INAUGURAL ADDRESS

Prof HG Brink

7 October 2025

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Closing the Loop: Waste Valorisation as the Pattern for Sustainable Innovation

Inaugural Address – Prof HG Brink
Department of Chemical Engineering, University of Pretoria
7 October 2025

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1. Introduction: A Golden Thread

Weaving Purpose into Research

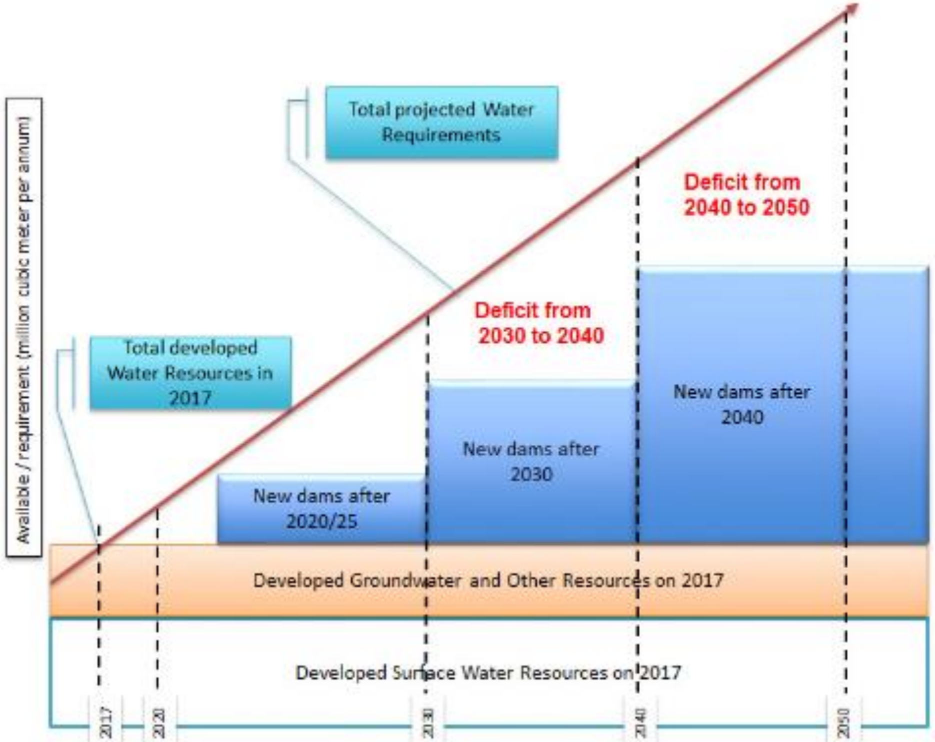
Why am I personally doing this research?

"Be part of the solution and not part of the problem"

1. Introduction: A Golden Thread

Weaving Purpose into Research

Why should we be doing this?



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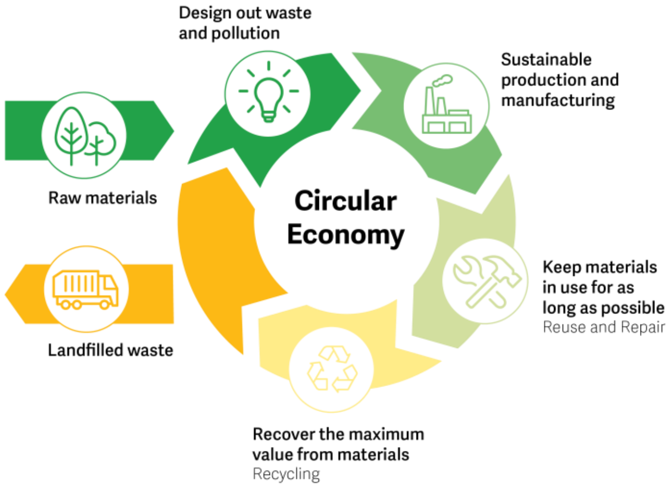
1. Introduction: A Golden Thread

Weaving Purpose into Research

How?

“How can waste be reimagined as a resource?”



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1. Introduction: A Golden Thread

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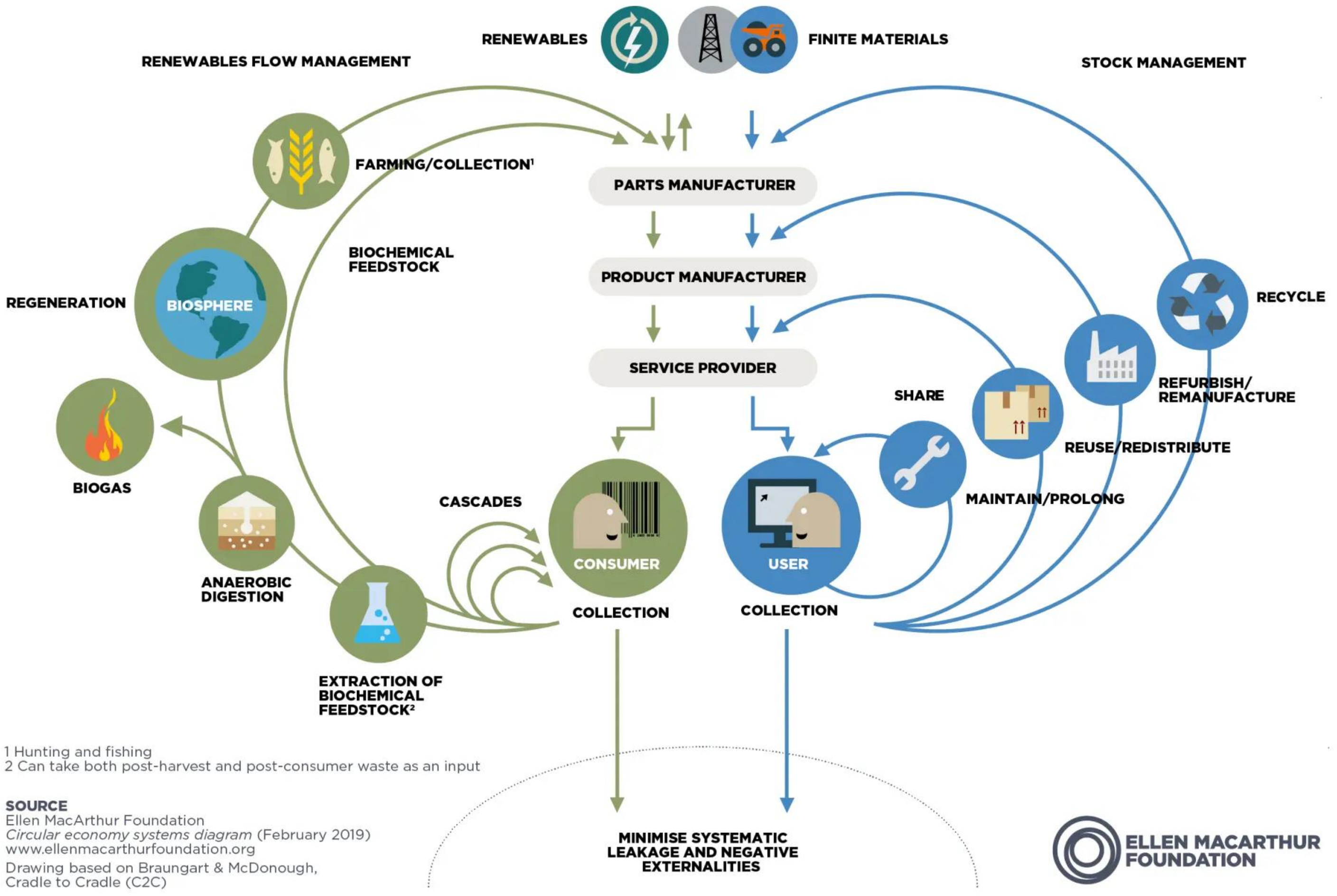

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1. Introduction: A Golden Thread

Weaving Purpose into Research

💧 **SDG 6** – *Clean Water and Sanitation*
(e.g. Bioremediation, pollutant removal, AMD treatment)

⚙️ **SDG 9** – *Industry, Innovation, and Infrastructure*
(e.g. Advanced materials, industrial valorisation of waste)

♻️ **SDG 12** – *Responsible Consumption and Production*
(e.g. Circular systems, bio-based technologies)

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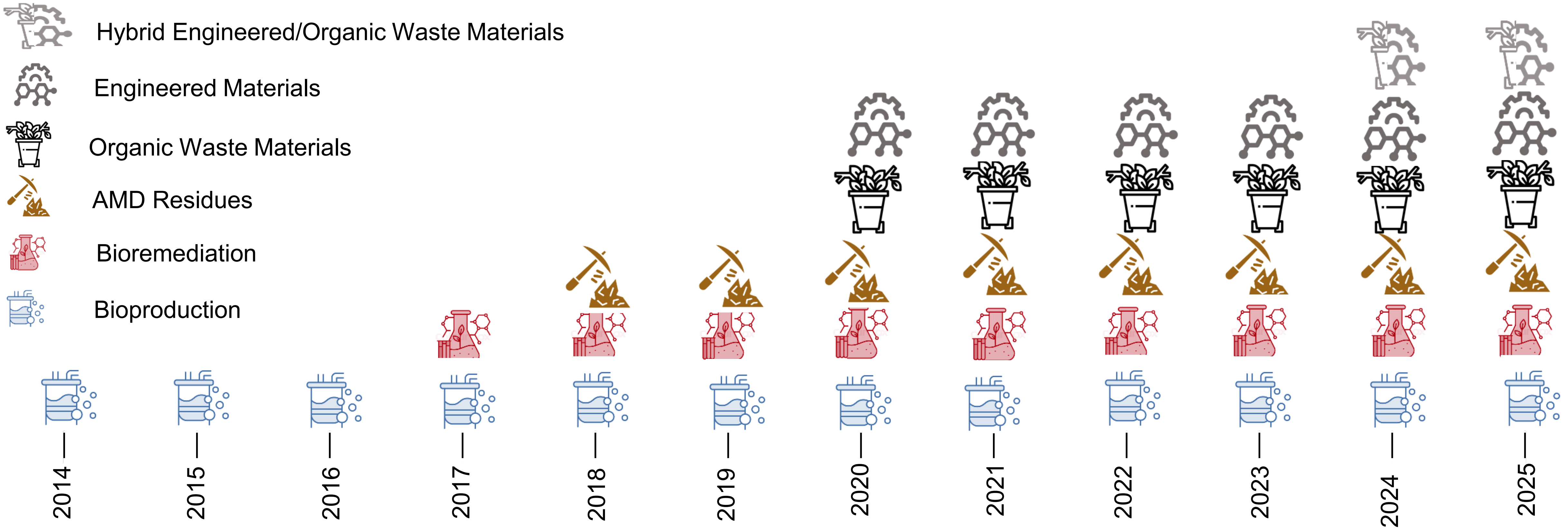
Weaving Innovation:
A timeline of Research Threads



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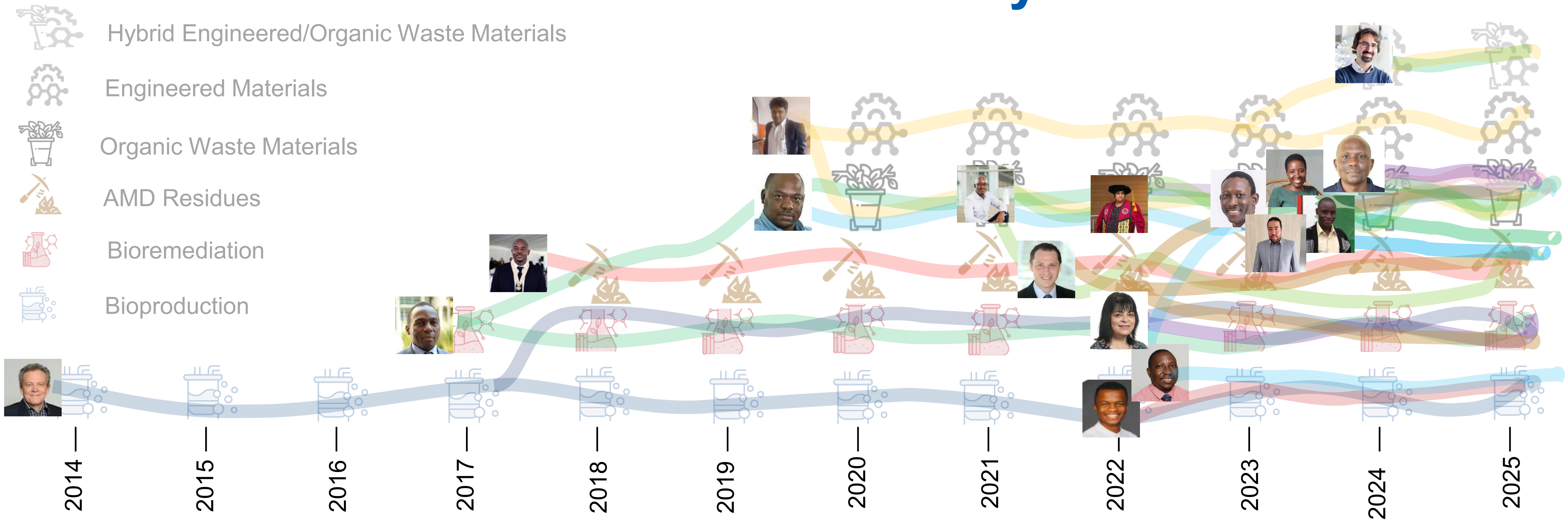
Weaving Innovation:
Collaborations for Shared Discovery



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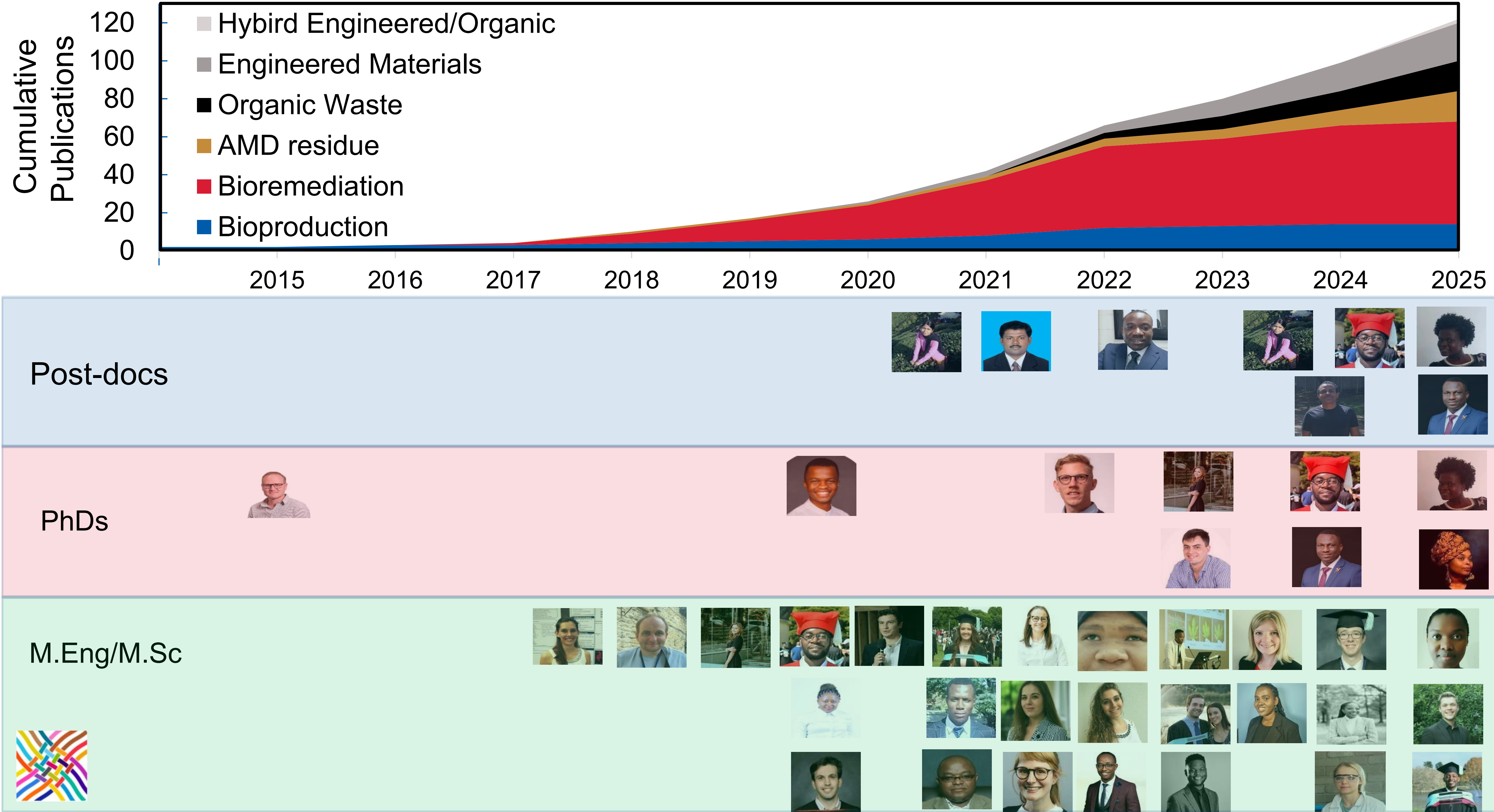

Cumulative Publications
120
100
80
60
40
20
0
Hybird Engineered/Organic
Engineered Materials
Organic Waste
AMD residue
Bioremediation
Bioproduction
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Post-docs
PhDs
M.Eng/M.Sc

Thread 1: Bioproduction









RESEARCH PAPER New Biotechnology • Volume 31, Number 5 • September 2014
ELSEVIER

The influence of shear on the metabolite yield of *Lactobacillus rhamnosus* biofilms

Hendrik Gideon Brink and Willie Nicol
University of Pretoria, Department of Chemical Engineering, Lynnwood Road, Hatfield, Pretoria 0002, South Africa

Brink and Nicol *Microbial Cell Factories* 2014, **13**:111
http://www.microbialcellfactories.com/content/13/1/111
MICROBIAL CELL FACTORIES
RESEARCH Open Access

Succinic acid production with *Actinobacillus succinogenes*: rate and yield analysis of chemostat and biofilm cultures

Hendrik Gideon Brink and Willie Nicol*

fermentation MDPI
Article

***Rhizopus oryzae* for Fumaric Acid Production: Optimising the Use of a Synthetic Lignocellulosic Hydrolysate**

Reuben Marc Swart, Hendrik Brink and Willie Nicol *

Original Article
Biofpr Biofuels Bioproducts & Biorefining

Malic acid production by *Aspergillus oryzae*: the immobilized fungal fermentation route

Hendrik G. Brink, Monique Geyer-Johnson, Reuben M. Swart, Willie Nicol, Department of Chemical Engineering, University of Pretoria, Pretoria, South Africa

Bioprocess and Biosystems Engineering (2020) 43:1253–1263
https://doi.org/10.1007/s00449-020-02322-8
RESEARCH PAPER
Check for updates

Effect of shear on morphology, viability and metabolic activity of succinic acid-producing *Actinobacillus succinogenes* biofilms

Sekgetho Charles Mokwatlo[1] · Hendrik Gideon Brink[1] · Willie Nicol[1]

Chemical Engineering Journal 407 (2021) 127220
Contents lists available at ScienceDirect
Chemical Engineering Journal
journal homepage: www.elsevier.com/locate/cej
ELSEVIER

Internal mass transfer considerations in biofilms of succinic acid producing *Actinobacillus succinogenes*

Sekgetho Charles Mokwatlo, Willie Nicol, Hendrik Gideon Brink *
Department of Chemical Engineering, University of Pretoria, Lynnwood Road, Hatfield 0002, Pretoria, South Africa

catalysts MDPI
Article

Identifying Energy Extraction Optimisation Strategies of *Actinobacillus succinogenes*

Waldo Gideon Lexow, Sekgetho Charles Mokwatlo, Hendrik Gideon Brink and Willie Nicol *

Applied Microbiology and Biotechnology
https://doi.org/10.1007/s00253-019-09888-8
APPLIED MICROBIAL AND CELL PHYSIOLOGY
Check for updates

Impact of metabolite accumulation on the structure, viability and development of succinic acid–producing biofilms of *Actinobacillus succinogenes*

Sekgetho Charles Mokwatlo[1] · Makhine Ernest Nchabeleng[1] · Hendrik Gideon Brink[1] · Willie Nicol[1]

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Article

The Effect of pH, Metal Ions, and Insoluble Solids on the Production of Fumarate and Malate by *Rhizopus delemar* in the Presence of $CaCO_3$

Dominic Kibet Ronoh, Reuben Marc Swart, Willie Nicol and Hendrik Brink *

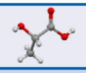
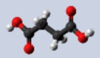
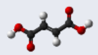
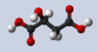
Thread 1: Bioproduction

Bioproduction of Organic Acids from Renewable Feedstocks

Why Produce Organic Acids?

Platform Organic Acids: Building Blocks for a Sustainable Bioeconomy

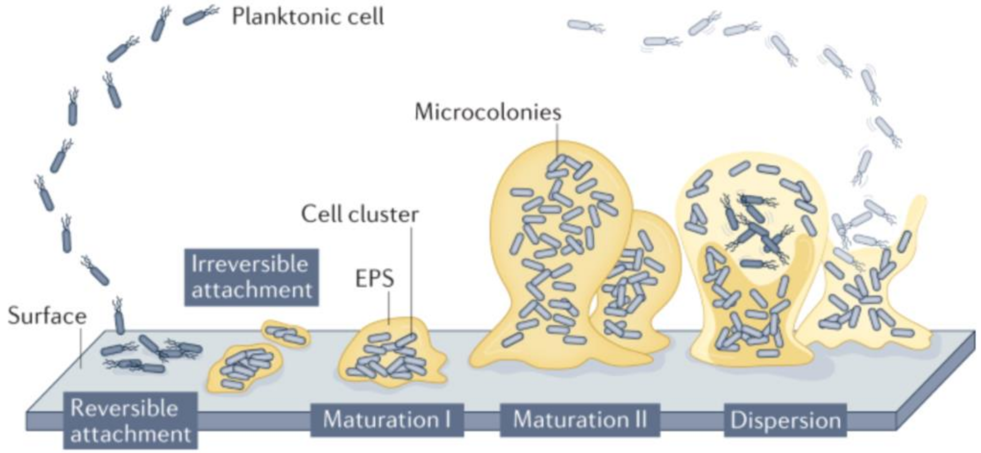
Purpose: These C_4 (and C_3) dicarboxylic acids are *key platform chemicals* – central to both **biobased chemical industries** and **green material production**.

Lactic	Monomer for PLA (polylactic acid) – a leading biodegradable plastic	
Succinic	Precursor for 1,4-butanediol (solvents, plastics), biodegradable polyesters (PBS)	
Fumaric	Food additive, alkyd resins, crosslinking agents, pharmaceutical precursors	
Malic	Acidulant in food and beverages, precursor to specialty chemicals	

Thread 1: Bioproduction

Bioproduction of Organic Acids from Renewable Feedstocks

- **Goal:** Produce platform chemicals (lactic, succinic, fumaric, malic acids) from glucose or waste-derived substrates.
- **Microorganisms used:**
  - *Lactobaccillus rhamnosus – Lactic acid*
  - *Actinobacillus succinogenes* – Succinic acid
  - *Rhizopus oryzae/delemar* – Fumaric acid
  - *Aspergillus oryzae* – Malic acid



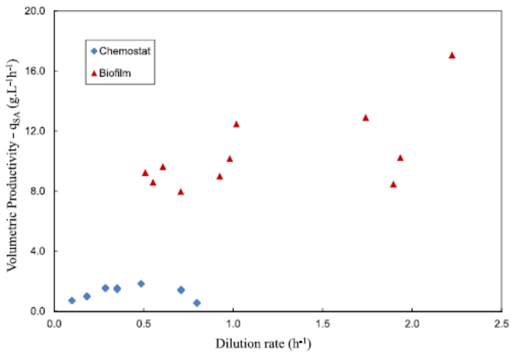
- **Approach:** Shift from free-cell to immobilised/biofilm systems for higher stability, yield, and process control.

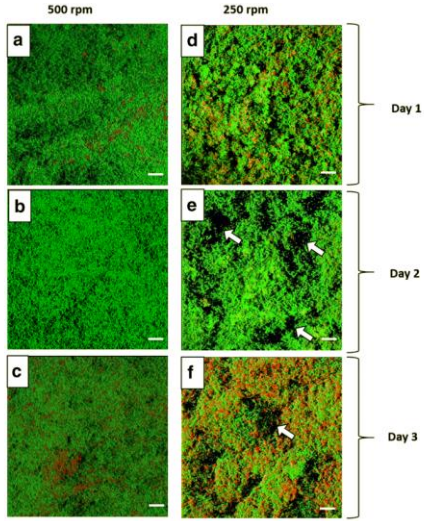
Thread 1: Bioproduction

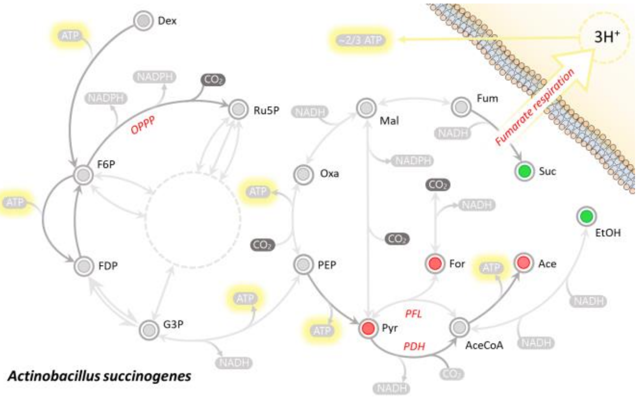
Bioproduction of Organic Acids from Renewable Feedstocks

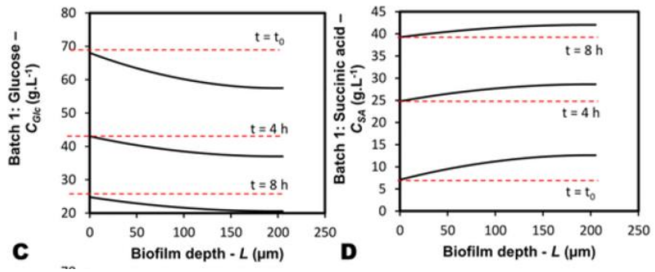
Highlights:

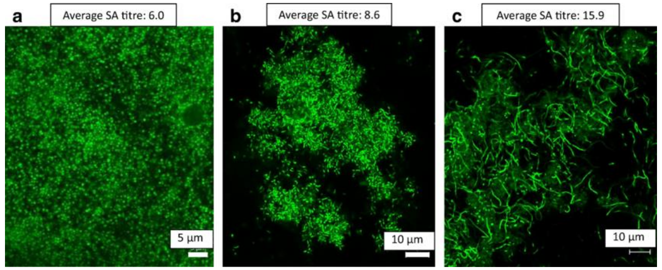
- **Succinic acid** (*A. succinogenes*):
  - Biofilm reactors increase tolerance to shear and improve yields.
  - Internal mass transfer limitations and metabolite accumulation are critical control points.
  - Pathway analysis reveals strategies for enhanced energy recovery.











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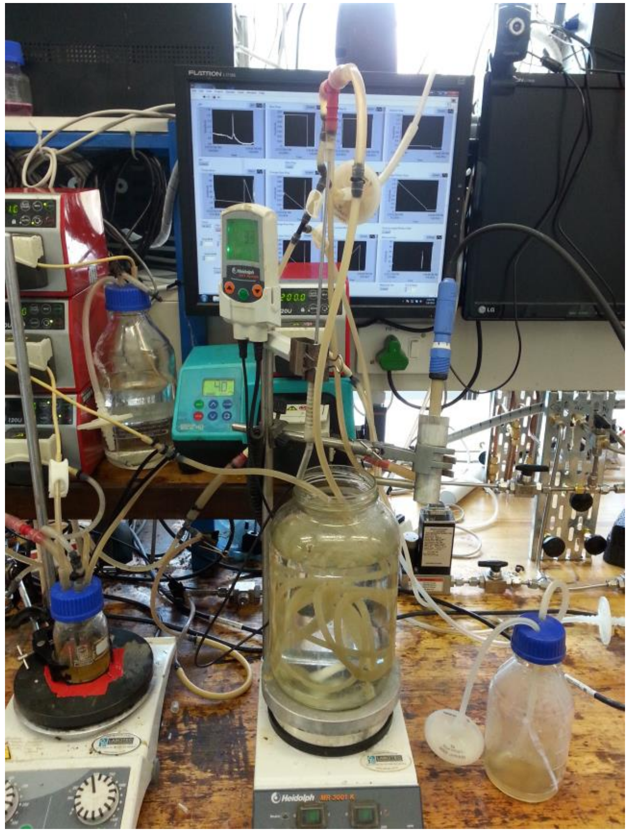
Thread 1: Bioproduction

Bioproduction of Organic Acids from Renewable Feedstocks

Highlights:

- **Lactic acid (*L. rhamnosus*)**
  - **Silicone tubing-based biofilm reactor** enabled robust, stable lactic acid production under continuous flow and low pH, showcasing a simple and effective design.
  - **Shear rate had a significant impact** — moderate shear enhanced metabolite yield, while excessive shear led to biofilm detachment and decreased productivity.
  - Achieved a **maximum lactic acid yield of 0.88 g/g glucose**, demonstrating high efficiency with potential for industrial-scale bioproduction.



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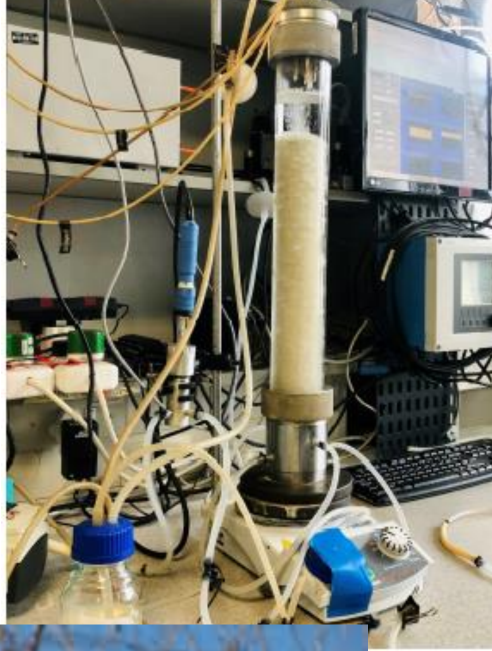
Thread 1: Bioproduction

Bioproduction of Organic Acids from Renewable Feedstocks

Highlights:

- **Fumaric acid** (*Rhizopus delemar*):
  - **Continuous immobilised systems** show strong performance with both glucose and glucose/xylose mixtures (simulating lignocellulosic biomass)
- **Malic acid** (*Aspergillus oryzae*):
  - **Immobilised Fungal System**: *Aspergillus oryzae* immobilised in polyurethane foam enabled robust malic acid production from glucose under controlled pH and nutrient-limited conditions.
  - **Ion Effects and Environmental Mimicry**: **Calcareous conditions** ($CaCO_3$ addition) were essential for optimal production, likely reflecting the fungus's natural habitat. In contrast, **Na^+ ions inhibited glucose uptake**, reducing productivity.



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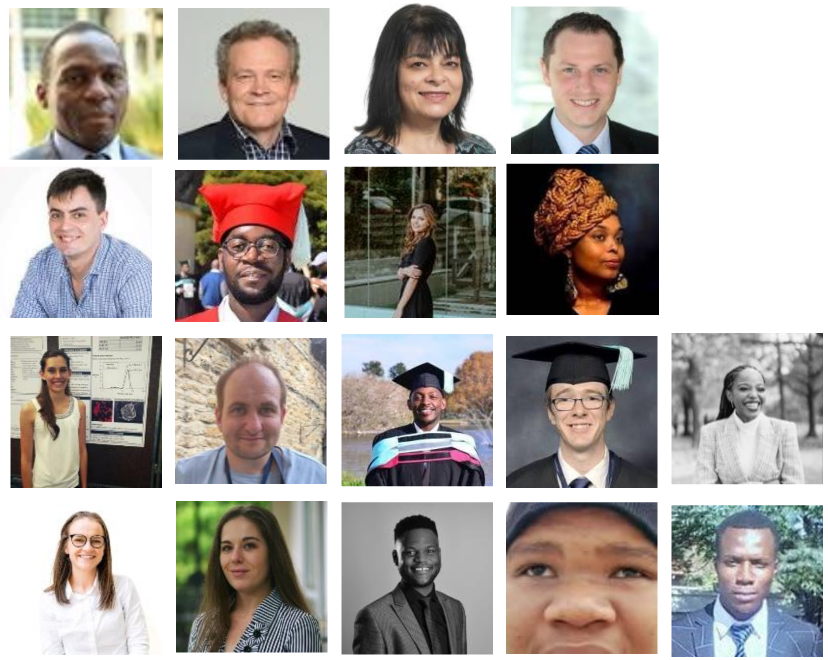
Thread 2: Bioremediation



International Journal of Environmental Science and Technology
https://doi.org/10.1007/s13762-019-02502-4

ORIGINAL PAPER

Microbial Pb(II)-precipitation: the influence of oxygen on Pb(II)-removal from aqueous environment and the resulting precipitate identity

H. G. Brink[1] · C. Hörstmann[1] · J. Peens[1]

International Journal of Molecular Sciences — MDPI

Article

Microbial Precipitation of Pb(II) with Wild Strains of *Paraclostridium bifermentans* and *Klebsiella pneumoniae* Isolated from an Industrially Obtained Microbial Consortium

Olga Neveling, Thato M. C. Ncube, Ziyanda P. Ngxongo, Evans M. N. Chirwa and Hendrik G. Brink *

sustainability — MDPI

Article

Pb(II) Bio-Removal, Viability, and Population Distribution of an Industrial Microbial Consortium: The Effect of Pb(II) and Nutrient Concentrations

Carla Hörstmann, Hendrik G. Brink * and Evans M.N. Chirwa

plants — MDPI

Article

Optimal Growth Conditions for *Azolla pinnata* R. Brown: Impacts of Light Intensity, Nitrogen Addition, pH Control, and Humidity

Maria Emelia Jesus da Silva, Lebani Oarabile Joy Mathe, Ignatius Leopoldus van Rooyen, Hendrik Gideon Brink and Willie Nicol *

catalysts — MDPI

Article

Microbial Removal of Pb(II) Using an Upflow Anaerobic Sludge Blanket (UASB) Reactor

Jeremiah Chimhundi [1,2,3], Carla Hörstmann [3], Evans M. N. Chirwa [3] and Hendrik G. Brink [3,*]

Journal of Cleaner Production 374 (2022) 133973

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Microbial Pb(II)-bioprecipitation: Characterising responsible biotransformation mechanisms

Carla Cilliers, Olga Neveling, Shepherd M. Tichapondwa, Evans M.N. Chirwa, Hendrik G. Brink *

plants — MDPI

Article

Online Control of *Lemna minor* L. Phytoremediation: Using pH to Minimize the Nitrogen Outlet Concentration

Kwanele Sigcau, Ignatius Leopoldus van Rooyen, Zian Hoek, Hendrik Gideon Brink and Willie Nicol *

molecules — MDPI

Article

Insight into the Metabolic Profiles of Pb(II) Removing Microorganisms

Carla Cilliers, Evans M. N. Chirwa and Hendrik G. Brink *

sensors — MDPI

Article

Non-Destructive Impedance Monitoring of Bacterial Metabolic Activity towards Continuous Lead Biorecovery

George Andrews [1,*], Olga Neveling [2], Dirk Johannes De Beer [1], Evans M. N. Chirwa [2], Hendrik G. Brink [2] and Trudi-Heleen Joubert [1]

catalysts — MDPI

Article

Performance Evaluation of Selenite (SeO_3^{2-}) Reduction by *Enterococcus* spp.

Job T. Tendenedzai, Evans M. N. Chirwa and Hendrik G. Brink *

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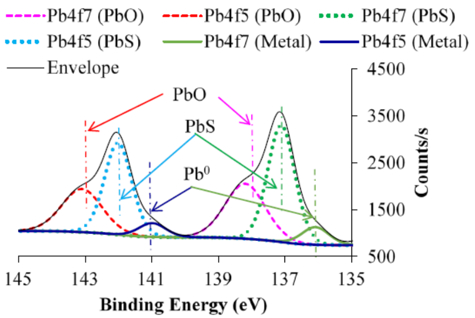
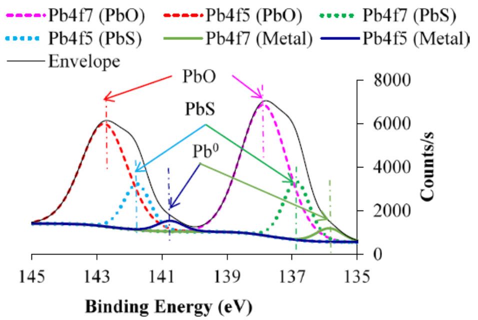
Thread 2: Bioremediation

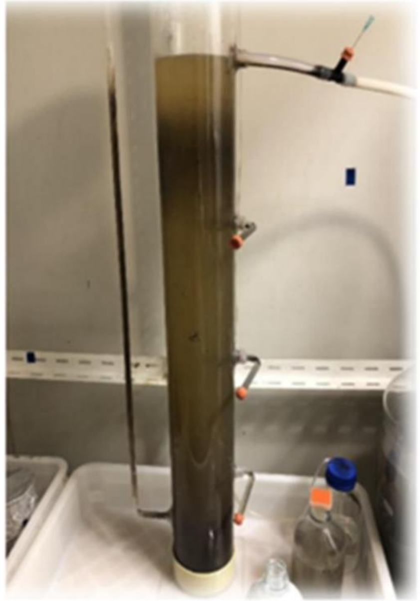




Microbial Bioremediation of Lead (Pb^{2+})

Highlights:

- **Anaerobic, aerobic, and facultative systems** were explored using mixed and pure cultures for Pb(II) removal from wastewater.
- **Precipitation & biosorption** were identified as dominant mechanisms—often involving Pb^0, Pb0, Pb-phosphate, Pb-sulphide formations depending on microbial species and redox conditions.
- Key strains: *Paraclostridium bifermentans*, *Klebsiella pneumoniae*, and *Pseudomonas sp.* showed strong Pb-tolerance (>1000 ppm) and removal capacity (up to 99%) in both batch and continuous systems (e.g. UASB).

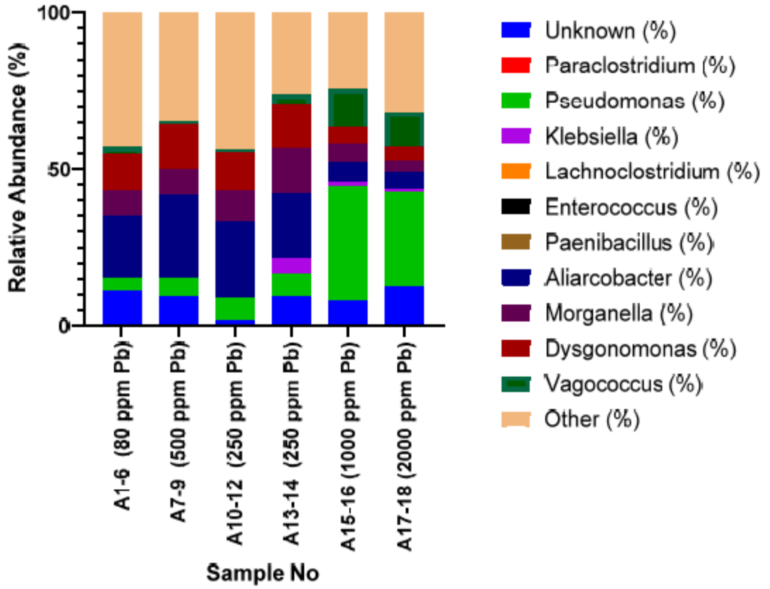


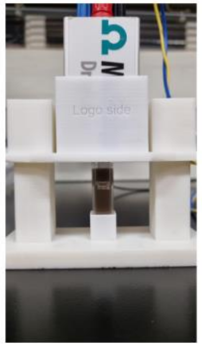
Thread 2: Bioremediation

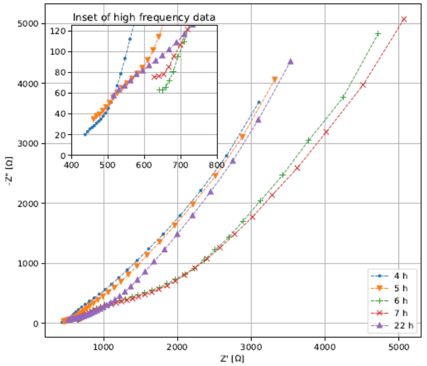
Insights into Mechanisms & Process Control

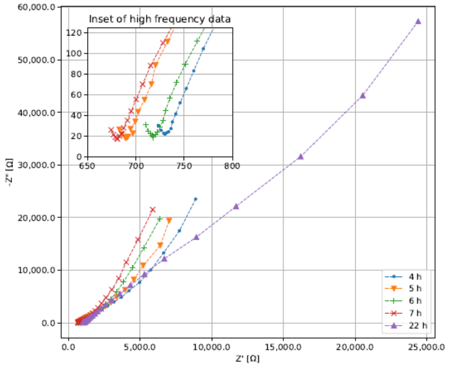
Highlights:

- **Metabolomic profiling** revealed shifts in amino acids, fatty acids, and secondary metabolites under Pb stress—suggesting metabolic adaptation and bio-precipitation linkage.
- **Oxygen presence** significantly influenced Pb speciation and microbial community structure; strict control was needed to direct towards bioprecipitation rather than sorption alone.
- **Monitoring innovations:** Impedance-based biosensors provided real-time tracking of metabolic activity during Pb recovery—enabling potential for continuous bioremediation control.









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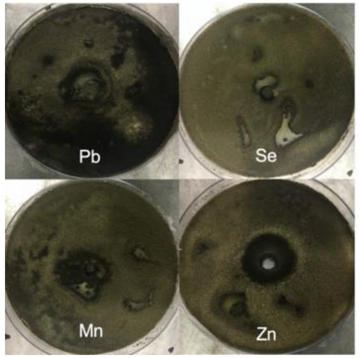
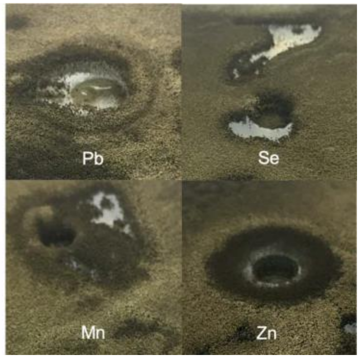
Thread 2: Bioremediation

Expanding the Toolkit – Plants, Consortia, and Control

Highlights:

- **Phytoremediation** with *Lemna minor* and *Azolla pinnata* demonstrated pH- and nitrogen-sensitive growth, offering low-cost polishing stages after microbial treatment.
- **Mycoremediation** with Aspergillus spp can remove heavy metals and degradation byproducts after treatment





Thread 3: AMD Residues






Journal of Radiation Research and Applied Sciences 18 (2025) 101528

Contents lists available at ScienceDirect

Journal of Radiation Research and Applied Sciences

journal homepage: www.journals.elsevier.com/journal-of-radiation-research-and-applied-sciences

Radioactivity distribution in soil, rock and tailings at the Geita Gold Mine in Tanzania

Jerome M. Mwimanzi[a,b], Nils H. Haneklaus[a,c,d,*], Tomislav Bituh[e], Hendrik Brink[f], Katarzyna Kiegiel[g], Farida Lolila[h], Janeth J. Marwa[a,i], Mwemezi J. Rwiza[a], Kelvin M. Mtei[a]

Resources, Conservation & Recycling 207 (2024) 107694

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Review

Rare earth elements and uranium in Minjingu phosphate fertilizer products: Plant food for thought

Nils H. Haneklaus[a,b,*], Dennis A. Mwalongo[a,c], Jacob B. Lisuma[d], Aloyce I. Amasi[a,c], Jerome Mwimanzi[a,c], Tomislav Bituh[e], Jelena Ćirić[f], Jakub Nowak[g], Urszula Ryszko[h], Piotr Rusek[h], Ali Maged[i,j], Essaid Bilal[k], Hajar Bellefqih[k], Khaoula Qamouche[b], Jamal Ait Brahim[l], Redouane Beniazza[l], Hamid Mazouz[m], Elizabet M. van der Merwe[n], Wayne Truter[o], Hilda D. Kyomuhimbo[p], Hendrik Brink[p], Gerald Steiner[b,q], Martin Bertau[r,s], Raghav S. Soni[t], Ashwin W. Patwardhan[t], Pushpito K. Ghosh[t], Thomas T. Kivevele[a], Kelvin M. Mtei[a], Stanisław Wacławek[u]

Journal of Hazardous Materials 414 (2021) 125491

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

Effective removal of arsenate from wastewater using aluminium enriched ferric oxide-hydroxide recovered from authentic acid mine drainage

K.L. Muedi[a], H.G. Brink[a,*], V. Masindi[b], J.P. Maree[c]

sustainability MDPI

Article

Facile Recovery of Polycationic Metals from Acid Mine Drainage and Their Subsequent Valorisation for the Treatment of Municipal Wastewater

Khathutshelo Lilith Muedi[1], Job Tatenda Tendenedzai[1], Vhahangwele Masindi[2], Nils Hendrik Haneklaus[3,4,*] and Hendrik Gideon Brink[1,*]

Discover Sustainability

Research

The phosphorus negotiation game (P-Game): first evaluation of a serious game to support science-policy decision making played in more than 20 countries worldwide

Nils Haneklaus[1,37,38] · Mary Kaggwa[2] · Jane Misihairabgwi[3] · Sherif Abu El-Magd[4] · Naima Ahmadi[5] · Jamal Ait Brahim[6] · Aloyce Amasi[7] · Andrea Balláné Kovács[9] · Łukasz Bartela[10] · Hajar Bellefqih[11] · Redouane Beniazza[6] · Jaroslav Bernas[12] · Essaid Bilal[11] · Tomislav Bituh[13] · Yelizaveta Chernysh[14,15] · Viktoriia Chubur[14] · Jelena Ćirić[16] · Claudia Dolezal[17] · Andrea Figulová[18] · Janja Filipi[19] · Gordana Glavan[20] · Tibor Guzsvinecz[21] · László Horváth[22] · Sasho Josimovski[23] · Martin Kiselicki[23] · Maja Lazarus[13] · Maja Kazazić[24] · István Komlósi[9,39] · Ali Maged[4] · Tebogo Mashifana[25] · Gordana Medunić[26] · Emina Mehić[24] · Felhi Mongi[5] · Kelvin Mtei[7] · Dennis Mwalongo[7,8] · Jerome Mwimanzi[7,8] · Jakub Nowak[27] · Oqba Basal[39] · Khaoula Qamouche[1] · Małgorzata Rajfur[28] · Hynek Roubík[14] · Mijalche Santa[23] · Cecília Sik-Lányi[22] · Maike Sippel[29] · Gerald Steiner[1,30] · Anna Skorek-Osikowska[10] · Anton Slavov[31] · Paweł Świsłowski[28] · Ali Tlili[5] · Kalina Trenevska-Blagoeva[23] · Ivan Tschalakov[32] · Tomáš Vlček[33] · Stanisław Wacławek[34] · Ivan Zlatanović[35] · Matúš Mišík[40] · Hendrik Brink[36] · Tzong-Ru Lee[37]

nanomaterials MDPI

Article

Effective Adsorption of Congo Red from Aqueous Solution Using Fe/Al Di-Metal Nanostructured Composite Synthesised from Fe(III) and Al(III) Recovered from Real Acid Mine Drainage

Khathutshelo Lilith Muedi[1], Vhahangwele Masindi[2,3], Johannes Philippus Maree[4], Nils Haneklaus[5,6] and Hendrik Gideon Brink[1,*]

Journal of Xenobiotics MDPI

Article

Coal Fly Ash-Based Adsorbents for Tetracycline Removal: Comparative Insights into Modification and Zeolite Conversion

Eric E. Houghton[1], Litha Yapi[1], Nils Haneklaus[2,3], Hendrik G. Brink[1] and Shepherd M. Tichapondwa[1,*]

minerals MDPI

Article

Rapid Removal of Cr(VI) from Aqueous Solution Using Polycationic/Di-Metallic Adsorbent Synthesized Using Fe^{3+}/Al^{3+} Recovered from Real Acid Mine Drainage

Khathutshelo Lilith Muedi[1], Vhahangwele Masindi[2,3], Johannes Philippus Maree[4] and Hendrik Gideon Brink[1,*]

Minerals Engineering 234 (2025) 109745

Contents lists available at ScienceDirect

Minerals Engineering

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

Hydrothermal synthesis of aragonite from acid mine drainage (AMD) of the Witwatersrand basin in Gauteng, South Africa

R.D.S. Khumalo, H.G. Brink, E.M.N. Chirwa[*]

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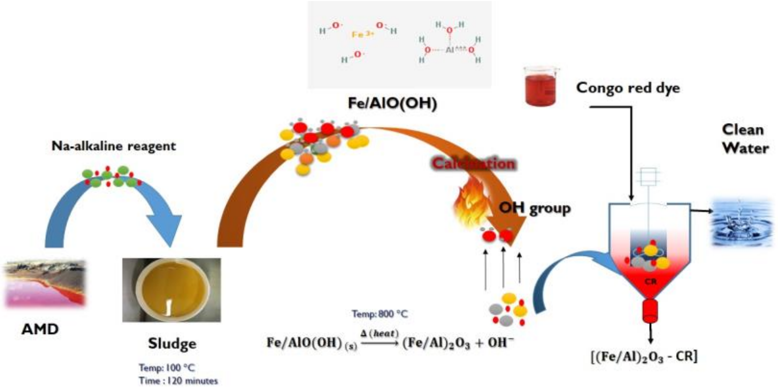
Thread 3: AMD Residues

Acid Mine Drainage (AMD): From Pollution to Potential

- **Challenge:** AMD is a persistent environmental issue rich in Fe^{3+}, Al^{3+}, and trace elements (e.g., REEs, U, Cr(VI)).
- **Approach:** Valorisation of AMD residues via metal recovery, nanocomposite synthesis, and reuse in pollutant removal.
- **Impact**: Enables **waste-to-resource transitions**, reducing AMD hazards while supporting **circular economy principles**.

🔍 *Case studies*:

- Cr(VI), arsenate, dye, and nutrient removal using **Fe_3Al_3 polycationic composites**
- Upcycled AMD by-products for industrial wastewater polishing.



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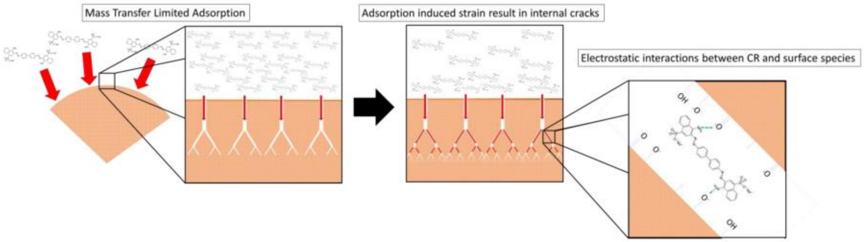
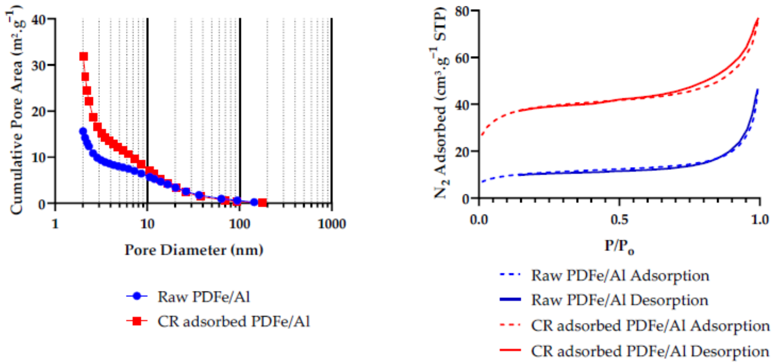
Thread 3: AMD Residues

From Mine Waste to Water Treatment and Beyond



- **Functional Adsorbents:** AMD-derived composites showed:
  - High surface area and reactivity
  - Superior removal of toxicants (As(V), Congo Red)
  - Effective performance in real-world waters
- **Broadened Scope**:
  - Fertiliser trace metal studies → REEs and uranium risk/potential
  - **Coal fly ash (CFA)** valorisation for **antibiotic removal** (tetracycline)



Thread 3: AMD Residues

Science-Policy Nexus and Systemic Reuse

- *The P-Game:* a serious game to facilitate stakeholder engagement on phosphorus circularity, linking environmental tech with governance
- **Vision**: Repurposing industrial residues (AMD, CFA) as key **feedstocks** in sustainable environmental technologies.

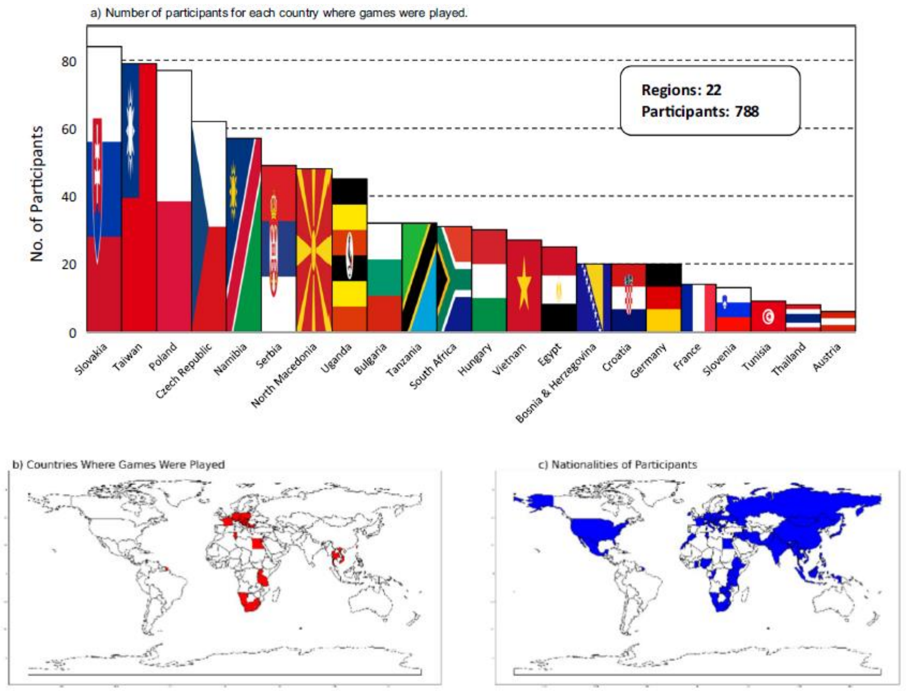


Fig. 6 **a** Number of participants in the games as well as countries where the game was played, **b** Geographic distribution of countries where games were played, **c** Geographic distribution nationalities of participants

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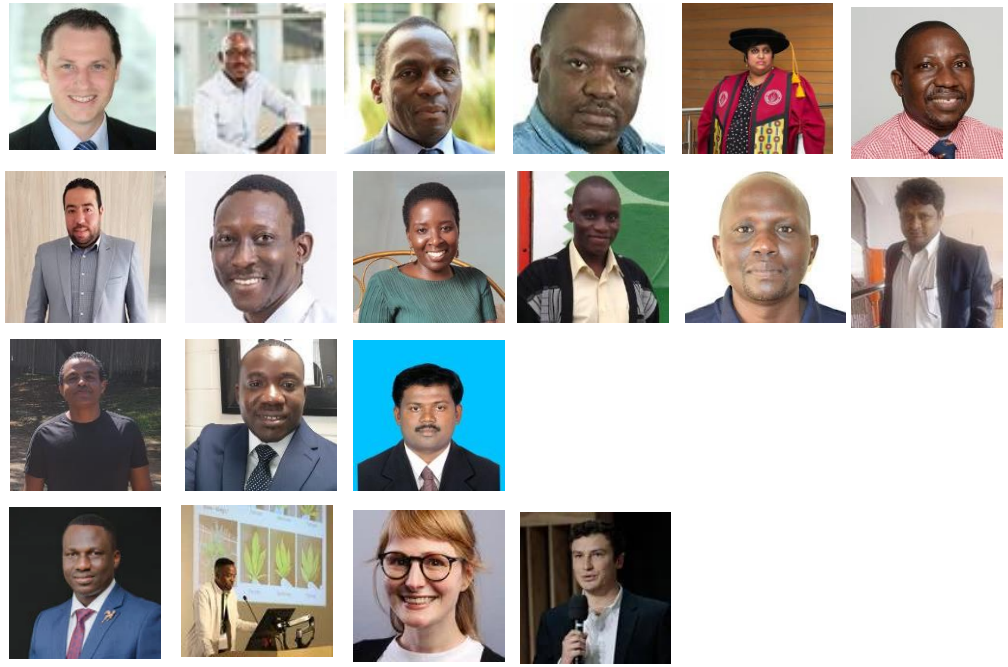
Thread 4: Organic Wastes



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Article

Lead Biosorption Characterisation of *Aspergillus piperis*

Maria Martha Marthina de Wet and Hendrik Gideon Brink *

Journal of Hazardous Materials 416 (2021) 125943

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

High capacity Pb(II) adsorption characteristics onto raw- and chemically activated waste activated sludge

B. van Veenhuyzen [1], S. Tichapondwa [2], C. Hörstmann [3], E. Chirwa [4], H.G. Brink [*,5]

RESEARCH ARTICLE Global Challenges www.global-challenges.com

Synthesis and Evaluation of 3D Nitrogen Doped Reduced Graphene Oxide (3D N@rGO) Macrostructure for Boosted Solar Driven Interfacial Desalination of Saline Water

*Fisseha A Bezza, Samuel A. Iwarere, Shepherd M. Tichapondwa, Hendrik G. Brink, Michael O. Daramola, and Evans MN Chirwa**

water MDPI

Article

Comparative Screening Study on the Adsorption of Aqueous Pb(II) Using Different Metabolically Inhibited Bacterial Cultures from Industry

Biomass Conversion and Biorefinery (2025) 15:12347–12367
https://doi.org/10.1007/s13399-024-05999-z

ORIGINAL ARTICLE

Sunlight-driven photocatalytic degradation of methylene blue using ZnO/biochar nanocomposite derived from banana peels

Prabakaran Eswaran[1] · Priya Dharshini Madasamy[2] · Kriveshini Pillay[3] · Hendrik Brink[1]

molecules MDPI

Article

Synthesis and Assessment of Antimicrobial Composites of Ag Nanoparticles or $AgNO_3$ and Egg Shell Membranes

Samuel Tomi Aina [1], Hilda Dinah Kyomuhimbo [1], Shatish Ramjee [1], Barend Du Plessis [1], Vuyo Mjimba [2], Ali Maged [3], Nils Haneklaus [4] and Hendrik Gideon Brink [1,*]

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CET CHEMICAL ENGINEERING TRANSACTIONS

VOL. 110, 2024

A publication of AIDIC The Italian Association of Chemical Engineering Online at www.cetjournal.it

Guest Editors: Marco Bravi, Antonio Marzocchella, Giuseppe Caputo
Copyright © 2024, AIDIC Servizi S.r.l.
ISBN 979-12-81206-10-6; ISSN 2283-9216

DOI: 10.3303/CET24110035

Mechanistic Modelling of the Adsorption of Aqueous Pb(II) by Metabolically Inhibited Bacterial Cultures from Industry

Hendrik G. Brink, Patrick Y. Kpai, Evans M.N. Chirwa

Biomass Conversion and Biorefinery (2024) 14:22703–22716
https://doi.org/10.1007/s13399-023-04702-y

ORIGINAL ARTICLE

Rose and lavender industrial by-products application for adsorption of Acid Orange 7 from aqueous solution

Gergana Marovska[1] · Mariya Dushkova[2] · Galena Angelova[3] · Mariya Brazkova[3] · Hendrik Brink[4] · Nils Haneklaus[5,6] · Nikolay Menkov[2] · Anton Slavov[1]

minerals MDPI

Article

Efficient Aqueous Copper Removal by Burnt Tire-Derived Carbon-Based Nanostructures and Their Utilization as Catalysts

Iviwe Cwaita Arunachellan [1,2], Madhumita Bhaumik [3], Hendrik Gideon Brink [3,*], Kriveshini Pillay [1] and Arjun Maity [2,3,*]

International Journal of *Molecular Sciences* MDPI

Article

Cytotoxic-Ag-Modified Eggshell Membrane Nanocomposites as Bactericides in Concrete Mortar

Samuel Tomi Aina [1], Hilda Dinah Kyomuhimbo [1], Barend Du Plessis [1], Vuyo Mjimba [2], Nils Haneklaus [3] and Hendrik Gideon Brink [1,*]

Journal of *Xenobiotics* MDPI

Article

Green Carbon Dots from Pinecones and Pine Bark for Amoxicillin and Tetracycline Detection: A Circular Economy Approach

Saheed O. Sanni [1,2], Ajibola A. Bayode [1,3], Hendrik G. Brink [2,*], Nils H. Haneklaus [4,5,*], Lin Fu [1], Jianping Shang [1] and Hua-Jun Shawn Fan [1]

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Thread 4: Organic Wastes

Circular Approaches with Organic Waste Materials

Key Concepts:

- **Waste-to-resource philosophy:** Transforming agricultural and food by-products into high-value adsorbents and functional materials.
- **Examples of valorised materials:**
  - Eggshell membranes
  - Pine bark and cones
  - Banana peel biochar
  - Industrial herb by-products (rose, lavender)
  - Spent microbial biomass (metabolically inhibited)
  - Waste tyres
- **Technologies used:** Adsorption, photocatalysis, fluorescence sensing, nanocomposite formation

Why it matters:

- Offers a **sustainable route for pollutant removal**
- Supports **SDGs 6, 9, and 12** through green chemistry and resource circularity

Thread 4: Organic Wastes

Highlights from Recent Studies

📌 Sanni et al. (2025):

- *Pine-derived carbon dots* used for fluorescent detection of antibiotics (amoxicillin, tetracycline)

📌 Eswaran et al. (2025):

- *Banana peel–derived ZnO@biochar* nanocomposites showed >95% photocatalytic removal of methylene blue
- Combines **waste valorisation** with **solar-driven water treatment**

📌 Marovska et al. (2024):

- *Lavender and rose residues* effectively adsorbed Acid Orange 7 dye
- Achieved high removal rates at low cost, proposing a **zero-waste industrial loop**

Thread 4: Organic Wastes

Advanced Biosorbents and Mechanistic Insights

📌 Brink et al. (2024) & Kpai et al. (2023):

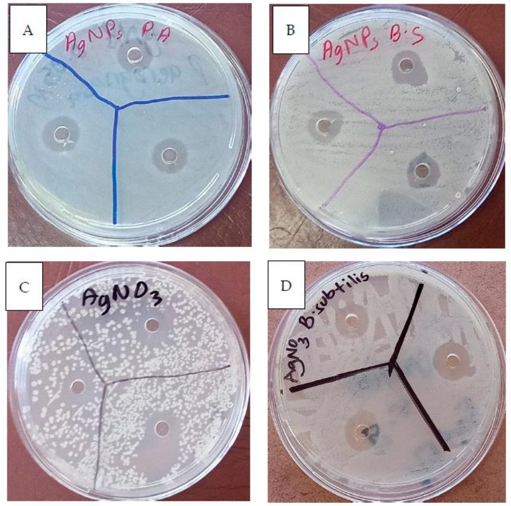
- *Inhibited bacterial cultures* from organic waste showed high Pb(II) adsorption capacity
- **Mechanistic modelling** validated surface interactions and saturation behaviour

📌 de Wet & Brink (2021):

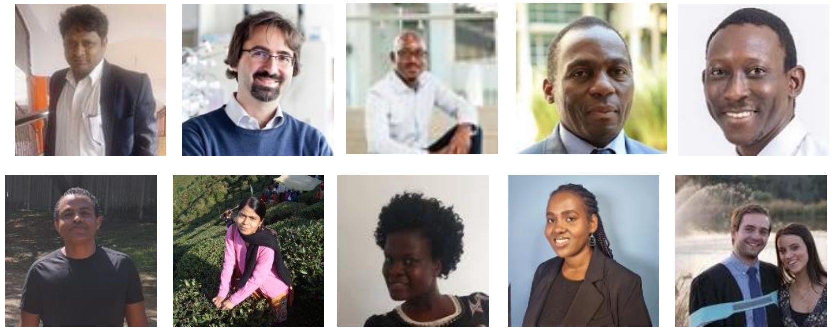
- *Aspergillus piperis* biosorption for Pb(II): rapid uptake, stable performance
- Promising fungal alternative for industrial wastewaters

📌 Aina et al. (2023):

- *Eggshell membrane & AgNPs hybrid material* used for pathogen and heavy metal removal
- Demonstrates **hybrid synergy** between bio-waste and nanotechnology



Threads 5 & 6: Engineered and Hybrid Materials



Journal of Water Process Engineering 71 (2025) 107212

Contents lists available at ScienceDirect

Journal of Water Process Engineering

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

ELSEVIER

Highly effective antibiotic mineralization via laccase-immobilized nanocomposite beads coupled with fungal phycoremediation

Hilda Dinah Kyomuhimbo[a,*], Usisipho Feleni[b], Hendrik Gideon Brink[a,*]

Journal of Environmental Chemical Engineering 11 (2023) 111229

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

ELSEVIER

Removal of chromium from aqueous solution using a nanocomposite of nickel ferrite and polyaniline doped with 2-naphthalene sulfonic acid

Ruth N. Kasavo, Madhumita Bhaumik, Hendrik G. Brink[*]

Chemosphere 370 (2025) 143929

Contents lists available at ScienceDirect

Chemosphere

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

ELSEVIER

Highly efficient removal of Pb^{2+} from aqueous solution using polyaniline-cobalt composite nanorods: Kinetics, isotherm and mechanistic investigation

Madhumita Bhaumik[a,**], Arjun Maity[b,c,*], H.G. Brink[a,***]

Chemical Engineering Journal 417 (2021) 127910

Contents lists available at ScienceDirect

Chemical Engineering Journal

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

ELSEVIER

Zero valent nickel nanoparticles decorated polyaniline nanotubes for the efficient removal of Pb(II) from aqueous solution: Synthesis, characterization and mechanism investigation

Madhumita Bhaumik[a,*], Arjun Maity[b,c,*], Hendrik G. Brink[a,*]

IOP Publishing — Journal of Physics D: Applied Physics

J. Phys. D: Appl. Phys. 57 (2024) 045302 (12pp) https://doi.org/10.1088/1361-6463/ad039d

Resistive switching behaviour of nickel nanoparticle-embedded naphthalene sulphonic acid-doped polyaniline nanocomposites

Madhumita Bhaumik[1,*], Arjun Maity[2,3], Hendrik G Brink[1], Zolile Wiseman Dlamini[4] and SrinivasuVijaya Vallabhapurapu[1]

RESEARCH ARTICLE — Global Challenges — www.global-challenges.com

Synthesis and Evaluation of 3D Nitrogen Doped Reduced Graphene Oxide (3D N@rGO) Macrostructure for Boosted Solar Driven Interfacial Desalination of Saline Water

*Fisseha A Bezza, Samuel A. Iwarere, Shepherd M. Tichapondwa, Hendrik G. Brink, Michael O. Daramola, and Evans MN Chirwa**

Journal of Molecular Liquids 389 (2023) 122931

Contents lists available at ScienceDirect

Journal of Molecular Liquids

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

ELSEVIER

High-capacity adsorption of hexavalent chromium by a polyaniline-Ni(0) nanocomposite adsorbent: Expanding the Langmuir-Hinshelwood kinetic model

Luca Lohrentz[a], Madhumita Bhaumik[a], Hendrik G. Brink[a,*]

scientific reports

OPEN

Design and fabrication of porous three-dimensional Ag-doped reduced graphene oxide (3D Ag@rGO) composite for interfacial solar desalination

Fisseha A. Bezza, Samuel A. Iwarere, Hendrik G. Brink & Evans M. N. Chirwa

Journal of Colloid and Interface Science 611 (2022) 408–420

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

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

ELSEVIER

Metallic nickel nanoparticles supported polyaniline nanotubes as heterogeneous Fenton-like catalyst for the degradation of brilliant green dye in aqueous solution

Madhumita Bhaumik[a,*], Arjun Maity[b,c,*], Hendrik G. Brink[a,*]

Surfaces and Interfaces 73 (2025) 107624

Contents lists available at ScienceDirect

Surfaces and Interfaces

journal homepage: www.sciencedirect.com/journal/surfaces-and-interfaces

ELSEVIER

Effective degradation of Congo red dye in aqueous solution using highly recyclable silver nanoparticles decorated polyaniline nanowires

Madhumita Bhaumik[a,*], Arjun Maity[b,*], Hendrik G. Brink[a,*]

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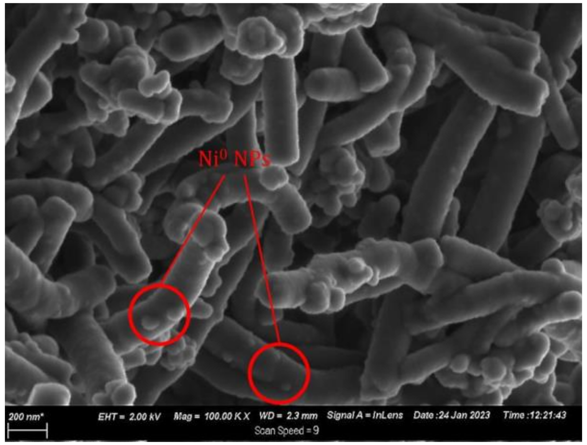
Threads 5 & 6: Engineered and Hybrid Materials

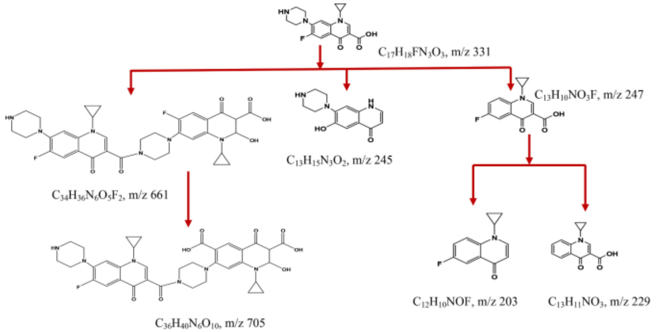
Engineered Materials for Pollutant Capture



Focus: Tailor-made nanostructures for high-efficiency adsorption and degradation

Key Materials & Outcomes:

- **Polyaniline-based composites**:
  - Ni(0), Co(0), and Ag nanoparticle-decorated nanotubes or nanorods achieved exceptional Pb(II) and Cr(VI) removal.
  - NSA-doped polyaniline (PANI-NSA) structures optimised for high Cr(VI) adsorption capacity
- **Chitosan–PVPP composites**:
  - Demonstrated rapid dye adsorption dynamics, particularly for methylene blue, indicating tunable surface affinity.
- **Biochar-functionalised PANI**:
  - Combined conductivity and porosity for enhanced Cr(VI) adsorption .



Impact: Controlled morphology and doping strategies enabled targeted pollutant removal at low dosage and high speed.

Threads 5 & 6: Engineered and Hybrid Materials

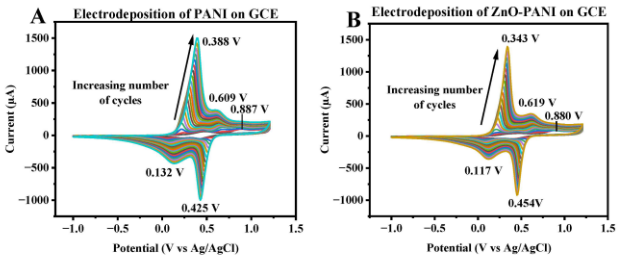
Hybrid Materials for Multifunctionality

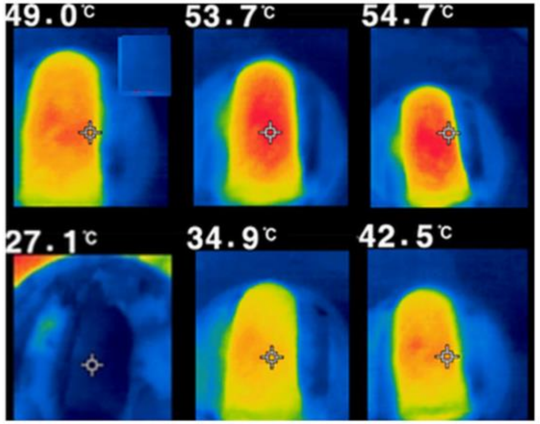
Focus: Integrating enzymes, metals, and carbon frameworks

Hybrid Systems:

- **Laccase-immobilised composites**:
  - ZnO–PANI–Laccase and chitosan-alginate beads with immobilised laccase facilitated **electrochemical detection** and **biodegradation** of pharmaceuticals such as cetyltrimethylammonium bromide (CTAB) and antibiotics
- **3D rGO frameworks (N-doped and Ag-doped)**:
  - Used for sunlight-driven photocatalysis and solar-driven degradation of methylene blue, phenol, and tetracycline, offering scalable remediation pathways.
- **$CuFe_2O_4$-doped rGO solar absorbers**:
  - Enabled **solar desalination** applications, highlighting cross-sector potential.

Insight: Hybrid systems bridge biological and advanced material functionality, expanding use beyond adsorption into detection, degradation, and energy applications.



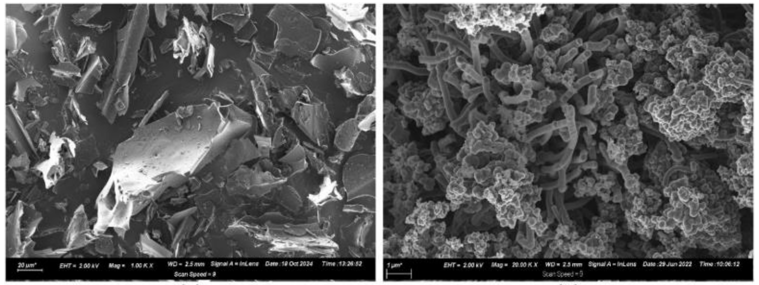


Threads 5 & 6: Engineered and Hybrid Materials

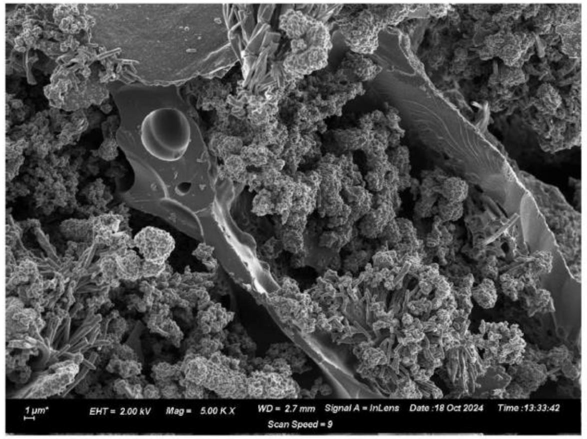
Innovation Drivers and Sustainable Impact

Key Design Strategies:

- **Metal selection (Ni, Co, Ag, $CuFe_2O_4$)** dictated oxidation capacity and reusability.
- **Support matrices (PANI, rGO, biochar, PVPP, chitosan)** enhanced dispersion, mechanical stability and recyclability.
- **Enzyme integration** provided specificity and mild operational conditions.



(a) (b)



Threads 5 & 6: Engineered and Hybrid Materials

Innovation Drivers and Sustainable Impact

Outcomes:

- Multiple systems showed >95% removal or degradation of pollutants.
- **Recyclability** (≥5 cycles with minimal efficiency loss) was achieved in several studies.
- Functional versatility addressed contaminants such as:
  - **Heavy metals** (Pb^{2+}, Cr(VI))
  - **Synthetic dyes** (Congo red, methylene blue)
  - **Pharmaceuticals** (antibiotics, CTAB)
  - **Phosphate**

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Lessons Learnt: Weaving Knowledge Through Threads of Innovation

- **Waste is not a burden, but a resource**: Across all six research threads, valorisation has emerged as a unifying paradigm, whether through microbes, materials, or mining residues.
- **Integration is more powerful than isolation**: Bridging disciplines – biology, chemistry, materials science, and engineering – enabled tailored, synergistic solutions to complex water and waste problems.
- **Collaboration is the loom of impact**: Success was amplified through networks — students, postdocs, industry, and international partners — each interwoven into a shared fabric of sustainability and innovation.
- **From lab to real-world relevance**: Translating fundamental understanding into field-ready systems (e.g. AMD-derived adsorbents, laccase-immobilised composites) proved critical to enabling systemic change.
- **Scientific storytelling matters**: Thematic metaphors (e.g., threads, weaving, loops) were powerful in aligning research, communication, and stakeholder engagement — including policy tools like the *P-Game*.

Future Prospects: Extending the Pattern

- **From proof-of-concept to scale-up**: Advance technologies like PANI-based nanocomposites, immobilised fungi, and AMD-derived materials into **pilot- and industry-scale implementation**.
- **Smart integration of biotic and abiotic systems**: Design **hybrid systems** that couple enzymatic degradation with solar-driven photocatalysis, opening doors for smart water purification and green chemical production.
- **Circularity beyond water**: Extend waste valorisation to broader sectors — **soil remediation**, **air filtration**, and **catalyst regeneration** — anchored in circular economy principles.
- **Digital twinning and predictive tools**: Use **AI, mechanistic modelling, and biosensors** to control and optimise systems in real time — closing the loop in both matter and data.
- **Train the next generation**: Equip students and postdocs with skills to lead **transdisciplinary, solution-oriented research** — making *WATER4Water* not just a project, but a **pipeline of future-ready talent**

Acknowledgements

- **Kim Brink-Flores, Ella Brink, and Audrey Brink** — My wife and daughters have been the cornerstone of this journey. Kim's unwavering patience and support made everything possible, and life is infinitely more joyful (and lively!) with my girls constantly keeping me on my toes.
- **Prof. William Nicol** — My PhD supervisor and academic mentor. He recognised potential in me long before I saw it in myself. I remain deeply grateful for his guidance and belief.
- **Prof. Evans Chirwa** — A steadfast mentor and ally on South Campus for the last decade. His support helped me navigate challenges that would have otherwise been far more difficult.
- **My colleagues in the Department of Chemical Engineering** — Thank you for your constant encouragement and camaraderie. I am truly fortunate to be part of this exceptional team.
- **My students and postdoctoral fellows** — You are the true architects of this research. I would be a loom without thread if not for your work, insight, and creativity. You gave shape and colour to every idea – you brought it to life.