[2]	*2 times[2]*	
Irrigation		**C-emission[3,4] from irrigation** (tCO_2e/ha)	**Net Carbon footprint** (tCO_2e/ha)[3]		
Scheduling approach	**mm/yr**				
Dryland[1]		0	-1.50 tCO_2e/ha		
Leaching[5]	620	1.14	-0.78	-1.31	-2.35
Field capacity[6]	535	0.98	-0.95	-1.47	-2.51
Deficit[7]	395	0.72	-1.20	-1.73	-2.77

Table 1: Effect of irrigation on carbon footprint

Notes
1. SOC sequestration of Regenerative Agriculture (RA) with maize-oats and soyabean-oats rotation.
2. Increase in C-capture of -2.09 tCO2e/ha: 1.25, 1.5, 2 times = -2.61, -3.14, -4.18 tCO2e/ha.
3. C-emissions and increase in C-footprint are reported as positive values (+) and C-capture and reduction in C-footprint is reported as negative values (-).
4. Excludes C-emissions of 0.69 tCO2e/ha for crop production.
5. Irrigation to 120% of field capacity, resulting in deep percolation & leaching (over-irrigation).
6. Irrigation up to field capacity (irrigation scheduling).
7. Irrigation to 80% of field capacity to allow moisture storage for rain (irrigation scheduling).

3.5. Agroforestry

Predicted C-capture rates for agroforestry are noticeably higher than cropland and pastures due to the carbon sequestration of the woody species in addition to SOC sequestration (Table 2). The biomass production and root mass

POTENTIAL ON CARBON CAPTURE, EMISSIONS AND FOOTPRINT REDUCTION OF REGENERATIVE POST-CLOSURE AGRICULTURAL LAND USE OF COAL MINES

Albert van Zyl, Terrasim Inc., Dr Stuart Christie and Dr Tony Knowles, Cirrus Group

Tree survivorship[2] (% planted trees)	Carbon sequestration rate (tCO_2/ha/yr)		
	Silvopasture	Silvopasture with high density grazing	Strip of trees around area of pasture
90	-3.07	-3.50	-4.24
75	-2.56	-2.92	-3.53
50	-1.71	-1.94	-2.36

Table 2: Carbon sequestration potential of agroforestry[1]

Notes: 1 Carbon sequestration is reported as negative values (-) as it removes CO2 from atmosphere.

2 Tree survivorship based on data from Platt (2009) for trees planted at rehabilitated mined land of the Mpumalanga Highveld coalfield.

of woody species are also higher. Predicted sequestration rates is marginally higher than for RA for silvopasture with low tree survivorship. The combined effect of low fertiliser and fuel usage requirements of silvopasture that facilitates low C-emissions and high carbon sequestration results in that silvopasture has the highest potential to reduce and offset carbon footprints.

4. Planning and Management Information on Potential Opportunities

The exploration of future land-use scenarios has highlighted the potential of RA, irrigation and agroforestry in optimising carbon sequestration and reducing GHG emissions.

Principal opportunities for optimising carbon sequestration and reducing GHG emissions lie in adopting RA and agroforestry practices such as the implementation of appropriate farming systems, including irrigation and double cropping with cover crops, the integration of mixed pastures and intensive grazing and the development of silvopasture and forestry projects. In addition to responding to climate change, these practices can act to create seepage barriers and enhance transpiration, thereby mitigating the impact of acid mine drainage (AMD).

5. Conclusions and recommendations

The study highlights Regenerative Agriculture (RA), irrigation and agroforestry as the principal opportunities to optimise C-capturing and reduce C-emissions and footprints for mines.

These land uses, integrated into land use plans for both pre and post coal mine closure, offer significant potential climatic, socio-economic, land quality and water quality benefits.

RA that involves the combination of a no till, double cropping system with the inclusion of cover crops, and improved grazing practices clearly emerged as the most important element in facilitating SOC sequestration for rainfed/dryland agricultural land use. The extent of sequestered SOC can effectively act as a CO_2 sink which will reduce and offset C-emissions and footprint.

It is important that only land suitable for irrigation is utilised for irrigation and that irrigation scheduling is implemented. This is to ensure that the irrigation of land can produce the necessary higher biomass that is required for increased C-capturing to offset the C-footprint of energy (electricity) used for pumping and operating an irrigation system.

For agroforestry, tree survivorship needs to be enhanced by utilising drought and cold-tolerant species for the Mpumalanga Highveld climate and by strategically planting trees in areas with shallow lateral seepage from mine residue facilities, dumps and pits to intercept seepage and act as a seepage barrier.

SOC sequestration on rehabilitated land appears to be more challenging as it tends to have low(er) biomass production to be an effective C-footprint sink. This emphasises the need to maximise the productive potential of farmland at mines to provide the higher annual biomass production required to effectively offset areas with low or positive (nett C-emission) C-footprints.

A TECHNOLOGY TO CONDITION PLANTS WITH ADAPTED RHIZOSPHERIC SOIL/SUBSTRATE BACTERIAL SPECIES TO IMPROVE VEGETATION RESILIENCE AND GROWTH ON REHABILITATED LAND

Prof Wayne F Truter and Claudia Schimmer - Enterprises University of Pretoria & FPLRI Research, Technology and Innovation Institute

1. Introduction

This study addressed a critical and persistent challenge in South Africa's coal mining sector where mine rehabilitation programmes battle to deliver sustainable, ecologically functional post-mining landscapes. South Africa has many derelict and ownerless mines, reflecting challenging closure practices and a longstanding emphasis on abiotic soil amendment approaches that often fail to ensure long-term ecosystem resilience.

Traditionally, mine rehabilitation efforts have focused on the chemical and physical enhancement of post-mining soils, emphasising aspects like pH correction, fertilisation, and the selection of adaptive plant species. While these are essential, they ignore a vital component of the system, microbial communities.

Soil microorganisms, particularly those in the rhizosphere (root zone), play critical roles in nutrient cycling, organic matter decomposition, soil aggregation, and supporting plant health. Their absence or dysfunction limits vegetation establishment and prevents ecosystems from progressing toward a self-sustaining state.

This study proposes, and investigates, a more integrated model for post-mining restoration that emphasises the interaction between **plants, substrates, and rhizospheric microbial communities (Figure 1)**.

It aims to quantify how different grass species influence bacterial community structures and to evaluate how physicochemical properties of coal-based substrates affect microbial development.

Importantly, the study also explores whether spontaneous microbial recovery in untreated coal spoil environments can support natural regeneration, potentially reducing the need for extensive artificial intervention.

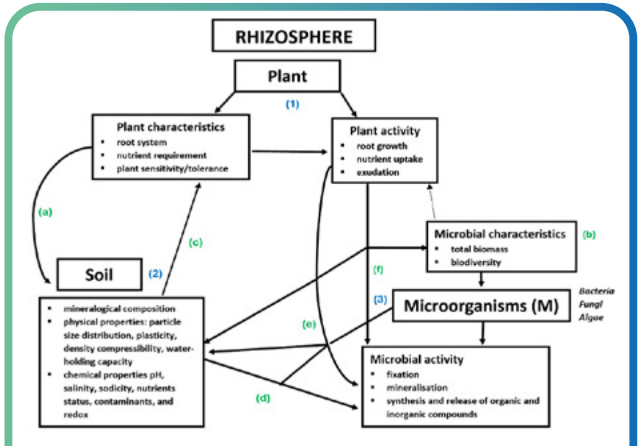

Figure 1: Plant-soil-microbe interactions and the importance of multiple ecosystem functions

2. Objectives of the Study

The research sets out six primary objectives:

1. **Evaluate plant species diversity's impact** on bacterial communities in different coal substrates.
2. **Characterise bacterial communities** in naturally recovering and actively restored coal spoil areas of different ages.
3. **Identify key abiotic factors** (pH, nutrients, trace elements) that shape microbial community structure.
4. **Investigate biotic-abiotic feedback** by assessing the effects of plant functional traits on bacterial dynamics and soil chemistry.
5. **Determine spatiotemporal effects** of plant-soil-microbe interactions on rehabilitation progress.
6. **Develop a bio-fertiliser decision-making framework** using functional microbial groups adapted to specific environmental conditions.

These objectives aim to enable the design of microbial-assisted rehabilitation strategies that can improve long-term sustainability and reduce the cost and time associated with failed revegetation efforts.

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3. Methodology Overview

The study was structured into three key research components:

Study 1: Microbial Communities in Controlled Environments

- Grass species (e.g., *Chloris gayana*, *Cynodon dactylon*, *Urochloa brizantha*) were grown in three substrate types: coal spoil, coal discard, and natural agricultural soil.
- Greenhouse trials were used to control environmental variation.
- Microbial communities were assessed via 16S rRNA gene sequencing.
- Soil physicochemical analyses (pH, EC, N, P, K, trace metals) were performed before and after planting.

Study 2: Impact of Grass Species Diversity

- Seven grass species were grown individually in the same substrate types (e.g., *Chloris gayana*, *Melinis repens, Cynodon dactylon*).
- The effect of grass traits (biomass, root depth, shoot density) on bacterial diversity and composition was measured.
- Alpha diversity (richness) and beta diversity (community structure) were compared across treatments.

Study 3: Long-Term Field Monitoring of Coal Spoils

- Field plots were established on coal spoils of varying restoration ages (1–17 years).
- Some areas were left to recover naturally without topsoil (Figure 2); others were actively restored.
- Grass yield, soil chemistry, and microbial communities were assessed seasonally.

4. Results and Analysis

4.1 Influence of Substrate Characteristics

A central finding across all three studies was that **substrate type** had a dominant influence on bacterial community structure. Agricultural soil supported significantly higher microbial richness and evenness compared to coal discard and coal spoil. Trace element content, organic matter levels, and pH were critical variables affecting microbial diversity.

Key correlations included:

- **High salinity and acidity** in coal spoil reduced microbial diversity.
- **Organic carbon and phosphorus levels** positively correlated with bacterial richness.
- **Trace elements** (e.g., Fe, Zn, Cd) had both stimulatory and inhibitory effects depending on concentration and form.

Figure 2: Field sampling of old aged coal spoils with no-topsoil

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These results confirmed that substrate physicochemical properties—not plant species—are the **primary determinants** of rhizosphere microbial community structure, especially in extreme environments like coal waste.

4.2 Grass Species Effects on Soil Chemistry and Microbes

Although plant species had **modest direct effects** on microbial community composition, they did influence several key chemical properties of the substrates:

- **pH, electrical conductivity, and macro-nutrient concentrations** were all affected by grass species, particularly in coal discard.
- **Shoot and root biomass** of grass species influenced microbial beta-diversity more than alpha-diversity, likely due to differences in root exudates and rhizodeposition rates.

Interestingly, shoot biomass showed a **positive correlation** with microbial diversity in agricultural soils, but this relationship did not hold in coal substrates. This suggests that substrate constraints override potential plant-driven microbial enhancement in these harsh conditions.

4.3 Field Study Findings on Restoration Age and Vegetation

The field study revealed that **restoration age** significantly influenced microbial and soil recovery.

Key insights include:

- **Naturally recovering coal spoils** showed improved soil chemistry over time, including reductions in trace metal bioavailability.

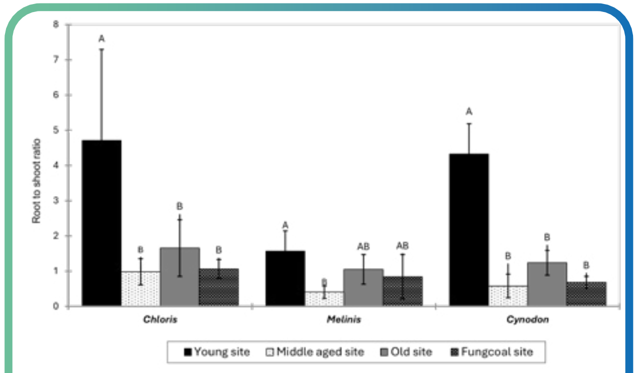

Figure 3: Root: shoot ratio for naturally established grasses in different aged coal mine spoils and actively restored sites. Bars followed by letters on the top significantly differ between grasses at $p < 0.05$ by Tukey's HSD test. Error bars are standard deviation values (n = 15)

- Nutrient levels, however, remained below optimal, even after 17 years, emphasising the limitations of passive restoration.
- **Active restoration** led to better vegetation cover and improved microbial metrics within shorter timeframes.
- **Vegetation yield traits** (shoot/root mass) were indirectly correlated with microbial structure and diversity.

4.4 Bacterial Community Composition

- Across all studies, **Proteobacteria**, **Actinobacteriota**, and **Firmicutes** were the dominant phyla.
- Community composition varied significantly across substrate types and restoration strategies.
- In coal spoil environments, microbial diversity was more tightly linked to **organic C, Ca, P, and trace metals** than to plant traits.

5. Discussion

The overarching message of this research is clear: **successful mine rehabilitation depends on substrate rehabilitation** as much as, if not more than, vegetation establishment. Without improvements to the chemical and biological properties of mine waste substrates, vegetation success will be limited and transient.

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This has direct implications for the use of **microbial-assisted restoration**. Instead of focusing exclusively on planting adaptive species or adjusting soil chemistry with amendments like lime or fertiliser, future efforts should prioritise:

- The **re-establishment of heterotrophic microbial communities** to replace the acidifying iron- and sulphur-oxidizing autotrophs.
- **Amendment of substrates** with organic matter, biochar, or composts that can support microbial recolonization.
- **Inoculation or conditioning** of plants with rhizospheric microbial consortia adapted to specific coal substrates.

The study demonstrates that vegetation alone, especially in short timeframes, may not be sufficient to restore microbial function. However, long-term succession, particularly under conditions of thoughtful substrate management, can support the development of stable, diverse microbial communities.

The implications are far-reaching. Integrating microbial metrics into rehabilitation monitoring frameworks could help refine success criteria beyond traditional measures like vegetation cover or erosion control. It also opens the door for **bio-fertiliser development tailored to substrate conditions**, moving beyond generic applications toward precision restoration inputs using the proposed bio-fertiliser decision-making framework using functional microbial groups adapted to specific environmental conditions.

6. Conclusions

- **Substrate physicochemical properties**, particularly pH, EC, organic matter, and trace metal concentrations, are the dominant factors controlling bacterial community structure in coal mine rehabilitation.
- **Grass species influence substrate chemical properties** but have **limited short-term effects on microbial diversity**, particularly in coal-derived substrates.
- **Restoration age and intervention** strategies significantly shape microbial development, with active restoration accelerating recovery compared to natural regeneration.
- There is potential to **design microbial-assisted rehabilitation protocols**, including bio-fertiliser recommendations, based on functional microbial group tolerance to specific abiotic conditions as illustrated in this study.
- **Long-term field studies** are essential to understanding plant-microbe-soil interactions and should be prioritised in future research.

7. Recommendations

1. **Integrate microbial assessments** into rehabilitation monitoring and mine closure evaluations.
2. Prioritise **substrate-specific amendment strategies** using compost, biochar, or microbial inoculants.
3. Develop and refine **microbial functional group classification systems** to guide bio-fertiliser design for post-mining substrates.
4. Encourage **long-term, landscape-scale field trials** to assess animal-plant-microbe-soil dynamics in real-world conditions, especially by including livestock.
5. Expand future studies to include **fungi, archaea, and protists**, and consider ecological network analysis to map belowground interactions more holistically.

8. Implications for Practice and Policy

This study has provided compelling evidence that **microbial communities are foundational** to long-term mine rehabilitation success. Incorporating microbial understanding into reclamation policy, environmental governance, and operational mine closure criteria could significantly enhance ecological outcomes. This research promotes a paradigm shift from viewing soil merely as a growth medium to recognising it as a **living ecosystem**. Such a transition is essential not only for restoring productivity and biodiversity in mining-affected areas but also for meeting broader national goals around land stewardship, carbon management, and sustainable development.

PHYTOMINING AND HYPERACCUMULATION OF CONSTITUENTS OF POTENTIAL CONCERN ON REHABILITATED MINE SOILS AND IRRIGATED SITES

Prof Wayne F Truter, Ernestine Schmidhuber, and JW HurterInstitutions: University of Pretoria & FPLRI Research, Technology and Innovation Institute

1. Introduction and Contextual Overview

South Africa, endowed with vast coal reserves and reliant on coal for energy, faces mounting challenges due to environmental degradation caused by coal mining.

Mpumalanga's coalfields are especially affected, with the release of acid mine drainage (AMD) (**Figure 1)**, soil contamination, and compromised vegetation establishment being central concerns. Traditional rehabilitation practices, which rely heavily on the availability of quality topsoil and conventional revegetation, often fall short due to chemical and physical constraints in mined substrates, along with the scarcity of fertile topsoil. Rehabilitation involves more than just replanting vegetation; it requires developing sustainable ecosystems with improved soil functions, increased resilience, and reduced pollution risks. Unfortunately, rehabilitation is often hampered by low pH, high salinity, and elevated concentrations of trace elements, which inhibit plant growth and microbial activity.

Figure 1: Source of AMD used for research trials

Phytoremediation is the use of plants to extract, immobilise, or degrade pollutants and contaminants and has emerged as a cost-effective and eco-friendly approach. When specific plants absorb and concentrate heavy metals or rare earth elements (REEs), this process becomes phytomining, potentially allowing for metal recovery and reuse. Given the abundance of coal fly ash (FA) and its limited industrial use, this study also explored the feasibility of using FA as a soil ameliorant. Its benefits include improved drought resistance, enhanced plant growth, improved soil pH, better trace metal accumulation and particularly silicon-associated mechanisms that increase stress tolerance in plants.

The primary aim of the study is to assess the potential of selected pasture species that can be used in mine revegetation programmes for hyperaccumulation of REEs and other constituents of potential concern (CoPCs), while evaluating the impact of substrate amelioration with FA and AMD irrigation on plant growth and phytoremediation performance.

2. Methodology Overview

The project involved four main studies:

Study 1: Hyperaccumulation Potential

- **1a – Screening of Species in Aeroponic Systems**: Evaluated numerous species' ability to absorb REEs and heavy metals without soil interference to select the best.
- **1b – Aeroponic Phytomining Trials**: Explored accumulation differences between plant organs under AMD exposure.
- **1c – *In Situ* Trials**: Used FA-amended and unamended soils under AMD irrigation to assess species performance and accumulation behaviour.

Study 2: Soil and Spoil Analysis

Characterised chemical and physical properties of AMD-contaminated soils and coal spoils from the Highveld coalfields, with comparisons to clean agricultural controls and inert sand.

Study 3: Plant Growth Response

Measured plant establishment and growth on various substrates, analysing the influence of FA and AMD irrigation on biomass, plant protein content, and visual health indicators.

Study 4: Phytoremediation Performance

Examined key physiological and biochemical responses, including chlorophyll content, nutrient uptake, and stress adaptations such as silicon trichome development.

3. Key Findings and Discussion

3.1. Soil and Water Properties

Soils contaminated with AMD showed high acidity (low pH), increased salinity, and low macronutrient levels. However, concentrations of trace elements remained below South

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African Soil Screening Values (SSVs), suggesting no immediate toxic risk under controlled conditions. AMD sources contributed to elevated levels of sulphates and salinity, while coal spoils displayed poor physical structure and low organic content, making them hostile to uninformed rehabilitation efforts. However, AMD can potentially have a valuable REE content (**Figure 2**).

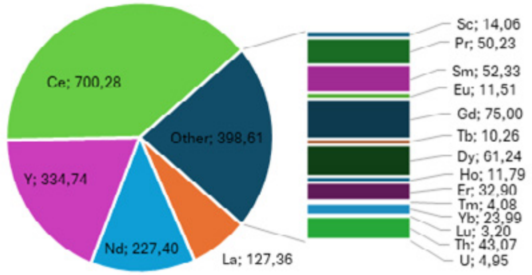

Figure 2: Example of Rare earth elements' concentration of AMD (micrograms per kilogram) (µg/kg)

Importantly, FA amendments enhanced water retention and nutrient availability, while neutralising soil acidity. These improvements facilitated better root development and increased plant survival under drought and saline stress.

3.2. Species-Specific Hyperaccumulation Patterns

Across the trials, the performance of species was as follows:

Chloris gayana

- Exhibited the most promising phytomining potential.
- Accumulated the highest REE concentrations in **aboveground plant tissues**—particularly leaves and stems.
- Tolerated 100% AMD concentrations in both aeroponic and soil-based systems.
- FA significantly enhanced accumulation potential and biomass production.

Urochloa brizantha

- Displayed **even distribution** of REEs across roots, stems, and leaves.
- Accumulated more heavy metals in roots but showed moderate translocation.
- Adapted well to both 50% and 100% AMD treatments.
- Did not outperform *C. gayana* but remained robust and drought tolerant.

Medicago sativa

- Failed to survive 100% AMD irrigation.
- Under 50% AMD, accumulated the **highest REEs in roots** rather than shoots.
- Had the lowest phytoremediation value due to poor survival and translocation characteristics.
- Being a Fabaceae species, it followed the typical root-centric accumulation pattern.

Cynodon dactylon

- Demonstrated strong performance in high-stress conditions, especially in *in situ* trials.
- Contributed to carbon sequestration and soil organic matter enhancement, as noted in other referenced studies.
- While REE accumulation was moderate, its resilience makes it suitable for multi-purpose rehabilitation goals.

3.3. Fly ash amended Soil Results

FA application (30 tons/ha) provided multiple benefits:

- **Increased water retention**, especially in inert sand setups.
- **Improved drought resistance**, supported by visible silicon-based trichome development in *C. gayana*.
- Enhanced **REE accumulation**, particularly under AMD stress.

FA not only improved soil texture and fertility but also acted as a catalyst for physiological stress resistance, likely due to its silicon content.

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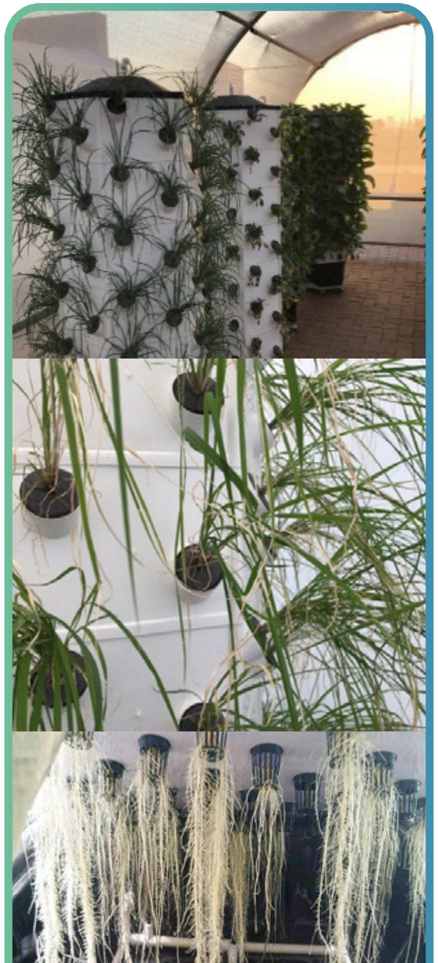

A.

B.

C.

Figure 3: A. Aeroponic towers B. First 2 weeks of growth C. 2 weeks root growth

3.4. Aeroponic Phytomining Insights

Aeroponics allowed researchers to eliminate soil interference and directly evaluate trace element uptake dynamics. Findings show:

- Biomass distribution of REEs was species dependent.
- Increasing AMD concentration led to higher REE content, particularly in aerial parts of *C. gayana*.
- Plant health deteriorated slightly at higher AMD exposure, except in resilient species like *U. brizantha* and *C. gayana*.

These insights are valuable for future controlled phytomining systems, where soil-free environments could enhance trace metal extraction efficiency (Figure 3).

3.5. Plant Growth and Forage Quality

Interestingly, AMD affected soils and coal spoil, even when untreated, yielded comparable or even superior biomass to control soils:

- **EAMD (acid mine drainage-contaminated soil)** produced more biomass in two of three harvests with variable levels of elements for each species (Figure 4).
- **ESP (coal spoil material)** had the **highest crude protein percentage**, indicating excellent forage quality.
- Visual signs of plant stress (e.g., leaf yellowing) were mitigated with regular irrigation and nutrient supplementation.

These results suggest that **substrate constraints may not be as limiting** as previously thought—**post-planting care** plays a more critical role in establishment and productivity.

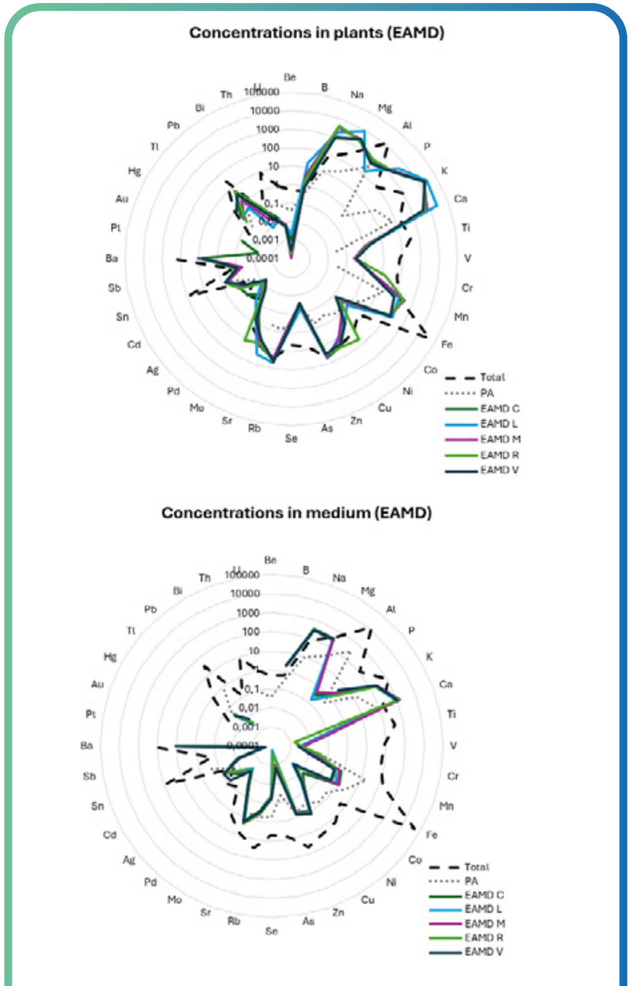

Figure 4: Plant and growth medium concentrations (mg·kg⁻¹) in AMD contaminated soil (EAMD)

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4. Discussion: Comparative Analysis and Indices

The study employed several indices to quantify hyperaccumulation efficiency:

a. Mobility Factor (MF)

- Indicates element movement from roots to aboveground tissues.
- *C. gayana* and *U. brizantha* had higher MF values for REEs.

b. Translocation Factor (TF)

- Ratio of shoot to root concentration.
- A, **TF** ≥1 indicates good translocation capacity; again, *C. gayana* excelled.

c. Tolerance Index (TI)

- Biomass under stress relative to control biomass.
- *U. brizantha* and *C. gayana* scored highly, reflecting drought and AMD resistance.

These quantitative assessments validate *C. gayana* as a top-performing species for phytomining, followed by *U. brizantha*, while *M. sativa* fell short across all metrics.

5. Conclusions

5.1. Summary

- **Coal spoils and AMD contaminated soils** do not inherently inhibit plant growth or forage quality and nutrient uptake, especially with FA amendment and aftercare.
- ***Chloris gayana* and *Urochloa brizantha*** are viable candidates for large-scale phytoremediation and phytomining, especially in acidic, saline, or metal-laden environments.
- **FA** improves drought resistance and metal uptake, offering a practical coal by-product reuse strategy.
- **Aeroponic systems** show promise for controlled REE recovery.
- **Post-rehabilitation maintenance**, including irrigation and fertilisation, is critical for successful establishment and natural succession.

5.2. Recommendations

1. **Field validation**: Larger-scale trials under real environmental conditions are necessary to confirm pot and greenhouse results.
2. **Fly ash application optimisation**: Determine ideal rates and long-term impacts for different soil types.
3. **Species rotation and diversity**: Introduce multi-species planting schemes to build resilience and optimize nutrient cycling.
4. **Metal recovery strategy**: Develop post-harvest biomass processing methods for REE extraction.
5. **Community integration**: Leverage rehabilitated lands for forage, biofuel, or essential oil production, supporting rural livelihoods.

6. Broader Implications and Final Thoughts

This study contributes significantly to the evolving field of phytoremediation and post-mining land rehabilitation in South Africa. Its novelty lies in merging ecological restoration with resource recovery—phytomining of REEs or other metals of value from degraded soils and waste streams. In addition, the integration of FA into restoration strategies promotes a circular economy approach, minimizing waste 'by-products' while maximising ecosystem service delivery.

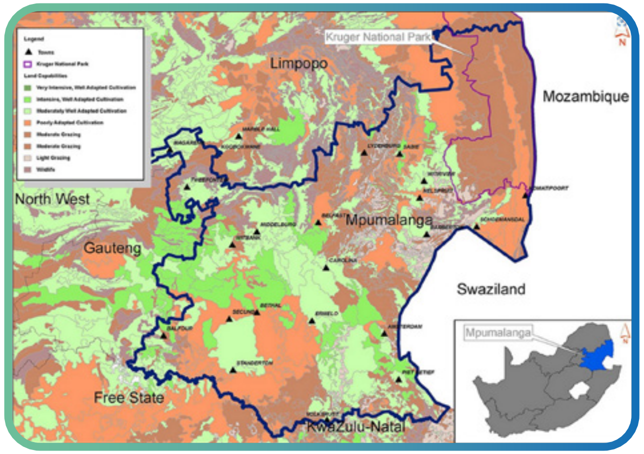
Future research can build on these findings by:

- Exploring **long-term soil microbiome changes**,
- Evaluating **seasonal variations in REE uptake**, and
- Testing the economic viability of **phytomining as a revenue stream** for post-mining communities.

By combining soil science, plant physiology, and industrial by-product reuse, this work charts a practical path forward for sustainable post-mining landscapes in South Africa and beyond.

SOILS HANDBOOK FOR COAL MINING INDUSTRY

Dr Gary Paterson



Our planet is covered at its surface by soil. This living material is vital to our continued survival, but we tend not to give much thought to the soil beneath our feet. This is especially unfortunate where coal mining is concerned, as the main mining area is underlain by high quality soils that are irrevocably disturbed during the mining process.

To help mining personnel better understand the soil, its properties and how to handle it properly in the mining process, aproject produced a concise, easy-to-understand handbook covering all the relevant soil-related aspects.

The map shows how the coal-producing zone (the red line) is underlain by high potential soils (the green areas on the map), perfectly illustrating the conflict.

Produced by retired soil scientist **Dr Garry Paterson**, who has over 40 years' experience that includes many coal mining environment projects. He has also been involved with previous Coaltech projects that looked at the soil stockpiling process and some of the pitfalls that have to be avoided.

The handbook covers many topics, arranged in a logical order, mainly to reflect the sequence of events affecting the soil as mining progresses.

The book was also reviewed by two experienced soil scientists, also with many decades of work in the coal mining environment. Their comments and suggestions made a significant contribution to the content and the level of understanding of the book.

The intention is to have several field copies printed and if possible an on-line version for ease of reference.

Photos and diagrams illustrate the concepts discussed, which is designed to be a handy, pocket-size reference, useful to almost everyone who works on a mine.

The table of contents of the book is as follows:

1. ***Introduction and background*** - what is soil and how is it formed?
2. ***Basic soil properties and definitions*** - such as texture, structure, effective rooting depth and more?
3. ***Soil identification and basic classification*** - why do we classify soil and what does it mean?
4. ***Pre-mining soil survey*** - what is involved and why is it necessary?
5. ***Land capability*** - what systems are used in South Africa and for the mines?
6. ***Rehabilitation planning*** - what aspects are important?
7. ***Stripping*** - how to strip the soils properly for maximum environmental post-mining benefit.
8. ***Stockpiling*** - how to optimally store the stripped soil types.
9. ***Rehabilitation*** - how to do it properly and sustainably and to avoid potentially costly mistakes.
10. ***Post-rehabilitation*** – monitoring, surveys and soil evaluation.
11. ***Soil health and Fertility*** - what is a "fertile" soil and how to achieve this in the rehabilitation environment?
12. ***Conclusion*** - summary of the most important soil-related aspects.
13. ***References*** - a list of published sources that give more details about various aspects of soils and their properties. This is for reference and for further reading, if desired.

The layout of the book follows the logical sequence of soil handling on a coal mine, with some introductory background and general information (Chapters 1 to 3), followed by the survey and planning phase (Chapters 4 to 6), stripping and stockpiling (Chapters 7 to 9), rehabilitation aspects (Chapters 9 to 11), and some conclusions with a comprehensive list of references for anyone requiring more specific information.

SOILS HANDBOOK FOR COAL MINING INDUSTRY

Dr Gary Paterson


Pre-mining soil survey


Soil stockpile


Monitoring rehab

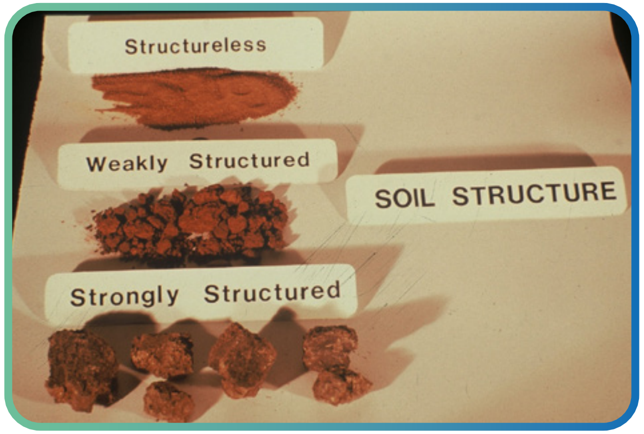
A typical concept of a soil profile, with the various horizons (layers), is shown here, along with the various diagnostic horizon names, as identified by the South African soil classification system.

The need for the pre-mining soil survey to be closely adhered to and the change in soil properties that occur during the storage phase, are emphasised.

Close attention is also given to the vital rehabilitation phase, whereby the land should be restored as close as possible to the original conditions.

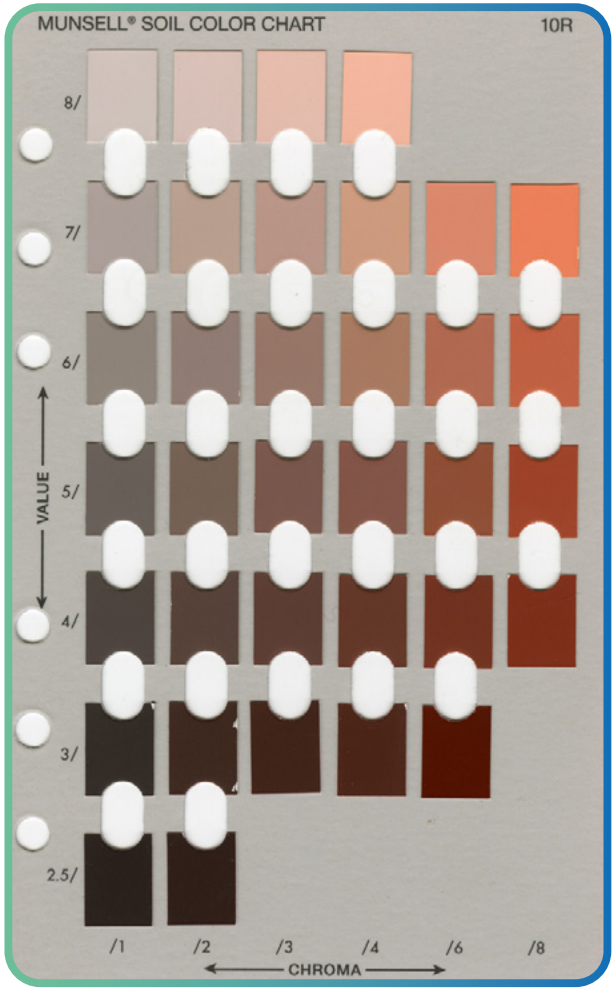
The below photos show how soil structure can vary as well as the way that the soil colour is recorded. This is all part of the initial soil survey process on the mine.

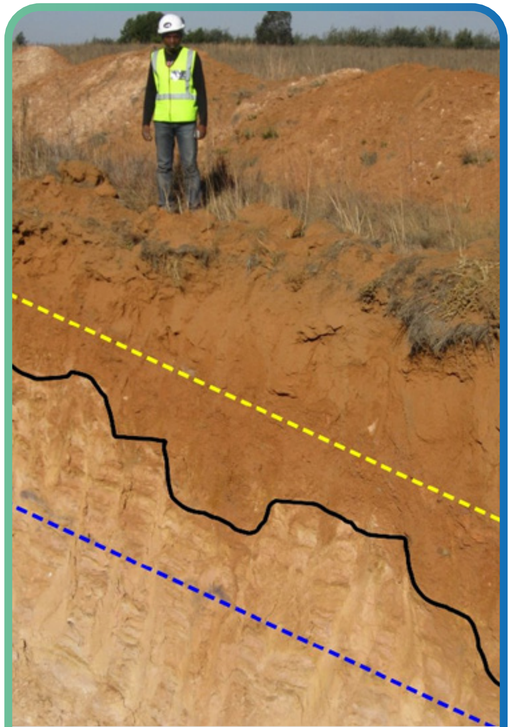
Important soil properties, such as texture, effective depth, bulk density/compaction, water holding-capacity and chemical aspects (such as organic



SOILS HANDBOOK FOR COAL MINING INDUSTRY

Dr Gary Paterson





carbon, pH and soil nutrients) are also addressed.

Once the soil has been mapped and characterised, it needs to be stripped and stored (stockpiled. This process needs to be managed correctly, as correct practices will enable the best possible rehabilitation, tor the benefit of the post-mining environment. Proper soil handling will also ensure the mine does not have to spend unnecessary funds to fix rehab done incorrectly.

Image 1 shows how the depth to the underlying material can vary (black line), and how easy it would be to over strip (blue line) or to under strip (yellow line).

Image 2 shows a high, likely excessively compacted stockpile, that will cause problems in the rehabilitation phase.

In that rehab phase, good knowledge of the soil, from microbiology, fertility, drainage and many other aspects, is essential to ensure that the pre-mining conditions, as far as possible, are regained.

The soils handbook will provide a handy, relevant and easy-to-understand guide to most of the important aspects of soil science on the mine.

It will make a significant contribution to the level of understanding of our valuable soils and how they are affected by mining.

In this way, coal can make a contribution to the environment while supplying energy to the country.

As the closing statement in the book makes clear:

“Don’t treat soils like dirt”

PROCESSING

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UPGRADING OF COAL FINES WITH A CENTRIFUGAL CONCENTRATOR

W Roux, N Naude, T Mashike, University of Pretoria

Introduction

The beneficiation of fine coal is a critical issue in the South African coal industry, where the generation of coal fines as a by-product of mining and processing operations presents economic and environmental challenges. Traditionally, the recovery and upgrading of these fines rely on gravity separation methods such as spirals and fluidised bed separators as well as flotation and oil agglomeration. However, these conventional techniques often struggle to efficiently process fine and ultrafine coal particles, resulting in significant losses of potentially valuable material to waste streams and tailings dams. This not only reduces the overall yield and profitability of coal operations but also contributes to environmental concerns, including the risk of acid mine drainage (AMD) and the accumulation of large volumes of coal waste.

Recent technological advancements have led to the development of enhanced gravity separation techniques, most notably centrifugal concentrators such as the Knelson and Falcon units. These devices generate high centrifugal forces, which improve the separation of fine particles based on density differences, making them particularly suitable for the beneficiation of coal fines. The adoption of centrifugal concentrators in mineral processing has shown promising results, and their application to coal fines is gaining increasing attention in the recovery of valuable coal from waste, reduce ash and sulphur content, and improve the calorific value of the final product.

The motivation for this research stems from the need to address the limitations of traditional coal fines beneficiation methods and to explore the potential of centrifugal concentrators for upgrading South African coal fines. The primary objectives were to evaluate the performance of different centrifugal concentrators in reducing ash and sulphur content, to optimise process parameters for maximum efficiency, and to assess the scalability and industrial applicability of these technologies. By focusing on coal samples from major South African collieries, this study aims to provide practical insights into the effectiveness of centrifugal concentrators in real-world coal processing environments. Ultimately, the successful implementation of these technologies could lead to improved resource utilisation, reduced environmental impact, and enhanced economic returns for the coal industry.

Methodology

The research was conducted using coal fines sourced from two major South African operations: the Tweefontein colliery (thickener underflow) and the Khwezela Navigation Plant (spiral discard and product). The samples were first characterised to determine their ash content, total sulphur, and calorific value. To enhance the efficiency of subsequent beneficiation, the samples underwent a desliming process, which involved removing ultrafine slimes that can interfere with gravity-based separation. This step was found to be critical in improving the performance of the centrifugal concentrators.

Laboratory-scale batch tests were performed using three types of centrifugal concentrators: the Knelson KC-MD3, the Falcon L40, and the SB-4A gold concentrator. Each device was operated under a range of conditions, with key variables including feed solids concentration, bowl speed (G-force), and fluidisation water pressure. The aim was to identify the optimal settings for maximum reduction of ash and sulphur content while maintaining a high yield of clean coal. The laboratory tests provided a controlled environment to compare the performance of the different concentrators and to assess the impact of desliming on separation efficiency.

Following the laboratory work, pilot-scale tests were conducted using the Knelson CVD6 concentrator (Figure 1), which is capable of processing up to two tonnes per hour. The pilot tests were designed to simulate industrial conditions and to evaluate the scalability of the process. Various feed types were tested, including as-received thickener underflow, deslimed samples, spiral reconstituted feed, and composite blends. The performance of the pilot plant was monitored by analysing the ash and sulphur content of the product and tailings streams and by tracking changes in calorific value. Throughout the study, a combination of analytical techniques was used to ensure accurate measurement of key parameters and to provide a comprehensive assessment of the upgrading process.

UPGRADING OF COAL FINES WITH A CENTRIFUGAL CONCENTRATOR

W Roux, N Naude, T Mashike, University of Pretoria

Figure 1: Keelson CVD6 pilot scale setup

Results and Discussion

The study results demonstrate the effectiveness of centrifugal concentrators in upgrading coal fines. Initial characterisation of the Tweefontein thickener underflow revealed a high ash content of 35.2% and a total sulphur content of 0.68%. After desliming, the ash content dropped to 25.05%, highlighting the importance of removing ultrafine slimes prior to beneficiation. Laboratory tests using the Knelson KC-MD3 concentrator achieved a significant reduction in ash and sulphur in a single-stage upgrade, with ash content falling to 18.47% and sulphur to 0.36%. Figure 2 shows the effect of desliming on the performance of the Knelson concentrator.

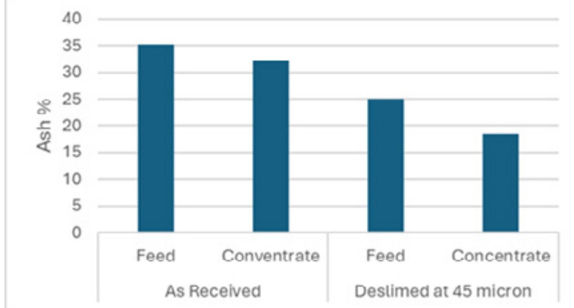

Figure 2: Effect of desliming on the performance of the Knelson KC-MD3

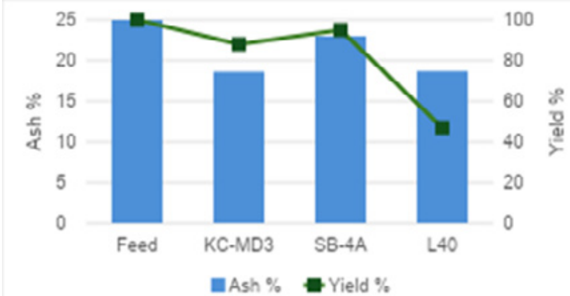

Figure 3: Comparison of the three batch concentrators

Comparison of the three batch concentrators showed varying performance levels. The KC-MD3 outperform the other two concentrators by achieving the lowest ash% concentrate and a high yield, as seen in Figure 3.

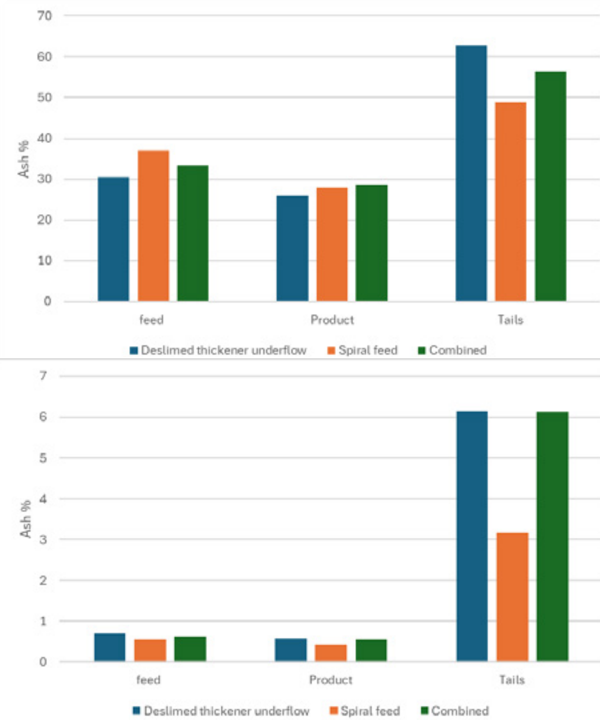

Figure 4: Ash % and Sulphur % for the feed product and tails of the three samples tested on the CVD 6 pilot scale Knelson concentrator

The pilot-scale tests with the Knelson CVD6 concentrator further validated these findings. Three samples were used for the pilot scale work on the CVD6: a deslimed thickener underflow, spiral feed and a blend of the two. Figure 4 shows the

UPGRADING OF COAL FINES WITH A CENTRIFUGAL CONCENTRATOR

W Roux, N Naude, T Mashike, University of Pretoria

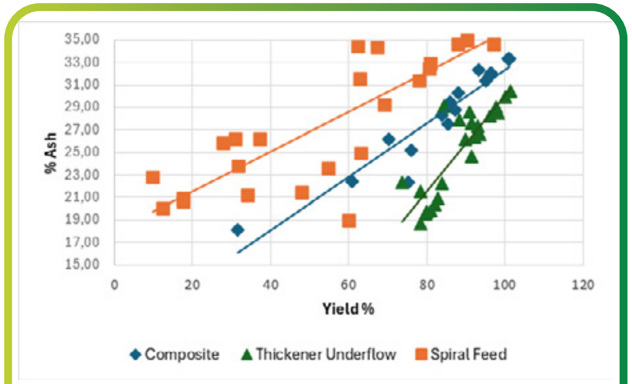

Figure 5: Ash vs Yield relationships obtained for the three different feeds on the CVD

average results obtained for each of the samples. The ash was on average reduced by 4.5% for the deslimed thickener underflow, nine percent for the spiral feed and 4.7% for the combined sample. The best individual tests showed a reduction of ash down to 19%. Figure 5 shows the Ash% vs. Yield% relationships generated for the three samples, and from this graph, the thickener underflow feed yielded the best results, achieving up to 80% yield at sub-20% ash content. The spiral feed performed the worst, with the composite feed showing intermediate results.

The study also explored the relationship between operating variables such as G-force and fluidisation water pressure, and the performance of the concentrators. Although consistent trends were observed, the correlation was not always straightforward, suggesting that further optimisation and process control are needed to maximise efficiency. Overall, the research confirms that centrifugal concentrators can play a key role to reclaim valuable coal from fines, reduce environmental impact by minimising waste, and improve the economic viability of coal processing operations.

Conclusions

This research demonstrates that centrifugal concentrators, particularly the Knelson KC-MD3 and CVD6, are highly effective for the beneficiation of fine coal. The ability to significantly reduce ash and sulphur content while increasing calorific value makes these technologies valuable tools for the coal industry. Desliming prior to concentration is essential for achieving the best results, as it enhances separation efficiency and product quality. The successful application of these concentrators at laboratory and pilot scales suggests strong potential for industrial implementation, with benefits including improved resource utilisation, reduced environmental impact, and increased profitability. Future work should focus on further optimisation of operating parameters and the validation of economic feasibility at full industrial scale.

RECOVERING OF REE'S FROM SOUTH AFRICAN RUN-OF-MINE (ROM) COAL AND DISCARD COAL (DC)

John Nkuna, University of the Witwatersrand

This study aimed to evaluate the potential of South African run-of-mine (ROM) coal and discard coal (DC) as alternative sources of rare earth elements (REEs), in response to global concerns over supply concentration and China's dominance in REE production. South Africa generates approximately 60 million tonnes of discard coal annually, which poses environmental and resource wastage challenges. This research explored innovative beneficiation strategies to valorise this waste.

The experimental work focused on using a High Internal Phase Water-in-Oil (HIP W/O) emulsion binder during flotation to improve separation of REE-bearing minerals from coal fractions.

ROM and DC samples, collected from the Waterberg coalfield in the Limpopo province, underwent detailed characterisation, including proximate analysis, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS), and Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Initial results reveal coal types with ash contents above 50%, classifying them as carbonaceous rock, and TREE (total REE) concentrations of approximately 260ppm for ROM and 265ppm for DC, which is well above the global economic cutoff grade of around 130ppm for REE recovery from coal.

Despite reductions in ash content following HIP W/O flotation, for example, ROM ash reduced from 51% to approximately 37%, flotation alone did not significantly enrich REE concentrations in either the concentrate or tailings streams.

Recognising this limitation, the study implemented calcination of flotation products at 700°C for two hours, aimed at removing carbon and break encapsulating mineral structures. Calcination led to modest improvements in TREE content, raising concentrations to approximately 285–289ppm. Subsequent acid leaching tests using 2M HCl at 50 °C, with a solid to liquid ratio of 10g/L, demonstrated rapid initial REE dissolution, with most recovery occurring within one to 15 minutes. However, overall recovery remained modest, about 51% for DC concentrates and up to 60% for ROM concentrates, suggesting that REEs remained partly locked in acid-insoluble phases or intimately associated with major silicate minerals.

The study suggests that ROM and discard coals from the Waterberg basin could be viable REE sources due to their high TREE concentrations in the coals used. While Figure 1 presents the elemental composition in the REE-bearing minerals (monazite and xenotime). Ce-monazite ((Ce, La, Nd, Th)PO4) with variable composition was the most dominant REE mineral observed in both samples, predominantly as fine grains approximately 1–2µm often locked within silicate matrices. This aligns with REE mineralisation patterns, especially in ash-rich or tonstein-bearing coal seams.

Note that data has been arranged with monazite grains on the left and xenotime grains on the right

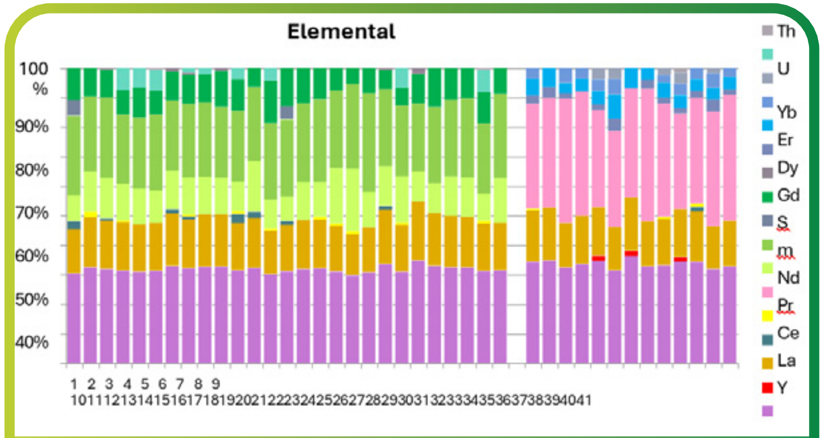

Figure 1 Semi-quantitative composition of monazite and xenotime grains

Nonetheless, the work also highlights critical challenges to be addressed, such as the limited enrichment achievable through current flotation strategies, incomplete liberation during calcination, and suboptimal acid-leaching recoveries.

The report recommends further research into advanced mineralogical characterisation of calcined residues, improved flotation reagents or conditions, staged leaching processes to remove contaminants and enhance REE solubilisation, and a more comprehensive mass balance of REE distribution in process streams to fully evaluate commercial viability.

By combining innovative beneficiation approaches with environmental stewardship, this study contributes valuable insights toward developing sustainable, locally sourced REE supplies for South Africa's technological and clean-energy industries.

MINING

Guideline for Best Practice for Respirable Dust Sample Processes – A Quality Assurance Programme	39

GUIDELINE FOR BEST PRACTICE FOR RESPIRABLE DUST SAMPLE PROCESSES – A QUALITY ASSURANCE PROGRAMME

Liska Cronje – Ventgiene, Alan Cook, Zanele Jordaan, Rodney Fourie - Latona

1. Introduction and Background

Respirable dust exposure remains a critical occupational health risk in coal mining operations. This Guideline addresses the need for a coherent, standardised approach to dust sampling and quality assurance. It consolidates best practices identified across the sector, promoting industry-wide alignment and proactive risk management.

2. Project Objectives

- To consolidate and document best practices in respirable dust sampling.
- To develop a quality assurance framework adaptable to diverse mining operations.
- To improve data accuracy and support regulatory compliance.
- To enhance stakeholder collaboration and information sharing.

3. Methodology

3.1 Phase 1: Project Initiation and Preparation

Project initiation includes notifying seven major coal mining groups, general managers, occupational hygiene practitioners, and contractors. The objective was to invite participation and site access for collecting best practice observations across large and small operations. The aim was collaborative improvement, not auditing.

3.2 Phase 2: Site Visits and Observations

A structured observation log sheet, approved by the Coaltech Steering Committee, guided data collection during mine and service provider visits. Observations included equipment use, sampling procedures, and QA/QC practices. Interviews were conducted informally or formally, depending on site context, with log sheets completed post-visit to ensure transparency and comfort.

3.3 Phase 3: Data Review and Analysis

Data from the visits were compiled into electronic log sheets. Evaluation involved aggregating practices across categories and subcategories into a master spreadsheet. Observations were visualised through bar charts illustrating best practices per category (Chart 1) and subcategory (Chart 2), facilitating comparative analysis.

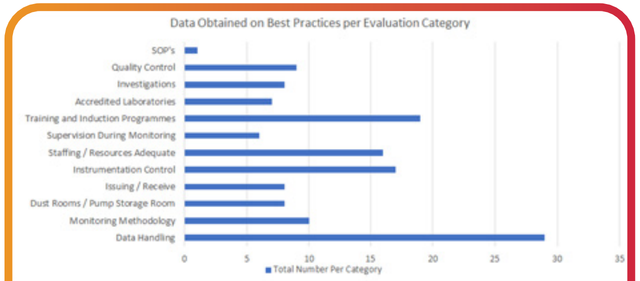

Chart 1: Best Practices Observed per Evaluation Category

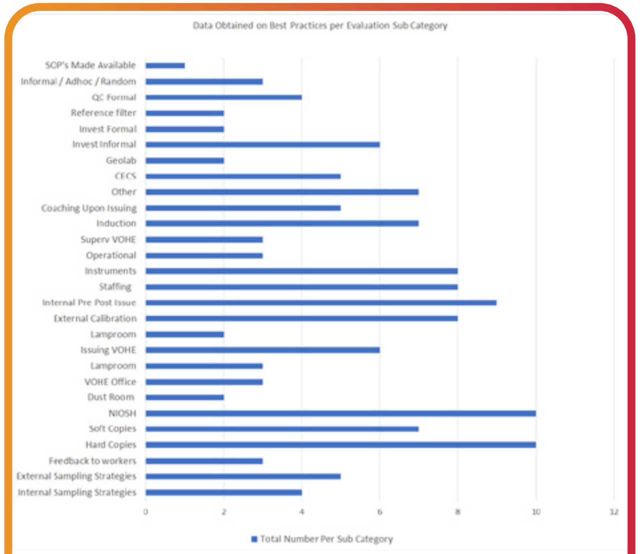

Chart 2: Best Practices Observed per Evaluation Subcategory

3.4 Phase 4: Compilation of the Guideline

The final phase focused on synthesising findings into the guideline. Emphasis was placed on quality assurance rather than methodology, as scientific standards (e.g., NIOSH 0600 and 7602) were uniformly applied. The layout aligns with the "Mandatory Code of Practice for a Quality Assurance Programme for a System of Occupational Hygiene and Ventilation Engineering Measurements," allowing seamless integration into mine-specific programmes.

GUIDELINE FOR BEST PRACTICE FOR RESPIRABLE DUST SAMPLE PROCESSES – A QUALITY ASSURANCE PROGRAMME

Liska Cronje – Ventgiene, Alan Cook – Latona, Zanele Jordaan – Latona, Rodney Fourie – Latona

4. Key Areas of Focus of the Guideline

- **Sampling Equipment and Procedures:** Recommendations for equipment calibration, flow rate control, and sampler placement.
- **Quality Control and Assurance:** Emphasis on chain-of-custody, pre/post-sampling checks, and documentation.
- **Data Handling and Interpretation:** Accurate, traceable data recording and alignment with regulatory limits.
- **Training and Competency:** Importance of ongoing training and demonstrated proficiency.
- **Continuous Improvement:** Mechanisms for regular review, technology adoption, and feedback loops.

5. Recommendations

5.1 Adherence to Codes of Practice (COPs) and Standard Operating Procedures (SOPs)

- Ensure strict compliance with approved methodologies, including NIOSH 0600 and 7602.

5.2 Training and Competency

- Implement ongoing training and competency assessments for all sampling personnel.
- Develop industry-standard educational material on dust exposure and sampling.

5.3 Calibration and Maintenance of Equipment

- Maintain and calibrate equipment in line with manufacturer specifications.
- Store calibration certificates and logs for verification.

5.4 Sample Integrity

- Apply rigorous chain-of-custody procedures.
- Explore digital tools to manage and verify sample handling processes.

5.5 Independent Verification

- Conduct regular third-party audits of equipment and practices.

5.6 Data Management and Reporting

- Centralise digital data systems for reporting and analytics.
- Use technology to identify trends and support early intervention.

5.7 Continuous Improvement

- Review the guideline annually or when changes in regulation or technology occur.
- Investigate advanced tools like continuous real-time monitoring (CRTM) and TARPs.

5.8 Stakeholder Engagement

- Promote transparent communication among mines, regulators, labs, and worker representatives.

6. Conclusion and Way Forward

This Guideline aims to unify best practices for respirable dust sampling under a quality assurance framework that protects worker health and supports compliance. Through site visits, stakeholder engagement, and data analysis, it captures practical, actionable insights for small and large-scale operations. Going forward, collaboration and technology adoption will be key in achieving sustained improvements in dust monitoring and exposure control.

The coal mining sector is encouraged to adopt and adapt these practices, while actively contributing to ongoing refinement of the guideline as industry conditions evolve.

ANNUAL FINANCIAL STATEMENTS

The reports and statements set out below comprise the annual financial statements presented to the shareholders:

General Information

Country of Incorporation and Domicile	South Africa
Registration Number	2007 /012495/08
Registration Date	25 April 2007
Nature of Business and Principal Activities	The non-profit company promotes the communal and group interest by the development of technology and the application of research findings in the South African Coal Industry.
Directors	PP Mulder (Chairperson) N Haniff M Smith SV Sibiya MD Thenga CIT Teffo CM Saolose AC Nengovhela (Chief Executive Officer)
Registered Office	The Mandela Mining Precinct, Cnr Carlow and Rustenburg Road, Melville, Johannesburg, 2109
Postal Address	Postnet Suite # 95, Private bag X04, Fountainebleau. Johannesburg, 2032
Bankers	ABSA Group Limited
Auditors	Ransome Russouw Inc.
Company Secretary	AC Nengovhela is the duly appointed secretary of the company appointed in the current year.

Directors’ Responsibilities and Approval

The directors are required to maintain adequate accounting records and are responsible for the content and integrity of the annual financial statements and related financial information included in this report. These annual financial statements have been prepared in accordance with the IFRS for SMEs® Accounting Standard as issued by the International Accounting Standards Board (IASB®) and it is their responsibility to ensure that the annual financial statements satisfy the financial reporting standards with regards to form and content and present fairly the statement of financial position, results of operations and business of the non-profit company, and explain the transactions and financial position of the business of the non-profit company at the end of the financial year. The annual financial statements are based upon appropriate accounting policies consistently applied throughout the non-profit company and supported by reasonable and prudent judgements and estimates.

The directors acknowledge that they are ultimately responsible for the system of internal financial control established by the non-profit company and place considerable importance on maintaining a strong control environment. To enable the directors to meet these responsibilities, the directors set standards for internal control aimed at reducing the risk of error or loss in a cost effective manner. The standards include the proper delegation of responsibilities within a clearly defined framework, effective accounting procedures and adequate segregation of duties to ensure an acceptable level of risk. These controls are monitored throughout the non-profit company and all employees are required to maintain the highest ethical standards in ensuring the non-profit company’s business is conducted in a manner that in all reasonable circumstances is above reproach.

The focus of risk management in the non-profit company is on identifying, assessing, managing and monitoring all known forms of risk across the non-profit company. While operating risk cannot be fully eliminated, the non-profit company endeavours to minimise it by ensuring that appropriate infrastructure, controls, systems and ethical behaviour are applied and managed within predetermined procedures and constraints.

The directors are of the opinion, based on the information and explanations given by management, that the system of internal control provides reasonable assurance that the financial records may be relied on for the preparation of the annual financial statements. However, any system of internal financial control can provide only reasonable, and not absolute, assurance against material misstatement or loss. The going-concern basis has been adopted in preparing the financial statements. Based on forecasts and available cash resources the directors have no reason to believe that the non-profit company will not be a going concern in the foreseeable future. The annual financial statements support the viability of the non-profit company.

The financial statements have been audited by the independent auditing firm, Ranrus Incorporated, who have been given unrestricted access to all financial records and related data, including minutes of all meetings of the member, the directors and committees of the directors. The directors believe that all representations made to the independent auditor during the audit were valid and appropriate. The external auditor’s unqualified audit report is presented on pages 5 to 6.

The financial statements set out on pages 7 to 16 which have been prepared on the going concern basis, were approved by the directors and were signed on 3 July 2025 on their behalf by:

PP Mulder (Chairperson)

AC Nengovhela (Chief Executive Officer)

Directors' Report

The directors present their report for the year ended 31 March 2025.

1. Review of activities

Main business and operations

The non-profit company promotes the communal and group interest by the development of technology and the application of research findings in the South African Coal Industry. There were no major changes herein during the year.

The operating results and statement of financial position of the non-profit company are fully set out in the attached financial statements and do not in our opinion require any further comment.

2. Going concern

The annual financial statements have been prepared on the basis of accounting policies applicable to a going concern. This basis presumes that funds will be available to finance future operations and that the realisation of assets and settlement of liabilities, contingent obligations and commitments will occur in the ordinary course of business.

The directors believe that the non-profit company has adequate financial resources to continue in operation for the foreseeable future and accordingly the annual financial statements have been prepared on a going concern basis.

The directors are not aware of any new material changes that may adversely impact the non-profit company. The directors are also not aware of any material non-compliance with statutory or regulatory requirements or of any pending changes to legislation which may affect the non-profit company.

3. Events after reporting date

All events subsequent to the date of the annual financial statements and for which the applicable financial reporting framework requires adjustment or disclosure have been adjusted or disclosed.

4. Directors

The directors of the non-profit company during the year and up to the date of this report are as follows:

PP Mulder (Chairperson)

N Haniff

M Smith

SV Sibiya

MD Thenga

CIT Teffo

CM Saolose

AC Nengovhela (Chief Executive Officer appointed in the current financial year)

5. Secretary

AC Nengovhela is the duly appointed secretary of the company appointed in the current year.

6. Independent Auditors

Ranrus Incorporated were the independent auditors for the year under review.

Independent Auditor's Report

To the Members of Coaltech Research Association NPC

Opinion

We have audited the financial statements of Coaltech Research Association NPC set out on pages 7 to 16, which comprise the statement of financial position as at 31 March 2025, and the statement of comprehensive income, the statement of changes in equity and the statement of cash flows for the year then ended, and notes to the financial statements, including a summary of significant accounting policies.

In our opinion, the financial statements present fairly, in all material respects, the financial position of Coaltech Research Association NPC as at 31 March 2025, and its financial performance and cash flows for the year then ended in accordance with the IFRS for SMEs Accounting Standard as issued by the International Accounting Standards Board.

Basis for Opinion

We conducted our audit in accordance with International Standards on Auditing (ISAs). Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Statements section of our report. We are independent of the non-profit company in accordance with the Independent Regulatory Board for Auditors' Code of Professional Conduct for Registered Auditors (IRBA Code) and other independence requirements applicable to performing audits of financial statements in South Africa. We have fulfilled our other ethical responsibilities in accordance with the IRBA Code and in accordance with other ethical requirements applicable to performing audits in South Africa. The IRBA Code is consistent with the corresponding sections of the International Ethics Standards Board for Accountants' International Code of Ethics for Professional Accountants (including International Independence Standards). We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Other Information

The directors are responsible for the other information. The other information comprises the information included in the document titled "Coaltech Research Association NPC Financial Statements for the year ended 31 March 2025", which includes the Directors' Report, and the statement of Directors' Responsibilities and Approval, which we obtained prior to the date of this report. The other information does not include the financial statements and our auditor's report thereon.

Our opinion on the financial statements does not cover the other information and we do not express an audit opinion or any form of assurance conclusion thereon.

In connection with our audit of the financial statements, our responsibility is to read the other information and, in doing so, consider whether the other information is materially inconsistent with the financial statements or our knowledge obtained in the audit, or otherwise appears to be materially misstated. If, based on the work we have performed, we conclude that there is a material misstatement of this other information, we are required to report that fact. We have nothing to report in this regard.

Responsibilities of the Directors for the Financial Statements

The directors are responsible for the preparation and fair presentation of the financial statements in accordance with the IFRS for SMEs Accounting Standard as issued by the International Accounting Standards Board, and for such internal control as the directors determine is necessary to enable the preparation of financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, the directors are responsible for assessing the non-profit company's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless the directors either intend to liquidate the non-profit company or to cease operations, or have no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with ISAs will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

Independent Auditor’s Report

As part of an audit in accordance with ISAs, we exercise professional judgement and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial statements, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations or the override of internal control.
- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the non-profit company’s internal control.
- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the directors.
- Conclude on the appropriateness of the directors’ use of the going concern basis of accounting and based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the non-profit company’s ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor’s report to the related disclosures in the financial statements or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor’s report. However, future events or conditions may cause the non-profit company to cease to continue as a going concern.
- Evaluate the overall presentation, structure and content of the financial statements, including the disclosures, and whether the financial statements represent the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the directors regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

3 July 2025

Ranrus Incorporated

Per: JA Barnard CA(SA)

Director

Registered Auditor

1 Mowbray road, Greenside, Randburg, 2193

Statement of Financial Position

	Note(s)	2025 R	2024 R
ASSETS			
Non-current assets			
Property, plant and equipment	4	**24,993**	838
Current assets			
Trade and other receivables	5	**32,771**	226,434
Cash and cash equivalents	6	**20,780,717**	18,809,978
Total assets		**20,813,488**	19,036,412
EQUITY AND LIABILITIES			
Equity			
Accumulated surplus		**14,977,545**	13,359,384
Other non-distributable reserves	7	**1,416,111**	934,939
Total equity		**16,393,656**	14,294,323
Liabilities			
Current liabilities			
Trade and other payables	9	**4,444,825**	4,742,927
Total equity and liabilities		**20,838,481**	19,037,250

Statement of Comprehensive Income

	Note(s)	2025 R	2024 R
Revenue		**10,800,583**	8,601,624
Other income		**1,310,689**	429,213
Operational expenses	11	**(10,756,988)**	(9,924,344)
Surplus/ (deficit) from operating activities		**1,354,284**	(893,507)
Interest received	12	**745,048**	1,441,110
Surplus for the year		**2,099,332**	547,603
Other comprehensive income		**-**	-
Total Comprehensive income		**2,099,332**	547,603

Statement of Changes in Equity

	Revaluation Reserve R	Accumulated surplus R	Total R
Balance at 1 April 2023	582,951	13,163,768	13,746,719
Changes in equity			
Surplus for the year		547,604	547,604
Revaluation reserve movement	351,988	(351,988)	
Other comprehensive income			
Total comprehensive income for the year	351,988	195,616	547,604
Balance at 31 March 2024	934,939	13,359,384	14,294,323
Balance at 1 April 2024	934,939	13,359,384	14,294,323
Changes in equity			
Surplus for the year		2,099,333	2,099,333
Revaluation reserve movement	481,172	(481,172)	
Other comprehensive income	-	-	-
Total comprehensive income for the year	481,172	1,618,161	2,099,333
Revaluation gain	-	-	-
Balance at 31 March 2025	1,416,111	14,977,545	16,393,656
Note			7

Statement of Cash Flows

	Note(s)	2025 R	2024 R
Cash flows (used in)/ from operations Surplus for the year		**2,099,332**	547,603
Adjustments to reconcile surplus			
Adjustments for finance income		**(745,048)**	(1,441,110)
Adjustments for decrease/ (increase) in trade accounts receivable		**39,089**	(39,089)
Adjustments for decrease/ (increase) in other operating receivables		**154,575**	(156,735)
Adjustments for (decrease)/ increase in trade accounts payable		**(344,236)**	363,115
Adjustments for increase in other operating payables		**46,134**	59,188
Adjustments for depreciation and amortisation expense		**10,626**	9,007
Total adjustments to reconcile surplus		**(838,860)**	(1,205,624)
Net cash flows from/ (used in) operations		**1,260,472**	(658,021)
Interest received		**745,048**	1,441,110
Net cash flows from operating activities		**2,005,520**	783,089
Cash flows used in investing activities			
Purchase of property, plant and equipment		**(34,781)**	
Cash flows used in investing activities		**(34,781)**	
Net increase in cash and cash equivalents		**1,970,739**	783,089
Cash and cash equivalents at beginning of the year		**18,809,978**	18,026,889
Cash and cash equivalents at end of the year	6	**20,780,717**	18,809,978

Accounting policies

1. General information

Coaltech Research Association NPC ('the non-profit company') promotes the communal and group interest by the development of technology and the application of research findings in the South African Coal Industry.

The non-profit company is incorporated as a Non-Profit Company and domiciled in South Africa. The address of its registered office is The Mining Precinct, Cnr Carlow and Rustenburg Road, Auckland Park, Gauteng, 2109.

2. Basis of preparation and summary of significant accounting policies

The financial statements of Coaltech Research Association NPC have been prepared in accordance with the IFRS for SMEs Accounting Standard as issued by the International Accounting Standards Board. The financial statements have been prepared under the historical cost convention. They are presented in South African Rand.

The preparation of financial statements in conformity with the IFRS for SMEs Accounting Standard as issued by the International Accounting Standards Board requires the use of certain critical accounting estimates. It also requires management to exercise its judgement in the process of applying the non-profit company's accounting policies. The areas involving a higher degree of judgement or complexity, or areas where assumptions and estimates are significant to the financial statements are disclosed in note 3.

The principal accounting policies applied in the preparation of these financial statements are set out below. These policies have been consistently applied to all the years presented, unless otherwise stated.

2.1 Property, plant and equipment

Property, plant and equipment is stated at historical cost less accumulated depreciation and any accumulated impairment losses. Historical cost includes expenditure that is directly attributable to bringing the asset to the location and condition necessary for it to be capable of operating in the manner intended by the directors.

Asset class	Useful life/ depreciation rate
Machinery	5 years
Office furniture	5 years
Computer equipment	3 years
Computer software	2 years
Equipment	2 - 5 years

The assets' residual values, useful lives and depreciation methods are reviewed, and adjusted prospectively if appropriate, if there is an indication of a significant change since the last reporting date.

An asset's carrying amount is written down immediately to its recoverable amount if the asset's carrying amount is greater than its estimated recoverable amount.

Gains and losses on disposals are determined by comparing the proceeds with the carrying amount and are recognised within 'other gains/ (losses)' in the statement of comprehensive income.

Accounting policies

2.2 Financial instruments

Trade and other receivables

Trade receivables are recognised initially at the transaction price. They are subsequently measured at amortised cost using the effective interest method, less provision for impairment. A provision for impairment of trade receivables is established when there is objective evidence that the non-profit company will not be able to collect all amounts due according to the original terms of the receivables.

Cash and cash equivalents

Cash and cash equivalents includes cash on hand, demand deposits and other short-term highly liquid investments with original maturities of three months or less. Bank overdrafts are shown in current liabilities on the statement of financial position.

Trade and other payables

Trade payables are recognised initially at the transaction price and subsequently measured at amortised cost using the effective interest method.

2.3 Revenue

Revenue is measured at the fair value of the consideration received or receivable by the members as stated in the memorandum of agreement net of value added tax.

Interest income is recognised using the effective interest method.

2.4 Income in advance

Income received in advance is deducted from gross revenue to arrive at the net revenue and is treated as a liability at year end, as this amount has been received but the related expenses have not yet been incurred.

3. Critical accounting estimates and judgements

Estimates and judgements are continually evaluated and are based on historical experience and other factors, including expectations of future events that are believed to be reasonable under the circumstances.

No significant estimates and adjustments have been applied in the preparation of these financial statements.

Notes to the annual financial statements

4. Property, plant and equipment

Balances at year end and movements for the year

	Machinery	Fixtures and fittings	Computer equipment	Computer software	Total
Reconciliation for the year ended 31 March 2025					
Balance at 1 April 2024					
At cost	18,780,927	2,865	179,687	99,475	**19,062,954**
Accumulated depreciation	(18,780,926)	(2,029)	(179,687)	(99,474)	**(19,062,116)**
Carrying amount	1	836		1	**838**
Movements for the year ended 31 March 2025					
Additions from acquisitions			34,781		**34,781**
Depreciation			(10,626)		**(10,626)**
Property, plant and equipment at the end of the year	1	836	24,155	1	**24,993**
Closing balance at 31 March 2025					
At cost	18,780,927	2,865	214,468	99,475	**19,097,735**
Accumulated depreciation	(18,780,927)	(2,029)	(190,312)	(99,474)	**(19,072,742)**
Carrying amount		836	24,156	1	**24,993**
Reconciliation for the year ended 31 March 2024					
Balance at 1 April 2023					
At cost	18,780,927	2,865	179,687	99,475	**19,062,954**
Accumulated depreciation	(18,780,926)	(2,029)	(171,156)	(99,474)	**(19,053,585)**
Carrying amount	1	836	8,531	1	**9,369**
Movements for the year ended 31 March 2024					
Depreciation			(8,531)		**(8,531)**
Property, plant and equipment at the end of the year	1	836		1	**838**
Closing balance at 31 March 2024					
At cost	18,780,927	2,865	179,687	99,475	**19,062,954**
Accumulated depreciation	(18,780,926)	(2,029)	(179,686)	(99,475)	**(19,062,116)**
Carrying amount	1	836	1	-	**838**

Notes to the annual financial statements

		2025 R	2024 R
5.	**Trade and other receivables**		
	Trade receivables		39,089
	Value added tax	**32,771**	187,345
		32,771	226,434
6.	**Cash and cash equivalents**		
	Cash and cash equivalents included in current assets:		
	Cash		
	Balances with banks	**20,780,717**	18,809,978
	Cash and cash equivalents		
	ABSA Current account	**1,343,388**	1,251,807
	ABSA Depositor Plus	**123,301**	115,254
	Credit card		
	ABSA Aims investment		
	- Market value - B/fwd	**17,442,917**	15,885,514
	- Reinvestment net of charges	**1,389,938**	1,205,415
	- Redemption - net		
	- Unrealised gain/(loss) on revaluation of investment	**481,172**	351,988
	- Market value		
		19,314,028	17,442,917
		20,780,717	**18,809,978**
7.	**Reserves**		
	No reserves are distributable to the members and on liquidation of the company any remaining reserves must be transferred to a company with similar objectives.		
8.	**Revaluation Reserve**		
	Revaluation reserve - ABSA Aims Investment		
	- Balance B/fwd	**934,939.00**	582,951.00
	- Unrealised gain/(loss)	**481,172.12**	351,988.00
		1,416,111	934,939

Notes to the annual financial statements

		2025 R	2024 R
9.	**Trade and other payables**		
	Trade and other payables comprise:		
	Research project accruals	**4,267,255**	4,611,491
	Sundry accruals	**167,490**	131,436
	Credit card liability	**10,080**	
	Total trade and other payables	**4,444,825**	4,742,927
10.	**Director's emoluments**		
	- Executive		
	- Remuneration for managerial services	**3,102,794**	1 837 360
11.	**Operating expenses**		
	Operational expenses comprise:		
	Accounting fees	**172,435**	121,476
	Advertising	**94,832**	29,476
	Annual report		
	Auditors remuneration-fees	**36,236**	16,000
	- current year	**95,043**	77,493
	Bank charges	**6,626**	4,535
	Computer expenses	**48,409**	29,949
	Conference and functions	**236,624**	92,288
	Consulting		500
	Depreciation	**10,626**	9,008
	Employee and related costs (note 10)	**3,490,148**	2,380,026
	Insurance	**15,730**	14,771
	Interest and penalties	**18,299**	
	Legal Expenses	**28,078**	4,418
	Office running costs		6,581
	Printing, stationery and postage	**5,102**	9,364
	Investment management fees	**136,172**	142,647
	Research costs	**6,106,762**	6,894,185
	Subscriptions	**40,694**	9,301
	Telephone and fax	**15,587**	25,050
	Travelling expenses - local	**28,320**	52,837
	Website costs	**79,124**	4,438
	Total operating expenses	**10,756,988**	9,924,343

Notes to the annual financial statements

		2025 R	2024 R
10.	**Interest received**		
	Interest received comprises:		
	Interest received	**745,048**	1,441,110
	Total finance income	**745,048**	1,441,110

13. Taxation

The company has been approved as a Public Benefit Organisation in terms of section 30 of the Income Tax Act, and the receipts and accruals are exempt from income tax in terms of section lO(l)(cN) of the Income Tax Act.

14. Events after the reporting date

The directors are not aware of any matter or circumstance arising since the end of the financial year to the date of this report that could have a material effect on the financial position of the non-profit company.

15. Going concern

The annual financial statements have been prepared on the basis of accounting policies applicable to a going concern. This basis presumes that funds will be available to finance future operations and that the realisation of assets and settlement of liabilities, contingent obligations and commitments will occur in the ordinary course of business.

The directors believe that the non-profit company has adequate financial resources to continue in operation for the foreseeable future and accordingly the annual financial statements have been prepared on a going concern basis.

The directors are not aware of any new material changes that may adversely impact the non-profit company. The directors are also not aware of any material non-compliance with statutory or regulatory requirements or of any pending changes to legislation which may affect the non-profit company.

16. Approval of the annual financial statements

The financial statements were approved by the board of directors and authorised for issue on 3 July 2025.

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