POSTGRADUATE CONFERENCE

DEPARTMENT OF PROCESS ENGINEERING

13 September 2019

Celebrating 50 years of research, innovation and excellence

1969 – 2019

FOREWORD

Prof. JH Knoetze

The Department of Chemical Engineering at Stellenbosch University was established in 1969 – 25 years after the Faculty of Engineering. Prof N.J. (Nico) Louw was the first professor and Chair of the Department. In 1977 the specialization in Extractive Metallurgy was introduced and students had the option to do either a BEng (Chemical Engineering) or a BEng (Chemical Engineering – specialization Extractive Metallurgy). This lead to a separate Department of Metallurgical Engineering in 1985, but the two departments were again amalgamated in 1994 to form the Department of Chemical Engineering. In the early 2000s the name was changed to the present Department of Process Engineering.

Prof Louw will be remembered for his work in developing the chemical engineering programme and developing study material in Afrikaans. He was joined by the first three senior lecturers in the Department, namely, Mr Carel Nel, Dr Eric Horsten and Dr Mike Connor. Prof John de Kock was appointed at the end of 1976 as the first professor in Extractive Metallurgy.

Initially, the Department was housed in the old Engineering Building in Victoria Street (the present Visual Arts Building) and the laboratories were in the present Polymer Science Building. The Department moved to the present building in 1979 and by 2011 the student numbers increased to such an extent that the Annex had to be added.

An excellent undergraduate programme, dedicated academics and excellent laboratory facilities have always been a hallmark of the Department. Employers have always been very impressed with the quality of graduates from the Department.

From the 1980s postgraduate education and research started to play an ever-increasing role in the Department. The first MEng degree was awarded in 1983 and Jannie van Deventer received the first PhD in the Department in 1985. Since then the Department has become known worldwide for the work in minerals processing/extractive metallurgy, bioresource engineering, separation technology, intelligent process systems, water technology and waste valorisation. At present three of the five academics with the highest Scopus h-factors in the faculty are from the Department of Process Engineering, and the Department has awarded six DEng, 101 PhD and 393 MEng degrees.

The Department is well-positioned and looking forward to the next 50 years to continue delivering excellent graduates and research that will contribute towards a sustainable and prosperous future.

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WORD OF WELCOME

Prof. AJ Burger

Welcome to this very special postgraduate conference!

The Department of Process Engineering has its roots in a rather momentous and extraordinary year, 1969. In the same year, a monstrous Saturn V rocket gulped a combined volume of 3.5 million litres of kerosene, liquid oxygen and liquid hydrogen to catapult three astronauts to the surface of the moon; a very special year indeed.

Half a century later, astute and internationally acclaimed researchers – proud products of this department – return to their alma mater as plenary and keynote speakers at this 50-year celebratory event. They, together with postgraduate students, will provide examples of the high-quality human capital and research work produced by the Department.

Current research projects in the department typically fall into the following categories: Bioresource Engineering, Extractive Metallurgy, Separations Technology, Waste Valorisation and Water Technology. Of the 120 currently registered postgraduate students, 14 get the opportunity to present their work orally at this conference, while 25 poster presentations are on display. The rest, together with other delegates, are invited to take part as active members of the audience.

Please enjoy every moment and join us in setting a positive tone and strong vision for the next 50 years' research.

CONFERENCE PROGRAMME

08:00 – 08:30	**Registration [S251]**	
	E352/3 **Session chair: Prof. CE Schwarz**	
08:30 – 08:40	Welcoming, general proceedings and announcements	
08:40 – 09:25	Plenary: Prof. Jannie van Deventer *The chemical engineer as a business disruptor – the fun has just started*	
	E202/3 **Session chair: Prof. AJ Burger**	**E352/3** **Session chair: Dr NJ Goosen**
09:30 – 10:15	Keynote: Prof. Izak Nieuwoudt *Separation technology – a cornerstone of chemical engineering*	Keynote: Dr Elroy Goliath *Supply chain reinvention and food engineering in FMCG*
10:15 – 10:45	Lamprecht JH, Burger AJ *Characterisation of the droplet and stream sizes within randomly packed columns using electric impedance tomography*	Teke GM, Pott RWM *Design and investigation of a semi-partitioned bioreactor for continuous extractive fermentation*
10:45 – 11:30	**Coffee break and poster session [S251]**	
	E202/3 **Session chair: Dr LJ du Preez**	**E352/3** **Session chair: Dr TM Louw**
11:30 – 12:00	Swanepoel RM, Schwarz CE *Improving the predictions of (solvent + LLDPE) phase boundaries of commercial interest*	Gakingo GK, Clarke KG, Louw TM *A numerical investigation of the hydrodynamics and mass transfer in a multiphase bioreactor for paraffin activation*
12:00 – 12:30	Bosman CE, Schwarz CE *Single and binary component adsorption of 1-alcohols from an alkane using activated alumina*	Apiyo D, Mouton JM, Sampson SL, Louw TM *The effect of environmental conditions on growth and phenotype switching in Mycobacterium smegmatis*

12:30 – 13:00	Motang N, Knoetze JH, Schwarz CE *Density and viscosity measurements at phase transition in CO_2 + 1-dodecanol + 2-dodecanol mixtures*	van Schalkwyk DL, Mandegari M, Görgens JF *Techno-economic analysis of bio-oil production from forest residues via non-catalytic and catalytic pyrolysis*
13:00 – 14:00	**Lunch [S251]**	
	E202/3 Session chair: Prof. C Dorfling	**E352/3 Session chair: Dr E van Rensburg**
14:00 – 14:45	Keynote: Dr Lidia Auret & Dr Derick Moolman *Process Engineering 4.0 in action*	Keynote: Dr Annie Chimphango *From trash to high value bio-products: Taking advantage of nature and natural processes to unlock value from plant biomass waste*
14:45 – 15:15	Basson M, Kroon RS, Auret L, Coetzer RLJ, Cripwell JT *Bayesian methods for ordinary differential equation parameter estimation*	Mapholi Z, Goosen NJ *Optimization of fucoidan recovery by ultrasound-assisted enzymatic extraction from South African brown kelp, Ecklonia Maxima*
15:15 – 15:45	Tucker M, Dorfling C, Tadie M *The development of an electrowinning model to predict process performance*	van der Westhuizen S, Collard FX, Görgens JF *Pyrolysis of waste plastic packaging, to optimise the production of oil/wax for fuel application*
15:45 – 16:15	Manjengwa ER, Tadie M, Dorfling C *Incorporating sustainable practise principles into development of solutions for mitigation of mine waste*	Border AF, Görgens JF, Goosen NJ *Techno-economic analysis of macroalgae biorefinery scenarios for production of HVP's and biogas*
16:15 – 16:20	Closing: Prof. CE Schwarz [S251]	
16:20 – 17:00	**Social [S251]**	
17:00	End	

POSTER PRESENTATIONS

1. Albertus GJ, Auret L, Dorfling C
   Control performance monitoring and relay auto tuning of a milling circuit
2. Bedzo OKK, Görgens JF
   Optimization of inulooligosaccharides production from various inulin substrates obtained from Jerusalem artichoke tubers using a commercial enzyme
3. Ceaser R, Chimphango AFA
   Extraction of high value products from wheat straw and wheat bran
4. Chibwe C, Tadie M
   Influence of electrolyte composition on the electrodeposition of copper in electrowinning process
5. Claase A, Goosen NJ
   Enzymatic hydrolysis optimisation of Ecklonia Maxima for extraction of bioactive compounds
6. Coetzee A, Knoetze JHK, Schwarz CE
   Numerical modelling of high pressure thermodynamic data using neural networks
7. Cronjé IA, Burger AJ
   Seed crystal preparation for effective gypsum crystallisation in seeded slurry precipitators
8. Dantu RK, Schwarz CE, Knoetze JHK
   Fractionation of tyre derived oil as a fuel additive
9. de Klerk DL, Schwarz CE
   Quaternary phase equilibrium data of quaternary water + (ethanol and 2-propanol) + isooctane system
10. du Toit CM, Tyhoda L, Görgens JF
    Enzymatic modification of technical lignin to establish viable valorisation routes
11. Herbst J, Pott RWM
    Aqueous two-phase systems for the extraction of polyphenols from spent wine pomace
12. Hurter RM, Cripwell JT, Burger AJ
    Comparison between the SAFT-VR Mie equation of state and its group contribution variant, SAFT-γ Mie

13. Lambert M, Wahl H, Görgens JF, Auret L, Louw TM
Influence of pulping variables on NSSC pulp properties: pilot plant modelling and optimization

14. Mkwananzi T, Auret L, Louw TM, Görgens JF
Development of an energy monitoring system for sugarcane mills using optimal sensor network design techniques

15. Moorcroft JJ, Schwarz CE
High-pressure phase behaviour of saturated and unsaturated fatty acid esters in supercritical carbon dioxide

16. Morison S, van Rensburg E, Pott RWM
The in-situ extraction of volatile fatty acids from anaerobic digester systems

17. Pottinger RM, Wahl H, Auret L, Louw TM
Mathematical modelling of a neutral sulphite semi-chemical (NSSC) process

18. Pretorius R, Goosen NJ
Design and modeling of an experimental tilapia and African catfish recirculating aquaculture system

19. Smith SAM, Cripwell JT, Schwarz CE
Accurate thermodynamic description of quadrupolar molecules and their mixtures in Cubic Plus Association

20. Swart LJ, van Rensburg E, Görgens JF
Xylo-oligosaccharide production from brewers' spent grains: Hydrothermal process intensification

21. Theron W, van Rensburg E, Diedericks D, Görgens JF
Pre-treatment of lignocellulosic biomass with steam explosion for feed of Black Soldier Fly larvae

22. Thompson AC, Cripwell JT, Burger AJ
Vapour-liquid equilibrium of ternary systems containing 2-butanone, 1-propanol, 2-propanol, and three C4 esters

23. van Breda DJ, Goosen NJ
Optimisation of enzyme assisted extraction of 1,3-ß-glucan / laminarin from Ecklonia maxima kelp

24. van Zyl HA, Akdogan G, Dorfling C
Influence of thermal treatment processes of printed circuit board waste on hydrometallurgical metal recovery

PLENARY PRESENTATION

We are honoured to be hosting Prof. Jannie van Deventer as plenary to the 2019 Postgraduate Conference.

The chemical engineer as a business disruptor – the fun has just started

Prof. Jannie van Deventer

A culture of innovation in information technology, material science and more recently biotechnology, has led to the disruption or evolution of most industries, as well as the creation of behemoths like Microsoft, Apple, Google, Amazon, Facebook and Netflix within a short timeframe. A feature of these companies is that they were all founded by entrepreneurs whose vision was not constrained by the culture of an existing industry, and with the support of venture capitalists from the famed Sand Hill Road in Silicon Valley, with an eye for opportunity still unparalleled in the conventional investment community. Despite a few attempts, Sand Hill venture capitalists have not been successful in disrupting the bulk material processing industries which is the domain of the chemical engineer, usually as an employee.

Large industries like mining and minerals, oil, gas and petrochemicals, cement and construction, water and power generation have such a protective moat of regulation, logistical infrastructure and capital intensity that the barriers to entry are too high to attract entrepreneurs and venture capital. It is simply easier to focus risk capital on new digital and biotech innovations where an investor can exit more profitably.

The chemical engineer can indeed be a disruptor of existing capital-intensive industries, so future opportunities are only limited by a lack of imagination. The entrepreneurial chemical engineer should utilise findings in network science to combine the skills of unconventional inventors with imaginative pathways to market and visionary investors. It is seldom possible to radically change the existing bulk material processing industries, so new companies must be established to compete from the outside instead of the inside of such industries. While peer-reviewed research is important for building reputation and for research training, it too often inhibits radical innovation as a result of its funding framework, perpetuating the status quo.

It will be shown how innovative ideas in material science, reactor design and systems thinking can be used to develop new value chains and hence replace inefficient industries as follows:

a. Reducing CO_2 emissions by 80% in cement production and construction;
b. Decrease grinding costs by 70% in the mining industry;
c. Eliminate the use of reagents or smelting in many mineral processing operations;
d. Utilise low-grade hydrocarbon sources not amenable to existing refining processes;
e. Convert all carbonaceous waste into liquid or gaseous fuel;
f. Replace expansive wastewater treatment plants by geographically distributed plants of small footprint converting sewage sludge into fuel or hydrogen, cement, fertilizer and potable water;
g. Geographically distributed power generation and electricity storage using batteries based on cheap carbon nanotubes; and
h. Intensive production of food. In some jurisdictions, regulations aimed at protecting existing industries will prevent the above inventive ideas from being implemented, resulting in economic inefficiency and inability to compete. In such instances, the entrepreneur should move on, as opportunities elsewhere are without bounds.

For the young chemical engineer and those more experienced but young at heart, the fun has just started!

KEYNOTE PRESENTATIONS

We are delighted to be hosting the following researchers and industry leaders as keynotes to the 2019 Postgraduate Conference: Prof. Izak Nieuwoudt, Dr. Elroy Goliath, Dr. Derick Moolman, Dr. Lidia Auret and Dr. Annie Chimphango.

Separation Technology - a cornerstone of chemical engineering

Prof. Izak Nieuwoudt

The exploitation of organic chemicals has been playing a tremendous part in the improvement of the human condition over millennia. This included the use of ethanol, plant oils, crude oil, pigments, monomers, polymers, pharmaceuticals and many more. One common thread is that almost all of the organic molecules have to be isolated from naturally occurring mixtures or reaction broths to make them useful. Without separation technology this would not be possible. The inter-molecular forces between molecules complicates these separations. Over a period of 1200 years all kinds of separation methods were devised. During the last 200 years, and especially during the last 100 years separation technology developed significantly. During this period the term chemical engineering was coined and chemical engineers took the lead in developing separation technology. New techniques, such as azeotropic distillation, extractive distillation, pressure swing distillation, liquid extraction, absorption, supercritical extraction, and heat integrated distillation were developed. This also spurred the development of new separation technology equipment. In this presentation the history and latest developments in the field of separation technology and separation technology equipment will be covered.

Supply chain reinvention and food engineering in FMCG

Dr. Elroy Goliath

The fast-moving consumer goods (FMCG) sector in South Africa is typically characterized by global commodity volatility, low cost and intense competition. The probability of success in balancing the ever increasing consumer demand pressures with shareholder margin expectations remains a precarious paradox.

Disruption is intensifying, putting customers, employees and consumers at the heart of the business who attempts to stay ahead of changing customer needs in a volatile market. The industry is expected to go through more

change in the next ten years than in the past 40 combined. The market simply requires delivery faster, with more reliability, sustainable products, tailored service and a wide range of choice.

At the heart of facing up to this challenge is consumer packaged goods companies' capability in food engineering and reinventing their supply chains. This culminate in a careful balance between capital resource allocation, engineering, and technology adaptation while ensuring flexibility across the value chain. This challenge further speaks to supply chain intelligence, strategic architecture, an integrated operational model and resilience. Fundamentals of engineering design, systems thinking and process optimization governed by global food safety standards remains core to the goal of customer fulfilment.

The latest acquisition of Pioneer Foods by Pepsico International as case study also brings together global capabilities where scale, innovation, technology and market reach determines survival and market leadership, or ultimately failure.

Process Engineering 4.0 in Action

Dr. Derick Moolman & Dr. Lidia Auret

The Fourth Industrial Revolution is differentiated from the Third, or Digital Revolution, by the rate and extent of its technological disruption, resulting in an increasingly pervasive impact by the Internet of Things, robotics and Artificial Intelligence on how we live and work. Process Engineering has not been spared in being significantly affected by these technologies, and, in our opinion, for the better, provided a proactive and informed approach to distinguish between the unfortunate hype on the one hand, and on the other pragmatic, sustainable solutions that are guided by or at least aligned with conventional process engineering principles to solve new problems, or to solve old problems faster, in real-time, more economically or to better anticipate them. The benefits of these technologies in operational productivity, predictive asset performance and workplace safety have become clearer and will become compelling. To William Gibson's point, "The future is already here, it's just not very evenly distributed".

Improved process productivity can be achieved through appropriate measurement, insightful diagnostics based on these measurements, and optimal actions determined from these diagnostics. In highly automated process plants, measurements may include advanced new sensor technology (e.g. machine vision); diagnostics may include big data analytics combined with domain knowledge encapsulated in complex, first-principles models; and actions include automated regulatory and supervisory control, as well as condition-based maintenance. Diagnostic analyses evolve from descriptive (what happened) to

diagnostic (why did it happen) to predictive (what will happen) to prescriptive (what steps to take) as the complexity of measurements and analytics increases. Research in the robust, de-risked and cost-benefit optimal application of data analytics is essential to ensure effective technology transfer from theoretical insights to production-ready solutions.

Increasingly safe industrial operations will result from more stable process operations (enabled by diagnostic analyses and automated control) as well as through innovation in specialized technologies such as workplace safety monitoring through computer vision and wearables. The end-goal (even if only aspirational) may be a so-called lights-off process plant: where no humans are required to be physically present in hazardous environments. The social impact of a lights-off process plant must be geared to be positive: removing humans from harmful environments, as well as optimizing plant expert skills (focusing on productivity) and creating new, safer jobs for instrumentation and interpretation technicians – emphasizing life-long learning in an ever-changing world. Centralized remote monitoring for such plants leverages domain knowledge and exposure to multiple sites. The path to a lights-off process plant (or a less ambitious but still highly automated process plant) should be further explored through careful research and mapped to ensure optimal cost-benefit trade-off for each progressive automation investment decision.

The Department of Process Engineering has an opportunity to become a proactive Thought Leader in what we dub "Process Engineering 4.0", through research, innovation but most importantly by appropriately equipping a new generation of process engineers educated in Data Science, in a manner that will leverage and enhance tried and tested process engineering knowledge to the benefit of a more competitive, safer and more sustainable industry.

From trash to high value bio-products: Taking advantage of nature and natural processes to unlock value from plant biomass waste

Dr. Annie Chimphango

Agriculture and forestry are key sectors in achieving low carbon economies. The sectors generate large volumes of plant biomass wastes, which often are disposed of to the environment and/or are used in low economic activities. However, these biomass wastes are inherently, locked with lots of value emanating from the complex structure and composition of the plant cell wall matrix. The value from the biomass waste can be unlocked and recovered in a biorefinery set up, governed by "zero waste" and "green" engineering principles,

leading to the production of high value bio-based products such as bioenergy, biomaterials, nanomaterials, chemical, functional foods and nutraceuticals for industrial applications. Therefore, the current research on biomass waste value addition is dominated by exploring of different biorefinery conversion pathways and value addition methods through experiments, simulations and modelling, which provide key information on maximizing the economic, environmental and social gains from what is considered "trash" to enable strategic investments. Consequently, the composition and structure of the plant biomass matrix and the natural bioprocesses such as microbial fermentation and enzyme degradation involved in the breaking down of the biomass plant structures and modification of the bio-products are being manipulated and optimized using engineering and biological approaches. However, the development of sustainable biomass waste supply and product value chains requires knowledge and expertise beyond the engineering disciplines, thus, highlighting the need for systematic and integrated approaches as well as multidisciplinary research, innovations and industry partnerships.

ABSTRACTS

ORAL PRESENTATIONS

The effect of environmental conditions on growth and phenotype switching in Mycobacterium smegmatis

Apiyo D, Mouton JM, Sampson SL, Louw TM

The ability for bacteria to survive antibiotic treatment, despite genetic susceptibility, is a potential contributor to latent tuberculosis (TB) infection. These bacteria exist as a small, viable but non-replicating (VBNR) population, characterised by their insensitivity to bactericidal antibiotics, and have been aptly named 'persisters'. Little is known about this subpopulation, owing to their supposed quiescent metabolic state and limited numbers. Nevertheless, recent work has developed and exploited a dual fluorescence reporter for use in Mycobacterium tuberculosis to identify, isolate, and characterise VBNR persister populations. Furthermore, the role of persisters in mycobacterial biofilms is being investigated, as biofilms generate a spatially heterogenous microenvironment that could lead to phenotype switching of individual cells and subsequent population heterogeneity.

In this study, the growth, metabolism, and persister formation of *Mycobacterium smegmatis* – a non-pathogenic model organism of *M. tuberculosis* – is assessed under different environmental stresses involving nutrient starvation and acidic pH. A computational model of the planktonic cellular system, based on the Monod equation, is established and used, together with the experimental data from a variety of growth conditions, to estimate and validate the growth parameters of the organism. Additionally, flow cytometry is used to investigate persister formation under each growth condition through the measurement of fluorescence dilution of the organism's dual fluorescence reporter system.

Results from this study can be used to infer the effect of varying experimental conditions on growth and persister formation in a biofilm model, and ultimately, be used in establishing novel treatment strategies targeting drug-tolerant persister cells.

Bayesian methods for ordinary differential equation parameter estimation

Basson M, Kroon RS, Auret L, Coetzer RLJ, Cripwell JT

Mechanistic models derived from physical processes are useful tools for modelling dynamic system behaviour in many domains ranging from physics and engineering to ecology and various biomedical research fields. These models often take the form of ordinary differential equations (ODEs); however,

the physical principles underpinning the model development phase provide no insight into selecting suitable values for the adjustable parameters that parameterise the ODE model. In a typical setting, the model can be derived from expert knowledge, however, the model parameters are unknown and cannot be measured directly from the system. These model parameters have to be estimated from noise-corrupted time series data which introduces uncertainty into the estimation problem. The resulting ODEs typically do not have closed-form solutions and practitioners resort to using numerical integration techniques, in conjunction with standard methods for statistical inference, to estimate the model parameters.

In recent years Bayesian methods have developed from a specialist niche to become a mainstream technique. Nonparametric Bayesian modelling based on Gaussian Process regression over time series data has established itself as a successful alternative for estimating the parameters of ODEs with the additional benefit of explicitly modelling the uncertainty associated with noise-corrupted experimental observations. The Gaussian Process alternative directly interpolates the state variable from the experimental data and calculates the state variable derivative to which the ODE can be fitted directly, thus avoiding the need for numerical integration while simultaneously producing a posterior distribution over the model parameters that express the estimated parameter uncertainty. ODE parameter estimation via the Gaussian Process regression route will be demonstrated on an isothermal, constant volume continuous stirred tank reactor simulation case study.

Techno-economic analysis of macroalgae biorefinery scenarios for production of HVPs and biogas

Border AF, Görgens JF, Goosen NJ

The South African seaweed sector is currently limited to low-tech, low return activities and its viability is subject to international market fluctuations. Brown seaweeds contain diverse, endemic compounds that have high bioactivity. Research has been conducted into the extraction and isolation of these compounds, namely fucoidan, laminarin, and alginate, for application as functional foods. These compounds have high values and growing markets. A cascading biorefinery approach has been applied to E. maxima, a species of brown seaweed endemic to South Africa, in order to maximise the inherent value of all components in the biomass through the fractionation of the different compounds.

This project focuses on the techno-economic analysis for multiple biorefinery scenarios. Primarily, three processing options for the hydrolysis step are compared: enzyme-assisted extraction (EAE), ultrasound-assisted extraction

(UAE), and sub-critical water extraction (SWE). In-house data were generated for realistic process simulation, which is performed on Aspen Plus to establish material and energy balances. A biogas cogeneration scenario is also developed to provide on-site generation of heat and power for the process from seaweed residue. An experimental design was conducted to determine the optimum temperature, solids loading, and inoculum to substrate ratio for the anaerobic digester. Pilot scale runs were conducted in order to validate the results achieved at bench scale. IRR and pay-back time calculated to determine economic viability. If successful, this project could lead to the development of a local, sustainable macroalgal based business with the potential to be globally competitive within the framework of high value products.

Single and binary component adsorption of 1-alcohols from an alkane using activated alumina

Bosman CE, Schwarz CE

Alcohol-alkane streams are produced during surfactant production. Distillation is used to separate the alcohols from the alkane stream; however, some alcohol contaminants remain in the alkane stream. Adsorption has been shown to be a technically viable process for the removal of these residual alcohols from the alkane stream. The aim of this study was therefore to gain knowledge on the single as well as binary component adsorption of alcohols from an alkane using activated alumina adsorbents.

Using a bench-scale water bath and beaker setup, data was measured for both single and binary component adsorption systems containing various 1-alcohols (1-hexanol, 1-octanol, and 1-decanol) in n-decane, using three industrially relevant adsorbents (Selexsorb CDx®, Selexsorb CD®, and Activated Alumina F220).

The effect of different variables was investigated whereby it was found that both temperature and initial adsorbate concentration had positive effects on the adsorption in the ranges investigated, i.e. when the specific variable was increased, a corresponding increase was exhibited in the adsorption. The effect of the carbon chain length of different 1-alcohols was also investigated. The chain length proved to have a very small effect, with the shorter chain alcohols adsorbing slightly better than the longer chain alcohols comparatively.

For the single component systems, the Redlich-Peterson isotherm model was found to provide the best correlation of the equilibrium data whereas the Freundlich model proved to be the best model for the binary component data. For both, the pseudo-second-order model proved to be the most suitable kinetic model. Interestingly, however, the intra-particle diffusion model was

also found to be suitable for the correlation of both the single and binary component data. Collectively, this suggests that both the surface reaction as well as intra-particle diffusion influenced the rate of adsorption.

In the binary component systems, antagonistic interaction was exhibited indicating competitive adsorption behaviour. It was also found that adsorption of the longer carbon chain alcohols was inhibited more in the presence of a shorter carbon chain alcohol than the other way around.

A numerical investigation of the hydrodynamics and mass transfer in a multiphase bioreactor for paraffin activation

Gakingo GK, Clarke KG, Louw TM

Biological paraffin activation is an industrially relevant bioprocess for the valorisation of linear alkanes. The multiphase process consists of an aqueous growth medium and an immiscible alkane phase that is aerobically metabolized by active micro-organisms. Thus, the oxygen transfer rate from sparged gas is a key design parameter for which empirical correlations have been proposed to inform bioreactor design. However, a fundamental predictive approach is needed to enable the evaluation of novel multiphase bioreactor designs in silico.

This study reports on the development of a fundamental predictive model of oxygen transfer based on computational fluid dynamics. Key findings suggest that the alkane phase impacts the hydrodynamics by turbulence modulation rather than a change in fluid properties. The model-predicted oxygen transfer rate is compared to experimental measurements and shown to have an accuracy similar to empirical correlations. However, only the fundamental model captures complex interactions arising due to the alkane phase and can thus be more readily extrapolated to novel multiphase bioreactor designs. The insights gained in this study will guide future investigations into the simulation of hydrodynamics and oxygen transfer in the presence of micro-organisms, thereby providing a fundamental approach to bioreactor scale-up.

Characterisation of the droplet and stream sizes within randomly packed columns using electric impedance tomography

Lamprecht JH, Burger AJ

Column-internals play a prominent role in the economic viability of distillation setups due to their contribution to both operating and capital costs. Progression in both the understanding and characterisation of column-internals is therefore paramount. Both hydrodynamic and kinetic characterisation methodologies

consider the influence of the interfacial area, whether directly (effective interfacial area) or indirectly (pressure drop and liquid holdup).

Literature concerning random packing evaluates only the overall interfacial area without quantifying the individual contributions of the droplet size distributions and the coated packing pieces. This limits the fundamental basis of the available models and introduces regressed empirical constants. Attempts have been made to address the limitations by obtaining approximations of the flow distributions within structured packing, using x-ray tomography. This expensive and laborious technique introduces significant safety risks and is limited by slow sampling frequencies. The application of x-ray tomography is consequently not applicable to random packing evaluations where sudden flow path changes are prevalent.

Improved fundamental understanding of interfacial distributions inside counter-current columns is consequently proposed by developing and using a dual-modality electric impedance tomography (EIT) system for multiphase flow mapping of counter-current columns. The EIT system utilises both high and low sinusoidal frequency response for concurrent evaluation of electrical resistance and capacitance, thereby relating droplet and stream distributions. The nature of the dual-modality EIT system offers applicability to both conductive and non-conductive liquids with a high degree of sensor linearity and excellent calibration capabilities.

Incorporating sustainable practice principles into development of solutions for mitigation of mine waste

Manjengwa ER, Dorfling C, Tadie M

Waste rock and mine tailings dumps are associated with notable degrees of environmental and sociological consequences resulting from primary and secondary effects. The poor legacy, however, remains within the industry. Tailings dumps are part of that legacy and their impact on the environment and communities needs to be addressed, particularly in Africa where poverty is a major social issue. The most accessible recourse to mitigation of mine tailings is the recovery of value (unrecovered valuable commodity) which removes the vast amounts of waste stored in tailings dumps in some cases and creates a platform for extending the value chain of some mining and metallurgical operations.

The proposed project aims to address the issue of mine tailings treatment and the associated environmental and social impacts by answering the key question regarding the effectiveness of proposed solutions and technologies that positively address the economic, environmental, and sociological aspects

associated with the handling of mine tailings. A framework encompassing the three fundamental pillars of sustainability will be developed. In addition to the evaluation of the economic performance of the processes under study, tools such as environmental life cycle assessment (E-LCA) and the social life cycle assessment (S-LCA) will be considered to assist this effort. The UNEP/SETAC framework (ISO standard 14040) will guide the life cycle assessment studies. Using the traditional measures of project profitability and business sensitivity analysis, Excel, SimaPro/Gabi software, and at least two impact assessment methods of the economic and environmental performance will be evaluated, respectively, and results reviewed using the developed framework.

Optimisation of fucoidan recovery by ultrasound-assisted enzymatic extraction from South African brown kelp, Ecklonia maxima

Mapholi Z, Goosen NJ

Seaweed polysaccharides have significant applications in functional foods, nutraceuticals, cosmetics, and pharmaceuticals industries. These applications are due to the bio-functionalities they possess. Specifically, fucoidan, which is a sulfated polysaccharide of a fucose monomer backbone, has a wide range of bio-functionalities such as antioxidant, anti-tumour, anti-coagulant, anti-apoptosis, contraceptive, and anti-peptic. Like many other seaweed polysaccharides, fucoidan structure and hence its bio-functionalities is affected by season, location, species type, and the extraction method used. Fucoidan is found within the cell wall of brown seaweed. The high content of cell wall carbohydrates act as a limitation to the extraction of fucoidan.

This work is based on the extraction and optimisation of fucoidan by enzymatic extraction intensified with ultrasound cavitation in a flow through system. Four factors (ultrasound intensity, temperature, pH, and enzyme-substrate ratio) which affects the fucoidan extraction in the proposed extraction system were evaluated using ANOVA and response surfaces, and the optimal conditions were determined. Results reveal enzymatic extractions intensified with ultrasound cavitation have fucoidan yields 30% higher than individual enzymatic extraction and ultrasound extractions.

Density and viscosity measurements at phase transition in CO_2 + 1-dodecanol + 2-dodecanol mixtures

Motang N, Knoetze JH, Schwarz CE

Supercritical fluid fractionation is used in various industries to separate liquid mixtures that would otherwise be difficult to separate with conventional processes such as distillation or liquid-liquid extraction. These mixtures may contain components that are close-boiling, heat-sensitive, or will be used in food applications. The design of columns used in supercritical fluid fractionation is not well understood, and is currently achieved using correlations developed for sub-critical processes. This leads to large errors in the column design. Since physical properties such as density and viscosity appear in the column design correlations, the errors encountered with the use of the sub-critical correlations may be reduced by incorporating measured physical properties of supercritical fluid mixtures.

In this work, the density and viscosity were measured at phase transition in a mixture of carbon dioxide and (1-dodecanol + 2-dodecanol). Two binary mixtures of carbon dioxide and each alcohol, as well as a ternary mixture, were investigated. The phase transition was detected visually in a synthetic view variable volume cell. The density was determined from a calibrated volume, while the viscosity was determined from the resonant frequency of a torsional quartz crystal immersed in the mixture. Both binary mixtures and the ternary mixture showed temperature inversion in the phase transition pressure, indicating possible multimer formation in the mixtures. The results from this study will be used in further investigations to model the mass transfer in a supercritical fluid fractionation process.

Improving the predictions of (solvent + LLDPE) phase boundaries of commercial interest

Swanepoel RM, Schwarz CE

Linear low-density polyethylene (LLDPE) is the fastest-growing form of polyethylene. It is frequently produced in the solution process by copolymerising ethylene and α-olefins which are dissolved in an inert hydrocarbon diluent. Collectively, ethylene, the comonomers, and the diluent constitute the solvent in which the produced LLDPE is dissolved. Efficient operation of the solution process requires detailed knowledge of the (solvent + LLDPE) phase behaviour. Although experimental measurement is the most reliable way to determine phase behaviour, measurements of polymer systems are difficult and time consuming. Therefore, this work aimed to improve predictions of

(solvent + LLDPE) systems' phase boundaries; four approaches were taken to this end.

First, since a systematic study into the effects of α-olefin length and concentration was lacking, this was investigated experimentally for the C_2 to C_{10} linear α-olefins in (α-olefin + n-hexane + LLDPE) systems. This showed that phase transition pressures (i) change linearly with polymer-free α-olefin concentration, (ii) increase for the C_2 to C_6 α-olefins and decrease for the C_8 and C_{10} α-olefins, and (iii) are significantly influenced by an antisolvency effect caused by ethylene.

It is, however, not feasible to measure (ethylene + comonomer + n-hexane + LLDPE) phase boundaries for all possible solvent compositions. Hence, a second experimental investigation related average solvent properties to (solvent + LLDPE) phase boundaries. For all systems studied, it was found that ethylene–comonomer interactions are negligible, and that solvent average molar mass correlates well to a characteristic temperature found in each system. It was also shown that previously established density correlations are incapable of providing phase behaviour predictions in systems containing C_6 or heavier α-olefins.

A systematic investigation was subsequently undertaken to determine the predictive capabilities of the perturbed-chain statistical associating fluid theory (PC-SAFT) when modelling each of the factors influencing phase behaviour. Two different branching concepts were compared, and the advantages of group-contribution-estimated binary interaction parameters were evaluated. Although PC-SAFT provides qualitatively fair predictions, quantitative accuracy remains unsatisfactory due to inherent deficiencies within the framework. A new parameterisation scheme was proposed specifically for commercial systems.

This work finally culminated in a new corresponding states theory for (solvent + LLDPE) systems. As inputs, the theory requires only common reference properties of the solvent and a single cloud point pressure of a (solvent + LLDPE) system with a similar polymer, but any solvent. The complete fluid phase boundaries of the required (solvent + LLDPE) system can then be estimated over any required temperature range.

Design and investigation of a semi-partitioned bioreactor for continuous extractive fermentation

Teke GM, Pott RW

Fermentation technology is used in various industries (pharmaceuticals to fine chemicals) to convert simple substrates to valuable products with support of micro-organisms. While these technologies are commonly used, there are nonetheless still faced with challenges, specifically low product yield and productivity caused by product inhibition, mass transfer and selective metabolic issues. Hence, these limitations have greater impacts on process optimization and operation. Extractive fermentation based on in-situ product removal (or recovery) was introduced to combat several of these issues over the years, but its failure in wide spreading towards industrial development has demonstrated its persistent lab scale usage, prevailed with batch production compared to other modes of operation. Our aim of this study is to design a bioreactor for the continuous in-situ product recovery/removal during extractive fermentation using liquid-liquid extraction. The bioreactor was designed for continuous mixing and settling of two immiscible liquids. This was proven using a generated separation profile, while mixing studies and mathematical models were developed and studied for mass transfer analysis.

The results demonstrate a generated separation profile which elaborates on continual mixing and settling. A perfectly fitted model that generates a 0.019l/s and 3.768l/m^2.s of flowrate and mass transfer (KL) values respectively of the designed bioreactor after triplicates runs. This high rate of material exchange is evident in the rapid homogeneity of the system as shown during conducted mixing studies. A continuous simulated process demonstrated a 95.3% recovery. The results above and a simulated system shows the design of a novel mixer-settler bioreactor through control measures of product removal and phase recycling.

The development of an electrowinning model to predict process performance

Tucker M, Dorfling C, Tadie M

Electrowinning is the final step in the hydrometallurgical production of high purity copper, which involves passing an electric current through a copper-containing electrolyte and the consequent plating of solid copper onto cathodes. Key electrowinning performance indicators are current efficiency, specific energy consumption, yield, and quality of the metal product. The high energy demand and associated cost mean that determination of performance

indicators is critical during operation, but online measurement is impractical due to the corrosive environment caused by acid mist. A manual approach to process control is currently utilised in industry, whereby operators adjust input conditions or diagnose faults after analysing copper plates which have spent days undergoing electrowinning.

This research considered the shift towards a pre-emptive approach to attaining plant performance data. The objectives were to develop a model to predict electrowinning performance, to develop a parameter fitting approach to calibrate the model to bench-scale experimental data, and to apply the model to an industrial operation. The scope involved the development of a steady state electrowinning model with iron as an impurity, to predict current efficiency, specific energy consumption, and yield of copper produced, based on operational and geometrical input variables and a first principles approach. Model development involved conceptualising a circuit diagram backbone and combining, in MATLAB, reaction rate and mass transfer kinetics, mass balances, electrochemical and thermodynamic equations, and property correlations. The parameter fitting approach involved designing experiments on a bench-scale electrowinning setup and using the data generated to calibrate parameters (for reaction and mass transfer rates and current loss) to the model through a set of non-linear regressions.

The rate kinetics parameters fit relatively well to the experimental data, with an adjusted R2 of 0.86 for copper reduction, 0.74 for water oxidation, 0.72 for iron reduction, and 0.66 for iron oxidation. The electrowinning model accurately predicted the performance of the bench-scale setup, with average absolute errors of 3.2% for the current efficiency, 3.0% for the specific energy consumption, and 7.0% for the copper plating rate, demonstrating the potential of the model to predict performance in an electrowinning system with specifically fit parameters. Performance data for industrial tank houses were scattered due to large variation in parameters between electrowinning setups. The predictive model could be used directly in operator training or combined with the parameter fitting approach as a first step towards process control in an industrial electrowinning process.

Pyrolysis of waste plastic packaging to optimise the production of oil/wax for fuel application

van der Westhuizen S, Collard F-X, Görgens JF

It has been stated that by 2050 the ocean could contain more plastic than fish by weight. Aside from the growing global environmental threat of waste plastic,

it also represents an economic loss in terms of the energy and chemicals that can be recovered from the waste plastic (especially plastics that cannot be recycled via primary and secondary methods due to mixing of different plastics and contamination) via tertiary recycling methods such as pyrolysis.

Plastic pyrolysis is the degradation of plastic at high temperature (400-700°C) in an inert environment to obtain three products: oil/wax, gas, and char. The aim of this study is to optimise the yield and the quality of the oil/wax (for fuel utilisation) from the pyrolysis of two plastic waste stream fractions: contaminated polystyrene; and contaminated multi-layer of LDPE and PET.

To achieve the aim, statistical optimisation of the pyrolysis operating conditions (such as temperature and heating rate) for maximum oil/wax yield and energy content was performed in a semi-batch bench-scale reactor. The scalability of these results to a pilot scale rotary kiln reactor was then tested.

The optimum oil yield achieved for polystyrene was 93.03±2.71 wt% at 550-600°C and 82.50±1.43wt% at 550°C for bench and pilot scale, respectively, with an HHV of 42.51±0.36 MJ/kg. For the LDPE/PET multi-layer the optimum oil/wax yield achieved was 75.37±0.04 wt% at 500°C and 60.74 wt% at 475-500°C for bench and pilot scale, respectively, with an HHV of 40.71 MJ/kg. The HHV of both the plastic oil/wax products is comparable to that of commercial diesel.

Techno-economic analysis of bio-oil production from forest residues via non-catalytic and catalytic pyrolysis

van Schalkwyk DL, Mandegari M, Görgens JF

Forest residues are a high fire risk and often disposed of by in-field burning. The 1.5 million dry MT/year of forest residues available in South Africa can instead be converted into liquid bio-oil and solid biochar through pyrolysis. Furthermore, bio-oil can be upgraded by in-situ catalytic pyrolysis with CaO to reduce its high oxygen content.

Process simulations were developed in Aspen PlusTM based on pilot plant data for non-catalytic and catalytic pyrolysis of Eucalyptus grandis forest residues. Non-catalytic pyrolysis produced 22.6 wt% biochar (net) and 19.8 wt% crude bio-oil, while catalytic pyrolysis produced 16.5 wt% biochar and 18.4 wt% upgraded bio-oil.

The process simulations were evaluated in terms of economic feasibility and environmental impact. The minimum selling price (MSP) of upgraded bio-oil was $1.35/L, whereas the MSP of crude bio-oil was $0.75/L for a desirable 22% internal rate of return (IRR). Bio-oil can be co-processed with vacuum gas oil

(VGO) to produce bio-derived transportation fuels. However, co-processing crude bio-oil can more negatively impact downstream processing at the oil-refinery than co-processing upgraded bio-oil. Furthermore, the estimated market price of VGO was significantly lower at $0.35/L than the MSP of crude and upgraded bio-oils. The global warming potential (GWP) for crude and upgraded bio-oil production corresponded to -0.30 and -0.14 kg CO_2 eq/MJ, while the GWP for VGO production was between 0.0052 (crude-oil) and 0.013 (diesel) kg CO_2 eq/MJ. Therefore, the significantly lower environmental impact of crude and upgraded bio-oil production can substantiate their price premium.

ABSTRACTS

POSTER PRESENTATIONS

Control performance monitoring and relay auto-tuning of a milling circuit

Albertus GJ, Auret L., Dorfling C.

Relay auto-tuning is an automated procedure that changes the tuning parameters of the process controller when required. However, it is not known in industry when relay auto-tuning should be implemented, and present literature studies do not extensively address this problem. The main objectives of the investigation are to determine when it is suitable to implement relay auto-tuning, using a milling circuit simulation model as a case study, and to evaluate if the relay auto-tuner is viable in minerals processing through economic performance evaluations.

Several control performance monitoring techniques have evaluated the variance of the controlled variable as a good indicator of the controller performance, most notably the Harris index. This study utilizes the controlled variable's variance as an indicator for when relay auto-tuning should be applied, specifically if there has been an increase in the variance in comparison to a period where control performance was seen as acceptable.

Literature studies have related the product particle size from the milling circuit to the downstream flotation circuit recovery; as a result, the product particle size is perceived as having a significant economic impact. Due to the abrasive nature of milling circuits, a valve degradation model is directly applied to the product particle size controller to incite poor controller performance. Preliminary results indicate that valve degradation does not have a significant impact on economic performance. This is possibly due to the product particle size not drifting from the controller set point. However, valve degradation significantly increases the variance of the product particle size. When relay auto-tuning is applied there is a noteworthy reduction in the variance.

Optimisation of inulo-oligosaccharides production from various inulin substrates obtained from Jerusalem artichoke tubers using a commercial enzyme

Bedzo OKK, Görgens JF

Commercial production of inulo-oligosaccharides (IOS) relies largely on chicory roots. However, Jerusalem artichoke (JA) roots provide a suitable alternative due to its high inulin content and low cultivation requirements. The inulin from JA tubers are also amenable for IOS production with superior sweetness and prebiotic properties.

In this study, JA powder was prepared from fresh JA tubers. Inulin powder was also prepared from the JA powder. A powdered solid residue was also obtained post protein extraction from the JA powder. A commercial endoinulinase whose pH and temperature optima were determined to be 6.0 and 60°C, respectively, was deployed in IOS production from the various inulin substrates. The IOS production from the substrates was optimised by central composite design with response surface methodology experimental design.

At the optimal conditions, high IOS yields of 79.2, 76.3, 71.0, and 77.1% (w/w_{inulin}) were obtained from pure chicory inulin, JA powder, JA solid residue, and the JA inulin extract, respectively. For all the inulin substrates the optimal enzyme dosage was determined to be 14.8 U/g_{inulin} with the reaction time less than 6 h. The prediction model accuracies were found to be more than 90% which indicate the sufficiency of the models to accurately predict the IOS yields. The results obtained here with the JA tubers exhibit potential for commercial production of IOS with possible savings on cost of biomass and increased productivity.

Extraction of high value products from wheat straw and wheat bran

Ceaser R, Chimphango AFA

Biomass waste conversion and valorisation into high-valued product has been the focus of recent research. Wheat, a globally produced crop, results in the generation of wheat straw and wheat bran as field waste and processing waste, respectively. Wheat straw and wheat bran contain high value products such as cellulose, hemicellulose, lignin, and phenolic compounds that, when separated, can improve the process economics.

Whereas wheat straw contains a high amount of p-coumaric acid, wheat bran contains ferulic acid as its phenolic compound. However, due to the complex nature of the biomass cell wall, selective fractionation becomes a challenge. Current fractionation methods involve alkaline treatment for the extraction of hemicelluloses, phenolic compounds, and lignin at optimally different treatment conditions. The aim of this study was to optimise a two-stage alkaline treatment for fractionating both wheat straw and bran to sequentially extract these products.

The treatment resulted in significant extraction of all targeted products from wheat straw and bran. Hemicellulose yields of 77 and 52% whereas lignin yields of 68 and 94% were obtained for wheat straw and bran, respectively. In addition, yields of 1.74 mg/g p-coumaric acid and 1.05 mg/g ferulic acid were obtained for wheat straw and bran co-extracted phenolics, respectively. After a two-

stage alkaline treatment a cellulose recovery of 97% and 83% was obtained for wheat straw and wheat bran, respectively. The wheat straw cellulose fraction was deemed suitable for application as feedstock in nanocellulose production, further improving process economics. The release of these products was found to be possible due to the partial breakdown of the cell wall bundle structure of both wheat straw and bran during the two-stage alkaline treatment by using a scanning electron microscopy analysis.

Influence of electrolyte composition on the electrodeposition of copper in electrowinning process

Chibwe C, Tadie M

In electrowinning, uniformity and quality of the deposit are of paramount importance. Controlling the growth and structure of the deposit is essential in improving deposit morphology. Current distribution, which is dependent on cell design, cell geometry, electrolyte conductivity, electrode kinetics, mass transfer of ions, and operating conditions, is influential in controlling the growth and structure of the deposit. Since electrolyte composition influences mass transfer of ions and electrolyte conductivity, the control of electrolyte composition offers an opportunity to improve the current distribution in electrowinning.

This work investigated the influence of electrolyte composition on current distribution in electrowinning of copper and aimed at developing a model to predict current distribution for improved performance. An electrowinning cell was set up to deposit copper at various electrolyte compositions (35 to 45 g/dm^3 copper, 160 to 180 g/dm^3 H_2SO_4, 1 to 6 g/dm^3 iron at 45°C). The deposit thickness measurements were taken and used to determine current density distribution at the electrode surface by utilizing Faraday's equation. The model was developed using COMSOL Multiphysics 5.3a and validated using experimental data.

The results indicate that an increase in copper and acid concentration increased the thickness of the deposit. This was attributed to improved mass transfer and increased electrolyte conductivity. However, there was variation between the modelled and experimentally determined current density profile roughness and magnitude. Investigations are ongoing to explain the observed variation. A possible explanation is that the deposit had time to fully develop roughness compared to the model which depended on deforming geometry.

Enzymatic hydrolysis optimisation of Ecklonia maxima for extraction of bioactive compounds

Claase A, Goosen NJ

Nutrients come in forms that plants are unable to utilise and insufficient amounts of nutrients are released to meet the requirements of crops or other large plantations. This has led to the use of fertilizers to provide the necessary nutrients. However, excessive use of conventional fertilisers has been found to pollute nearby water sources. An alternative that has been gaining traction is the use of biostimulant products which contain bioactive compounds and do not have the negative effects on the environment that chemical fertilisers do. The use of seaweed as a source of bioactive compounds has very significant advantages over other terrestrial plant sources. Therefore, an optimised process to produce biostimulant products derived from the local South African seaweed species *Ecklonia maxima* has some potential to contribute to the industry. The goal of this study was to optimise an enzymatic assisted extraction (EAE) of bioactive compounds from the brown seaweed *Ecklonia maxima* using a protease and carbohydrase.

The optimisation in this study was done using response surface methodology (RSM) with a central composite design (CCD) where three factors were varied, namely temperature, pH, and enzyme to substrate ratio (E:S ratio). The responses measured were reducing sugars, neutral sugars, solubilised alginate, phenolic compounds, antioxidants, dry material, and crude protein. Utilising a desirability analysis and further process development the optimal parameters were determined to be a temperature of 46.6°C, a pH of 5.5, E:S ratio of 0.74% (w/w) and a hydrolysis time of 16 hours.

Numerical modelling of high-pressure thermodynamic data using neural networks

Coetzee A, Knoetze JH, Schwarz CE

Thermodynamic data, such as vapour-liquid equilibrium, are important when designing a processing system. Most industrial designs use equations of state to determine phase equilibrium behaviour, but these equations can become inaccurate near the critical region. It is therefore important to find the most accurate method to predict thermodynamic data.

In this study, neural networks were used to model vapour-liquid equilibrium of binary systems near the critical region of the mixture. The models were used to predict the bubble and dew point pressures of binary systems containing

carbon dioxide (CO_2) and organic compounds such as alkanes, alcohols, carboxylic acid, esters, and acetates using the critical temperature and pressure, the chain length, and the molar mass of the organic compounds, the system temperature, and the vapour and liquid composition of CO_2. The aim of the project is to provide accurate results for binary systems containing CO_2 and organic compounds with different functional groups for a wide range of chain lengths, compositions, and pressures. This was done by collecting isothermal vapour-liquid equilibrium data sets between a temperature range of 300 to 400 K for a variety of functional groups and a wide range of chain lengths in order to train a neural network to accurately predict the bubble and dew point pressures of binary systems with different chain lengths.

After training the proposed neural network, using 86 binary systems containing CO_2 and alkanes with chain lengths from n-pentane to n-dotriacontane, the average absolute relative deviation percentage (AARD%) and the coefficient of determination (R^2) were 21.98% and 0.93, respectively.

Seed crystal preparation for effective gypsum crystallisation in seeded slurry precipitators

Cronje IA, Burger AJ

Many mines in South Africa generate large volumes of acid mine drainage (AMD), containing relatively high concentrations of sulphates. Several mine water treatment plants utilise intermediate seeded slurry crystallisation, between stages of reverse osmosis (RO), where gypsum ($CaSO_42H_2O$) is precipitated and removed to enable further desalination by RO in the presence of anti-scalants.

This study aimed to determine the effect of various methods of treatment on re-used seed crystals, considering the efficiency and rate of gypsum precipitation in the presence of anti-scalants. Four different treatment methods were evaluated: 1. vigorous mixing; 2. aeration; 3. addition of hydrogen peroxide; 4. addition of alum. The experiments were performed in sets of three, while seed crystals were re-used and dosed at three-times gypsum saturation in the presence of 9 ppm Flocon260 anti-scalant.

The effectiveness of gypsum precipitation was characterised in terms of calcium removal, while assuming an equivalent sulphate removal. The most effective physical treatment method was found to be mixing of the seed crystal mixture for 10 minutes at 400 rpm, removing an average of 31.4% calcium, compared to the control where only 15.3% calcium was removed without such mixing. Aeration as a treatment method was found to be ineffective, with a maximum

calcium removal of 18.6%. The dosing of alum proved to be a very effective chemical treatment method. In the presence of 4.5 ppm aluminium, 41.2% of the calcium could be removed, compared to a maximum removal of only 25.3% in the presence of 90 ppm hydrogen peroxide.

Fractionation of tyre derived oil as a fuel additive

Dantu RK, Schwarz CE, Knoetze JH

With an increasing demand for energy security, waste valorisation and energy production through the use of a variety of waste products are of primary focus worldwide. Non-biodegradable waste such as end-of-life tyres is increasing rapidly due to the significant growth of the automobile industry. The difficulty of end-of-life tyre recycling arises due to the complex chemical make-up of the tyre. Pyrolysis is a popular and effective waste management process for waste tyre valorisation.

Tyre-derived oil (TDO) is a potential fuel source due to the large array of hydrocarbons present in the oil. Chemical properties of the oil such as calorific value, density, and viscosity have been proven to be of a similar standard to those of common fuel types found in industry. Oil fractionation follows similar guidelines to that of conventional crude oil distillation. Light naphtha, gasoline, diesel, and marine bunker oil fraction are all possible fuel fractions which can be extracted from the oil.

The aim of this study is to fractionate tyre-derived pyrolysis oil with the end objective of obtaining a variety of fuel types. TDO assay data will be collected using an advanced distillation curve approach prior to the fractionation process. A pilot plant batch distillation set-up will be constructed where reflux ratio, operating pressure, and cut-temperature intervals will be tested. Refinery optimisation is of utmost importance to optimise profit and to create the greatest economic return on the owner's investment. This work will use linear programming to optimise the complex crude tyre oil blending process. Gross profit margin, density, and sulphur content will be optimised and evaluated against the market specification and demand.

Quaternary phase equilibrium data of quaternary water + (ethanol and 2-propanol) + isooctane system

de Klerk DL, Schwarz CE

Low molecular mass alcohols, such as ethanol and 2-propanol, are widely used in industry as fuel additives or in the semiconductor industry. Most of these applications require anhydrous alcohols. However, very often commercial processes, such as fermentation, produce dilute aqueous mixtures with more than one alcohol present. Normal distillation is unable to sufficiently remove water from the system due to the presence of a water-alcohol azeotrope. Heterogenous azeotropic distillation is a more advanced technique which is widely used to overcome the azeotrope to produce anhydrous alcohols. Commercially benzene has been used as a successful entrainer, but is unfortunately carcinogenic. Isooctane has been shown to be a viable possible substitute entrainer. In addition to being non-carcinogenic, trace amounts of isooctane are not detrimental if the alcohols are to be used as fuel additives.

Existing thermodynamic models struggle to accurately predict the phase behaviour of such systems, and as such reliable phase equilibria data are required to understand the system's phase behaviour, for use in modelling correlation and subsequently in process design. While LLE, VLE and VLLE data is available for ternary systems with only one alcohol, little information is available with respect to quaternary systems where two alcohols are present. The aim of this contribution is therefore to investigate the phase equilibria of the quaternary water + ethanol + 2-propanol + isooctane system by presenting (1) liquid-liquid equilibrium (LLE) data for a range of temperatures; (2) vapour-liquid equilibrium (VLE); and (3) vapour-liquid-liquid equilibrium (VLLE) data of the system at three 2-propanol : ethanol ratios at 101.3 kPa.

Enzymatic modification of technical lignin to establish viable valorisation routes

du Toit CM, Tyhoda L, Görgens JF

Lignin is an amorphous polymer providing structure and strength to the cell walls in plants, especially woody plants. In the process of paper making the lignin is degraded, removed, and burnt for steam production. Interest in alternatives uses of these lignins has increased considerably owing to the possibility of lignin being a source of renewable aromatic chemicals and various other applications. Furthermore, the isolation and characterisation techniques of lignin have improved, leading to a better understanding of the structure and potential valorisation routes.

Ligninolytic enzymes have shown significant potential in repolymerising these degraded lignins. The potential high value application of theses lignins include stronger polymeric packaging, composites, and active packaging. In this project, different industrial lignins from the South African pulping industry was isolated and reacted with various enzymes to cause repolymerisation and hence increase the molecular weight of the these lignins.

Aqueous two-phase systems for the extraction of polyphenols from spent wine pomace

Herbst J, Pott RWM

Polyphenols, such as resveratrol, an antioxidant with positive health benefits sourced from grapes, are currently extracted for nutritional supplements using methods which are not efficient or environmentally sustainable. Aqueous two-phase systems (ATPSs) have previously been deemed to be greener alternatives for the extraction, separation, and purification of biomolecules. The extraction or partition behaviour of compounds in a given system are specific to that compound.

This study aims to characterise the parameters needed in the ATPS for optimal purification of polyphenols from wine solid-waste (skins, seeds, and stems). Phase diagrams for different polymer/salt systems were used as a starting point for identifying suitable ATPSs. ATPSs were then varied and tested for polyphenol extraction from wine solid-waste using different polyethylene glycol (PEG) molecular weights, salt types, pH, and temperature. The optimum variable combinations were informed by the polyphenol yield and partition coefficient of each system, which was determined using a Folin-Ciocalteu quantification method. Polyphenols have been successfully extracted and separated from wine pomace using this methodology. ATPSs with PEG 8000 (MW 8000 g/mol) together with a tartrate salt was deemed the best system for the purposes of this study. Other variables, such as the tie-line length, temperature, pH and biomass loading had an effect on the yield and partitioning of the polyphenols.

Comparison between the SAFT-VR Mie equation of state and its group contribution variant, SAFT-γ Mie

Hurter RM, Cripwell JT, Burger AJ

Thermodynamic modelling forms a fundamental part of the design and understanding of chemical processes. Industry most often relies on activity coefficient models and cubic equations of state, yet the application of these models is limited to a narrow range of thermodynamic properties and systems. A complex model based on the statistical associating fluid theory, called

SAFT-VR Mie, is able to accurately model a wide array of different properties, including second-derivative properties, at both high and low pressures.

The group contribution method (GCM), SAFT-y Mie, assumes that a system can be modelled using the contributions of the different functional groups present. GCMs make the modelling of new systems more convenient and can be used for computer-aided molecular design. However, first-order GCMs assume that the arrangement of groups does not contribute to a component's properties and that the characteristics of a group are independent of its surroundings — most cannot distinguish between isomers. This is called the structural independence assumption.

A study was done to investigate the consequences of the structural independence assumption, along with other considerations such as the need for a polar contribution and modelling consistency between isomers. It was found that predictions for small, nonideal dipolar species are less accurate in SAFT-y Mie and that predictions for branched alkanes are particularly weak. The modelling of these common petrochemical and pharmaceutical constituents provided insight into the GCMs strengths and limitations. A change to SAFT-y Mie's representation of intramolecular bonding is proposed which could allow the model to negate problems associated with first-order GCMs.

Influence of pulping variables on NSSC pulp properties: Pilot plant modelling and optimisation

Lambert M, Wahl H, Görgens JF, Auret L, Louw TM

A neutral sulphite semi-chemical (NSSC) pulping process is performed at a pulp and paper mill. The objective of this work was to determine the effect of process variables on pulping at pilot scale, and to evaluate the utility of the equipment and experimental procedure as a tool for process improvement for the industrial process.

A qualitative screening exercise was completed to identify key variables for the pulping process. Eucalyptus was used as the raw material to complete two sets of experiments using the pilot plant equipment. The first set of experiments was executed with the intention to establish the reliability of the experimental procedure that was developed, while the second set of experiments used a central composite design to evaluate the pulp, black liquor, and paper properties by examining three design factors at five levels (eight factorial points, six axial points, and three centre points). Response surface methodology was used to parametrize empirical models to find the optimal conditions for the system, and the validity of the derived models was checked against non-training data.

Development of an energy monitoring system for sugarcane mills using optimal sensor network design techniques

Mkwananzi T, Auret L, Louw TM, Görgens JF

Increasing energy demands and global warming concerns have made bagasse, a fibrous residue from sugarcane processing, a vital raw material to produce renewable electricity, biochemicals, and biofuels. This recognition coincides with the nationwide energy efficiency drivers that have urged the government to include renewable energy in the country's energy mix and the growing need of the sugar industry to diversify revenue streams from sugar production. It is essential to evaluate the traditional closed energy balance approach in sugarcane mills to enable the generation of surplus bagasse for the manufacture of bio-based products. One such strategy is the development of an energy monitoring system for sugarcane manufacturers which will identify, quantify, and correct energy inefficiencies, resulting in surplus bagasse.

In this study, energy indicators have been defined for energy consumption monitoring in sugarcane mills to provide a basis for estimating and reporting the factory energy performance. Statistical methods have been adopted to develop energy prediction correlations based on key process variables related to energy consumption in sugarcane mills. This was done to provide a means for strategized energy targeting and root-cause analysis during operation. Process disturbances, and inadequate and imprecise measurements are further barriers to optimal operation and energy monitoring in sugarcane mills. The final study objective is to develop an optimal sensor network design and self-optimizing control strategy to maximize mill profitability.

High-pressure phase behaviour of saturated and unsaturated fatty acid esters in supercritical carbon dioxide

Moorcroft JJ, Schwarz CE

Fatty acids and their derivatives are used in a variety of industries, ranging from biodiesel to pharmaceuticals. Regardless of application, these compounds are frequently processed in the form of fatty acid ester (FAE) oils, such as fatty acid methyl esters (FAMEs). They are often produced in mixtures of varying molecular mass and degree of unsaturation. In order to upgrade the quality of the oil for the intended application, it is desired to adapt both the average molar mass and the average degree of unsaturation.

Supercritical fluids are already used in the extraction and production of FAEs. It has been shown that supercritical CO_2 is capable of fractionating FAEs based

on their molecular mass. Little work has been done to investigate fractionation based on the degree of unsaturation independently of molecular mass, however, and phase data available in literature is inconclusive.

The aim of this investigation was thus to investigate the phase behaviour of FAMEs in supercritical CO_2. This was done by measuring binary data for saturated, monounsaturated, and polyunsaturated FAMEs of equal chain length (methyl stearate, methyl oleate, and methyl linoleate) to establish a baseline, and to then measure multicomponent data to investigate the relative solubility of the esters. It was found that unsaturated FAMEs are more soluble in supercritical CO_2 than saturated FAMEs, and that there was no solubility difference between the different unsaturated FAMEs. This indicates that there is separation potential to use supercritical CO_2 to concentrate a mixture to be rich in saturated or unsaturated equal-length FAMEs.

The in situ extraction of volatile fatty acids from anaerobic digester systems

Morison SD, van Rensburg E, Pott RWM

Anaerobic digestion (AD) is a process consisting of a series of microbial transformations of organic material to volatile fatty acid (VFA) intermediates and biogas, a renewable energy source. With the growing demand for alternative sustainable energy sources, AD is emerging as a process option for power generation. A key challenge faced in AD, which leads to digester failure, is a phenomenon known as acid crash, where high rates of VFA formation result in the pH of the system decreasing such that the methanogenic bacteria are inhibited. However, VFAs are an economically valuable commodity and are widely used in industrial applications. It is therefore opportune to extract the VFAs formed during AD as a valuable co-product, simultaneously acting to control the system pH.

This project aims to investigate the simultaneous separation and in situ recovery of VFAs using liquid-liquid extraction (LLE). Extractants and diluents will be selected based on their VFA extraction capacity, biocompatibility, and feasibility for back extraction. The extraction will be investigated in situ, elucidating the pH control mechanism and effect of LLE on the microbial consortium, allowing evaluation of the proposed process as a solution to inhibitory effects of acid production, with the benefits of valorised waste effluents.

Mathematical modelling of a neutral sulphite semi-chemical (NSSC) process

Pottinger RM, Wahl H, Auret L, Louw TM

A general mathematical model was developed for the neutral sulphite semi-chemical process. The model takes into account diffusion effects and reaction kinetics that occur within solid wood chips. The model comprises of partial differential equations (PDE's) that are used to describe the dynamic behaviour of solid wood chips that are introduced to chemicals in the liquid phase. The finite difference method was used to discretize the three dimensional space of the wood chip and an ODE solver was used to simulate the mass balances in a batch reactor.

Experiments were conducted to obtain reaction rate parameters under conditions where there was no diffusion limitations. Non-linear regression was used to fit the model to the data and find the optimal parameters. The model is able to predict the sulphite concentration and pH of the spent liquor as well as the lignin content of the pulp. The model also allows process parameters to be changed to see the effect it has on the system such as the liquor to wood ratio, sulphite to carbonate ratio, temperature, and initial sulphite charge.

The model was compared to pilot scale experimental data and was found that more research is required in order to predict the outputs accurately for industrial usage. Model improvements include adding a population balance model for the wood chips and refining on delignification reactions that are modelled.

Design and modelling of an experimental tilapia and African catfish recirculating aquaculture system

Pretorius R, Goosen NJ

As part of planned upgrades to the existing experimental facilities at Stellenbosch University, a new warm-water recirculating aquaculture system (RAS) is planned that has flexibility to rear both African catfish (*Clarias gariepinus*) and Mozambique tilapia (*Oreochromis mossambicus*). This study aimed to employ an engineering and mathematical modeling approach to design a new RAS. The facility is to be built within existing buildings and should maintain stable conditions when rearing either African catfish or Mozambique tilapia preferably at their commercial stocking densities of 200 kg/m^3 and 100 kg/m^3 respectively.

Unit operations were designed to achieve the following treatment steps: biofiltration (nitrification), solids removal, aeration, CO_2 degassing, UV sterilization and temperature control. Commercial stocking densities required

large equipment sizes and consequently the design basis was adjusted to 50 kg/m^3. For biofiltration, 2 moving bed bioreactors of 1.5m^3 each were designed using reaction rate kinetics with ammonium as the rate-limiting substrate and reaction rate reduction by biological oxygen demand. A slanted settler with 9m^2 settling area was designed to remove coarse settleable particles (> 100 µm). The settler was sized using experimentally measured settling rates. An aeration system (18 std m^3/h) was designed based on empirical data. The addition of air through in-tank diffusers was found to be sufficient to maintain oxygen above the required minimum of 5mg/L limit CO_2 concentrations below 15mg/L. The heat pump sizing was based on heat transfer modeling that estimated heat to be added to the system. Temperature is maintained at 27°C using a heat pump.

Accurate thermodynamic description of quadrupolar molecules and their mixtures in Cubic Plus Association

Smith SAM, Cripwell JT, Schwarz CE

This work focuses on an improved thermodynamic description of quadrupolar molecules and their mixtures. Quadrupolar forces are found on molecules such as carbon dioxide and alkyl benzenes. Efficient design of processes containing these components relies on a firm understanding of the process mixture's underlying phase behaviour and accurate thermodynamic description of the mixture. Complex thermodynamic models, such as polar variants of Statistical Associating Fluid Theory (SAFT), accurately model the behaviour of mixtures containing polar or associating components; however, these models are computationally intensive. It is useful to consider numerically simpler models that provide similar performance to SAFT.

The Cubic Plus Association (CPA) equation of state (EoS) combines the numerically simple Soave-Redlich-Kwong EoS with the SAFT-association term. Polar forces are not treated explicitly in the original model formulation. As a simplifying assumption, polar molecules are often treated as pseudo-associating; however, this approach is not a physical representation of the intermolecular forces at work.

To address this limitation, terms accounting for quadrupolar interactions have been developed. In this work two CPA model modifications are evaluated: the first model incorporates the quadrupolar term developed by Gross (CPA-G), while the second model incorporates the quadrupolar theory of Larsen (CPA-L). The models are applied to the following binary mixtures: quadrupolar + nonpolar; quadrupolar + associating; and quadrupolar + quadrupolar. This allows one to determine the significance of accounting for quadrupolar

interactions in different molecular environments. It is shown that accounting for quadrupolarity improves the thermodynamic description of quadrupolar molecules and their mixtures, and that CPA-L outperforms CPA-G.

Xylo-oligosaccharide production from brewers' spent grains: Hydrothermal process intensification

Swart LJ, van Rensburg E, Görgens JF

Brewers' spent grains (BSG) make up to 85% of a brewery's solid waste, and is either sent to landfill or sold as cheap animal feed supplement. Xylo-oligosaccharides (XOS) obtained from BSG are antioxidants and prebiotics that can be used in food formulations as low calories sweeteners and texturisers. XOS production from BSG is reported through hydrothermal treatment (HTT) at 9 to 11% dry matter content, using the catalytic action of water alone (>180°C). Yet, extremely low acid (ELA) dosing in HTT can lower the temperature required, while higher dry matter concentration can provide increase product concentrations and reduced process heat requirements.

Therefore, using ELA dosing in HTT was assessed, using dry matter content of 15%, and 25% achieved with screw press dewatering prior to HTT. Results from batch experiments show acid loading (5, 12.5, and 20 mg/g dry mass) and temperature (130, 150 and 170°C), including their interactions, significantly affected XOS yield. Maximum XOS yields of 76.4% (16.6 g/l) and 65.5% (30.7 g/l) were achieved from raw BSG and screw pressed BSG respectively, both at 170°C and using 5 mg acid/g dry mass, after 15 min and 5 min respectively. These XOS yields were obtained using up to 63% less water and temperatures at least 20°C lower than that reported in literature – a significant XOS production intensification. The characterisation of the effects of ELA dosing with high solids loadings on HTT can support a novel valorisation concept for BSG.

Pretreatment of lignocellulosic biomass with steam explosion for feed of Black Soldier Fly larvae

Theron W, van Rensburg E, Diedericks D, Görgens JF

With the rapid increase in the human population, alternative sources of protein and energy will have to be considered. The black soldier fly larvae (BSFL) are veracious consumers of waste and can be reared on a wide variety of substrates. The larvae consist of approximately 40% protein and 30% oil and can be used for animal feed and biodiesel production respectively.

Lignocellulosic wastes are common in the agricultural industry and could potentially be an economically viable option as a carbohydrate source in the feed of BSFL. The lignocellulosic biomasses selected for this study are sugarcane bagasse and corn stover. Lignocellulose consist of three fibre components that are highly resistant to chemical and biological conversion and thus the pretreatment of lignocellulosic biomasses are vitally important to make it more digestible for the BSFL.

Steam explosion (SE) is a high-pressure high-temperature process that is used to defibrillate the lignocellulosic fibres. High-pressure saturated steam is used to diffuse into the plant cell walls and condensate. The pressure is then rapidly released to evaporate the diffused water, and this achieves the separation of the fibres. After SE the fibres are more accessible for bioconversion. This study will consider SE in combination with enzymatic hydrolysis for the pretreatment of the lignocellulose. The results from these experimental investigations will be used to do a techno-economic analysis of the pre-treatment process.

Vapour-liquid equilibrium of ternary systems containing 2-butanone, 1-propanol, 2 propanol, and three C4 esters

Thompson AC, Cripwell JT, Burger AJ

Majority of experimental vapour-liquid equilibrium (VLE) data generated uses compounds that are commonly needed within systems in industry. In this research, four ternary systems with associating and polar non-associating compounds are tested. Each system contained a ketone (2-butanone) and an alcohol (1-propanol), with the third compound in the four systems being one of three C4 esters (ethyl acetate, methyl propanoate, or propyl formate) or an alcohol (2-propanol). The isobaric VLE data of the four systems are measured at 101.3 kPa using a Gillespie still in which the equilibrium temperature, and vapour and liquid compositions are recorded.

Although these systems are not pertinent to industry, the use of the Statistical Associating Fluid Theory (SAFT) equation of state to describe binary VLE data with similar compounds has become firmly established. It is mathematically assumed that the SAFT equation of state can also be used for multi-component systems. However, limited published data for ternary systems containing these types of compounds exists. Considering the effects of the functional groups (differences between ketone-alcohol-alcohol and ketone-alcohol-ester) as well as the placement of these functional groups (differences between the three C4 esters), will indicate the effectiveness of the SAFT equation of state, and whether it describes the systems better than Van der Waal type equations of state.

Optimisation of enzyme assisted extraction of 1,3-β-glucan / laminarin from *Ecklonia maxima* kelp

van Breda DJ, Goosen NJ

Response surface methodology was used to investigate the enzymatic assisted extraction of laminarin from *Ecklonia maxima*. A commercial carbohydrase was used, with independent variables in the study including pH (3.0 to 6.0), temperature (40 to 60°C), and enzyme-to-substrate ratio (E/S) (0 to 4% v/dw). Hydrolysis was studied and sampled over 6 hours in each experiment, incorporating time as a fourth independent variable. A selective enzymatic hydrolysis method was developed as a laminarin assay, making use of the 3,5-dinitrosalicylic acid reducing sugar test.

Peak laminarin of 14.4 $mg \cdot g^{-1}$ on a dry weight basis was found in the range of the central composite design (pH = 3.9, T = 60°C, E/S = 4%, and $t \approx 30$ minutes), with a rise to 43 $mg \cdot g^{-1}$ predicted by increasing temperature up to 80°C, keeping pH and E/S set. Within the confines of the study a decreasing laminarin trend was observed over time, suggesting co-specificity of the carbohydrase towards laminarin as a substrate. Other predicted responses at peak laminarin extraction conditions include solubilised dry matter (0.52 $g \cdot g^{-1}$), soluble inorganic sulfate (18.2 $mg \cdot g^{-1}$), solubilised carbohydrates (0.13 $GlEg \cdot g^{-1}$), reducing sugars (0.07 $GlEg \cdot g^{-1}$), total phenolics (6.0 $GAEmg \cdot g^{-1}$), and antioxidant capacity (21.2 $TEmg \cdot L^{-1}$).

Influence of thermal treatment processes of printed circuit board waste on hydrometallurgical metal recovery

Van Zyl HA, Akdogan G, Dorfling C.

One of the most feasible ways for recycling of and value recovery from the non-metallic fraction of printed circuit board (PCB) waste is thermal treatment. This treatment also has the potential to increase the downstream metal recovery and, combined, these processes could provide a holistic recycling process for PCBs. The heat treatment processes selected from literature and investigated in this report were pyrolysis, and pyrolysis followed by oxidation of the residue.

The main objective for this project was to determine the influence of these heat treatment processes on the downstream metal recovery. The metal recovery process investigated was the hydrometallurgical recovery of metals using glycine as lixiviant, chosen for environmental reasons. Bench-scale leaching tests were performed to determine the rate and extent of metal leaching at different conditions.

For determining the influence of the oxidant both air and pure oxygen were used as oxidants in the leaching process. The influence of the lixiviant concentration was investigated at concentrations of 1 and 2 molar glycine. The possibility of the copper glycine complex acting in an autocatalytic manner for the copper oxidation process was also investigated making use of copper(II) nitrate to adjust the initial copper concentration.

Comparison of results with a previous study conducted at similar conditions with raw PCBs and the same oxidants showed a significant increase in the dissolution rate of copper for both residues obtained from the two heat treatment processes investigated.

DEng and PhD Recipients

DEng

1993	J Svoboda	2005	CT O'Connor	2015	C Aldrich
1999	JSJ van Deventer	2006	MA Reuter	2018	SW Kingman

PhD

1985	JSJ van Deventer	2003	JF Görgens	2014	Y Benjamin
1988	FLD Cloete		AW Kleingeld		GA Bezuidenhout
	VE Ross	2004	AVE Conradie		NJ Goosen
1989	AC Vosloo		JJ Eksteen		JWDV Groenewald
1990	JH Knoetze		AB Erasmus		M Karimi
1991	MA Reuter		KS Mcintosch		EL Thyse
	JJ Thiart		N Musee		M Zamudio
	PF van der Merwe		M Walsh	2015	CA Biley
1992	TJ van der Walt	2005	CE Schwarz		E Charikinya
1993	C Aldrich		LD van Dyk		BM Cole
	L Lorenzen	2006	W Banda		AM Petersen
	J Louw		JP Theron		CA Snyders
1994	AJ Burger	2007	GT Jemwa	2016	RA Agudelo Aguirre
	I Nieuwoudt		RM Lamya		S Krishnannair
1995	FP de Kock		W Mwase		J Louw
	DW Moolman	2008	PL Moolman		KA Mwandawande
	FW Petersen		BP Mtotywa		MN Ondiaka
	JAM Rademan	2010	AY Ali		AMCJJ Ridout
1996	N Saayman		L Auret	2017	JT Cripwell
1997	B Eigenhuis		AFA Chimphango	2018	ML Chitawo
1998	KRP Petersen		M Daramola		M Ferreira
	JHS Roodt		R Lalloo		FCvN Fourie
1999	FS Gouws		NH Leibbrandt		NM Mkhize
	G Schmitz		N Naudé		J Mundike
	WA van Dyk		JC Terblanche		EC Nienaber
2000	JP Barnard	2011	AJ de Villiers		F Nsaful
	ER Els		CW Rousseau	2019	LJ Brown
	DJ Holtzhausen	2012	AO Aboyada		G Coetzee
	JN Keuler		JJ Burchell		BS Lindner
2001	JC Crause		C Dorfling		T Mokomele
	BC Qi		ER James		DR Naron
	B van Dyk		JdT Steyl		M Nieder-Heitman
	DL Venter		WJ Swart		C Latsky
2002	PGR de Villiers		EC Uys		NCC Breckwoldt
	EM Goliath	2013	D Diedericks		
			PF Vena		

LOGISTICAL ARRANGEMENTS

The conference will take place in the Electrical & Electronic Department's wing of the Engineering building. All guests are welcome to park in the student engineering parking area at the back of the Engineering building, which can be accessed from the circle in Hammanshand Road, Stellenbosch. Signage will be visible from the circle to the allocated parking area and into the building to the conference venues.

Should you need assistance with finding the conference venues, you are welcome to contact:

Mieke de Jager: 079 650 6192 or

Sonja Smith: 082 713 4891