



OVERVIEW OF DEPARTMENT OF CHEMICAL ENGINEERING

Standing & Research Themes



Faculty of Engineering, **Built Environment and** Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Tikologo ya Kago le Theknolotši ya Tshedimošo

UNIVERSITY OF PRETORIA

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Make today matter

www.up.ac.za

Vision and Strategic Goals

UP Reimagined: 2022 - 2026

Our Vision: To be a leading research-intensive university in Africa, recognised internationally for its quality, relevance, and impact, and for developing people, creating knowledge and making a difference locally and globally.





University of Pretoria Global Rankings









University Ranking by Academic Performance

| Ranking | 2020 | 2021 | 2022 | 2023 |
|---------|---------|---------|---------|----------|
| QS | 551-560 | 561-570 | 601-650 | 591-600 |
| THE | 601-800 | 601-800 | 601-800 | 800-1000 |
| ARWU | 401-500 | 401-500 | 401-500 | 401-500 |
| URAP | 462 | 458 | 474 | 459 |

| Subject | 2020 | 2021 | 2022 | 2023 |
|------------------------------|------------|------------|------------|---------|
| Arts & Humanities | 383 | 397 | 401-450 | 341 |
| Engineering and Technology | 364 | 356 | 352 | 284 |
| Life Sciences & Medicine | 348 | 348 | 337 | 325 |
| Natural Sciences | Not ranked | Not ranked | Not ranked | 451-500 |
| Social Sciences & Management | 320 | 314 | 323 | 283 |
| | | | | 2022 |

Please note that ranking's year is one year ahead, hence 2023 refers to 2022.

Source: UP Department of Institutional Planning, Monitoring & Evaluation

Sustainability Rankings-2023

| SDG | 2021 | 2022 | 2023 |
|--|---------|---------|---------|
| 3: Good Health and Wellbeing | 201-300 | 201-300 | 101-200 |
| 4: Quality Education | 201-300 | 201-300 | 101-200 |
| 5: Gender Equality | - | - | 14 |
| 8: Decent Work and Economic Growth | 101-200 | 44 | 4 |
| 9: Industry, Innovation and Infrastructure | 101-200 | 88 | 91 |
| 10: Reduced Inequalities | - | 101-200 | 76 |
| 15: Life on Land | 76 | 30 | 81 |
| 16: Peace, Justice and Strong Institutions | 201-300 | 101-200 | 97 |
| 17: Partnership For The Goals | 101-200 | 86 | 92 |
| Overall Rank | 201-300 | 101-200 | 69 |
| Overall Score | 76.9 | 88.2 | 90.1 |

1,705 universities ranked in 2023





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VISION:

A Chemical Engineering Department **growing professionals** to contribute towards African development.

MISSION:

We achieve that by being excellent, innovative and sustainable in teaching, research and human empowerment.

Strategic Goals: in 2020



Program Accreditation



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Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Program ECSA-accredited for the next 5 years (2022-2027)

Department of Chemical Engineering





UP Chemical Engineering





| | Global Rank Domestic F | | | | Rank | | |
|---------------------------------------|------------------------|---------|---------|------|------|------|--|
| Subject | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 | |
| Architecture/Built Environment | - | 151-200 | 201-240 | - | 2 | 2 | |
| Computer Science & Information System | 401-450 | 501-550 | 501-550 | 2 | 2 | 2 | |
| Chemical Engineering | 301-350 | 251-300 | 251-300 | 5 | 2 | 1 | |
| Electrical & Electronic Engineering | 251-300 | 301-350 | 351-400 | 1 | 1 | 1 | |
| Mechanical Engineering | 301-350 | 251-300 | 301-350 | 2 | 1 | 1 | |
| Mineral & Mining Engineering | 48 | 33 | 35 | 2 | 2 | 2 | |

Source: UP Department of Institutional Planning, Monitoring & Evaluation

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| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|-------|-------|-------|-------|-------|-------|
| % Academic staff with Doctorate degrees as their highest qualification (Perm + Fixed term) | 81.25 | 75.00 | 75.00 | 77.78 | 71.43 | 71.43 |
| <u>% Black Academic Staff (Perm + Fixed term)</u> | 18.75 | 18.75 | 18.75 | 22.22 | 35.71 | 35.71 |

In 2023:

| Staff | No. | Male | Female | | |
|--|-----|------|--------|--|--|
| Academic | 25 | 22 | 3 | | |
| Support | 6 | 1 | 5 | | |
| Total 31 23 8 | | | | | |
| White: 58.06%, Black: 35.48% , Coloured: 6.45% | | | | | |



% Academic staff with PhD: 80

Source: UP Department of Institutional Planning, Monitoring & Evaluation 17 Dec 2023

Degree Programmes

Degree Programmes



More information:

UG programme: <u>https://www.up.ac.za/chemical-engineering/article/2984922/preview?module=cms&slug=content-pages&id=2984922</u> PG programme: <u>https://www.up.ac.za/chemical-engineering/article/2985654/preview?module=cms&slug=content-pages&id=2985654</u>

Custom-made Short Courses

□Environmental Management and Regulation

□Water Quality Management and Effluent Treatment

□Operation of Water and Wastewater Treatment Plants

□Advanced Course in Water Treatment Processes

□Water Analysis and Monitoring

□21st Century Waste Management and Resource Recovery



BEng Hons M PhD

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|-------|-------|-------|-------|-------|-------|
| Number of international contact PG students | 19.00 | 19.00 | 16.00 | 18.00 | 25.00 | 22.00 |
| % Black contact Students to total contact students | 59.93 | 59.98 | 60.52 | 59.32 | 63.34 | 66.72 |

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Source: UP Department of Institutional Planning, Monitoring & Evaluation

*ENGAGE program included

17 Dec 2023

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Graduation 2017-2023

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|--|-------|-------|-------|-------|-------|-------|
| % successful FTE students to total FTE students (contact) | 80.27 | 77.98 | 80.97 | 78.63 | 84.05 | 77.69 |
| Total contact FTE students per FTE teaching staff member (ratio)* | 28.02 | 27.93 | 25.39 | 21.27 | 22.29 | 18.66 |
| Total Master graduate output | 20.00 | 12.00 | 19.00 | 10.00 | 22.00 | 18.00 |
| Total Doctoral graduate output | 6.00 | 6.00 | 5.00 | 6.00 | 8.00 | 7.00 |

April & September 2023

| Degree | No of Graduate |
|--------------|------------------------------------|
| PhD | 9 |
| MEng/MSc | 16 (8 graduated with distinction) |
| HonsBEng/BSc | 36 (11 graduated with distinction) |
| BEng | 64 (10 graduated with distinction) |

Source: UP Department of Institutional Planning, Monitoring & Evaluation

UP Chemical Engineering



Source: UP Department of Institutional Planning, Monitoring & Evaluation

Research & Innovation

Future Chemical Engineer



Courtesy: Partha S. Gosh:

http://web.mit.edu/psgleadership/pdf/1_required_reading/How%20Chemical%20Engineering%20will%20Drive%20the21st% 20Century%20Woburn.pdf (Accessed 27-10-2020)

Research

The research has a two-fold focus with a good balance between <u>fundamental research</u> and <u>industrial application</u> to provide solutions to various problems mitigating affordable water, sustainable energy and clean environment in Africa and the world at large.

Main objectives of research themes in the Department are:

- Pursue and encourage conduct of cutting-edge research that could potentially proffer solutions to African problems;
- Encourage conduct of breakthrough multi-disciplinary and inter-disciplinary research activities that promotes sustainability with great positive impact on Africa and the global society;
- Train and graduate appropriate high-quality and resourceful postgraduate students, postdoctoral as capacity development in these research areas for South Africa, Africa and the world at large.



Research Themes & Interdependence



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Advanced & Applied Materials

Advanced and Applied Materials

- Development, evaluation and application of novel and advanced materials (polymer-based, Layer Double Hydroxide(LDL), etc.) to facilitate sustainability and wealth creation. Application of these materials in areas such as environment, medicine, sensing and monitoring is a focus;
- Synthesis, characterization and evaluation of nanomaterials (e.g. carbon nanotubes, carbon nano-yarns, graphene, carbon nanowires) and other materials like zeolites, biocomposites, biopolymers, fluoropolymers are studied for application in catalysis, separation technology, energy and environment;
- Understanding dynamic behaviour, structural integrity and interaction of these materials using molecular modelling approach towards enhancing sustainable synthesis and applicability of these materials;
- □ In-depth understanding of resistance of these materials to wear, tear and corrosion via tribology is considered.



Outdoor malaria protection: The UP-developed repellent azeotrope outperforms the so-called "gold standard" system



Izadi H, Focke WW, Asaadi E, Maharaj R, Pretorius J, Loots MT. A promising azeotrope-like mosquito repellent blend. Scientific Reports. 2017;7(1).



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Prof Focke & his team walter.Focke@up.ac.za

Pest Control using Zein-cellulose Matrix



Pests reduce food security

- Overuse of insecticides kill bees
- Plastic litter accumulates



- Zein-cellulose films as matrix for fruit fly attractants
- Attractant: TMA butyrate
- Wedged between netting containing a contact poison

Prof Focke & his team walter.focke@up.ac.za

This project is proudly sponsored by PAMSA and the Department of Science and Innovation.





LDH in Renewable Energy

LDH materials research – FJ Labuschagne

H₂ production from water and sunlight with LDH catalyst





rsc.li/materials-advance



johan.labuchagne@up.ac.za



Sustainable & Efficient Energy Processes

Sustainable & Efficient Energy Processes

- Development and evaluation of sustainable and energy-efficient technologies and processes for conversion of waste materials (liquid, solid, gas, biomass) to energy. Strategies such as thermo-chemical, biochemical, biological and combination of these will be investigated.
- Development and techno-economic feasibility assessment of technologies, materials, processes in the context of clean coal technologies with the main focus on carbon capture, storage and utilization (CCSU) to encourage sustainable use of coal resources for energy generation using coal-fired power plants;
- Application of concepts of process integration, process synthesis, process intensification, and process control and optimisation in developing sustainable and efficient-energy processes towards reducing energy consumption in industrial and domestic applications

Thermal Treatment of Biomass

Started in 2010

- Focus areas
 - Fluidised bed technology (A)
 - Spouted bed technology (B)
 - Catalytic upgradation (C & D)
 - Pyrolysis oil and biochar synthesis (D)



New research: Biochar

valorisation

Prof Heydenrych, Dr Merckel & their team mike.heydenrych@up.ac.za; ryan.merckel@up.ac.za

Thermal Treatment of Biomass



Prof Heydenrych, Dr Merckel & their team mike.heydenrych@up.ac.za; ryan.merckel@up.ac.za

Biowaste Effluent into (Bio) H₂

Hydrogen as an energy source is non-polluting and has high energy yield; 2.75 times higher than hydrocarbon fuels



Exploring treatment and valorization of municipal waste via MICROBIOAL FUEL CELLS

Sekoai & Daramola (2015) Biofuel Research Journal, 6:223-226; Sekoai,..., Daramola(2018) Biofuels, 9 (5):595-604; Sekoai,..., Daramola, M.O. (2019) Waste & Biomass Valorization, 10:117-1189; Sekoai,..., Daramola, ...(2020) Biomass and Bioenergy (in press); Marks,..., Daramola (2020) Environmental and Climate Technologies, 24(2): 67-78; Sekoai,..., Daramola (2018)Critical Reviews in Biotechnology, 38 (2): 157-171; Sekoai,..., Daramola (2018) Chemical Engineering Communications, 205(8):1011-1022.

Sustainable Environment and Water Utilisation Processes

Sustainable Environment & Water Utilisation Processes

- Wastewater treatment and beneficiation using biological, chemical, catalytic, membrane-based technology (such as nanofiltration, microfiltration, ultrafiltration, reverse/forward osmosis, electrodialysis plasma-based technology), plasma-based technology, and other suitable methods. The focus will be on development of methods/strategies/materials for treatment and beneficiation of industrial, domestic, and municipal wastewater towards enhancing sanitation and effective disposal of these waste waters;
- Development of monitoring devices or techniques for determination of toxic and environmentally unfriendly compounds/substances in environmental processes and techno-economic evaluation of these devices and techniques;
- Development and evaluation of strategies for valorization of waste materials (solid, liquid, gas, biomass) into value-added products (food, chemicals, materials) using biological/biotechnological concepts.



Biological Analogues for Application in Advanced Water Treatment – NSTF-32 Water Research Commission Award, 2022



Prof Evans Chirwa and his team (evans.chirwa@up.ac.za)

Application of Heterogeneous Photocatalysis in H₂ Production – NSTF-22 Award, 2022

Analogues of Photosystem I and Photosystem II in Plant Photosynthesis



Concurrent Hydrogen Generation using Metal-Halide Heterogeneous Photocatalysis ~ Advanced Concept Using Modified Carbon Nitride (NTE)



Eleveation of electrons in a potential nitrogen generating photocatalyst

Prof Chirwa and his team (evans.chirwa@up.ac.za)

3D Printed Graphene Layers Supported on Cellulose Sponge Nanocubes

With Application to Solar Desalination of Sea Water, Current WRC Funded Project



Results Achieved:

Elevation of water tempratures from 25°C to 65°C in 30 seconds with graphene without cellulose support

Introduction of 3D printed graphene-oxide nanolayer is expected to increase heat delivery and efficiency of water recovery from Sea water.

Prof. Chirwa and Dr Fisseha Pezza (Postdoc) Email: evans.chirwa@up.ac.za

Syntrophic Phytoremediation and Bioremediation of Toxic Metals Using Bacteria and Plants



Prof. Chirwa and Dr Mpumelelo Matsena Email: evans.chirwa@up.ac.za

Microbial Fuel Cells, Wastewater Treatment and the "Green" Energy Economy







Air Cathode System to Reduce – Internal Resistance and Increased Voltage Output Results



Prof. Chirwa and Dr Mpumelelo Matsena Email: evans.chirwa@up.ac.za

Energy Saving Solutions in Water Treatment



Prof. Chirwa, Prof Tichapondwa, Prof Brink & their team ^{17 D}evans.chirwa@up.ac.za; deon.brink@up.ac.za; shepherd.tichapondwa@up.ac.za

"Green" Water Treatment Technologies

- Bioremediation of heavy metals
- Adsorption by AMD recovered pigment



- ³As(V)



Plasma-based Technology & Membrane Technology for Wastewater Treatment

Dr Iwarere , Prof Daramola, & their team <u>Michael.Daramola@up.ac.za</u>; <u>Samuel.Iwarere@up.ac.za</u>

Locally developed atmospheric continuous flow dielectric barrier discharge reactor for water & wastewater treatment



Our PhD student presenting his findings on Tramadol degradation at 49th IEEE ICOPS in Seattle, USA, May 2022.



- Removal efficiency in a WWTP was 13% in a recent literature report.
- Our study so far for 5 ppm TRA in D.I and FWWE degraded to 93.4% and 26.8% respectively after an 1 h of treatment

Dr Iwarere, Prof Daramola & their team Samuel.iwarere@up.ac.za; Michael.Daramola@up.ac.za

Plasma Simulation



Images: Profile of velocity magnitude in a plasma reactor towards improving plasma reactor design for water application 45

Project: "small-scale, solar-powered water purification systems using plasma technology"



Project: Production of CNTs using plasma technology"



Membrane Separation



Scale-up Study & Mass Production Opportunity

Nanomaterial infused Membrane



Waste Treatment, Valorisation & Biobased Economy

Research effort in this area involves:

- Treatment and valorization of bioresource and waste materials (solid/liquid/gaseous) into value-added products (biomaterials, biobased chemicals, biofuels, biohydrogen, green adhesives, silicon for solar cell, etc.) and clean energy sources.
- Developing sustainable solutions deployable in energy and environment (e.g. CO₂ capture, storage and utilization; F-T process, investigation and understanding of co-gasification/gasification/hydrogasification and desulphurization technologies)

Prof Daramola, Dr Iwarere & their team <u>Michael.Daramola@up.ac.za</u>; <u>Samuel.Iwarere@up.ac.za</u>

Waste to Nanoparticles









Prof Daramola, Dr Iwarere & their team <u>Michael.Daramola@up.ac.za</u>; <u>Samuel.Iwarere@up.ac.za</u>



Develop a "one-pot" bioprocess unit via process intensification that combines pretreatment with biocatalytic conversion of South African Corncob to Succinic Acid



Waste Plastics to CNTs for Membranes

Catalytic production of plastic wastes-derived ferromagnetic carbon nanotubes and its application in membrane removal of heavy metals from mine drainage (AMD)



Value from waste sulphate compounds



Prof. van Vuuren & his team Dawie.vanvuuren@up.ac.za

- Sulphur, high-purity and nano-precipitated CaCO₃ from gypsum
- Na₂CO₃, Na₂S and NaHS from Na₂SO₄
- Project partners: Universities of Limpopo and Pretoria, and ROC Water (Pty) Ltd
- Funding: The dti, Technology Innovation Agency, WRC.
- Industry participants: Anglo Coal &, Eskom
- Main focus of UP: Gypsum carbothermal reduction technology



Process Modelling, Optimisation & Control

This research theme considers:

- Application of mathematical and engineering concepts in developing models (mechanistic/empirical) that are employed in simulation, control and optimization of processes/systems.
- Application of relevant mathematical tools involved in the Fourth Industrial Revolutions (4IR) to ensure that the 4IR permeates the research activities in the Department.



Lubricant Performance Modeling & Control



Source: UP Department of Institutional Planning, Monitoring & Evaluation

2021 Publications

Chem Eng tops EBIT



EBIT Total: 405.23 units

2022 Publications



NRF-rated Researchers

| Prof HG Brink | Y2 |
|-----------------------|----|
| Prof EMN Chirwa | C2 |
| Prof S. Tichapondwa | Y2 |
| Prof MO Daramola | C2 |
| Prof FJWJ Labuschagne | C3 |
| Prof W Nicol | B3 |
| Prof WF Focke | B3 |
| Dr SA Iwarere | Y2 |

NSTF-South32 Awards 2022

Congratulations to all our finalists, who push us to higher levels.





Prof Nigel C Bennett









Prof Michael Olawale Daramola



Prof Wanda Markotter Prof Bob Pattinson



Prof Yves van de Peer





Prof Theresa Rossouw



Prof Brenda Wingfield





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Prof Evans Chirwa NSTF-Water Research Commission Award 60

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International Research Visibility

"Team Tujenge"

Project: "small-scale, solar-powered water purification systems using plasma technology"



Victor (Team Leader)



Samuel & Michael (Mentors/Supervisors)



Universities contested at Final:



UNIVERSITY OF GOTTINGEN GERMANY



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"Team Tujenge" wins second place in international climate solutions competition





Team Leader



Members of the UP team worked with the residents and leaders of Tshikuwi village in Limpopo to obtain water for testing and shoot the video for their submission.



Team Members

Source: https://www.up.ac.za/usr/news/post_3102590-upreashi-Wins-second-place-in-international-climate-solutions-competition

Collaborability

Because notody has all the answers



Triple Helix Model

Source: Farinha, Luis and João Ferreira. Triangulation of the triple helix: A conceptual framework (working paper). Triple^vHelix Association. 2013



Transdisciplinary Research: Digital Twin



Prof Brink, Prof Daramola & their team Deon.Brink@up.ac.za; Michael.Daramola@up.ac.za

Transdisciplinary Research: York Timber

Collaboration between

York Timbers Chair in Wood Structural Engineering

&

Department of Chemical Engineering Focus area: Increasing the value of wood products or manufacturing through by-product processing, treatment, preservation or bio-based glues.

Current Projects:

- Strategies for converting wood wastes to energy
- Design and synthesis of mechanically strong carbon nanotube/wood nanofibres/cellulose composite adhesive

Prof Daramola & his team <u>Michael.Daramola@up.ac.za</u>

International Conference: Chem Eng



Managing Guest Editor: Prof MO Daramola



Guest Lectures

Hydrogen production and utilization Prof. Osvaldo José Venturini Biorefineries and Energy Efficiency in Universities Buildings Prof. Dr. José Carlos Escobar Palacio

Global Pursuit of Sustainable Energy: Powering a Greener Future Worldwide

Hydrogen from biomass gasification Prof. Electo Eduardo Silva Lora Theoretical and experimental research on biomass gasification at UNIFEI Prof. Diego M Y Maya Date: 25 August 2023 Time: 10:00am Venue: Hartfield Main Campus, Engineering II, Room 3-60







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PG Supervision Style

Student-Supervisor Research Collaboration (SSRC)



Abbas et al. (2020) " Element of students' expectation towards teacher-student research collaboration in higher education," in 2020 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 2020 (DOI 10.1109/FIE44824.2020.9273902)

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