



ABSTRACTS

***Global Congress of
Chemical Engineering 2024***

To
Sustainability
& Beyond



SAIChE

South African Institution
of Chemical Engineers



Cape Town International Convention Centre, South Africa

6-11 October 2024

GCCE2024 SPONSORED BY



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South African National Energy
Development Institute



SASOL



NEUTRINO TECHNOLOGIES



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

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

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

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG



SAIChE





SAIChE
South African Institution
of Chemical Engineers



CONGRESS PROGRAMME 7 OCTOBER 2024

Auditorium 1		
Time		
Begin	End	Description
07:30	08:30	Registration & Tea (Foyer Auditorium 1)
09:00	09:15	Opening of Congress (Mr J Scholtz Congress President)
09:15	09:40	Welcome (Prof Lizelle van Dyk SAIChE President)
09:40	10:30	Plenary Talk: The Climate Change Act 22 of 2024 (Prof Tracy-Lynn Field - University of the Witwatersrand, Johannesburg)
10:30	11:00	Tea (Foyer Auditorium 1)
11:00	11:10	Word from SAIChE (Mr Elly Obwaka - SAIChE secretary)
11:10	11:50	Plenary Talk: Progress on Sustainable Development Goals (Dr Deshni Pillay Nature, Climate and Energy Portfolio Manager at UNDP - South Africa)
11:50	12:30	Plenary Talk: Water challenges (Ms Phindile Mahlangu - Scientific Services Manager: Magalies Water)
12:30	13:30	Lunch (Collection - Foyer Auditorium 1)
13:30	14:20	Plenary Talk: South Africa - Energy Transition that is Just, Inclusive Equitable, Affordable and Sustainable to ensure Energy Security whilst assisting with meeting Global Climate Goals (Dr Titus Mathe - Chief Executive Officer: SANEDI)
14:20	15:00	Plenary Talk: Chemicals RDI for Sustainability at the CSIR (Dr Setobane Mangena - Executive Cluster Manager: Chemicals CSIR)
15:00	15:30	Tea (Foyer Auditorium 1)
15:30	17:00	Chemical Engineering Think Tank (All attendees - Meeting Room 1.4)
17:00	18:30	Cocktail Opening Event (Foyer Auditorium 1)

	Auditorium 1	Meeting Room 1.6	Meeting Room 1.4	Meeting Room 2.4
8 October	1	2 Process Engineering and Fundamentals	3 Environmental Engineering	4 Materials and Corrosion
	5 Water	6 Chemical and Biochemical Production	7 Environmental Engineering	8 Green mining
	9 Water	10 Chemical Engineering Education and Profession	11 Environmental Engineering	12 Health and Pharma
	13 Water	14 Health & Safety	15 Energy	16 Other Topics for Sustainability and Beyond
9 October	17 Energy	18 Process Engineering and Fundamentals	19 Environmental Engineering	
	20 Water	21 Chemical and Biochemical Production	22 Environmental Engineering	
	23 Energy	24 Chemical and Biochemical Production	25 Environmental Engineering	
	Poster Viewing Session			
	26 Water	27 Energy	28 Food and Agriculture	
10 October	29 Energy	30 Process Engineering and Fundamentals	31 Environmental Engineering	
	32 Water	33 Chemical and Biochemical Production	34 Operational Excellence and Process Control	
	35 Energy	36 Chemical and Biochemical Production	37 Other Topics for Sustainability and Beyond	
	38 Water	39 Materials and Corrosion	40 AI and the 4th Industrial Revolution	



CONGRESS PROGRAMME 8 OCTOBER 2024

Auditorium 1			Meeting Room 1.6		
Time			Time		
Begin End			Begin End		
07:30 08:30	Tea (Foyer Auditorium 1)		07:30 08:30	Tea (Foyer Auditorium 1)	
	Session 1			Session 2: Process Engineering and Fundamentals	
08:30 09:10			08:30 09:10	Keynote 2.1 Nitric Acid Plant improvement – Getting back to basics (Elizca Lategan)	
09:10 09:30			09:10 09:30	Talk 2.2 Fractionation of 1-alcohol and n-alkane systems via supercritical CO ₂ (Alida Brown, Cara Schwarz, Neo Motang)	
09:30 09:50			09:30 09:50	Talk 2.3 Fundamental behaviour and micronisation of Fischer-Tropsch waxes via supercritical CO ₂ PGSS processing (Andri Swanepoel, O. Hillary Jayeola, Philip W. Labuschagne, Cara E. Schwarz)	
09:50 10:10			09:50 10:10		
10:10 10:15			10:10 10:15		
10:15 10:45	Tea (Foyer Auditorium 1)		10:15 10:45	Tea (Foyer Auditorium 1)	
	Session 5: Water (Sponsored by Magalies Water)			Session 6: Chemical & Biochemical Production	
10:45 11:10	Keynote 5.1 NEWGenerator Off-Grid Non-Sewerage Sanitation: System Performance, Black-Water Recovery, and Lessons Learned from Implementation at a Rural School and Informal Settlement (Timothy Fisher, Gunter Rencken, Aphiwe Mapetere, Daniel Yeh, Robert Bair)		10:45 11:10	Keynote 6.1 Bioprocess development and scale-up for cis, cis-muonic acid production from glucose and xylose by Pseudomonas putida (Sekgetho (Charles) Mokwatlo)	
11:10 11:30	Talk 5.2 The Treatment of Poultry Processing Effluent to Potable Water Standard for In-Factory Reuse to Ensure Production Security and Minimise Water Footprint (Pierrie van Zyl, Elspeth Grahn)		11:10 11:30	Talk 6.2 Magnetic field control of heterogeneous catalysis: application to low temperature Fischer-Tropsch synthesis (Durante Naidoo, David Lokhat)	
11:30 11:50	Talk 5.3 Remediation of Cationic and Anionic Dyes from Aqueous Systems Using Yellow Mozambican Bentonite Clay (Shepherd Tichapondwa, Carol Luposo, Nathan Ndalamba)		11:30 11:50	Talk 6.3 A techno-economic analysis of the steel production process for the production of methanol using top blast furnace gas (Nduvho Makakavhule, Paramespri Naidoo)	
11:50 12:10			11:50 12:10		
12:15 13:30	Lunch (Collection - Foyer Auditorium 1)		12:15 13:30	Lunch (Collection - Foyer Auditorium 1)	
	Session 9: Water (Sponsored by Magalies Water)			Session 10: Chemical Engineering Education & Profession	
13:30 13:50	Talk 9.1 Characterisation and Evaluation of Chlorella Vulgaris on Brewery Wastewater Treatment (Nikita Singh, Manimagalay Chetty, Sudesh Rathilal)		13:30 14:10	Keynote 10.1 Invited Keynote: Engineering Education for Sustainable Development: A Holistic and Collaborative Approach (Lelani Smith) - Online	
13:50 14:10	Talk 9.2 Removal of an array of contaminants of emerging concern from drinking water using biogenic powdered activated carbon (PAC) derived from macadamia nuts: A pilot study (Paki Dikobe)		14:10 14:30	Talk 10.2 An enquiry-based learning approach for first-year chemical engineering design (Linda Jewell, Mulenga Ilunga)	
14:10 14:30	Talk 9.3 Utilising Raw Mining-Influenced Water (MIW) Sludge as an Adsorbent for Pb(II) Adsorption: Modelling Mass Transfer Effects (Nokuthula Nchabeleng, Hendrik Brink)		14:30 14:50	Talk 10.3 Enhancing the Delivery of Fluid Mechanics Education Through the Use of Low-Cost Phone-Based Particle Streak Velocimetry (Jeffrey Muriithi, Fabian Nachbur, Josephat Tanui, Godfrey Gakingo)	
14:30 14:50	Talk 9.4 Adsorption of Methylene Blue Dye onto Carbon Foams Derived from Wheat and Bulrush Bread (Ebrahim Kadwa, David Lokhat)		14:50 15:10		
14:50 15:10					
15:10 15:40	Tea & Poster Session (Foyer Auditorium 1)		15:10 15:40	Tea & Poster Session (Foyer Auditorium 1)	
	Session 13: Water (Sponsored by Magalies Water)			Session 14	
15:40 16:00	Talk 13.1 Adsorption of Tetracycline Using Adsorbents Derived from Fly Ash (Eric Houghton, Shepherd Tichapondwa)		15:40 16:20		
16:00 16:20	Talk 13.2 Efficient Degradation of Organic and Inorganic Contaminants in Water Using ZnO-BiOI Heterojunction Photocatalyst (Darlington Ashiegbu, Herman Potgieter)		16:20 16:40		
16:20 16:40	Talk 13.3 Adsorptive Removal of Carbamazepine from Synthetic Wastewater Using Seed Coat (Exocarp) of Moringa Oleifera (Peace Azeh, Mabafokeng Mashita, Michael Daramola)		16:40 17:00		
16:40 17:00					

CONGRESS PROGRAMME 8 OCTOBER 2024

Meeting Room 1.4		Meeting Room 2.4	
Time		Time	
Begin	End	Begin	End
07:30	08:30	07:30	08:30
	Tea (Foyer Auditorium 1)		Tea (Foyer Auditorium 1)
	Session 3: Environmental Engineering (Chair: Dr Neil Stacey)		Session 4: Materials & Corrosion
08:30	09:10	08:30	09:10
	Keynote 3.1 Broadening the waste horizon: Demonstration of industrial organic waste conversion to ethanol (Eugene van Rensburg, Johann Görgens)		Keynote 4.1 Electric Double Layer (EDL) Repulsive force Being Responsible for the Time-dependent Behavior of Clay Gels in the Structural Rejuvenation Mode: Direct Evidence and Unusual Salt Effects (Yee-Kwong Leong)
09:10	09:30	09:10	09:30
	Talk 3.2 Effect of Gypsum Addition on Syngas Production During CO ₂ -Assisted Gasification of Pinewood (Athi-ekosi Mavukwana, Kiran Burra, Ashwani K. Gupta)		Talk 4.2 Application of Eutectic Salts and Ionic Liquids as sustainable corrosion inhibitors on mild steel surface in acidic medium: Experimental and DFT studies. (Hamed Hashemi, Mogomotsi Leshetla, Josias van der Merwe)
09:30	09:50	09:30	09:50
	Talk 3.3 Valorisation of challenging-to-recycle wastepaper streams through ethanol fermentation and anaerobic digestion (Juliana Naudé, Daneal Rorke, Johann Görgens, Eugene van Rensburg)		Talk 4.3 Synthesis of <60 nm CaCO ₃ Crystals from Gypsum (Patrick Casserly, David van Vuuren)
09:50	10:10	09:50	10:10
	Talk 3.4 Steel slag for precipitated calcium carbonate synthesis for carbon capture (Nyasha Chinobva, Paramespri Naidoo, Kuveneshan Moodley)		Talk 4.4 REE betadiketone complexes as corrosion inhibitors for mild steel and Type 304 stainless steel in corrosive media. (Herman Potgieter, David Whitefield, Michael Bodunrin, Johnson Lawal, Thobile Dladla)
10:10	10:15	10:10	10:15
10:15	10:45	10:15	10:45
	Tea (Foyer Auditorium 1)		Tea (Foyer Auditorium 1)
	Session 7: Environmental Engineering		Session 8: Green Mining
10:45	11:10	10:45	11:10
	Keynote 7.1 Hydrometallurgical recovery of cobalt, nickel, lithium and manganese from spent lithium-ion batteries (Jenny Falconer, Lesego Siwela, Ed Hardwick, Wesley Rolfe)		Keynote 8.1 Rare earth elements and uranium in Minjingu phosphate fertilizer products: Plant food for thought (Nils Haneklaus) - Online
11:10	11:30	11:10	11:30
	Talk 7.2 Modelling of Struvite Recovery from Anaerobically Digested Waste Activated Sludge using Response Surface Methodology. (Charmaine Kgomotso Funani, John Kabuba, Peter Osifo, Benton Onyango)		Talk 8.2 The use of amino acids in the green processing of gold (Anthony Tapfuma, Margreth Tadie, Guven Akdogan, Robert Luckay)
11:30	11:50	11:30	11:50
	Talk 7.3 Using Coco Peat to Improve the Water Retention Capacity of Petroleum-polluted Soils (Rishen Roopchund, Naadhira Seedat)		Talk 8.3 The hazardous waste Management in mining - call to action (Jaco Nel) - Online
11:50	12:10	11:50	12:10
	Talk 7.4 A Conceptual Investigation on the Co-Production of Hydrogen and Carbon Nanotubes (CNT) from the Gasification of Waste Biomass and Waste Tyres. (Lanrewaju Fajimi, Bilainu Oboirien, Thomas Adams II)		Talk 8.4 Facile recovery of polycationic metals from acid mine drainage and their subsequent valorisation for the treatment of municipal wastewater (Khathutshelo Liith Muedi, Job Tendenedzai, Vhangwele Masindi, Nils Hendrik Haneklaus, Hendrik Gideon Brink)
12:15	13:30	12:15	13:30
	Lunch (Collection - Foyer Auditorium 1)		Lunch (Collection - Foyer Auditorium 1)
	Session 11: Environmental Engineering		Session 12: Health & Pharma
13:30	14:10	13:50	14:10
	Keynote 11.1 Seaweeds to save the world: An overview of research completed toward establishing a seaweed biorefinery in South Africa (Neill Goosen, Allistair Border, Achinta Bordoloi, Ryan Cilliers, Johann Görgens, Zwonaka Mapholi, Matthew Noach, Robert Pott, Marianne Thomsen, Daniel Van Breda, Roelof Van der Merwe, Eugene Van Rensburg, Dylan Van Sittert, Gina Wilkinson, Xueqian Zhang)		Talk 12.1 Selectivity Studies of Gold Nanoparticle Bioconjugation for the Detection of SARS-CoV-2 (Charissa de Gouveia, Jean Mulopo, Palesa Diale, Yonela Mkono, Nkosazana Jameson)
14:10	14:30	14:10	14:30
	Talk 11.2 A nanocomposite of nickel ferrite and polyaniline doped with 2-naphthalene sulfonic acid as an adsorbent for the removal of chromium from an aqueous solution. (Ruth Kasavo & Hendrik Brink)		Talk 12.2 The Purification & Characterisation of Fucoidan from the South African Seaweed Ecklonia maxima (Gina Wilkinson, Zwonaka Mapholi, Neill Goosen)
14:30	14:50	14:30	14:50
	Talk 11.3 Development of Polybenzimidazole Nanofibrous Catalyst via Electrospinning for VOC Oxidation (Karel Soukup, Pavel Topka, Jana Balabánová, Olga Solcova)		Talk 12.3 Exploratory application of the U.S. Pharmacopeia Maritime Pine Extract Monograph to commercial Pycnogenol® samples (Laston Samuwi, Annegret Stark, Geoff Tomlinson)
14:50	15:10	14:50	15:10
			Talk 12.4 Intermolecular interactions and sorption behaviour of estrogenic compounds in poly(mannuronate): a computational study (Madison Lasich, Victoria Adeleke)
15:10	15:40	15:10	15:40
	Tea & Poster Session (Foyer Auditorium 1)		Tea & Poster Session (Foyer Auditorium 1)
	Session 15: Energy		Session 16: Other Topics for Sustainability and Beyond
15:40	16:00	15:40	16:00
	Talk 15.1 Thermal conversion of macroalgae <i>Macrocystis Pyrifera</i> and <i>Laminaria Japonica</i> for production of carbon-negative hydrogen (Carolina Arias Gallego, Shashank Sakleshpur Nagaraja, Mani Sarathy)		Talk 16.1 Towards sustainable chemical synthesis: Metathesis of sunflower-derived ethyl esters for synthesis of value-added oleochemicals (Corne Lourens, Neill Goosen, Margreth Tadie, Robbie Pott)
16:00	16:20	15:40	16:20
	Talk 15.2 Solid-state fermentation of whole sugarcane and paper sludge waste for first-and second-generation ethanol production (Janke van Dyk, Johann Görgens, Eugene van Rensburg)		Talk 16.2 Assessing the effects of nano and micro-particles on carbon dioxide gas hydrate formation (Paramespri Naidoo, Phakamile Ndlovu, Saeideh Babae)
16:20	16:40	16:20	16:40
	Talk 15.3 Pyrolysis of waste polypropylene plastics for energy recovery: study comparisons between bench scale and a commissioned kilogram-scale rotary kiln reactor (George Kofi Parku, François-Xavier Collard, Johann Görgens)		Talk 16.3 Aspen Plus® simulation of fractional condensation of lumped oil produced by waste tyre pyrolysis (Matimu Khosa, Cara Schwarz, Johann Gorgens)
16:40	17:00	16:40	17:00
	Talk 15.4 Sorption-enhanced chemical looping gasification of biomass for hydrogen and transportation fuel production (Lebohng Motsoeneng, Bilainu Oboirien, Andrea Lanzini)		



CONGRESS PROGRAMME 9 OCTOBER 2024

Auditorium 1			Meeting Room 1.6		
Time			Time		
Begin	End		Begin	End	
07:30	08:30	Tea (Foyer Auditorium 1)	07:30	08:30	Tea (Foyer Auditorium 1)
		Session 17: Energy			Session 18: Process Engineering and Fundamentals
08:30	08:50	Talk 17.1 Production of Piezoelectric Composite Nanofibres from Recycled Poly (ethylene terephthalate) (Rita Okpuwhara, Bilianu Oboirien)	08:30	08:50	Talk 18.1 Solvent selection methods in aromatic extraction processes towards optimal and sustainable design choices (Nivaar Brijmohan, Kuveneshan Moodley, Caleb Narasigadu)
08:50	09:10	Talk 17.2 Understanding Fischer-Tropsch Synthesis in Micro Reactors – A Three-phase One-dimensional Microchannel FT reactor Model (Botang Mamabolo, Saeideh Babae)	08:50	09:10	Talk 18.2 Measurement and modelling of hydrodynamics in a supercritical fractionation column (Neo Motang, Johannes Knoetze, Cara Schwarz)
09:10	09:30	Talk 17.3 Investigation of Ag, Al, Au, and Cu dopants for enhanced efficiency of cobalt catalysts in NH ₃ decomposition: A DFT study (Daniel Oduma, Nomcebo Motsa, Jannie Pretorius, Michael Daramola)	09:10	09:30	Talk 18.3 Stripping Hydrogen Sulphide from an Aqueous Solution of Sodium Hydrosulphide (David van Vuuren, Ryno Vermeulen)
09:30	09:50		09:30	09:50	Talk 18.4 Phase equilibrium studies for multicomponent mixtures (methane, propane, carbon dioxide, hydrogen sulfide, water, triethylene glycol and methanol) in the natural gas dehydration process (Paul Zvawanda, Paramespri Naidoo, Wayne M. Nelson, Kuveneshan Moodley)
09:50	10:10		09:50	10:10	Talk 18.5 An evaluation of extractive and azeotropic distillation for separation of 1-octene from oxygenates typically produced during Fischer-Tropsch synthesis (Christiaan S. van der Vyver, Bruce Möller and Andries J. Burger)
10:10	10:15		10:10	10:15	
10:15	10:45	Tea (Foyer Auditorium 1)	10:15	10:45	Tea (Foyer Auditorium 1)
		Session 20: Water			Session 21: Chemical & Biochemical Production
10:45	11:10	Keynote 20.1 The V&A Waterfront Seawater Desalination Plant - Designed for Sustainability (Hendri Verster, Andre Theys)	10:45	11:10	Talk 21.1 Techno-economic analysis of furfural derivatives that can be produced in an existing furfural alcohol plant. (Taonga Kabwe, Jeanne Louw, Johann Gorgens)
11:10	11:30	Talk 20.2 Aquatic Toxicity and Human Health Risk Assessments of Heavy Metals from Pretoria Wastewater (Mpho Qhubu, Ndeke Musee, Michael Daramola, P. N Nomngongo)	11:10	11:30	Talk 21.2 Manganese oxide, silver nanoparticles and activated carbon supported reduced graphene oxide 3D solar interface absorber for desalination of seawater (Bontle Manoto, Fisseha Bezza, Evan Chirwa)
11:30	11:50	Talk 20.3 Influence of Carbon Sources and Biosurfactants on Selenite and Lead Bioremediation from Wastewater by Enterococcus sp. (Job Tendenedzai, Evans Chirwa, Hendrik Brink)	11:30	11:50	Talk 21.3 Development and scale up of alginate lyase production from native alginate degrading microbes (Matthew Noach, Neill Goosen, Robert Pott, Eugene Van Rensburg)
11:50	12:10	Talk 20.4 Effects of Nano- and Micro-Chemicals Used in Sanitisers and Disinfectants in the South African Market on the Freshwater Snail, Physa Acuta (Lenah Motaung, Ndeke Musee, Michael Daramola)	11:50	12:10	Talk 21.4 Development of productivity to produce biochar from the biomass of marine algae and mushroom waste via pyrolysis (Emmanuel Zikhonjwa, David Lokhat)
12:15	13:30	Lunch (Collection - Foyer Auditorium 1)	12:15	13:30	Lunch (Collection - Foyer Auditorium 1)
		Session 23: Energy			Session 24: Chemical & Biochemical Production
13:30	13:50	Word from Sponsor	13:30	13:50	Talk 24.1 Heterogeneous Hydrogenations in Flow – Case Studies and Scale-up Considerations (Mike Kenny, Martin Monedero, Joshua Trenchard, Sarah Cleary, Holly Reeve, Tara Lurshay, Sofia Kazantzi, Jack Allman, Xu Zhao)
13:50	14:10	Talk 23.1 SS-LNG Technology and its role in the Just energy transition. (Christel Bonnet & Paul Botha)	13:50	14:10	Talk 24.2 Design and optimization of separation process alternatives for butanediol dehydration for use as a bio-fuel (Shivan Mavalal, Kuveneshan Moodley)
14:10	14:30	Talk 23.2 Development of highly durable PEM fuel cell ORR catalysts (Thelma Ngwenya, Katlego Tshehla, Nkateko Mkhabela)	14:10	14:30	Talk 24.3 Microwave-assisted pyrolysis of biomass using hzsm-5 catalyst derived from slag waste (Nhlanhla Nyembe, Yusuf Isa)
14:30	14:50	Talk 23.3 Application of nanostructured platinum-transition metal alloys to enhance ORR activity in PEMFCs (Siphelo Ngqoloda, Thelma Ngwenya, Mpfunzeni Raphulu)	14:30	14:50	
14:50	15:10		14:50	15:10	
15:10	15:40	Tea & Poster Session (Foyer Auditorium 1)	15:10	15:40	Tea & Poster Session (Foyer Auditorium 1)
15:40	16:20	POSTER Session (ALL presenters to be at their posters)			
		Session 26: Water			Session 27: Energy
16:20	16:40		16:20	16:40	Talk 27.2 Phase equilibrium data for CO ₂ /methane/CO/H ₂ + 2-methyl quinoline (Paul Zvawanda, Paramespri Naidoo, Wayne M. Nelson, Kuveneshan Moodley)
16:40	17:00		16:40	17:00	Talk 27.3 Flooded mineshaft compressed air energy storage in the Witwatersrand Goldmine Complex – case study of a proposed novel energy storage method (Neil Stacey, Peter Stacey, Diane Hildebrandt, James Fox, David Glasser) Energy)

CONGRESS PROGRAMME 9 OCTOBER 2024

Meeting Room 1.4

Time		
Begin	End	
07:30	08:30	Tea (Foyer Auditorium 1)
Session 19: Environmental Engineering		
08:30	08:50	Talk 19.1 The Synthesis and Characterization of Magnesium-based Metal-organic-framework-74 Suitable for Post-Combustion Carbon Dioxide Capture (Major Mabuza, Glory Makuwa)
08:50	09:10	Talk 19.2 Continuous Microbial Pb Removal by an Industrially Obtained Consortium Using an Upflow Anaerobic Sludge Blanket Reactor (Bayandza Manzini)
09:10	09:30	Talk 19.3 A circular economy approach for the beneficiation of slag, waste foundry sand, and plastic waste (Tebogo Mashifana, Thandiwe Sithole)
09:30	09:50	Talk 19.4 Development of bagasse-based recycled polypropylene composites (Justice Ipoteng Mphahlele, Joseph Gbadeyan, Vincent Ojijo, Viren Chunilall, Annegret Stark)
09:50	10:10	
10:10	10:15	
10:15	10:45	Tea (Foyer Auditorium 1)
Session 22: Environmental Engineering		
10:45	11:10	Keynote 22.1 Bioremediation of Cr(VI) and Other Hexavalent Transitional Metals in Soil and Aquatic Environments: A Review (Evans Chirwa, Buyisile Kholisa, Mpumelelo Mathseni, Phalazane Mtimunye, Neetu Bansal, Pulane Molokwane, Zainul Zakaria, Yi-Tin Wang)
11:10	11:30	Talk 22.2 Degradation of Rhodamine B dye on BiOIO ₃ /Bi ₁₂ O ₁₇ Cl ₂ Heterostructure Photocatalyst under Visible Light Activation (Osemeikhian Ogbeifun, Shepherd Tichapondwa, Evans Chirwa)
11:30	11:50	Talk 22.3 Implementation of human hair as a bio-adsorbent for gasoline spilled in sea water in Mozambique (Jonas Valente Matsinhe, Luis Helder Mendes Lucas, Iara Vaz Lopes Menete, Estevão Alberto Junior Pondja, Acacio Jose Zimbico)
11:50	12:10	Talk 22.4 The Use of Calcium Carbonate Recovered from the Acid Mine Drainage (AMD) of the Witwatersrand Eastern Basin in Preparation of Polypropylene Composites (Recardo Khumalo, Evans Chirwa)
12:15	13:30	Lunch (Collection - Foyer Auditorium 1)
Session 25: Environmental Engineering		
13:30	13:50	Talk 25.1 Optimizing mixing-assisted oxidative desulfurization: application of sludge-derived ferrate(VI) to dibenzothiophene and pyrolysis oil (Micah Haboc, Nathaniel Dugos, Angelo Earvin Choi, Meng-Wei Wan)
13:50	14:10	Talk 25.2 Valorisation of Iron-rich Acid Mine Drainage Sludge for Reusability Potential to Extract Valuable Material: The Synthesis of Barium Hexaferrite (Manthabiseng Thamae, Saeideh Babae, Palesa Diale)
14:10	14:30	Talk 25.3 Comparative performance of solvents in post-combustion CO ₂ capture using rotating packed bed technology (Atuman Samaila Joel, Yusuf Makarfi Isa)
14:30	14:50	Talk 25.4 Decay factor characterisation of paper materials using laboratory- and pilot-scale reactor studies (Thaakira Jabaar, Tobi Louw, Eugene Van Rensburg)
14:50	15:10	Talk 25.5 A sensitivity analyses on the cost of production and storage of green ammonia in South Africa (Clive Tinashe Moyo, Paramespri (Prathieka) Naidoo)
15:10	15:40	Tea & Poster Session (Foyer Auditorium 1)
15:40	16:20	POSTER Session (ALL presenters to be at their posters)
Session 28: Food & Agriculture		
16:20	16:40	Talk 28.2 An economic analysis for the production of food-type products in an integrated sugarcane biorefinery (Monique Klaver, Jeanne Louw, Johann Gorgens)
16:40	17:00	Talk 28.3 Soxhlet Extraction of Cinnamon Oil Comparing Particle Size with Different Functional Group Solvents (Naadhira Seedat, Rishen Roopchund)

CONGRESS PROGRAMME 10 OCTOBER 2024

Auditorium 1			Meeting Room 1.6		
Time	Begin	End	Time	Begin	End
07:30	08:30	Tea (Foyer Auditorium 1)	07:30	08:30	Tea (Foyer Auditorium 1)
		Session 29: Energy			Session 30: Process Engineering and Fundamentals
08:30	09:10	Talk 29.1 Commercial-scale trial feeding waste activated sludge to a Sasol fixed bed dry bottom gasifier (Andrei Koekemoer)	08:30	09:10	Talk 30.1 Invited Talk (Japie Scholtz)
09:10	09:30	Talk 29.2 The effect of UV/H ₂ O ₂ pre-treatment on the solubilization of bituminous coal fines waste for the biogenic production of methane gas (Ntombifuthi Hlatshwayo, Peter O Osifo, Tumisang Seodigeng)	09:10	09:30	Talk 30.2 On Bubble Deformation and Breakup in Liquids Containing Surface Active Agents (Maria Zednikova, Tereza Semlerova, Sandra Orvalho, Jaromir Havlica, Jaroslav Tihon)
09:30	09:50	Talk 29.3 An investigation into the Flocculation and Settling Behaviour of Coal Preparation Plant Tailings (Puja Hansdah, Herman Potgieter)	09:30	09:50	Talk 30.3 The Potential of Unconventional Statistical Methods in Chemical Engineering (Cila Botha, Frikkie Conradie, Frikkie Van der Merwe)
09:50	10:10	Talk 29.4 Combustion of mixed waste fuel (Milan Carsky, Olga Solcova, Karel Soukup, Stanislav Honus, Marek Jadlovec, David Lokhat)	09:50	10:10	Talk 30.4 Advancing the Understanding of Wet Ball Mill Loads: A Comprehensive Numerical Simulation Framework (Fortune Nkomo, Francois Mulenga)
10:10	10:15		10:10	10:15	
10:15	10:45	Tea (Foyer Auditorium 1)	10:15	10:45	Tea (Foyer Auditorium 1)
		Session 32: Water			Session 33: Chemical & Biochemical Production
10:45	11:10	Keynote 32.1 Assessing the water impact of carbon capture technologies (Prebantha Moodley, Kevin Harding, Thomas Alan Adams II)	10:45	11:10	Keynote 33.1 Biorefineries for the production of biochemicals, biofuels, biomaterials and food-products as viable diversification options for the sugar cane industry (Johann Gorgens, Jeanne Louw, Johannes Louw, Amir Behrouzifar)
11:10	11:30	Talk 32.2 Developing a theoretical predictive fouling model for a Polyethersulfone (PES) Ultrafiltration membrane for wastewater treatment. (Emmanuel Kasese, Kevin Harding, Keneiloe Sikhwivhulu, Diane Hildebrandt)	11:10	11:30	Talk 33.2 The efficient microbial production of cellobiose lipids (CBLs) as novel antifungal agents (Andre Valkenburg, Robert Pott, Eugene van Rensburg, George Teke)
11:30	11:50	Talk 32.3 Anticipating Environmental Risks: Harnessing Predictive Water Balances for Sustainable Power Generation at Kusile Power Station (Amelia Meyer, Hendrik Brink)	11:30	11:50	Talk 33.3 Withdrawn
11:50	12:10	Talk 32.4 Zinc Oxide and Silver Doped Zinc Oxide Nanoparticle-Chitosan-PVPP Composite Beads for Immobilization of Laccase Enzyme (Hilda Dinah Kyomuhimbo, Evans Chirwa, Usisipho Feleni, Hendrik Brink)	11:50	12:10	Talk 33.4 Eggshell-Derived Catalysts for Enhancing Biodiesel Synthesis from Waste Cooking Oil (Lebohng Macheli, Linda Jewell)
12:15	13:30	Lunch (Collection - Foyer Auditorium 1)	12:15	13:30	Lunch (Collection - Foyer Auditorium 1)
		Session 35			Session 36: Chemical & Biochemical Production
13:30	13:50		13:30	13:50	Talk 36.1 Process Development for Ethanol Production from Cellulose-Rich Furfural Residues Annexed to a Typical South African Sugar Mill (Godrick Bunga, Johann Gorgens, Eugene van Rensburg)
13:50	14:10		13:50	14:10	Talk 36.2 The Culturability of Five South African Vaginal Probiotic Lactobacilli in a Low-Cost, Plant-Based Soytone Growth Medium (Obakeng Jona, Marijke Fagan-Endres, Anna-Ursula Happel, Brian Kullin, Jo-Ann Passmore, Sue Harrison)
14:10	14:30		14:10	14:30	Talk 36.3 Environmental and Economic Benefits from Strain and Bioprocess Improvements for Sustainable Production of 3-Hydroxypropanoic in a Sugarcane Biorefinery (Manasseh Sikazwe, Johannes Malherbe, Jeanne Louw, Johann Gorgens)
14:30	14:50		14:30	14:50	Talk 36.4 Sustainable acrylic acid and propylene glycol production in a sugarcane biorefinery: A Techno-economic and environmental analysis (Mensah Brobbey, Jeanne Louw, Johann Gorgens)
14:50	15:10		14:50	15:10	Talk 36.5 Effect of corn cob hydrolysate on yield and productivity during fermentation by Lactobacillus cereus (Nhlamulo Sibiya, Hendrik Brink, Evans Chirwa, Michael Daramola)
15:10	15:40	Tea & Poster Session (Foyer Auditorium 1)	15:10	15:40	Tea & Poster Session (Foyer Auditorium 1)
		Session 38: Water			Session 39: Materials and Corrosion
15:40	16:00	Talk 38.1 Inclusion of nano-silver compounds in RO membranes as solutions to fouling by microbes and natural organic matter during seawater desalination (Obakeng Nchoe, Nosipho Moloto, Keneilo Sikhwivhulu, Phumlani Tetyana)	15:40	16:00	Talk 39.1 Characterization of corrosion products formed on carbon steel after exposure to a bacterial consortia from a cooling tower (Alicia Prithiraj, Shepherd Tichapondwa, Evans Chirwa)
16:00	16:20	Talk 38.2 Treating Persistent Pollutants, Pesticides, PFAS, with FILTRASORB® Granular Activated Carbon (Julien Terrematte, Alberto Barral) Water	16:00	16:20	Talk 39.2 Physicochemical properties of cellulose nanocrystals (CNCs) extracted from post-consumer cotton/polyester blended fabrics. (Rivalani Baloyi, Bruce Sithole, Viren Chuniwall)
16:20	16:40	Talk 38.3 A comparison between powdered activated carbon (PAC) and granular activated carbon (GAC) for water treatment (Wesley Rolfe, Jennifer Falconer, Edmund Hardwick)	16:20	16:40	Talk 39.3 Perspective on Metal-organic Frameworks-based Atmospheric Water Harvesting Systems Towards Universal Adoption (Jianwei Ren, Tonderai Manyimo)



CONGRESS PROGRAMME 10 OCTOBER 2024

Meeting Room 1.4		
Time	Begin	End
	07:30	08:30
	Tea (Foyer Auditorium 1)	
	Session 31: Environmental Engineering	
	08:30	09:10
	Keynote 31.1 Advances in Ion Exchange to Mitigate Climate Change (Ed Hardwick) Invited Keynote	
	09:10	09:30
	Talk 31.2 A novel approach to model the environmental impact of wastewater treatment processes: A case study of hydrometallurgical recycling of lithium-ion batteries (Roelof Maritz, Guven Akdogan, Christie Dorfling)	
	09:30	09:50
	Talk 31.3 A comparison of economic feasibility and environmental performance of biochemicals, biofuels, biomaterials and food-products as diversification options for the sugar industry (Jeanne Louw, Janus Louw, Johann Gorgens)	
	09:50	10:10
	10:10	10:15
	10:15	10:45
	Tea (Foyer Auditorium 1)	
	Session 34	
	10:45	11:10
	11:10	11:30
	11:30	11:50
	11:50	12:10
	12:15	13:30
	Lunch (Collection - Foyer Auditorium 1)	
	Session 37: Other Topics for Sustainability and Beyond	
	13:30	14:10
	Talk 37.1 Tin extraction from Food Tin Cans Using Organic Acids (Herman Potgieter)	
	14:10	14:30
	Talk 37.2 Novel application of biochar to improve hydrophilicity and the permeability of aramid nanofiber hybrid membrane (Kitenge Sumbu Eloge, David Lokhat)	
	14:30	14:50
	Talk 37.3 Effect of ethanol as a solvent for surfactants in cassiterite ore flotation (Moeketsi Khomo, Henry Simonsen, Lizelle Van Dyk, Herman Potgieter)	
	14:50	15:10
	15:10	15:40
	Tea & Poster Session (Foyer Auditorium 1)	
	Session 40: AI & 4th Industrial Revolution	
	15:40	16:20
	Keynote 40.1 Evaluation of the water treatment plant performance using process capability assessment (Esper Jacobeth Ncube, Muzi Simon Sibiya, Evans Chiwa)	
	16:20	16:40





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CONGRESS PROGRAMME 11 OCTOBER 2024

Auditorium 1		
Time		
Begin	End	Description
07:30	08:30	Tea (Foyer Auditorium 1)
08:30	08:50	Reflection on the last four days
08:50	09:30	Plenary Talk: Recent Developments in CO ₂ Emissions Reduction and Resources Conservation Using Process Systems Engineering Approach (Prof Thokozani Majazi University of the Witwatersrand, Johannesburg)
09:30	10:10	Plenary Talk: Grouped Solar Carbon Credit Project (Dr Marco Lotz Carbon Disclosure SA)
10:15	10:45	Tea (Foyer Auditorium 1)
10:40	11:50	Discussion Forum: Chemical Engineering "To sustainability and Beyond"
11:50	12:30	Feedback Discussion: Think Tank
12:30	13:30	Lunch (Collection - Foyer Auditorium 1)
13:30	14:10	Plenary Talk: Dr Pulane Molokwane (OLOENVIRON Pty Ltd, Member Advisory Body to the President of South Africa (National Planning Commission)).
14:10	15:00	Prizes and Closing

2.1 Nitric Acid Plant improvement – Getting back to basics

Mrs Elizca Lategan

Sasol, Sasolburg, South Africa

Abstract

A Sasol Nitric Acid Plant (NAP) is a Mono Pressure plant commissioned in 1972 and located in the Sasolburg chemical complex. The plant uses the Ostwald process to produce 58% Nitric Acid. Steam is also produced from the waste process heat in the plant.

The performance of the NAP plant has been decreasing over the last few years with the annual production volumes decreasing and the number of trips increasing resulting in lower Overall Equipment Effectiveness (OEE) percentages. Equipment was also less reliable and available resulting in decreased equipment mean time between failures. Since this is the feed material for a downstream production facility that is required to comply to contracted production volume, this resulted not only in income losses but customer dissatisfaction.

A focused intervention was initiated where the OEE data was analyzed. The data for the internal production losses was then further analyzed and grouped into equipment availability and rate losses due to equipment damage or failure, planned shutdown related downtime and rate reduction due to process limitations. Root cause analysis investigations were completed to identify and understand the root cause resulting in each of these production losses. Each root cause was also evaluated to identify if it was a once off occurrence or a reoccurring root cause. Based on the identified root causes, multidisciplinary improvement plans were developed and implemented to address the root causes to improve the performance of the NAP plant.

At the NAP plant 3 different root causes were identified that resulted in poor plant performance and excessive downtime:

1. Poor equipment reliability and availability
2. An unpredictable plant
3. Rate reduction due to Process limitations

With the changes and improvements in quality control of equipment and catalyst conversion a large reduction in downtime resulted in a significant increase in OEE.

Keywords

Process Improvements, OEE, Reliability, Causes

2.2 Fractionation of 1-alcohol and n-alkane systems via supercritical CO₂

Ms Alida Brown, Prof Cara Schwarz, Ms Neo Motang

Stellenbosch University, South Africa

Abstract

Detergent range alcohols (C₈₋₂₀) that are often found in cleaning and personal care products present a large market. When commercially producing these alcohols via the Oxo process, alkane-alcohol mixtures are formed in product streams. The desired alcohols must be separated from the alkane-alcohol mixtures. However, overlapping melting and boiling points eliminate more traditional separation processes such as distillation and crystallization. Azeotropic distillation is currently employed in industry to separate the alkane-alcohol mixtures but has many drawbacks. Supercritical fluid fractionation (SFF) is proposed as an alternative separation technique.

SFF processes are operated above the critical point of the selected solvent and thus complex phase behaviour may arise in the system. This complex phase behaviour must be understood to explain results obtained from SFF processes and to develop accurate thermodynamic models and subsequently appropriate simulated process models. The process models are valuable since experimental data collection is costly.

This study aims to experimentally investigate the effect of complex phase behaviour found in mixtures of supercritical CO₂ and detergent range 1-alcohols and n-alkanes on the performance of SFF and to subsequently evaluate the prediction capabilities of a process model within commercial process simulating software.

Thus, the SFF of two multicomponent systems known to exhibit complex phase behaviour were examined, namely the CO₂ + 1-dodecanol + n-hexadecane system and the CO₂ + 1-dodecanol + n-tetradecane system. New SFF pilot plant data were produced for the separation of 1-dodecanol and n-hexadecane via supercritical CO₂ at varying process parameters such as temperature, pressure, solvent-to-feed ratio and solute feed composition. Experimental and literature pilot plant data over a wide range of conditions were subsequently used to assess the prediction capability and robustness of the SFF process model built in the process simulating software Aspen Plus®.

Keywords

supercritical fluid fractionation

2.3 Fundamental behaviour and micronisation of Fischer-Tropsch waxes via supercritical CO₂ PGSS processing

Ms Andri Swanepoel^{1,2}, Ms O. Hillary Jayeola², Dr Philip W. Labuschagne¹, Prof Cara E. Schwarz²

¹Council for Scientific and Industrial Research, Pretoria, South Africa. ²Stellenbosch University, Stellenbosch, South Africa

Abstract

Micronised wax particles are widely used in applications such as coatings and inks. The quality and effectiveness of these waxes are significantly dependent on characteristics such as particle size distribution and morphology.

The Particles from Gas Saturated Solutions (PGSS) process utilises supercritical CO₂ (sc-CO₂) as a plasticiser to micronise materials without the use of any organic co-solvents. The aim of this project was to investigate the micronisation of Fischer Tropsch (FT) waxes via the PGSS process by elucidating the interdependencies between particle characteristics and processing conditions, as well as obtaining an improved fundamental understanding of the thermodynamic behaviour of FT waxes in sc-CO₂ and how this behaviour affects the final product.

The melting and phase behaviour of binary mixtures of two FT waxes with different melting temperatures and sc-CO₂ were monitored. The waxes were subsequently processed via PGSS at a range of varied conditions by altering the processing temperature and pressure, the spraying nozzle size and the wax-CO₂ mixture composition. The size and shape distributions of the prepared particles were determined.

It was found that the melting temperatures of both waxes increased slightly with increasing sc-CO₂ pressure due to the domination of the hydrostatic pressure effect. The phase transition pressures for both waxes increased with increasing temperature and decreasing wax concentration.

Generally, spherical particles with smooth surfaces were produced at higher temperatures and lower pressures, while increases in processing pressure resulted in more porous foamed structures/particles. Sc-CO₂ micronisation of the lower melting point showed a general tendency towards particle agglomeration.

This study demonstrated the ability of sc-CO₂ fluids to micronise and modulate the physico-chemical characteristics of FT waxes and thereby the potential to engineer particles for optimal end-use performance.

Keywords

Supercritical-CO₂, micronisation, wax, particle

3.1 Broadening the waste horizon: Demonstration of industrial organic waste conversion to ethanol

Prof Eugene van Rensburg, Prof Johann Görgens

Stellenbosch University, Stellenbosch, South Africa

Abstract

Society constantly seeks alternatives to fossil-based resources, with ethanol emerging as a sustainable option for fuels and chemicals. While first- and second-generation ethanol from sugarcane, corn, and lignocellulosic biomass face challenges such as competition with food and high operational costs, industrial and household waste presents an overlooked resource. Globally, pulp and paper mills discharge approximately 200 million tons of solid, high-moisture (ca. 70% w/w) paper sludge annually, potentially yielding around 12.5 billion litres of ethanol. Pre- and post-consumer food waste offers even greater potential. However, waste-to-ethanol processes encounter hurdles including high bioburden, diverse material composition, and access to waste streams. To address these challenges, we developed a mobile, containerised demonstration plant housing a 1 000 L (264 gal) reactor equipped with a bespoke steriliser capable of treating difficult-to-sterilise waste. Operational results demonstrated the production of over 40 g/L ethanol using fed-batch culture and a robust fermenting yeast resilient to harsh conditions typical of paper sludge. Preliminary techno-economic analyses indicated a potential internal rate of return (IRR) exceeding 20% for a plant processing 50 dry tonnes per day, with ethanol selling at US\$980/tonne. This pricing aligns competitively with European Union rates for waste-based ethanol and is comparable to Brazilian first-generation ethanol prices. Our investment in technology development offers significant rewards by mitigating risks associated with waste-to-ethanol fermentations. This approach not only contributes to sustainable fuel production but also addresses environmental concerns related to waste management, fostering a more circular economy.

Keywords

Paper sludge, Bioethanol, Technology demonstration

3.2 Effect of Gypsum Addition on Syngas Production During CO₂-Assisted Gasification of Pinewood

Dr Athi-enkosi Mavukwana¹, Dr Kiran Burra², Prof Ashwani K. Gupta³

¹University of South Africa, Roodepoort, South Africa. ²University of Maryland, College Park, USA. ³University of Maryland, College Park, USA

Abstract

The present study investigates the potential synergistic effects of incorporating gypsum during CO₂-assisted gasification of pinewood. It is anticipated that the synergistic interplay between pinewood and gypsum will enhance the efficiency of pinewood conversion into syngas, while simultaneously facilitating the conversion of gypsum into chemically valuable substances, such as calcium sulfide. During the process of gasification, pinewood generates substantial quantities of tars and unreactive char. Tars, being compounds of considerable stability, present a significant obstacle in terms of achieving high conversion efficiency. The presence of gypsum would increase the syngas yield from the conversion of char and tars. The primary aim of this study was to empirically examine the impact of varying quantities of gypsum on the production of hydrogen (H₂) and syngas during pinewood-CO₂-assisted gasification. The mass of pinewood was kept constant at 10 grams, while gypsum was varied from 2 grams to 10 grams accordingly to get the desired waste to gypsum proportions of 16.67 wt.%, 33.33 wt.%, and 50 wt.%. The 50 wt.% proportion represents a case where there is a 1:1 ratio of pinewood to gypsum, 33.33 wt.% represents a case where pinewood is twice the amount of gypsum (2:1 pinewood to gypsum), etc. The overall yield of syngas increased by up to 11.7% while the LHV improved by 12.5% when 16.67 wt.% of gypsum was added. However, increasing the gypsum mass proportion to 50 wt.% negatively affected the syngas production and reduced the syngas yield and LHV by 41.89% and 44% respectively. These results, therefore, provide a new potential for synergistic disposal of low-value wastes which can improve the techno-economic viability of energy and material recovery from pinewoods.

Keywords

CO₂-gasification, Pinewood, Gypsum, Syngas, Synergy.

3.3 Valorisation of challenging-to-recycle wastepaper streams through ethanol fermentation and anaerobic digestion

Ms Juliana Naudé, Dr Daneal Rorke, Professor Johann Görgens, Professor Eugene van Rensburg

Chemical engineering department of Stellenbosch University, Stellenbosch, South Africa

Abstract

The wastepaper streams, namely label backing paper, multilayer paper-based packaging, potato paper sacks and repulped liquid board packaging, are challenging to recycle using technologies and processes currently available in South Africa. These wastepaper streams consist of additives and paper-based material (lignocellulosic material). Utilising the paper-based material, allows the wastepaper streams to be potentially viable feedstocks for bioconversion. Four challenging-to-recycle wastepaper streams were investigated for their potential as feedstocks for valorisation through ethanol fermentation using simultaneous saccharification and fermentation (SSF) and anaerobic digestion (AD) to obtain bioethanol and biogas respectively. The wastepaper streams were milled and sterilised in an autoclave. Screening was conducted through enzymatic hydrolysis, at 2% (w/w) solids loading, with the cellulolytic enzyme Cellic® CTec3 (Novozymes) at a dosage of 15 FPU/g dry solids. The glucose concentrations obtained ranged from 1.15 g/L to 13.16 g/L. SSF was conducted using *Saccharomyces cerevisiae*, strain Ethanol Red®, at 10% (w/w) solids loading and cellulolytic enzyme Cellic® CTec3 (Novozymes) at a dosage of 10 FPU/g dry solids. The maximum ethanol concentrations obtained for the wastepaper streams were between 2.31 g/L and 37.09 g/L. AD was conducted with dairy cow manure at an inoculum to substrate ratio (ISR) of 2. Using an automatic methane potential test system (AMPTS), the biochemical methane potentials (BMPs) of the wastepaper streams were measured for 27 days. The BMPs obtained for the wastepaper streams were between 202.28 ml/gVS and 335.2 ml/gVS. The results from enzymatic hydrolysis, SSF and AD indicated that repulped liquid board packaging was not a viable feedstock for valorisation through ethanol fermentation or anaerobic digestion. However, the label backing paper, potato paper sacks and multilayer paper-based packaging proved to be viable feedstocks for ethanol fermentation and anaerobic digestion due to the high glucose concentrations, ethanol concentrations and BMPs obtained.

Keywords

wastepaper, ethanol, fermentation, anaerobic-digestion, saccharification

3.4 Steel Slag for Precipitated Calcium Carbonate Synthesis for Carbon Capture

Mr Nyasha Chinobva¹, Prof Paramespri Naidoo^{2,1}, Prof Kuvanesan Moodley¹

¹University of KwaZulu Natal, Durban, South Africa. ²Stellenbosch University Home Stellenbosch University, Cape Town, South Africa

Abstract

Iron and steel industries are one of the "hard-to-abate" industries responsible for 7-10% of the global CO₂ footprint. Moreover, the production of each tonne of steel results in 150 to 250 kilograms of CaO-rich slag, part of which is disposed of in landfills. This study investigated a slag-to-precipitated calcium carbonate process, wherein calcium from the slag is extracted using 1M NH₄Cl and converted to CaCO₃ using CO₂ from iron industries.

In this experimental work, an aqueous solution of calcium chloride, ammonium chloride, and ammonia was utilised to simulate a calcium-rich solution from the extraction stage. Based on a central composite design, the reaction temperature and CO₂ pressure were investigated at 303.15, 318.15, and 333.15K and pressures of 0.1, 0.3, and 0.5MPa. The carbonation reaction products were characterised using XRD, FTIR, and TGA. Particle size distribution was analysed using Laser Diffraction, and Scanning Electron Microscopy. A kinetic study was performed at atmospheric pressure and temperatures of 303.15, 318.15, and 333.15K through a titrimetric procedure using a calconcarboxylic acid indicator.

Results indicate a direct correlation between calcium conversion and temperature but an inverse relationship with pressure. The highest conversion (84.04%) was achieved at 333.15K and 0.1MPa, while the lowest (73.67%) occurred at 303.15 K and 0.5MPa.

The study concluded that temperature and pressure influence the polymorphism and particle size. All three crystalline forms of CaCO₃ were synthesised, with spherical vaterite particles produced exclusively at low temperatures, calcite at all temperatures and aragonite at 318.15K and 333.15 K for 0.1MPa pressure.

Furthermore, the produced PCC particles exhibited a smaller Sauter mean diameter compared to similar studies, ranging from 2.7 to 20 µm and increasing with temperature and pressure. A preliminary design based on processing 118 800 tonnes of steel slag containing 41.6% indicated that 19058 tonnes of CO₂ can be permanently sequestered annually.

Keywords

Carbon capture, mineralization, preliminary design

4.1 Electric Double Layer (EDL) Repulsive force Being Responsible for the Time-dependent Behaviour of Clay Gels in the Structural Rejuvenation Mode: Direct Evidence and Unusual Salt Effects

Professor Yee-Kwong Leong

University of Western Australia, Perth, Australia

Abstract

In 2018, we postulated that the EDL repulsive force controls the structural development process during ageing and was therefore responsible for the time-dependent behaviour of charge anisotropic clay gels. The same explanation goes with the structural rejuvenation process during stepdown in the shear rate. Now we have direct evidence that this is indeed the case. A strong EDL repulsive force was needed to accentuate the time-dependent behaviour of the stepdown shear stress response of the charge and shape anisotropic clay gels. This force was strengthened by $P_2O_7^{4-}$ adsorption increasing the negative charge density of the clay particles. At the stepdown shear rate of 10 s^{-1} it was strong enough to disrupt the flow-aligned structure attained at 1000 s^{-1} and orient the particles to form more bonds. As a result, the stepdown shear stress increased with time until these structure disruption and bond forming processes reached equilibrium. The number of lower energy approach configurations (-ve face - +ve edge) for bonding is reduced by the enhanced EDL repulsive force slowing down the bonding process. The time to reach this equilibrium state increased initially and then decreased and became zero at high negative charge density where charge anisotropy of the particles no longer exists. The need of a sufficiently strong EDL repulsive force for the display of time dependent behavior is true for all clay gels; Laponite, hectorite, NaMnt, sepiolite and kaolin gels. The untreated NaMnt gel already displayed time-dependent behaviour as the EDL force is already strong enough. The same EDL-control time dependent behaviour was obtained if pH was used to vary the negative charge density of the clay particles. Small amounts of 1:1 salt can cause a several-folds increase in the ageing yield stress of 2:1 smectite clay gels. The role played by the EDL repulsive force is highlighted.

Keywords

Thixotropy, bentonite, kaolin, sepiolite, hectorite

4.2 Application of Eutectic Salts and Ionic Liquids as sustainable corrosion inhibitors on mild steel surface in acidic medium: Experimental and DFT studies.

Dr Hamed Hashemi, Mr Mogomotsi Leshetla, Prof. Josias van der Merwe

University of the Witwatersrand, Johannesburg, South Africa

Abstract

Ionic liquids are benign environmentally friendly solvents which have shown a great potential to be used in different industrial and engineering applications. Given the rising requirements for environmentally friendly and sustainable materials with excellent solubility in polar electrolytes, ionic liquids are emerging as promising candidates for inhibiting metallic corrosion. In this research, we conducted a comprehensive analysis of the adsorption tendencies of numerous ionic liquids and deep eutectic solvents, employing both density functional theory (DFT) studies and experimental investigations. To facilitate this, an extensive dataset comprising various ionic liquids and eutectic salts was prepared for DFT analysis. The DFT results allowed us to determine the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbitals (LUMO), aiding in the identification of the most promising candidates. Subsequently, these selected candidates underwent experimental investigations using electrochemical analyses. The experimental studies were conducted in a 1M HCl test solution at three different concentrations: 100, 300, and 500 ppm.

Keywords

Corrosion, inhibition, Ionic Liquids

4.3 Synthesis of <60 nm CaCO₃ Crystals from Gypsum

Patrick Casserly, Prof Dawie van Vuuren

University of Pretoria, Pretoria, South Africa

Abstract

Calcium carbonate nanoparticles (CCNPs) are a useful compound utilised in many industries, particularly in the pharmaceutical industry for the purpose of drug delivery. A new method to synthesize CCNPs, using cheap, readily available, and impure gypsum was investigated. The goal of the investigation was to determine the feasibility of producing CCNPs, under 60 nm in diameter, from gypsum. Gypsum was converted into calcium sulphate ($CaSO_4$) by drying the powder at 350 °C. The $CaSO_4$, was subsequently converted to calcium sulphide (CaS) by carbothermic reduction at $\pm 1000^\circ\text{C}$. A suspension of CaS was reacted with hydrogen sulphide gas in water to create an aqueous solution of calcium di-hydrogen sulphide. Thereafter, calcium di-hydrogen sulphide was reacted with an aqueous solution of sodium carbonate in a blender. The contents were removed from the blender, filtered, and dried. The dried powder was examined using a scanning electron microscope. It was found that calcium carbonate vaterite crystals had formed with sizes ranging from 29 nm to 45 nm. This synthesis method not only opens the possibility of recycling waste by-product gypsum into a value-added product but creates new avenues for small-scale production of calcium carbonate nanocrystals from cheap, readily available gypsum, using simple laboratory equipment.

Keywords:

Nano, CaCO₃, gypsum, Na₂CO₃

4.5 REE betadiketone complexes as corrosion inhibitors for mild steel and Type 304 stainless steel in corrosive media.

Herman Potgieter, David Whitefield, Michael Bodunrin, Johnson Lawal, Thobile Dladla

Manchester Metropolitan University, Manchester, United Kingdom

University of the Witwatersrand, Johannesburg, South Africa

Abstract

This study examines the corrosion control effectiveness of rare earth element (REE) beta diketone compounds as environmentally friendly inhibitors for mild and stainless steel in corrosive environments. The aim is to replace traditional, toxic chromium-based inhibitors. This research focused on characterizing REE-diketone complexes, including Ce(acac)₃, La(acac)₃, Sm(acac)₃, and Pr(acac)₃, and evaluating their corrosion inhibition efficiency for mild steel and austenitic stainless steels (304) in chloride-rich and acidic conditions. SEM, and potentiodynamic analyses were employed to assess the inhibitor performance. The results show distinct behaviours of the inhibitors under different conditions. SEM analysis confirms the formation of a protective film layer comprising rare earth element oxides and iron oxide/iron oxyhydroxide on mild steel and 304 stainless steel. This investigation confirms the potential use of REE compounds as alternatives to chromates for corrosion protection.

Keywords:

Inhibitors, REE, chloride media, H₂SO₄

5.1 NEWGenerator off-grid non-sewered sanitation: System performance, black-water recovery, and lessons learned from implementation at a rural school and informal settlement

Mr Timothy Fisher¹, Dr Gunter Rencken¹, Dr Aphiwe Mapetere¹, Dr Daniel Yeh², Dr Robert Bair²

¹WEC Projects, Johannesburg, South Africa. ²University of South Florida, Tampa, USA

Abstract

Non-sewered sanitation systems (NSSS) will play a leading role in providing safe sanitation and dignity to millions of people across South Africa and the world. The NEWGenerator is a field-proven and commercialised technology to achieve these goals – making use of an anaerobic membrane bioreactor and adsorptive nutrient capture to treat and reuse black-water for toilet flushing. The NEWGenerator technology was invented by the University of South Florida, and rolled-out in South Africa by the South African Water Research Commissions (WRC), South African Sanitation Technology Enterprise Program (SASTEP) supported by the Bill and Melinda Gates Foundation, Department of Science and Industry (DSI) and Department of Water and Sanitation (DWS).

On the path to commercialisation with local EPC WEC Projects, two demonstration sites have been established (1) An informal settlement in Slovoville, Soweto (Nov 2021) and (2) A rural junior primary school in Bizana, Eastern Cape (Jan 2022). The sites have offered insight into the system performance, as well as community acceptance. Data has been taken from the sites on a monthly basis for: feed and product water quality, totalised reused volumes, and community feedback surveys. The results will be presented against ISO-30500, the working standard applied to NSSS. This paper will provide performance data in terms of product water compliance, water generation, and summarise the practical lessons learned in their implementation to improve future rollouts of the NEWgenerator. Further, commentary on improving the applicability of standards to rural and low-income areas will be provided.

Keywords

Non-sewered-sanitation, water reuse, nutrient recovery

5.2 The treatment of poultry processing effluent to potable water standard for in-factory reuse to ensure production security and minimise water footprint.

Dr Pierrie van Zyl¹, Mrs Elspeth Grahn²

¹PROXA, Cape Town, South Africa. ²PROXA, Gauteng, South Africa

Abstract

ASTRAL Foods is the largest producer of poultry products for the South African market. ASTRAL's facility in Standerton is capable of processing roughly 2 million birds per week and directly employs ~2 500 people from the local community. In 2019 the challenges with service delivery, left the Client with no alternative but to reduce and sometimes stop production. This culminated in production losses, which had a negative impact on profit and the local economy.

PROXA, a trusted water treatment technology provider, was selected to address these challenges due to their track record and relationship with ASTRAL Foods. A multi-phase solution was implemented:

Phase 1: PROXA managed the emergency delivery of critical equipment within hours to improve the municipal water supply to the factory.

Phase 2: PROXA installed a rapid deployment filtration unit of 2.5 million litre per day filtration unit to upgrade water from the Vaal River to potable quality. First on-specification water was produced from the filtration unit one week after request by the Client

Phase 3: PROXA provided the facility with a Reuse solution treating factory effluent to potable water, ahead of schedule, and within budget. The Reuse system upgrades biologically treated abattoir effluent to well within SANS241-2015 and WHO potable water standard for in-factory reuse. The new system was installed and commissioned and the first on-specification water was produced ahead of schedule in May 2020.

Phase 4: PROXA overall management (operations and maintenance) of the factory's entire freshwater treatment system

Phase 5: Installation of a second river to a potable filtration plant; enabling the factory to operate completely off-grid concerning potable water.

PROXA prioritised phased solutions that enabled the client to regain continuous production and stakeholder trust and decrease reliance on municipal water supply.

Keywords

production security, effluent treatment reuse

5.3 Remediation of Cationic and Anionic Dyes from Aqueous Systems Using Yellow Mozambican Bentonite Clay

Professor Shepherd Tichapondwa, Miss Carol Luposo, Mr Nathan Ndalamba

University of Pretoria, Pretoria, South Africa

Abstract

This study investigated the effectiveness of yellow Mozambican bentonite clay in eliminating organic dyes from wastewater. Sodium-based and polymer-based modifications were applied to enhance the performance of natural bentonite clay. The addition of a 5wt% polyamide (PA) modification resulted in a 46% reduction in the BET surface area, decreasing from an initial value of 46.12 m²/g to 24.19 m²/g. The 5 wt.-%-PA modified clay showed superior efficiency compared to other samples, successfully removing all the methylene blue (MB) and 85% of methyl orange (MO) from solutions with concentrations of 10 mg/L. Optimization studies revealed that MB removal was most effective under alkaline conditions (pH 10) with a loading of 0.30 g/L, while MO removal was optimal under acidic conditions (pH 1) with a loading of 0.80 g/L. Equilibrium data indicated that the adsorption capacity for (126 mg/g) on the MB the 5 wt.-%-PA modified was higher than that for MO(35 mg/g), and the Langmuir isotherm model provided a better fit for both dyes, suggesting monolayer adsorption on a surface with a finite number of identical sites. The pseudo first-order kinetic constants for MB and MO were determined to be 0.116 min⁻¹ and 0.047 02 min⁻¹ respectively. These results clearly indicate that the adsorption rate of MB is significantly higher than that of MO. Thermodynamic results indicated that the MB adsorption process was endothermic ($\Delta H=27\ 031.31\text{J/kg}$), while the MO adsorption process was exothermic ($\Delta H=-3681.02\ \text{J/kg}$). This research revealed that modified yellow Mozambican bentonite clay exhibited a greater efficacy in the removal of cationic organic pollutants as compared to that of anionic organic pollutants.

Keywords

water treatment; clay modification; organic pollutants; adsorption

6.1 Bioprocess development and scale-up for cis,cis-muconic acid production from glucose and xylose by *Pseudomonas putida*

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Abstract

cis,cis-Muconic acid (MA) is a bio-based chemical that can be converted to direct replacement chemicals or performance-advantaged bioproducts. We recently engineered the bacterium *Pseudomonas putida* KT2440 for the co-utilization of glucose and xylose to produce MA. This study evaluates the effect of additional genetic modifications, media composition, and bioprocess strategy on MA titer, productivity, and yield in bioreactor cultivations. We achieve a MA titer of 47.2 g L⁻¹, a productivity of 0.49 g L⁻¹ h⁻¹, and a yield of 0.50 C-mol C-mol⁻¹ from glucose and xylose supplemented with 5% (v/v) corn steep liquor with a *P. putida* strain harbouring the deletion of *gacS*. Additionally, we demonstrate efficient MA production from corn stover-derived sugars and scalability to 150 L bioreactors. Techno-economic analysis and life cycle assessment predict that adipic acid, derived from catalytic hydrogenation of MA, can achieve a selling price as low as \$2.60 per kg, approaching cost parity and reducing greenhouse gas emissions by up to 80% relative to fossil carbon-based adipic acid.

Keywords

cis,cis-muconic acid; *Pseudomonas putida*

6.2 Magnetic Field Control of Heterogeneous Catalysis: Application To Low Temperature Fischer Tropsch Synthesis

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Abstract

The initial step in any catalytic reaction is the adsorption of reactant molecules. The strength of the adsorption and orientation of the adsorbed molecules correlate well with the activity and selectivity of the catalyst. Most industrial catalysts are composed of various transition metals supported on relatively inert oxides. The interaction between reactant molecules and metallic active sites is governed by the electronic structure of the catalyst. This determines the adsorption strength and geometry. Modification of the electronic structure of the catalyst can alter the adsorption parameters of the reactant. This can be used to control the catalytic performance. In this study, low-pressure Fischer-Tropsch was carried out in a lab-scale fixed bed reactor system using an iron-based catalyst. The reactor was surrounded with an electromagnet and the effect of the induced electromagnetic field on the product distribution and yield was evaluated. The first prototype comprised a four-coil pair, concentric circle Helmholtz coil, providing a highly concentrated magnetic field parallel to the flow of reactants through the reactor vessel. The second was a Helmholtz cage that was able to exert three individual axes of magnetic field, and was also used to create an isolated, high intensity magnetic field system around the reaction zone, by activating all the coils in the cage at once. The magnetic field was shown to have a significant effect on methane selectivity and yield of higher alkanes.

Keywords

Catalysis, Electromagnetism, Catalytic enhancement, Fischer-Tropsch

6.3 A techno-economic analysis of the steel production process for the production of methanol using top blast furnace gas

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Abstract

The steel industry is a major emitter of CO₂, with two-thirds of annual steel production attributed to the conventional blast furnace route globally. This work presents a techno-economic analysis (TEA) of the steel process with the production of syngas methanol using top blast furnace gas (TBF_g) as the feedstock based on direct CO₂ hydrogenation within a commercial Blast Furnace-Basic Oxygen Furnace steel manufacturing plant.

The study was divided into three segments, viz., blast furnace, carbon capture (CC), and methanol synthesis units. It provides insights into traditional steel-making processes and proposes modifications, with a focus on the "Power-to-X" concept, with methanol being the fuel derivative of interest due to its potential to significantly reduce emissions and its chemical value.

A methanol plant producing chemical grade methanol was simulated on ASPEN PLUS including a sensitivity analysis on the TBF_g available to determine methanol production and purity. The second section delves into the CC unit using amine absorption.

Simulations were performed for plants with three different yearly capacities: 10, 50, and 250 kt/a.

They were contrasted with the option of purchasing the CO₂ or capturing it directly from flue gases through a CC unit connected to the methanol plant. The kinetic model utilizing both CO and CO₂ as carbon sources for methanol synthesis was thoroughly described. Simulation outcomes indicated successful production of chemical grade methanol, with optimised heat exchanger networks achieving substantial energy savings.

A TEA of the methanol (MeOH) plant was then conducted to determine the Net Present Value (NPV) and levelized cost of methanol (LCO_{MeOH}), comparing findings with literature to conclude on whether such a project would lay a positive impact economically. Thereafter sensitivity analyses of factors affecting the LCO_{MeOH} was done, mainly focusing on whether it is beneficial to own a CC plant or purchase CO₂ out of boundary.

Keywords

steel industry, carbon capture, methanol

7.1 Hydrometallurgical recovery of cobalt, nickel, lithium and manganese from spent lithium-ion batteries

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Abstract

Lithium-ion battery (LiB) demand has increased with advancement in technologies. The applications include electric vehicles, cell phones, laptops and many more devices.

Typical components the cathodes include lithium, cobalt, nickel and manganese. Recycling of the spent LiBs is necessary to reduce the ecological footprint of their production and use and to have a secondary source of the valuable metals.

A hydrometallurgical method was investigated for the recovery of cobalt and nickel from LiB cathodes. The cathodes were leached using a chloride solution. Ion exchange was then used to recover the chloro-complexes of the metals. The aim of the research was to determine the efficiency of a chloride leach, ion exchange operating capacities that can be achieved for LiB recycling and to establish the optimal operating conditions (ideal pH, temperature, leachant and eluant, flowrate and reagent concentrations) for the recovery of the cathode metals.

It was found that leaching of the cathodes could be hindered by the formation of refractory metal oxides of cathode metals. A reducing agent was necessary to improve the leaching rate and efficiency.

A modular unit has been built, and the operation has been monitored. Further work is currently underway to determine the optimal operating conditions for the recovery by ion exchange, and purity of final product.

Keywords

Lithium-ion batteries, ion-exchange, cobalt, circular-economy

7.2 Modelling of Struvite Recovery from Anaerobically Digested Waste Activated Sludge using Response Surface Methodology.

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Abstract

The waste-activated sludge (WAS) contains essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) which can be crystallized into struvite ($\text{NH}_4\text{MgPO}_4 \cdot 6\text{H}_2\text{O}$) and used as a fertilizer in agriculture. In this study, Response Surface Methodology (RSM) was used to optimize the recovery of struvite from the supernatant of anaerobically digested WAS. The central composite design (CCD) was used as a statistical tool to determine the effects of key parameters including Mg:P ratio and pH on phosphorus recovery. A second-order polynomial equation was established to correlate the parameters. ANOVA showed that all the investigated parameters had a statistically significant effect on the phosphorus recovery as their p-values were less than 0.05. SEM-EDX analysis revealed the formation of struvite crystals with an uneven structure and the presence of Mg, P, and O. The low levels of interfering ions (K and Ca) suggest that the formation of Ca-P and K-P compounds might have been insignificant. XRD and FTIR bands confirmed the formation of struvite in the retrieved samples.

The findings of the current study have the potential to significantly impact the environment, economy, health, and community. Adopting the proposed struvite recovery approach would have a significant impact on wastewater economics, environmental management, and community development. Struvite recovery contributes to a sustainable sludge management approach, which creates a circular economy. In this circular economy, the nutrients that are lost along the food value chain as organic and human excreta waste are recycled back into the soil. This improves food security and simultaneously enhances raw water quality. This is achieved through increased low-cost nutrient recycling as well as minimal use of expensive inorganic fertilizers. Furthermore, organic fertilizers such as processed sludge rich in organic matter improve soil properties as well as nutrient and water use efficiency.

Keywords

Anaerobic digestion; Circular economy

7.3 Using Coco Peat to Improve the Water Retention Capacity of Petroleum-polluted Soils

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Abstract

Petroleum, a vital energy source for numerous industries, comprises hydrocarbons and other organometallic components. Despite its significance, the processes involved in its extraction, effluent release, and accidental spills result in hydrocarbon pollution in terrestrial environments. This pollution poses severe hazards to living organisms and disrupts the delicate balance of terrestrial ecosystems, with soil being particularly vulnerable. Considering these environmental concerns, extensive efforts have been made to mitigate the aftermath of petroleum pollution. Various cleanup techniques, including solvent extraction, thermal desorption, and landfilling, have been documented, but they often come with substantial costs. As a result, there has been growing global interest in bioremediation, which utilizes microorganisms to detoxify pollutants in a cost-effective and eco-friendly manner.

This study focuses on evaluating the effectiveness of coco peat in mitigating petroleum-polluted soils. Specifically, it aims to investigate two key objectives: the impact of coco peat on water retention capacity (WRC) and its ability to reduce the leaching of petroleum range organics (PROs). To achieve these objectives, a series of experiments were conducted using soil samples spiked with petrol at varying concentrations. Different levels of coco peat were then applied to observe their effects on WRC and PROs leaching over a five-week period.

The results showed that petrol contamination led to a reduction in WRC, which was mitigated by the addition of coco peat. Furthermore, coco peat significantly reduced PROs leaching compared to untreated soils. FTIR analysis confirmed the presence of hydrocarbons in the contaminated soils. In conclusion, the findings demonstrate that coco peat is an effective bioremediation agent for improving WRC and reducing PROs leaching in petroleum-polluted soils. However, it is recommended to apply coco peat periodically to ensure sustained decontamination efforts.

Keywords

bioremediation; coco-peat; petrol-polluted-soils; water-retention-capacity; environmental-engineering

8.1 Rare earth elements and uranium in Minjingu phosphate fertilizer products: Plant food for thought (Nils Haneklaus) - Online

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Abstract

Minjingu phosphate ore is Tanzania's sole domestic supply of phosphorus (P). The ore contains medium to high concentrations of naturally occurring P₂O₅ (20–35 %) and relevant concentrations of uranium and rare earth elements (REEs) are also suspected to be present. Currently, neither uranium nor REEs are recovered. They either end up in mine tailings or are spread across agricultural soils with fertilizer products. This work provides a first systematic review of the uranium and REE concentrations that can be expected in the different layers of Minjingu phosphate ore, the way the ore is presently processed, as well as a discussion on alternative processing pathways with uranium/REE recovery. The study analyzed ten distinct Minjingu phosphate ore layers, four mine tailings, and five intermediate and final mineral fertilizer products from the Minjingu mine and processing plant located in northern Tanzania. The results confirm that the uranium concentrations and to a lesser degree, the REE concentrations are indeed elevated if compared to concentrations in other phosphate ores. The study does not identify a significant risk resulting from this. The development of techno-economic solutions for more comprehensive utilization of Minjingu ore is, however, strongly encouraged and suggestions on such processes are provided.

Keywords

Minjingu phosphate ore, Rare earth elements (REEs), Uranium, Circular economy, Tanzania

8.2 The use of amino acids in the green processing of gold

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Abstract

The world is transitioning towards green technology throughout all industries and the gold sector is one of those that has been pushed towards this by environmental regulations. Over the past century, gold has been processed using the popular chemical called cyanide. Cyanide has proven to be an effective processing chemical due to its high gold extractions, robustness, and relatively low costs. However, growing environmental concerns have sparked widespread apprehension regarding its use in gold processing.

In response to these concerns, extensive scientific research globally has explored alternative chemicals to replace cyanide and these alternatives have presented unique advantages and drawbacks. A group of organic compounds known as amino acids emerged as a promising leaching agent for gold. Focusing mainly on the smallest amino acid glycine.

This work focused on using glycine, alanine, histidine, and cysteine to compare applicability of these amino acids in gold leaching as well as to understand related chemical reactions and functionality of gold amino acid complex in extraction using Fourier transform infrared (FTIR) and Density Function Theory (DFT). Moreover, the amino acid applicability in gold extraction was tested on leaching pure gold to ascertain whether gold leaching is a sustainable method for extracting value from waste gold tailings.

FTIR and DFT corroborated one another in the analysis of functionality of gold amino acid complexes. Extractions over 80% were achieved in the leaching of the gold from tailings confirming that the amino acid system had the potential to be used in gold leaching.

In summary, this work through understanding the chemistry of gold amino acids systems, provided valuable insights into the use of amino acids as gold leaching agents. In addition, it highlighted the possibility of using the amino acid leach system for the processing of both primary and secondary sources of gold.

Keywords

amino-acids, FTIR, DFT, tailings, leaching

8.3 The hazardous waste Management in mining - call to action

Jaco Nel

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Abstract

South Africa faces a pressing challenge with hazardous waste, producing millions of tonnes annually, much of which comes from the mining sector. In terms of global ecological risk, problems relating to mining waste specifically are widely recognised as second only to global warming and stratospheric ozone depletion. With landfill space rapidly diminishing and environmental risks from mining waste intensifying, there is a critical need for innovative, sustainable waste management solutions. Current strategies are insufficient, but emerging zero-waste-to-landfill technologies offer a path forward.

This talk will explore the problem of hazardous waste in the context of green mining and our need to act from three perspectives – capacity of current solutions, legislation and environmental. This will be followed with practical solutions for mining sustainability, focusing on reducing hazardous waste through advanced treatment methods and industry-wide collaboration. The conclusion will highlight a bright way forward and some proposed steps each person with influence in the industry can take.

Keywords

Hazardous Waste; Green Mining; Sustainable Waste Management; Zero-Waste-to-Landfill; Mining Sustainability

8.4 Facile recovery of polycationic metals from acid mine drainage and their subsequent valorisation for the treatment of municipal wastewater

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Abstract

The presence of toxic and hazardous chemical species in municipal wastewater presents a significant environmental challenge, demanding sustainable and innovative treatment solutions. This study explores the recovery of polycationic metals from acid mine drainage (AMD) and their subsequent valorisation for the treatment of municipal wastewater. Advanced analytical techniques were employed to characterize both aqueous and solid samples, while batch experiments were conducted using real municipal wastewater to evaluate the efficacy of polycationic metals in removing key contaminants—ammonium (NH_4^+), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), and nitrate (NO_3^-). Optimum conditions were identified as 2 g of polycationic metals, 90 minutes of contact time, and 35°C. Under these conditions, the results demonstrated exceptional removal capacities, with the removal efficiencies following the order: $\text{PO}_4^{3-} > \text{NH}_4^+ > \text{NO}_3^- > \text{SO}_4^{2-}$, achieving final concentrations of <0.5 mg/L for PO_4^{3-} and NH_4^+ , 2.1 mg/L for NO_3^- , and 9.1 mg/L for SO_4^{2-} . The adsorption kinetics were best described by a pseudo-first-order model, indicating physisorption, while the adsorption isotherms fit the Two-Surface Langmuir model, suggesting a combination of homogeneous and heterogeneous adsorption mechanisms. FTIR, SEM-EDS mapping, and XRF analyses confirmed the presence of P, S, and N in the product sludge, verifying the adsorption and retention of these chemical species. This study highlights the dual benefits of using polycationic metals for AMD decontamination and municipal wastewater treatment, offering a cost-effective and sustainable approach to environmental management. Future research should focus on scaling up the technology for real-world water treatment applications.

Keywords

Acid mine drainage; municipal wastewater; recovery of valuable minerals; circular economy; nutrient removal; waste beneficiation and valorisation; polycationic metals

9.1 Characterisation and Evaluation of *Chlorella Vulgaris* on Brewery Wastewater Treatment.

Miss Nikita Singh¹, Prof Manimagalay Chetty^{2,1}, Prof Sudesh Rathilal¹

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Abstract

The global energy demand, projected to rise by 30 % by 2050, escalates the urgency for sustainable wastewater practices and alternative solutions to mitigate dependency on Earth's natural resources. Currently, 80 % of the world's population relies on fossil fuels, releasing 21.3 billion metric tons of CO₂ annually, contributing to our carbon footprint. The rapid industrial expansion caused by population growth results in significant wastewater generation, with 80 % of global wastewater discharged untreated into ecosystems, posing severe environmental hazards. Microalgae, an attractive non-food competitive feedstock presents a promising solution to simultaneously eradicate the challenges of fossil fuel shortages and wastewater management. Cultivation of microalgae in wastewater utilises the nutrients, organic content, chemical composition, toxicants, and contaminants in wastewater to generate biomass suitable for biofuel production. Moreover, microalgae absorb these constituents during growth, purifying the water for a safer discharge.

This study focuses on the growth and nutrient removal efficiency of *Chlorella vulgaris* (CV) in brewery wastewater. Using Design of Experiments (DoE) and bench-scale optimized experiments, CV was cultivated in Bold's Basal Medium (BBM) and brewery wastewater under controlled conditions. The physical characterization revealed moisture content, ash content, fixed carbon, and volatile solids, while the chemical characterization determined the C, H, N, S, and O composition. The biomass revealed a composition of 13.75 % lipids, 23.5 % carbohydrates, and 48.2 % proteins. The C and H content indicated biofuel potential in terms of yield and energy content, while N, S, and O provided combustion and emission characteristics. Characterisation of the brewery wastewater established the impact of CV on wastewater treatment. The overall efficiency achieved 79 % total nitrogen (TN), 92 % total phosphorus (TP), and 70.2 % chemical oxygen demand (COD) removal efficiencies, whilst heavy metals removal efficiency 98 % Ca²⁺, 84.35 % Mg²⁺, and 43.86 % Mn²⁺ removal. This integrated approach provides an in-depth understanding of biomass production using wastewater sources.

Keywords

brewery, characterization, dairy, microalgae, wastewater

9.3 Utilising Raw Mining-Influenced Water (MIW) Sludge as an Adsorbent for Pb(II) Adsorption: Modelling Mass Transfer Effects

Ms Nokuthula Nchabeleng, Professor Hendrik Brink

University of Pretoria, Pretoria, South Africa

Abstract

Contamination of water sources by heavy metals, such as Pb(II), presents a significant environmental challenge. A key focus in the remediation of contaminated water sources is employing sustainable wastewater treatment processes. Adsorption emerges as a preferred technology due to its simplicity, robust nature, and relative low cost.

In this study, the use of a water remediation waste by-product (MIW sludge) is explored for its applicability as an adsorbent for Pb(II) contaminated aqueous solutions. The focus of this study lies in understanding the mass transfer effects inherent in the adsorption process. Adsorption includes a series of steps, starting with the transport of the adsorbate from the bulk liquid phase to the boundary layer, followed by movement to the adsorbent surface (external mass transfer, EMT), and finally, diffusion through the material's pores to the active sites (internal mass transfer, IMT).

This study aims to identify the rate determining step by investigating the impact of varying average particle diameters—1 mm, 2 mm, and 3 mm—on the adsorption kinetics, particularly on the time required to achieve equilibrium and maximum Pb(II) removal efficiency. It is observed that at set conditions: same initial Pb(II) concentration, temperature, adsorbent dosage and adsorbate solution pH, adsorption kinetics are notably faster for 1 mm adsorbate particles compared to 3 mm particles. Twice the amount of contact time is required to reach equilibrium (90 to 180 minutes). The longer contact time required for equilibrium underscores the influence of internal and/or external mass transfer effects. Crank's mass transfer model is used to quantify the effective diffusivity providing operational parameters required for design of the process.

This research provides a sustainable remediation option by valorisation of a waste sludge that may be utilised in continuous flow processes thereby contributing to environmentally sound water treatment practices.

Keywords

Adsorption kinetics, Mass transfer, Sustainability

9.4 Adsorption of methylene blue dye onto carbon foams derived from wheat and bulrush bread

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Abstract

Organic contaminants in water is an area of concern as they can cause many adverse effects to health and the environment. Methods for the removal of organic contaminants include precipitation, photodegradation and adsorption onto a suitable medium. Adsorption is an attractive solution as it can be efficient, cost effective and amenable to decentralised water treatment. Activated carbon is the most widely used adsorbent but is expensive.

Carbon foams (CF) are a class of carbonaceous materials with a macroporous open pore structure which can accommodate other materials in the voids. CFs may be a cheaper alternative to activated carbons as they can be made from a variety of biomasses, resins and coal. Yuan reported making CF from bread baked with wheat flour. This procedure is attractive as the pores of the CF are formed during the baking process. Methylene blue (MB), a popular dye that can have harmful effects, was chosen as the model dye to monitor the adsorption capability of synthesised CFs.

The current study reports the synthesis of CF derived from bread baked with wheat flour and bulrush flour. Carbonisation time (1; 2; 3 h), carbonisation temperature (500; 600; 700 °C) and iron oxide dopant (2 and 3%) was varied to afford CF with different textural and adsorption characteristics. The extent of the MB removal from aqueous solution was monitored over 24 hours and the data analysed using the Langmuir and Freundlich adsorption isotherms. The Langmuir isotherm was found to be a better fit and the theoretical monolayer capacity was calculated. The bulrush-derived CF was found to have a higher adsorption capacity than the wheat-derived CF. The optimal carbonisation time and temperature was found to be 2 hours and 600 °C. Iron oxide was seen to increase the adsorption capacity, indicating more of this dopant can be added.

Keywords

Wastewater, methylene blue, adsorption

10.1 Engineering Education for Sustainable Development: A Holistic and Collaborative Approach

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Abstract

Engineering education plays a pivotal role in cultivating graduates who can actively contribute to the achievement of the Sustainable Development Goals (SDGs). This imperative underscores the need for quality education that addresses three critical areas: 1) the evolving nature of engineering work, emphasizing sustainability considerations; 2) global trends necessitating the development of skills like critical thinking, problem-solving, and teamwork alongside technical expertise; and 3) the growing importance of access, success, diversity, and inclusion within the engineering student body.

The Innovative Engineering Curriculum (IEC) project, funded by the Royal Academy of Engineering and the University Capacity Development Fund, is a collaboration with industry, the Engineering Council of South Africa (ECSA), and University College London (UCL), the project aims to formulate a contextually-relevant framework for engineering curricula in higher education institutions in South Africa. The value of these partnerships' manifests in creative problem-solving, capacity building, support mechanisms, and the more efficient utilization of resources.

This project addresses these challenges by establishing, developing, and nurturing partnerships, reimagining the structure of engineering curricula in South Africa. The goal is to foster the development of graduates equipped to address global sustainability challenges. Building on the insights on existing initiatives across South Africa, which highlighted the transformative role of partnerships in shaping the national landscape, this project facilitates national engagement and cross-institutional collaboration.

This presentation overviews the journey and approach to holistic systemic change in transforming curricula to produce graduates who not only meet the demands of the dynamic field but are also equipped to address the multifaceted challenges of sustainable development on a global scale. Specific case studies from the University of Pretoria of the process in the School of Engineering across the 7 Engineering Departments.

Keywords

Innovative Curriculum, Engineering Education, Sustainability

10.2 An enquiry-based learning approach for first-year chemical engineering design

Prof Linda Jewell, Prof Mulenga Ilunga

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Abstract

First year students are usually introduced to chemical engineering design via a mass balance problem that involves applying the skills necessary for the capstone design course at the end of the qualification. Given the intentionally flat structure of the first-year curriculum at University of South Africa (Unisa), where co-requisites are avoided, an innovative approach has been used in the curriculum of the new diploma in Chemical Engineering; the curriculum includes a course with the aim of exposing first year students to the impact of chemical engineering on society and the environment (Graduate Attribute 7). This has resulted in a broad syllabus, covering diverse topics such as: net zero emissions, risk, toxicity, the fate of chemicals in the environment, and environmental legislation. The student-centered approach of enquiry-based learning (EBL) has been used to increase student motivation and to avoid passive methods that result in surface learning. The assessments include low weighted, randomized Cloze assessments, with immediate feedback on the detailed content and more heavily weighted opened-ended EBL assessments. For the EBL assessments, the students use freely available web resources to select a case study matching certain criteria, and then analyze it by answering specific questions. This develops the students' ability to select and critically analyze information and write in a professional manner with ethical source-attribution. The EBL assessment also creates awareness of web resources like the USCSB reports and articles in The Chemical Engineer published by IChemE. Since these are first year students, the use of large language AI models in the submitted work is discouraged. The students are given feedback and permitted to improve and re-submit their answers. In general, the main finding is that the use of the open-ended EBL assessment tool results in highly motivated and actively engaged students, who are exposed to real-world problems.

Keywords

Enquiry-based learning, Chemical Engineering Design

10.3 Enhancing the Delivery of Fluid Mechanics Education Through the Use of Low-Cost Phone-Based Particle Streak Velocimetry

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Jeffrey Muriithi

Abstract

To enhance the delivery of Fluid Mechanics concepts, engineering instructors have found practical laboratory experiments useful. Various experimental methods exist with recent interest being in the use of low-cost particle image velocimetry (PIV). This method, similar to traditional PIV, involves seeding a flow with particles and recording the motion of the particles which is subsequently analysed to give the flow velocities. However, unlike traditional PIV, low-cost PIV focuses on the use of low-cost components such as low-powered continuous wave lasers for illumination (instead of high-powered pulse lasers) and low-cost recording devices such as mobile phone cameras (instead of high-end cameras). While the feasibility of low-cost PIV and its applicability for educational demonstrational purposes has been demonstrated, the flows tested have largely been limited to slow flows. This can be attributed to the nature of PIV which requires the use of two images to calculate velocity data. When using an averagely affordable phone camera, one is typically limited to a maximum recording speed of 30 – 60 fps (frames per second) and this implies that the shortest achievable timespan between two images is 1/60 seconds. This time resolution impacts the maximum measurable velocity. To overcome this limitation, while still keeping the noble idea of low-cost velocimetry for educational purposes, this study suggests the use of low-cost particle streak velocimetry (PSV) instead. This technique relies on a set up similar to that used for low-cost PIV. However, only one image is required. The image is obtained by allowing for over-exposure of the camera that leads to the streaking of the image. Velocities are computed by dividing the streak lengths with the camera's exposure time. Since the mobile phone cameras give good control over the exposure time (1/10000 seconds on the lower end), much higher velocities can be obtained in comparison to low-cost PIV.

Keywords

engineering-pedagogy, phone-based-experiments, low-cost-particle-streak-velocimetry, fluid-dynamics

11.1 Seaweeds to save the world: An overview of research completed toward establishing a seaweed biorefinery in South Africa

Prof Neill Goosen¹, Mr Alistair Border¹, Dr Achinta Bordoloi^{1,2}, Mr Ryan Cilliers¹, Prof Johann Görgens¹, Mr Zwonaka Mapholi¹, Mr Matthew Noach¹, Prof Robert Pott¹, Prof Marianne Thomsen³, Mr Daniel Van Breda¹, Mr Roelof Van der Merwe¹, Prof Eugene Van Rensburg¹, Mr Dylan Van Sittert¹, Ms Gina Wilkinson¹, Ms Xueqian Zhang³

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Abstract

Marine macroalgae (seaweed) is a likely future feedstock for biorefineries: they grow fast and can be farmed at large scale without requiring land, freshwater or fertilizer. Brown seaweeds contain unique polysaccharides that could form the basis for a seaweed-based biorefinery: alginate is valued for its gel-forming ability, laminarin is a glucose-based storage molecule and fucoidan is a fucose-rich sulphated macromolecule. In South Africa, the kelp *Ecklonia maxima* is the main potential biorefinery feedstock, but much new data are required before the feasibility of a seaweed biorefinery can be evaluated, including extraction and purification pathways of target compounds, the economic feasibility and environmental impact assessments.

The talk details research completed on *Ecklonia maxima* as biorefinery feedstock. New polysaccharide extraction methods were evaluated: laminarin was extracted using an enzyme-assisted method, fucoidan was extracted with subcritical water and with combined ultrasound-enzymatic extraction, and alginate was extracted with a combination of alkaline cellulase and ultrasound. To facilitate enzyme-assisted extraction in future work, a production system for the production of alginate lyase from marine microorganisms is being optimized. Downstream processing methods for recovery of multiple high-purity products are being developed: initial investigations on membrane ultrafiltration (UF) showed that UF alone does not result in high purity fractions of the targeted polysaccharides, but a dye-affinity adsorption method shows improved results. On the waste processing aspects, residual biomass has been employed for anaerobic digestion and for preparation of slow-release soil amendments. Finally, the initial techno-economic feasibility assessments show that in the South African context, alginate and fucoidan will contribute the largest proportion to the revenue in a seaweed biorefinery and the environmental life cycle assessment confirmed that beneficiation of side streams and minimization of waste biomass make significant contributions to decreasing the environmental impact of a potential future seaweed biorefinery.

Keywords

Biorefinery, Seaweed, Sustainable processing, Fucoidan

11.2 A nanocomposite of nickel ferrite and polyaniline doped with 2-naphthalene sulfonic acid as an adsorbent for the removal of chromium from an aqueous solution.

Miss Ruth Kasavo, Hendrik Brink

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Abstract

Chromium contamination in industrial effluents poses significant environmental concerns due to its high toxicity and mobility. This study explores the potential of a novel nanocomposite, PANI-NSA/NiFe₂O₄, for effective removal of Cr(VI) from solution. The nanocomposite was synthesized and characterized, revealing the formation of tubular-shaped rods with enhanced surface area due to NSA doping.

Optimization of key adsorption parameters including pH, adsorbent dosage, agitation time, and initial pollutant concentration was conducted. Maximum adsorption was observed at pH 2, achieving a remarkable 99.9% removal of Cr(VI) from a 50 mg/L solution with a 25 mg adsorbent dose. Adsorption isotherm models indicated the superiority of the Two-Surface Langmuir model in describing experimental data.

Kinetic studies demonstrated rapid adsorption within the initial 30 minutes, reaching maximum removal within 24 hours. Temperature studies revealed enhanced adsorption capacity at higher temperatures, with a maximum capacity of 420.0 mg/g at 45°C. Thermodynamic analysis suggested an endothermic and spontaneous adsorption process.

This study underscores the potential of PANI-NSA/NiFe₂O₄ nanocomposite as an efficient adsorbent for Cr(VI) removal, presenting a viable approach to mitigate chromium pollution in industrial settings.

Keywords

Polyaniline, Nickel-ferrite, Chromium, Adsorption, Nanocomposite

11.3 Development of Polybenzimidazole Nanofibrous Catalyst via Electrospinning for VOC Oxidation

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Abstract

Nanostructured materials such as e.g. nanofibers have great potential applications in fields of catalysis owing to their unique properties. Nano-size effect and interface effect or short transport lengths can be mentioned. Nanofibrous supports allow control of the specific surface area, the catalyst accessibility as well as the catalyst regeneration from the reaction mixture for subsequent applications. Application of nanofibers as excellent supports is connected to the fact that a variety of polymers can be electrospun. They meet the different requirements on supports, moreover, their high porosity and the interconnectivity as the electrospun supports endows them with a low mass transport resistance. The main aim of the study was focused on assessment of the specific properties of the novel polymeric nanofibrous catalysts prepared by electrospinning in environmental applications. Polybenzimidazole (PBI) was selected due to its high both thermal and chemical stability. Electrospinning was employed in order to prepare polymeric support with morphology, which would be beneficial for the application in catalysis. The electrospun catalyst support was impregnated with platinum(II) acetylacetonate solution employing either equilibrium adsorption or solvent evaporation methods. The catalysts were tested in the oxidation of volatile organic compounds involving ethanol, acetone and toluene. We have shown that tailoring the electrospinning parameters allows the control of the morphology and composition of the nanofibers, optimizing catalytic performance. Additionally, the preparation conditions can be tuned in order to obtain catalysts with a desired platinum particle size.

Keywords

Nanofibrous catalyst; Electrospinning; VOCs; Polybenzimidazole

12.1 Selectivity Studies of Gold Nanoparticle Bioconjugation for the Detection of SARS-CoV-2

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Abstract

The COVID-19 pandemic, caused by SARS-CoV-2, has devastated the world, with millions dying and over 771 million confirmed cases globally. Measures to control the virus led to widespread disruption, impacting societies and economies significantly. Ongoing efforts to mitigate its effects underscore the importance of early diagnosis for effective disease management and minimizing transmission rates. Initial diagnostic tools struggled to detect SARS-CoV-2 variants, including Reverse Transcription-Polymerase Chain Reaction, Rapid Antigen test, Antibody-based test, and serological testing, each with limitations in accurate infection diagnosis. This led to false-negative results which gave rise to the need for accurate diagnostic tools with advanced and more sensitive detecting material such as gold nanoparticles. This study aimed to optimise one of the critical parameters in the bioconjugation of nanoparticles for rapid detection of viral pathogens: the particle size of gold nanoparticles to enhance its selectivity in detecting SARS-CoV-2. The proteins that were used for selectivity were Human Immunodeficiency Virus and Tuberculosis. Human Immunodeficiency Virus is the desired protein to determine the selectivity of the bioconjugated gold nanoparticles. Human Immunodeficiency Virus and SARS-CoV-2 share viral characteristics, including heightened proinflammatory cytokine production and gut microorganism modifications. The synthesised gold nanoparticles were formed by reducing the gold ions in an organic solvent, and covalent bioconjugation was used to attach the antibody to the gold nanoparticle. The size of the gold nanoparticles varied due to concentrations of the sodium borohydride. The different concentrations of sodium borohydride were obtained from previous research. The optimal particle size range for gold nanoparticles in detecting SARS-CoV-2 was between 94.3 nm and 121.3 nm. The optimised nanoparticle conjugates demonstrated a high level of selectivity, as the Human Immunodeficiency Virus and Tuberculosis proteins were not detected. This research contributed to detecting SARS-CoV-2 and developed more reliable and accurate diagnostic tools using gold nanoparticles.

Keywords

SARS-CoV-2; Diagnostics, Gold Nanoparticles, Selectivity

12.2 The Purification & Characterisation of Fucoidan from the South African Seaweed *Ecklonia maxima*

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Abstract

The purification of fucoidan from mixed seaweed extracts is difficult due to the complexity of these extracts. Fucoidan is a family of sulphated, fucose-based polysaccharides, that has high economic potential due to their biological properties such as anticancer, anticoagulant, and antioxidant activity. Fucoidan is native to brown seaweeds, but their inherent heterogeneity and the co-extraction of contaminants has led to the difficulty in isolating sufficiently pure fucoidan that enables an accurate understanding of its structure-activity relationship. This project aims to develop a specific dye-based adsorption process for the selective recovery of fucoidan from crude seaweed extracts, and to further study the chemical structure of fucoidan extracted from the South African kelp, *Ecklonia maxima*.

Successful adsorption of fucoidan was demonstrated through immobilization of two dyes. Toluidine blue O and azure A was successfully immobilised onto ReliZyme™ EA 112/S for the recovery of fucoidan from *Ecklonia maxima* crude extract. The adsorption isotherms for each dye were approximated by a Sips model. Resulting maximum capacities of 214.7 and 235.1 mg fucoidan / g adsorbent were found for toluidine blue and azure a, respectively.

Furthermore, an improved methylene blue assay for the specific quantification of fucoidan has been developed. Fucoidan could be specifically determined at pH 1 up to 4g/L without the interference of alginate and other seaweed extract contaminants. At pH 7 and 11, quantification of fucoidan led to interference from alginate and gallic acid. Measuring the fucoidan and L-fucose concentration in crude seaweed extract through the methylene blue assay and Dische and Shettles (1948) method, respectively, confirmed the accuracy and specificity of the method. The quantification limit of the methylene blue assay at pH 1 was 0.62g/L of fucoidan.

Keywords

Fucoidan, Purification, Adsorption

12.3 Exploratory application of the U.S. Pharmacopeia Maritime Pine Extract Monograph to commercial Pycnogenol® samples

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Abstract

Pycnogenol® is the trademark name of the natural maritime pine extract that was developed by Horphag Research¹. The well-studied potential uses for Pycnogenol® include the treatment of cardiovascular dysfunctions, kidney diseases, hepatic dysfunctions, cancer, digestive and retinal disease.² A paper by Chen et al.¹ indicated that certain commercial products sold may actually be adulterated. This project aimed to extend on the data of Chen et al. by adding six commercial Pycnogenol® samples to their data set. For that purpose, their High-Performance Liquid Chromatography (HPLC) method was validated and further improved. This allowed for the quantification of the main components of these pine extracts, namely catechin, caffeic acid, ferulic acid and taxifolin. The data was subjected to Principal Component Analysis (PCA), allowing for the identification of non-compliant samples. Furthermore, the commercial samples were subjected to the tests of the US Pharmacopeia 35 monograph to assess whether they comply with its stipulations. Finally, one commercial sample was used to test for thermal stability of the active ingredients and the results show that hydrolysis of oligomeric or polymeric procyanidins may occur resulting in an increase of the procyanidin monomers catechin and taxifolin over time.

1. Chen, P., Song, F., Lin, L.-Z., *J. AOAC Int.*, 2009, 92(2), 624-632.
2. Rohdewald, P., *Int. J. Clin. Pharmacol. Ther.*, 2002, 40(4), 158-168.

Keywords

phytopharmaca, maritime pine bark extract

12.4 Intermolecular interactions and sorption behaviour of estrogenic compounds in poly(mannuronate): a computational study

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Abstract

Estrogenic compounds are an emerging contaminant in wastewater due to human activities, while also being important chemicals in terms agricultural practices as well as medical therapies. This contribution presents a systematic investigation of the intermolecular interactions and associated phase equilibria between estradiol, estriol, estrone, ethinylestradiol, diethylstilbestrol, mestranol, progesterone, and testosterone with poly(mannuronate). This polymer is a common biopolymer found in alginate. A computational approach combining molecular dynamics and Monte Carlo simulation is used to study the binding energy and configurational properties of polymer + estrogenic pollutant systems. Phase equilibria of these compounds, and water, with poly(mannuronate) is assessed using an extended Flory-Huggins approach. The results presented herein yield insights into the molecular-level behaviour of these emerging pollutants with this biopolymer, which can assist in future research for using this material both for environmental remediation as well as drug release applications.

Keywords

estrogen; polymer; molecular simulation; biopolymer.

13.1 Adsorption of Tetracycline using Adsorbents derived from Fly Ash

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Abstract

Tetracycline (TC) is an antibiotic with a complex structure that is not removed in conventional biological wastewater treatment and is classified as an emerging contaminants. In this study, Fly Ash (FA), a waste material produced from coal combustion, was modified with HCl (AM-FA) and NaOH (BM-FA), and pure Zeolite Na-P1 (Na-P1) was derived from FA. Several adsorption tests were conducted to evaluate the adsorption capacities of the materials for Tetracycline. Using the determined optimal process conditions (pH=5, dosage=5 g/L) and an initial concentration of 40 ppm, FA, AM-FA, BM-FA, and Na-P1 were shown to have removal efficiencies of 25 %, 15 %, 76 % and 97 %, respectively. The HCl-modification removed several metal cations as soluble salts. Tetracycline being a chelating agent bonds tightly with metal cations. The lack of metal cations in AM-FA reduced the adsorption of TC. BM-FA increased TC removal was attributed to the significant increase in the surface area ($S_{bet}=116 \text{ m}^2/\text{g}$) and small formation of Zeolite Na-P1 (15 %). The pure Na-P1 high adsorption performance was attributed to its unique structure, inherent ion exchange capacity and high surface area.

Keywords

Fly Ash, Tetracycline, Adsorption, Zeolites,

13.2 Efficient Degradation of Organic and Inorganic Contaminants in Water Using ZnO-BiOI Heterojunction Photocatalyst

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Abstract

Access to clean water is crucial for the sustenance of life on Earth, yet the presence of organic and inorganic contaminants poses a significant threat to human health and the environment. In this study, we synthesized, characterized, and applied a novel heterojunction photocatalyst comprising ZnO optimally doped with BiOI for the degradation of 2-chlorobiphenyl (2CBP), methyl orange dye (MO), and thiocyanates. The synthesized heterojunction was analyzed using SEM-EDS, X-ray diffraction, optical studies, and nitrogen adsorption-desorption isotherms, revealing a highly porous structure with a sponge-like morphology and crystalline patterns devoid of impurity peaks. Under optimal conditions, the heterostructure exhibited rapid and efficient destruction of thiocyanate and MO within 30 minutes and 120 minutes, respectively, while achieving a 56% removal efficiency for 2CBP within the same timeframe. Further investigation into process parameters demonstrated that higher photocatalyst mass and acidic pH conditions enhanced the degradation of MO, while the destruction of thiocyanates was influenced by initial concentration and peaked at pH 7.2. Photodegradation of 2CBP was optimal at neutral pH. Kinetic analysis revealed that all degradation processes followed a pseudo-first-order kinetic model. These results suggest that the ZnO-[10%]BiOI heterojunction photocatalyst holds considerable promise for the efficient treatment of contaminated water, offering a potential solution to the global challenge of water pollution.

Keywords

Thiocyanate, MO, 2-chlorobiphenyl, heterojunction, photodegradation

13.3 Adsorptive removal of Carbamazepine from synthetic wastewater using seed coat (exocarp) of *Moringa oleifera*

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Abstract

Biosorption has demonstrated effectiveness in eliminating emerging contaminants (CECs) that lack inclusion in current water quality standards. These pollutants impede progress towards UN Sustainable Development Goals 6 and 14, pertaining to clean water accessibility and marine life preservation. This research investigated the adsorption potential of the persistent pharmaceutical pollutant, carbamazepine, using *Moringa Oleifera* seed coat. The study examined the influence of various factors including pH (ranging from pH 4 to pH 9), agitation speed (0 rpm, 50 rpm, 100 rpm, 150 rpm, and 200 rpm), contaminant concentrations (100 mg/L, 150 mg/L, and 200 mg/L), and adsorption duration (ranging from 0 to 300 minutes) on CBZ removal in synthetic wastewater. Batch adsorption experiments utilized *Moringa* seed coat ($d < 45 \mu\text{m}$) with a specific surface area and total pore volume of $1.778 \text{ m}^2/\text{g}$ and $0.006215 \text{ cm}^3/\text{g}$, respectively. The experiments achieved over 97% removal and followed pseudo-second-order reaction kinetics, indicating chemisorption as the driving force. Additionally, the concentration experiments adhered to the Langmuir isotherm model, suggesting monolayered, homogeneous adsorption. Extending the adsorption duration may not necessarily influence removal efficiency. While the MO seed coat adsorbent exhibits efficacy in CBZ removal from water, further investigations into factors like temperature and adsorbate dosage are necessary for optimal utilization before commercial implementation. Alternative concentration estimation methods such as high-pressure liquid chromatography could support UV-Vis Spectrometry estimations. Additionally, the MO seed coat adsorbent should be evaluated for its efficacy in removing other pharmaceutical pollutants.

Keywords

Biosorption, Carbamazepine, Wastewater, *Moringa*; Sustainability

15.1 Thermal conversion of macroalgae *Macrocystis Pyrifera* and *Laminaria Japonica* for production of carbon-negative hydrogen

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Abstract

To tackle the issues of carbon emissions and global warming, electrification and a hydrogen-based economy are touted as alternatives. Hydrogen can be applied through different methods with different feedstocks in places where electrification has limited application. An attractive option is presented in marine sources, for example macroalgae. Macroalgal biomass is capable of capturing atmospheric carbon dioxide and can be produced in large quantities.

In this work, two different types of algae (*Macrocystis Pyrifera* and *Laminaria Japonica*) were compared as potential biomass for the production of hydrogen through three thermal conversion methods: pyrolysis, gasification, and supercritical water gasification (SCWG). Simulations were performed using Aspen Plus V12, and the process of carbon capture was also considered. Due to the larger C:H ratio and higher H composition of *L. Japonica* showed a better performance in all the studied technologies. Among them, supercritical water gasification presented the highest hydrogen yield and the simplest process configuration. Economically, the SCWG process showed the highest estimated price of hydrogen (51.61 USD/kg H₂) as a consequence of the elevated electricity consumption. The gasification process obtained the lowest hydrogen price (26.88 USD/kg H₂). Sensitivity analyses concluded that the solvent used for the carbon capture process is the most impactful variable in a carbon-negative scenario. Meanwhile a carbon-neutral gasification can be competitive in the market as the hydrogen price reduces to 7.48 USD/kg H₂.

Keywords

Hydrogen, SCWG, BECCS, Aspen, TEA.

15.2 Solid-state fermentation of whole sugarcane and paper sludge waste for first-and second-generation ethanol production

Ms Janke van Dyk, Prof Johann Görgens, Prof Eugène van Rensburg

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Abstract

The conversion of biomass to bioethanol typically occurs under conditions of submerged fermentation. Solid-state fermentation, in which the substrate contains low quantities of free water, is an attractive alternative, due to smaller reactor volumes, more concentrated final products, and a reduction in liquid waste. Paper sludge (PS) waste and whole sugarcane are two substrates that are potentially suitable for solid-state fermentation. Conventional methods of bioethanol production from sugarcane involve energy-intensive steps to extract and concentrate the sucrose-rich juice. Alternatively, solid-state fermentation can simplify the processing method and thereby reduce its energy consumption. This method may potentially find application in small-scale distilleries due to the simplified processing equipment and methods. Published reports on the production of ethanol from PS waste and sugarcane under solid-state conditions are limited, although examples of solid-state conversion of sweet sorghum stems into ethanol have been reported. PS waste is routinely fermented under submerged fed-batch process conditions at solids loadings below 20% (w/v), due to its high viscosity, resulting in a final ethanol concentration of approximately 40 g/L. The present study assessed solid-state fermentation as an alternative avenue for ethanol production from whole sugarcane and PS waste. Process parameters for both PS waste and whole sugarcane were optimised in 3 L horizontal, rotating reactors, followed by scale-up to a high-solids reactor, able to process up to 15 kg of wet material per run. A direct comparison was made between PS waste fermentation under submerged and high-solids conditions, while also assessing the performance of xylose-utilising and cellulase-secreting yeast strains. The ethanol concentration and yield were compared to determine specifically whether solid-state fermentation could improve ethanol concentrations of 40 to 50 g/L and ethanol yields of 70% to 80%, which are typically obtained under submerged conditions.

Keywords

Bioethanol, Solid-state-fermentation, Paper sludge, Sugarcane

15.3 Pyrolysis of waste polypropylene plastics for energy recovery: study comparisons between bench scale and a commissioned kilogram-scale rotary kiln reactor

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Abstract

Globally, polypropylene (PP) has been identified as the second most abundant plastic waste in landfills. One key reason being the limitation of conventional mechanical recycling techniques not being able to handle plastic wastes heavily contaminated with other organic wastes. Plastics recycling via pyrolysis has been identified as a promising route to managing these recalcitrant waste streams due to its ability of handling significant levels of contamination and consequently yielding products with huge fuel application prospects. Studies on the pyrolysis of waste PP have been previously conducted on a bench-scale setup, where the effects of temperature, heating rate and pressure conditions (atmospheric and vacuum) on the yields, calorific values and chemical composition of condensable products were probed and optimized. The quest to commercializing plastic waste conversion to fuels has received strong attention in the past years. However, studies at bench-scale are relatively fundamental and still require further improvements before commercialization is possible. Pilot scale setups act as a perfect transition point between these two stages. Investigations on pilot setups allow for the implementation of the key conclusions made from bench while also revealing possible bottlenecks that could possibly arise on commercialized scale setups. This makes provisions for prior mitigation of any such drawbacks. Hence, subsequent to a previously investigated bench-scale study, a 5 kg/h semi-continuous kilogram-scale rotary kiln reactor was assembled and commissioned on which conditions previously investigated at bench-scale were mimicked. In addition to the product yield investigations of the condensable products that were investigated, the products were also characterized in terms of fuel properties (including density, viscosity, boiling point range, flash point), which were compared with commercial diesel (C₁₁-C₂₃) and gasoline (C₆-C₁₀) fuels.

Keywords

Pyrolysis, Polypropylene, Fuel, Diesel, Gasoline

15.4 Sorption-enhanced chemical looping gasification of biomass for hydrogen and transportation fuel production.

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Abstract

A rationale of a sustainable energy system comprises a diverse portfolio of energy options with improved thermodynamic efficacy and control of effluents. Consequently, sustained efforts in improving alternative-to-fossil-fuel-based technologies to achieve energy provision at reduced commercial requirements and net-zero CO₂ emissions have intensified over the years. Among these, gasification for the conversion of biomass into energy vectors including H₂ and transportation fuels has been vigorously pursued. At present, technological adaptations have focused on improving CO₂ capture, limiting residual tar output, and, maximizing exergy availability for auto-thermal operation. As such, this study introduces an auto-thermal chemical looping integrated gasification of biomass. The adaptation is envisaged to facilitate inherent CO₂ capture, produce high-purity H₂, and set grounds for transportation fuel recovery at reduced commercial requirements and improved control of effluents.

The scope of the work will focus on thermodynamic modeling, techno-economic analysis, and life cycle assessment. For model development, the work will consider the use of multiple looping carrier solids in a parametric analysis. The results from the process modeling will further, be converted into detailed and practical-to-use variable forecasting algorithms using tools including MATLAB to enable the ease of exploration and application in linedated industries or interests. As arguably, the most important evaluation tools for process scale-up and commercial mobilization, TEA and LCA will also be demonstrated. TEA will cover capital and operational expenditures, equipment and additional costs, and fixed capital investment. Further profitability and sensitivity analysis inclusive of key factors like rate of return on investment and discounted payment period will be devised. The LCA will cover a life cycle inventory study, life cycle impact assessment, and further interpretation. A cradle-to-gate approach will be demonstrated.

Eventually, the capacity of H₂ and transportation fuels produced via SE-CLG to compete in the existing energy market will be evaluated.

Keywords

Chemical Looping Gasification Hydrogen Biofuels

16.1 Towards sustainable chemical synthesis: Metathesis of sunflower-derived ethyl esters for synthesis of value-added oleochemicals

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Abstract

Olefin metathesis is a powerful chemical reaction providing new avenues for producing essential chemicals. In the context of shifting focus towards sustainability and renewable resources, there is a growing demand for value-added surfactants and chemical intermediates sourced from renewable materials like natural oils and fats. This study explores self-metathesis of a mixture of unsaturated fatty acid esters derived from sunflower oil as an alternative method for producing value-added surfactants and chemical intermediates. Metathesis of this unrefined mixture was compared to that with a higher purity ethyl oleate feedstock. The product distribution from metathesis of these feedstocks revealed a range of unsaturated ethyl esters, internal alkenes and unsaturated diethyl diesters. The study investigated the effect of temperature, time and catalyst loading on metathesis efficiency, with varying results for the two feedstocks. The sunflower-based feedstock required higher catalyst loadings, possibly due to impurities in the feedstock, deactivating the catalyst. Organic solvent nanofiltration effectively removed the Grubbs 2nd generation catalyst from the reaction mixtures and allowed for partial product fractionation. However, complete fractionation was hindered by compound-membrane interactions and the proximity of the molecular weights of the products. Foaming tests suggested potential surfactant properties in the metathesis reaction mixtures, although critical micelle concentrations could not be determined for these mixtures due to low water solubility. Comparison of the surfactant efficiencies of the reaction mixtures to the feedstocks, indicated that the surfactant potential of the feedstocks were upgraded through metathesis. In summary, this study demonstrated that metathesis of sunflower oil-derived ethyl esters offers a promising pathway for producing a mixture of products (C12-C18 alkenes, C16-C21 ethyl esters and C18-C24 diethyl diesters) with surfactant properties. This pathway facilitates production of value-added surfactants and important chemical intermediates, contributing to a more sustainable and diverse chemical industry.

Keywords

Renewable, oils, metathesis, chemicals

16.2 Assessing the effects of nano and micro-particles on carbon dioxide gas hydrate formation

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Abstract

The mitigation of carbon dioxide from gas emissions is the central focus in meeting net zero targets by 2050 or earlier. Solid gas storage systems such as gas hydrates, metal organic frameworks (MOFs), zeolites and others have gained much attention. Gas hydrates are non-stoichiometric solids formed by the encapsulation of gas molecules within a lattice of water molecules. These exist under conditions of high pressure and low temperatures. Gas hydrates can be used to trap and store carbon dioxide molecules. Moreover, with gas hydrates having a large gas storage capacity (180 m³ per 1 m³ of hydrate) this is consequently a promising technology. The kinetics of hydrate formation and the hydrate equilibrium phase conditions inform the rate of gas hydrate formation and stability/instability of the gas hydrates. In this study, phase equilibrium hydrate dissociation data for CO₂ hydrate in the presence of CuO and Al₂O₃ nanoparticles, graphene nanoplatelets, ZnO microparticles, sodium dodecyl sulfate (SDS) and silica sand were measured experimentally over a temperature and pressure range of 279.1 to 283.2 K and 2.19 to 4.3 MPa, respectively. Results showed that the silica sand inhibited hydrate formation shifting the phase diagram to lower temperatures and higher pressures, especially at pressures greater than 3.676 MPa. Hence silica sand displays good potential for use as porous media in CO₂ gas storage systems. The nano particles and graphite tested in this study did not shift the CO₂ hydrate phase equilibrium, though the rate of CO₂ hydrate formation improved, by increasing the hydrate formation time. The inclusion of porous media demonstrates improved gas storage potential. This study shows how different additives affect the kinetics and phase conditions of the carbon dioxide hydrate phase behaviour. This ultimately provides valuable information for gas storage system designs.

Keywords

carbon capture, gas hydrate, storage

16.3 Aspen Plus ® simulation of fractional condensation of lumped oil produced by waste tyre pyrolysis

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Abstract

Waste tyre pyrolysis involves burning waste tyre at high temperatures in the absence of oxygen to produce light gases, volatiles, and char. These volatiles are condensed into liquids, potentially matching commercial fuels like diesel, naphtha, and marine bunker oil. Fractional condensation of the volatiles is proposed as the first step in the solution for the production of the fuels.

The heavy, medium, and light fractions—which resemble marine bunker oil, diesel, and naphtha, respectively—can be produced by the network of three condensers. The process was simulated using Aspen Plus V11.0® software to compare the results with experimental results on fractional condensation. The study focused on characteristics such as liquid density, flash point, viscosity, boiling points, and sulphur content. To simulate this process, the feedstock chemical composition had to be known, for Aspen Plus V11.0® to simulate the process. To this end, the chemical composition of the pyrolysis oil sample from previous work was analysed using the GC-MS method. About 27 components were calibrated, while the other 15 were tentatively identified.

Simulations using calibrated components did not match experimental data. Most density, flash point, and boiling point characteristics matched experimental data for heavy and medium fraction after adding tentatively identified components. However, the viscosity of all simulated liquid fractions was underestimated, although the experimental trend of increasing viscosity from heavy to light fraction was followed.

Adding components to the simulation software improved Aspen Plus® results predictability. A more extensive GC-VUV method was used to estimate oil chemical composition and showed a wider carbon number range (3-38) than the GC-MS method (7-12). The improved predictions estimated lighter fractions' lower initial and final boiling points and heavier fractions' higher better due to the expanded carbon range.

Keywords

liquid fractions, GC-MS, GC-VUV

17.1 Production of Piezoelectric Composite Nanofibres from Recycled Poly (ethylene terephthalate)

Dr Rita Okpuwhara, Professor Bilianu Oboirien

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Abstract

Piezoelectric materials were produced from waste polyethylene terephthalate and polyvinylidene fluoride polymers by electrospinning method. Different electrospinning experimental parameters were varied to obtain the highest productivity, well-aligned composite nanofibres without beads, reduced diameter and to maximise their piezoelectric property. Significant variations in nanofibres morphology were investigated by using different characterisation techniques, specifically Scanning Electron Microscope (SEM), and Fourier Transform Infrared (FTIR) Spectrometer, thermal analyses, and piezoelectric coefficient.

Keywords

Piezoelectricity, electrospinning, recycled polymer

17.2 Understanding Fischer-Tropsch Synthesis in Micro Reactors – A Three-phase One-dimensional Microchannel FT reactor Model

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Abstract

Micro-Fischer-Tropsch (FT) reactor systems offer the potential to harness overlooked natural resources, including biomass, waste materials, and unconventional carbon and hydrogen sources, through the Fischer-Tropsch process. This chemical reaction converts carbon monoxide and hydrogen into liquid hydrocarbons, such as synthetic fuels. These reactor systems are likely compact and efficient versions of the technology, suited for smaller-scale operations. However, understanding their governing mechanisms is crucial, given the relative novelty of micro-FT reactor applications.

To address this knowledge gap, in this work a comprehensive study was conducted, focusing on a three-phase slurry FT microreactor model developed in Simulink. This model, based on physical principles, particularly emphasized hydrodynamics. The study identified two key parameters influencing microchannel reactor performance: total superficial gas velocity and axial dispersion, especially in the gas phase. An increase in superficial gas velocity was found to enhance axial dispersion in both liquid and gas phases, resulting in increased large bubble-class hold-up and reduced syngas conversion due to decreased surface area for catalytic reactions.

It was also determined that an increase in the microchannel diameter resulted in an increase in syngas conversion through its obvious effect on residence time but also indirectly through its influence on the dispersion in the large bubble compartment. The solids concentration was found to enhance the syngas conversion up to a point ($=0.3825$) beyond which the effect of the decreasing small bubble-class hold-up outweighs the improved consumption rate of the reactants. A rising temperature was found to improve the reaction kinetics and reduce the large bubble axial dispersion which had the net result of improving the kinetics.

This study sheds light on the complexities of micro-FT reactor systems, emphasizing the importance of parameters such as superficial gas velocity, axial dispersion, channel diameter, solids concentration, and temperature in optimizing syngas conversion efficiency.

Keywords

Micro-Fischer-Tropsch reactor; Three Phases Modelling; Simulink; Gas Velocity; Axial Dispersion

17.3 Investigation of Ag, Al, Au, and Cu dopants for enhanced efficiency of cobalt catalysts in NH₃ decomposition: A DFT study

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Abstract

The effect of doping on cobalt (Co) clusters was investigated by doping 6-atom cobalt clusters with gold (Au), silver (Ag), aluminum (Al), and copper (Cu). The results showed that Ag or Al doping led to an increase in the adsorption energy of the cobalt catalyst by 0.082 eV and 0.354 eV, respectively, resulting in deviations from Ru's adsorption energy. Conversely, Au and Cu doping caused a reduction in the adsorption energy of the cobalt catalyst by 0.24 eV and 0.21 eV, respectively, approaching Ru's adsorption energy. Furthermore, zero-point energy calculations indicated that doping the Co catalyst with Au or Cu resulted in an increase in zero-point energy from 1.222 eV to 1.225 eV and 1.226 eV, respectively, approaching Ru's value of 1.237 eV. In contrast, doping with Ag or Al decreased the zero-point energy. Finally, IR spectra analyses showed that a Ru catalyst exhibited a lower-frequency ammonia bonding peak (1159.20 cm⁻¹) compared to pure cobalt (1167.13 cm⁻¹), indicating weaker NH₃ bonds. Furthermore, the introduction of metal dopants strengthened the NH₃-cobalt bonds, with the Co₅-Ag cluster exhibiting the highest bond strength (1193.56 cm⁻¹). These findings suggest that the limitations of cobalt catalysts doped with Au, Ag, Al, and Cu may arise from their effectiveness in desorbing NH₃ from their surfaces, potentially resulting in product inhibition. Au is the most promising potential dopant for enhancing the performance of cobalt catalysts in NH₃ decomposition. Since catalyst supports play a major role in reactivity of supported catalysts, further DFT studies should be carried out to find appropriate support that optimizes the efficiency of cobalt catalysts doped with Au.

Keywords

Catalysts, DFT, Cobalt, Ammonia, decomposition.

18.1 Solvent selection methods in aromatic extraction processes towards optimal and sustainable design choices

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Abstract

A novel process decision-making framework was developed that simultaneously considers all aspects of process systems engineering, applied to solvent extraction processes. Computer-Based Molecular Design (CAMD) of solvents using group contribution methods and Artificial Neural Network (ANN) Quantitative Structure Property Relationship (QSPR) models were amalgamated with Health, Safety, and Environmental (HSE) impacts using a rating-based risk assessment method. The ANN developed was found to serve as an effective supplement to group contribution methods in screening potential solvents. This QSPR model uses 31 descriptors as input with absolute average deviations of 0.23 and 0.19 for each pair of binary interaction parameters. Validation of CAMD results were done by conducting experimentally measured liquid-liquid equilibrium (LLE) compositions for the systems *n*-heptane + toluene + (butane-1,4-diol or glycerol) as well as *n*-nonane + *o*-xylene + (butane-1,4-diol or glycerol). The influence of 2-methyl-2,4-pentanediol on solvent capacity was determined by LLE experimental data for the quaternary system *n*-heptane + toluene + (butane-1,4-diol or glycerol) + 2-methyl-2,4-pentanediol. All ternary systems studied were found to exhibit type 2 LLE behaviour and were correlated with the NRTL and UNIQUAC models. Economic comparisons were conducted for the proposed co-solvent mixtures against that of conventional solvents used for this application. Indicators such as energy consumption, capital costs, operating costs and total annual costs were used to make an assessment with process simulations performed in ASPEN Plus. The results indicated that the co-solvent mixtures may offer benefits in reducing total annual cost. The energy intensity of the process varied between 1000 – 1400 kJ/kg. Capital costs ranged between 5.8 – 6.2 million dollars, and total annual costs between 2.4 – 2.6 million dollars. The outcome of the work was a platform based on systematic methods where solvent extraction processes are optimized by simultaneously considering interlinking steps of molecular design to the economics of large-scale processes in the context of sustainable development.

Keywords

Solvent selection, process optimization, AI

18.2 Measurement and modelling of hydrodynamics in a supercritical fractionation column

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Abstract

Supercritical fluid fractionation may be used as an environmentally friendly process for separating mixtures of close-boiling components. The solubility of these components in the supercritical fluid may be adjusted by simply changing the operating temperature and pressure. This is due to the large changes in properties of the supercritical fluid such as density and viscosity that may be achieved through relatively small changes in temperature and pressure. The temperature and pressure of the process must be chosen such that they fall within the operating window of the fractionation column used. Measurements of the hydrodynamics for columns operating under supercritical conditions, and hence the size of their operating window, are lacking. This leads to costly overdesign of equipment used in supercritical processes.

In this work, pressure drop, liquid hold-up and entrainment were measured to determine the size of the operating window in a process with supercritical carbon dioxide (CO₂) and polydimethylsiloxane 100 (PDMS100). Published measurements of the solubility of PDMS100 in CO₂ indicate there is limited mass transfer for this chemical system, allowing for reliable measurement of hydrodynamic data. Experiments were conducted in a 38 mm inner diameter column packed with 1/4" Dixon rings, and data were collected at 120 bar and 45 – 55°C over a range of flow rates.

When compared to published measurements for the same chemical system at 140 bar, the operating window of the column was found to widen with increase in temperature and decrease in pressure. Pressure drop and entrainment were found to be reliable indicators of column operability and the onset of flooding. The measured hydrodynamic data could be modelled reasonably well with correlations available in literature. Results from this work could be used to improve predictions of the operating window of columns of similar diameter and packing.

Keywords

supercritical fractionation; hydrodynamics; flooding; CO₂.

18.3 Stripping Hydrogen Sulphide from an Aqueous Solution of Sodium Hydrosulphide

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Abstract

One of the key steps of a novel process to convert sodium sulphate to sodium carbonate, is stripping of H₂S from an aqueous solution of NaHS with CO₂.

In order to design a suitable stripping column the concentrations of three components, i.e. CO₂, H₂S and H₂O in the gas phase and nine species dissolved in the aqueous phase, i.e. H⁺, OH⁻, CO₂(aq), H₂CO₃, HCO₃⁻, CO₃²⁻, H₂S(aq), HS⁻ and S²⁻ must be calculated for each equilibrium stage in the column.

Models to describe the system and the solution of the models are presented as well as non-steady state batch experiments to test the validity of the models.

Using the models, the minimum amount of CO₂ required as a function of the fractional recovery of H₂S and of the NaHS feed concentration was calculated as well as the number of equilibrium stages required as a function of the required H₂S recovery and excess CO₂ used.

Non-steady state, batch stripping tests showed that it is difficult to achieve equilibrium conditions and that it is necessary to also consider the rate of reaction between dissolved CO₂ and water to form carbonic acid.

Keywords

H₂S, stripping, CO₂, NaHS

18.4 Phase equilibrium studies for multicomponent mixtures (methane, propane, carbon dioxide, hydrogen sulfide, water, triethylene glycol and methanol) in the natural gas dehydration process

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Abstract

There is limited phase equilibria data for multicomponent mixtures consisting of methane, propane, carbon dioxide, hydrogen sulfide, water, methanol, and triethylene (TEG) glycol at high-pressure conditions typical to natural gas treating and transportation systems. This study presents new phase equilibria data for natural gas-related systems that are crucial in the design of gas dehydration treatment facilities. The phase equilibria data were measured using two equipment, namely, the static synthetic and the combined static synthetic/analytic apparatus. The static synthetic apparatus was used to measure the solubility of methane in TEG aqueous solutions (90, 95, and 98 wt.% TEG) over a temperature and pressure range of 298 to 323 K and 0.18 to 2.5 MPa respectively. The combined static synthetic/analytic apparatus was used to measure the bubble point pressures of the (methane + propane + water + methanol + TEG) and (methane + propane + carbon dioxide + hydrogen sulphide + water + methanol + TEG) systems for the following conditions (temperature of 283 to 323 K, and pressure up to 14 MPa). For these new data, the solubility of methane generally increased with an increase in temperature. An explanation for this trend is due to the temperature increase which creates voids in TEG, onto which alkanes are encapsulated, hence resulting in the increase in methane solubility. For the methane in TEG aqueous solutions (90, 95, and 98 wt.% TEG), the solubility of methane in the water/TEG solution increases as the mass fraction of water decreases. This conforms to the observation that water has an effect in reducing the solubility of methane in TEG. Thermodynamic modelling of the measured data was performed in Aspen Plus V12.1 utilising the Cubic Plus Association (CPA) equation of state (EOS). The CPA EOS yielded a maximum absolute average relative deviation in pressure of 4.30%.

Keywords

Gas-dehydration, Phase-equilibria, Static synthetic, CPA-EOS

18.5 An evaluation of extractive and azeotropic distillation for separation of 1-octene from oxygenates typically produced during Fischer-Tropsch synthesis

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Abstract

This study compared azeotropic distillation with extractive distillation for the separation of a C8 olefin (1-octene) from oxygenates with similar boiling points (α close to one) – as typically derived from Fischer-Tropsch synthesis. Apart from a standard literature survey on the topic, the work entailed the following: (a) a systematic identification and selection of potential entrainers and solvents for azeotropic and extractive distillation, respectively; (b) a detailed simulation of the two processes in Aspen Plus®; (c) and a basic comparison of costs and other factors, for final recommendation of the preferred method. For azeotropic distillation, the chemical screening process specifically targeted entrainers that could potentially be used in a mixture with water (binary entrainer) to form a water|1-octene|entrainer azeotrope for the separation of 1-octene from oxygenates. Among the screened list of entrainers, ethanol, isopropyl-alcohol and methanol stood out as the three strongest (optimal) contenders. The ethanol entrainer was used for simulation of the full-scale azeotropic distillation plant. For the extractive distillation option, n-methyl pyrrolidone (NMP), ethylene glycol (EG) and mono-ethanolamine (MEA) were identified as the three most promising solvents. The n-methyl pyrrolidone (NMP) solvent was used for the simulation of the full-scale extractive distillation plant. For simulation purposes, the full-scale plant feed was chosen to be 60 ton/h, which is well-representative of typical flow rates in the industry. Using the re-created patent simulation as baseline, the full-scale heterogeneous azeotropic system was successfully simulated, optimised and sized with a 1-octene recovery of 99.9%. The optimised entrainer feed flow rate and entrainer feed composition were determined to be at 180 ton/h and water mass percentage of 10 mass% (ethanol mass percentage of 90 mass%). An Aspen Plus® simulation was then successfully developed for a similar full-scale extractive distillation system delivering the same 1 octene recovery as the simulated azeotropic system (i.e. 99.9%). The optimised solvent feed flow rate for the extractive system was 60 ton/h. The NPV and IRR values at the different 1-octene cost values are higher for the full-scale extractive system compared to the full-scale azeotropic system. The IRR of the full-scale azeotropic system is higher than the hurdle rate at a 1-octene cost value of \$1500/ton. The IRR of the full-scale extractive system is higher than the hurdle rate at a 1-octene cost value of \$1300/ton. These cost estimates are applicable for the year 2023. Therefore, for a feed rate of 60 ton/h which is well-representative of typical flow rates in the industry, within the limitations of this study, the full-scale extractive system is preferred above the azeotropic system for the recovery of 1-octene from oxygenates.

Keywords

azeotropic distillation, 1-octene, oxygenates, Fischer-Tropsch synthesis

19.1 The Synthesis and Characterization of Magnesium-based Metal-organic-framework-74 Suitable for Post-Combustion Carbon Dioxide Capture

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Abstract

The growing global concern over greenhouse gas emissions, specifically carbon dioxide (CO₂), has led to extensive research efforts aimed at developing innovative materials and technologies to combat the impacts of climate change. Among these materials, metal organic frameworks (MOFs) have received significant attention in science due to their distinctive structural and adsorption properties. Within this context, magnesium-based-MOF-74 (Mg-MOF-74) has emerged as a potential candidate for efficient post-combustion CO₂ capture. This study undertakes a comprehensive exploration of the synthesis, characterization, and practical applications of Mg-MOF-74, with a particular emphasis on the intricate interplay between synthesis conditions and the material's efficacy as a sustainable solution for reducing CO₂ emissions from typical coal-fired power plants. The synthesis of Mg-MOF-74 was conducted at various reaction temperatures (100°C, 110°C, and 125°C) and time (8 and 24 hours).

Characterization techniques employed include X-ray Diffraction (XRD), Thermogravimetric Analysis (TGA), Fourier-Transform Infrared Spectroscopy (FTIR), Brunauer-Emmett-Teller (BET) surface area analysis, and Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX). The XRD data highlight temperature and time effects on crystallinity, with 100°C for 24 hours yielding well-defined structures indicating high crystallinity. TGA indicates stability at low temperatures (100°C) but mass loss at high temperatures (125°C). FTIR analysis identifies critical functional groups, such as C=O, Mg-O, and C=C groups, shedding light on chemical compositions. The low-pressure gas nitrogen gas adsorption (BET) study revealed Type III isotherms, signifying microporous and mesoporous features with varying surface area and pore size. The SEM micrographs display diverse morphologies with irregular patterns and cloud-like structures across samples.

Keywords

Characterization; Carbon-capture; Greenhouse-gases; Mg-MOF-74; Physicochemical-properties

19.2 Continuous Microbial Pb Removal by an Industrially Obtained Consortium Using an Upflow Anaerobic Sludge Blanket Reactor

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Abstract

The research aimed to gather more insight into the Pb-removing microbiome in a continuous setup. A continuous lead removal system, utilizing an upflow anaerobic sludge blanket reactor (UASB) was employed to remove Pb(II) while monitoring factors such as Pb(II) concentration, microbial growth and nitrate concentration at two axial heights in the system. The microbiome was assessed to identify any alterations resulting from changes in Pb(II) and nutrient concentrations. The UASB was operated under anaerobic conditions, and a nutrient-rich broth comprising exclusively of yeast extract (YE) at a concentration of 5g/L along with sodium chloride (NaCl) at a concentration of 1 g/L served as the growth medium. The results indicated an effective, robust method of Pb(II) removal. In this study concentrations of 80, 500 and 1000 ppm were fed into the UASB reactor and lower concentrations of Pb(II) were effectively removed with only 5 g/L YE, suggesting a cost-effective option for Pb(II) bioremoval. A maximum Pb-removal rate of 350.6 ppm/d Pb(II) and a maximum specific growth rate of 2.25 per day were observed. Increased concentrations of Pb(II) resulted in reduced metabolic activity (MA) and Pb removal. As is, the system is able to achieve approximately 100% of lower concentrations of Pb and increasing the yeast extract concentration could improve the system. This is the first known study conducted on a continuous flow column Pb(II) removal system. It provides much-needed insight into the spatial variation in the system under varying conditions, which could be beneficial in the future application of the technology on an industrial scale.

Keywords

Wastewater, Heavy metals, bioremediation

19.3 A circular economy approach for the beneficiation of slag, waste foundry sand, and plastic waste

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Abstract

Industrial waste, such as waste foundry sand (WFS), by-products such as blast furnaces/steelmaking slag (GBFS), and plastics are generated and readily available in voluminous quantities. These wastes and by-products occupy considerable land areas, contaminate the environment, groundwater, and soil, pollute the air, and adversely affect human health, aquatic life, and animals. This study explored the possibility of using High-Density Polyethylene (HDPE) waste plastic as a binding material, WFS, and GBFS to produce building material(s). Plastic was blended with either WFS or GBFS to produce a specimen. The physical, geochemical, and geotechnical properties of the specimens were studied.

For the WFS and HDPE specimens, the specimen with 10% plastic yielded low UCS (0.8 MPa), as the plastic was insufficient to bind the material. 30% HDPE yielded an optimum UCS of 29.96 MPa. The high UCS was due to the high Si in WFS and the strong bonds in the plastic waste aggregates. The water absorption percentage decreased with the increase in HDPE proportion, with the insignificant range of 0.2-0.7% by mass. For the GBFS and HDPE waste specimens, the specimens produced with 20% HDPE were not suitable for use as paving blocks as the UCS was less than 3.5 MPa. The specimen with 40% HDPE yielded an optimum UCS of 20.60 MPa.

A circular economy principle can be applied to produce WFS, GBFS, and HDPE specimens that can be used as paving blocks and roof tiles.

Keywords

Circular economy, waste to resource

19.4 Development of bagasse-based recycled polypropylene composites

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Abstract

The search for green materials from renewable sources is paramount for environmental, economic, and societal sustainability. Bagasse is the fibrous residue from sugar production with great potential for valorisation. This study seeks develop and produce biocomposites from bagasse and polypropylene (PP) by extrusion-injection moulding for application in construction, packaging, and in automotive parts.

For compatibilizer-free composites, initial studies indicated that the fabricated biocomposites show a decrease in tensile strength with increasing bagasse loading. On the other hand, the tensile modulus increased, while the impact strength decreased from 17.4 to 7.5 kJ/m², as the filler content is increased from 5 wt.% to 20 wt.%. This is attributed to weak bonding between bagasse and PP, which makes the composite ductility and stiffness inadequate for the envisaged applications, although thermogravimetric analyses indicate an increase of the thermal stability compared to neat bagasse. Encouraged by these preliminary results, systematic studies were conducted using various compatibilizers such as PP-grafted glycidyl methacrylate to achieve better bonding. The effect of the bagasse particle size, fibre-PP composition, PP-source, and other production variables on their physical properties, as determined by SEM, TEM, FTIR and TGA/DSC, are compared to the resulting mechanical properties (flexural and tensile strengths, hardness, water absorption and shear tests), as well as several industry standards specifying the minimum requirements in the above-mentioned industries.

Keywords

Composites; ductility; bagasse; properties

20.1 The V&A Waterfront Seawater Desalination Plant - Designed for Sustainability

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Abstract

February 2018 marked the “eve” of Day Zero for Cape Town, risking it becoming the first major city in the world running out of water. Tremendous efforts were launched by the City of Cape Town and the Private Sector to avert this dreaded day, and although Day Zero was thankfully avoided, most stakeholders had made a mind-shift towards water use.

The V&A Waterfront is an iconic tourist destination in Cape Town that makes a significant contribution to the South African economy (R335 billion from 2004 to 2018) with an estimated 24 million annual visits. In 2018 the CEO of the V&A Waterfront, David Green, highlighted the damage inflicted by the Day Zero messaging, as a decline of almost 30% in international tourism numbers was seen. He commented that industry realized the bigger crisis was the economic crisis caused by this messaging.

A decade prior to the peak of Cape Town’s water crisis, the V&A Waterfront had already launched their Sustainability journey. As part of this drive, one of their major recent investments was to install a scalable seawater desalination plant. The plant (currently under construction) will deliver between 3.3 million and 5 million litres of water per day, and has two main purposes:

1. To offset the demand of its visitors and residents on the natural fresh water resources;
2. To increase its sustainability.

The V&A Waterfront selected PROXA for the design, build and long term operation of the desalination facility. PROXA has more than 35 years of experience in membranes desalination and currently employs over 50 Chemical Engineers in South Africa.

This paper describes the following:

1. Design of the V&A Waterfront Desalination Plant - Increasing sustainability employing state of the art water treatment technologies
2. Sustainability and the future of seawater desalination – where to from here?

Keywords

Day Zero, Sustainability, Seawater Desalination

20.2 Aquatic toxicity and human health risk assessments of heavy metals from Pretoria wastewater

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Abstract

The surge in industrialization and urbanization coupled with improper environmental management have been reported to be the main source of discharge of untreated water into river systems. To explore the risks associated with heavy metals in Pretoria from both domestic and industrial wastewater influence and effluents and to establish the effects of spatial distribution of domestic and industrial activities in the surrounding area on the variation of the measured concentrations from the manholes, Apies river and the wastewater treatment plant (WWTP). The physicochemical properties such as pH, electrical conductivity (EC), chemical oxygen demand (COD), and liquid dissolved oxygen (LOD) were explored. The pH of the collected samples was within the threshold limit (6.5-7.5) set by the World Health Organization (WHO). The measured environmental concentration (MEC) of Al, As, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn was 3550 µg/L, 153.1 µg/L, 5.8 µg/L, 13168.3 µg/L, 347.4 µg/L, 2632.0 µg/L, 371.4 µg/L, 207.5 µg/L, 29.1 µg/L, 3856.7 µg/L, respectively. These values are above the threshold limits set by the WHO. The MEC of metals in the manholes was more concentrated as compared to the outlets from the wastewater treatment plant (WWTP). The risk quotient (RQ) for three subtropical aquatic organisms (algae, crustaceans, and fish) was modelled using the half-maximum effective concentration (EC₅₀/EC₁₀)/lethal concentration (LC₅₀)/ No Observed Effect Concentration (NOEC) from literature. All metals displayed RQ > 1 for both dry and rainy seasons therefore posing high risks to the three organisms. Co, Cr, and Ni displayed RQ < 1 displaying low risks. The non-carcinogenic and carcinogenic hazard quotients for children and adults were also modelled using inhalation, ingestion, and dermal contact as pathways and higher risks were observed through inhalation, especially during the dry season.

Keywords

Carcinogenic, Crustaceans, Concentration, Ecotoxicity, Hazard

20.3 Influence of Carbon Sources and Biosurfactants on Selenite and Lead Bioremediation from Wastewater by *Enterococcus* sp.

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Abstract

This study investigated the bioremediation potential of *Enterococcus* sp. in addressing selenite (SeO_3^{2-}) and lead (Pb^{2+}) contamination in the presence of different carbon sources while shedding light on the mechanisms responsible for bioremediation. Carbon source selection emerged as a critical determinant, significantly influencing SeO_3^{2-} and Pb^{2+} removal, elemental selenium (Se^0) formation, and protein synthesis. Glucose and cooking oil were identified as efficient carbon sources, facilitating rapid SeO_3^{2-} reduction of an initial concentration of 1mM (173 ppm) (58 % and 55 % reduction, respectively) in contrast to crude oil (39 %). Even though overall Pb^{2+} removal was lower, the trend remained the same as with SeO_3^{2-} and the influence of different carbon sources was evident. 38 %, 33 %, and 25 % of an initial Pb^{2+} concentration of 1 mM (207 ppm) was removed in the presence of glucose, cooking oil, and crude oil, respectively. The biggest disparity was in the mechanisms *Enterococcus* sp. employed for the reduction. SeO_3^{2-} precipitated to Se^0 as expected whereas no precipitate was observed in the Pb^{2+} system thereby indicating the absence of Pb^{2+} reduction to Pb^0 . Furthermore, *Enterococcus* sp. exhibited versatility in biosurfactant production across various carbon substrates. In summary, this study enriches the understanding of *Enterococcus* sp.'s adaptability and underscores the crucial role of biosurfactants in bioremediation. It highlights their potential to drive eco-friendly strategies for contamination mitigation, particularly in addressing selenium and other contaminant ions.

Keywords

Enterococcus, biosurfactants, selenite, lead, bioremediation

20.4 Effects of nano- and micro-chemicals used in sanitisers and disinfectants in the South African market on the freshwater snail, *Physa acuta*

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Abstract

To curb the spread of COVID-19 that became a global pandemic in March 2020, good hygiene practices e.g., the use of sanitizers and disinfectants were intensified due to their biocidal properties. A study on the sanitisers and disinfectants in the South African market found that antimicrobials were amongst the most used classes of chemicals, more so some chemicals within this class had multiple uses including their use as preservatives, wetting agents and as emulsifiers. The effects of three chemicals, titanium dioxide nanoparticles (nTiO₂), benzalkonium chloride (BAC) and Didecyldimethyl ammonium chloride (DDAC) were investigated on sediment dwelling snails, *Physa acuta*. In acute 96-h exposure studies results showed their survival was between 96.6% and 100% and no significant differences in the growth and reproduction effects were apparent over different environmentally relevant concentrations with exposure concentrations of up to 800 µg/kg and 800 µg/L in the sediment and overlaying water, respectively. The reproduction effects of the snails in the descending order were: nTiO₂ < DDAC < BAC compared to the control. However, biomarker results showed a notable inhibition of glutathione S-transferase (GST) antioxidant enzyme in the three-test groups examined and across all concentrations compared when compared to the control experiments. The snails exposed to DDAC showed the least GST inhibition except at 400 µg/kg and the snails exposed to nTiO₂ displayed the highest inhibition. The GST assay result indicate potential detrimental impact at molecular level that are not apparent at the organism level. In addition, it demonstrates the essence of investigating effects of chemicals at molecular level even over shorter exposure period. Since organisms are exposed to chemicals in the environment over much longer periods, the future work should consider the effect of these chemicals on these microorganisms under chronic exposure conditions.

Keywords

Ecotoxicology, Covid-19, Disinfectants, Sanitisers, Snail

21.1 Techno-economic analysis of furfural derivatives that can be produced in an existing furfural alcohol plant.

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Abstract

Diversity of revenue streams and product is an important strategy to secure sustainability of the global sugar industry, not only to alleviate the impact of current economic challenges, but also to contribute to the global growth of the bio-economy. Furfural is a chemical that is commercially produced from renewable sources such as sugarcane bagasse, and is suitable for transformation into a variety of different valuable products, typically through hydrogenation or oxidation. Derivatives of furfural include furfuryl alcohol, 2-methylfuran, tetrahydrofuran, tetrahydrofurfuryl alcohol, furoic acid, maleic anhydride, 1,5-pentanediol and 2-methyltetrahydrofuran. The main aim of this study was to determine whether alternative products that can be derived from furfural are more economically and environmentally feasible than furfuryl alcohol, without having to install a new equipment. An existing furfuryl alcohol plant located in South Africa was used as benchmark. To shortlist the possible products, existing electrolyser capacity to produce hydrogen and oxygen (for hydrogenation and oxidation) as well as market data (market selling prices and market sizes) of the above mentioned derivatives were compared. Based on these criteria, tetrahydrofurfuryl alcohol, maleic anhydride and tetrahydrofuran were selected, for process simulation using Aspen Plus®. Technical data was based on data from open-source literature while the design process flowsheet was based on the existing furfural alcohol plant. The minimum selling price of the selected derivatives was found to be lower than the commercial market price with a percentage difference of 22-58%. In addition, the greenhouse gas (GHG) emissions for each product were also determined based on the process simulations, indicating reductions compared to fossil-based chemicals.

Keywords

Furfural, derivatives, technoeconomic analysis, bioproducts

21.2 Manganese Oxide, Silver Nanoparticles and Activated Carbon Supported Reduced Graphene Oxide 3D Solar Interface Absorber for Desalination of Seawater

Mrs Bontle Manoto, Dr Fisseha Bezza, Prof Evan Chirwa

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Abstract

The synthesized 3D MnO₂/Ag-NP/AC@rGO material was characterized with SEM which gave a porous morphology which is the fundamental concept for interfacial solar absorber, the porous structure promotes a high efficiency and generation of steam due to high water transportation. TEM which depicts much clearer morphology showed the well displaced silver nanoparticles on the rGO sheets, this not only increases the evaporation rate of the device but assists with the antibacterial effect as well. The Raman spectrometry showed confirmed the graphene material; the D-peak, the disorder peak reflected some defects present whilst the graphitic band, G-peak, showed sp² hybridized carbon, in comparison with the 2D band it can be concluded that this is multilayered and clearly visible on TEM. The level of disorder in to be observed by the intensity ratio The X-ray diffraction results supported the Raman results and showed an interlayer spacing at 2 theta angle, GO clearly gave the peak at 2θ=10° and 23° due to incomplete oxidation while the functional groups, the shift of rGO peak curve shows the reduction in the oxygen functional groups on the material. Using Bruker Alpha II FTIR with platinum diamond ATR, the GO showed the peaks for OH⁻, C-O, C=O groups which are successfully reduced to rGO. The energy-dispersive spectroscopy gave a high peak of carbon.

The evaporation performance of the material was tested with solar simulation at 1 sun illumination using artificial seawater as per standard ASTM D1141-98, aiming to minimize heat loss, the material to give high water evaporation rate and efficiency. This test demonstrated evaporation rate of (1.3 kg. m⁻².h⁻¹) and photothermal conversion efficiency of ~95%. The MnO₂/Ag/AC@rGO device on PU insulator is very promising solar evaporator for efficient solar driven interfacial desalination of saline water meeting the current global water scarcity challenge.

Keywords

Reduced graphene oxide, photothermal, steam

21.3 Development and scale up of alginate lyase production from native alginate degrading microbes

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Abstract

There is an abundance of kelp (*Ecklonia maxima* and *Laminaria pallida*) along the western coast of South Africa, which is largely underutilised. At present there exists a scarcity of commercially available alginate lyases (ALs); this is also clear from the lack of literature focused on the upscaled production of ALs. ALs possess many characteristics which make them suitable for kelp processing and novel product development.

Native microorganisms capable of expressing AL were isolated from environmental samples, identified by gene sequencing, and thereafter the enzyme production and growth characteristics were investigated. Three selected AL producing microorganisms, i.e. *Bacillus subtilis*, *Lysinibacillus* sp., and *Rhodotorula mucilaginosa* were investigated for enzyme production and growth characteristics in various media. In addition, the crude enzyme preparation properties of optimal temperature and pH conditions for AL activity and the impact of alginate hydrolysis on alginate solution viscosity were investigated to determine potential future applications. Finally, the impact of reactor and fermentation conditions on oxygen transfer in an upscaled bioreactor (1.3L) was considered prior to upscaling production.

Keywords

Alginate-lyase, K_{La} , Alginate-hydrolysis, enzyme-production, hydrolysis

21.4 Development of productivity to produce biochar from the biomass of marine algae and mushroom waste via pyrolysis.

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Abstract

Agricultural wastes, such as plant residues, are progressively recognized as vital renewable feedstocks due to their carbon-rich composition (Bais-Moleman et al. 2013). Slow pyrolysis of the biomass (mushroom waste and marine macroalgae) at a constant heating rate of 15.0°C/min was performed at different temperatures (500°C, 600°C, 700°C, and 800°C) to produce biochar. The biochar produced at 500°C using mushroom waste gave relatively high yields of between 50.2 and 59.8weight %. The biochar used for soil amendment and the growth of microgreens was quantified to determine the biochar's ability to act as a fertilizer in both good and bad soil. Elemental compositions of derived biochar were also determined using BET, ICP (P, K), FTIR, XRD, SEM-EDX, and CNS analysis. This study aims to produce biochar from a mixture of biomass (mushroom waste and marine macroalgae) via pyrolysis in an oxygen-limited environment (Lehmann and Joseph, 2015; Kumar et al., 2021). Objectives are to increase the nutrient quality of biochar, enlarge the scale of producing biochar, and evaluate the soil quality during the application of biochar to the soil.

Algae-derived biochar at 500°C had the lowest surface area between 0.96 to 1.37m²/g. The highest BET surface area was obtained at 800°C (1:2 algae and mushroom waste) ranging between 62.2 to 89.5 m²/g. The FTIR spectra patterns revealed that all five different ratios of biochar samples peaks were H-C=O: C-H (hydroxy group) ranging from 2830 to 2695nm.

To test the efficiency of biochar, growth trials with amendments in purchased nutrient soil, and prepared nutrient deficient ("bad") soil. After 90days, the growth trials on microgreen seeds resulted in good soils having the best growth with the highest height of 165mm for algae-derived biochar at 500°C and on bad soil the highest height was 135mm for (1:2 algae and mushroom) derived biochar at 500°C.

Keywords

biochar, pyrolysis, mushroom waste, Algae.

22.1 Bioremediation of Cr(VI) and Other Hexavalent Transitional Metals in Soil and Aquatic Environments: A Review

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Abstract

Chromium has long been recognized as a toxic, mutagenic and carcinogenic metal. It is toxic to microorganism, plants, animals and humans. Chromium exists in environment in two stable forms: Cr(VI) and Cr(III). Cr(III) is less toxic and insoluble, while Cr(VI) is extremely toxic and highly soluble. Chromium is used in many industrial applications, but it poses a threat to local environment. The effluents and solid wastes from the mining, chrome-plating, leather-tanning, and dye-manufacturing industries are high in chromium concentration and identified as a major health hazard because of pollution to the environment. Industrial waste is used in landfilling, which causes the seepage, and the leaching of toxic chromium from soil into water bodies poses a threat to the environment. Waste materials discharged as tailings or industrial effluents from related industries contain high concentration chromium and other toxic metals. Inhalation is the major exposure route of the Cr(VI) toxicity in humans. The bioremediation of Cr(VI) to Cr(III) in the polluted site is a cost-effective and eco-friendly solution for preventing chromium detoxification. Bioremediation can be in situ or ex situ, and choice of remediation method depends upon the extent of pollution and the nature of the site. This paper summarizes the chromium pollution caused by ferrochrome industries, current remediation method adopted by ferrochrome industries, and the possible new methods for effective bioremediation. This paper focuses mainly on bioremediation techniques to convert the high-toxic form of chromium to less-toxic and mobile form of chromium. The observations from this study showcase advanced enzymatic Cr(VI) reductase structures in *B. thuringiensis* never observed in other microbial species before. Blocking of electron carrier enzymes suggested the involvement of dissolved thioredoxin in the cytosol and bulk media as possible biocatalytic activators for Cr(VI) reduction in resting cells.

Keywords

Biocatalysis, Cr(VI)-reduction, thioredoxin, mining-dump, effluent

22.2 Degradation of Rhodamine B dye on BiOIO₃/Bi₁₂O₁₇Cl₂ Heterostructure Photocatalyst under Visible Light Activation

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Abstract

Dye pollution resulting from industrial waste poses a substantial threat to both human health and the environment. The potential of photocatalysis technology employing Bi₁₂O₁₇Cl₂ and BiOIO₃ semiconductor photocatalyst materials were explored to address the issue of dye pollution. Heterostructure composites with varying mass ratios (BiOIO₃/Bi₁₂O₁₇Cl₂-x:y) were fabricated to enhance the effectiveness of individual materials in combating dye pollution. The inherent challenges associated with using these materials alone for visible-light photocatalysis include the rapid recombination of photogenerated electron-hole pairs in Bi₁₂O₁₇Cl₂ and the limited photon utilization beyond 420 nm in the light spectrum for BiOIO₃. Bi₁₂O₁₇Cl₂ displays visible light activity due to its narrow band gap energy, while BiOIO₃ possesses an internal electric field that promotes the separation of charges carriers. The combination of these materials produced a more potent heterostructure material, that synergizes the ability of Bi₁₂O₁₇Cl₂ to respond to visible light and BiOIO₃ capacity of separating charge carriers. The interface junction enhances spatial charge separation and boosts the redox power of photogenerated electrons and holes. Material characterisation by Electrochemical Impedance Spectroscopy (EIS), Photoluminescence (PL), and cyclic voltammetry (CV) revealed that the BiOIO₃/Bi₁₂O₁₇Cl₂-1:1 heterostructure exhibited the highest charge separation efficiency and redox potential among other heterostructures and individual materials. The average degradation rates of Rhodamine B and Methyl on BiOIO₃/Bi₁₂O₁₇Cl₂-1:1 were 1.9 and 2.3 times faster than the individual BiOIO₃ and Bi₁₂O₁₇Cl₂, respectively, which underscores the contribution of heterostructure formation in the photocatalytic degradation process. The proposed photocatalytic degradation mechanism highlights •OH and •O₂⁻ as the main participating species, and BiOIO₃/Bi₁₂O₁₇Cl₂-1:1 exhibited good stability after four cycles, with 86% efficiency retention. Therefore, BiOIO₃/Bi₁₂O₁₇Cl₂-1:1 heterostructure materials are promising in addressing the challenges of dye pollution.

Keywords

BiOIO₃, Bi₁₂O₁₇Cl₂, recombination, heterostructure

22.3 Implementation of human hair as a bio-adsorbent for gasoline spilled in sea water in Mozambique

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Abstract

Mozambique, an underdeveloped coastal country, used as a corridor for transporting fuel to internal countries, and is subject to the occurrence of spills, recalls the need for low-cost and bio-friendly measures that can be implemented in the cleaning and containment of such disasters. The present work studied the use of two types of human hair, straight and curly, as fuel oil adsorbents to prove the efficiency of this material in removing oil from water in cases of spillage. In the laboratory experiment, gasoline, with pH = 7, was used, together with seawater, to analyze the effects of contact time and amount of adsorbent using the UV-Visible spectrophotometer. The wavelength at which the spectrophotometer readings should be taken was determined, the calibration curve was constructed that allowed the definition of residual concentrations, the adsorption models and the respective isotherms were determined. Curly hair was the adsorbent with the best gasoline adsorption capacity, where 77% removal was obtained. At equilibrium, curly hair adsorbed 69% of gasoline and straight hair 67%. The experimental data fit the Freundlich isotherm model, indicating a chemisorption phenomenon, with correlation coefficients 0.9422 and 0.9536, in the adsorption of gasoline, and the kinetic model that described the oil adsorption was pseudo second order, with coefficient correlation 0.9936 and 0.9998. The present work confirms the applicability of human hair as suitable for cleaning spilled fuel.

Keywords

Human hair; gasoline; adsorption; isotherms and kinetics human

22.4 The use of calcium carbonate recovered from the Acid Mine Drainage (AMD) of the Witwatersrand Eastern basin in preparation of polypropylene composites

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Abstract

Calcium carbonate (chemically precipitated or ground mined) has been used extensively in polymer production as a functional filler to improve the mechanical properties and to reduce the material cost. Recently, an environmentally friendly method for the treatment of acid mine drainage has been reported where calcium carbonate was recovered from the three basins in the Witwatersrand region, in Gauteng, South Africa. The recovered calcium carbonate was the aragonite polymorph with needle/rod like morphology. In this paper, the focus was on the calcium carbonate recovered from the acid mine drainage of the Eastern Basin. To demonstrate the utility of the recovered mineral, it was compounded into an ethylene propylene copolymer.

The influence of mineral on the mechanical and thermal properties of the polypropylene composites were investigated and compared to a commercial grade of calcium carbonate. The recovered and commercial calcium carbonate characterized for their compositions, crystalline phases, morphologies, and decomposition profiles using state of the art techniques (FTIR, XRD, SEM-EDS, and TGA, respectively). Subsequently, the compounds prepared using the two minerals were characterized for their morphologies, tensile, mechanical, thermal, and rheological properties.

The study aims to demonstrate the industrial utility of the mineral recovered from acid mineral drainage, thus rendering the treatment method as self-sustaining.

Keywords

AMD, PP/CaCO₃ composites, AMD treatment method

23.1 SS-LNG Technology and its role in the Just energy transition.

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Abstract

Small-scale Liquefied Natural Gas (SS-LNG) production has become viable due to improved small-scale process technology and the increased role of natural gas in the just energy transition and its importance in the energy mix. SS-LNG enables the utilisation of isolated small gas reserves and distribution to isolated areas. This study aims to present the market opportunity for SS-LNG plants when compared to large-scale LNG and alternative energy, contrasting opportunities in the developed and developing world. In developed countries, SS-LNG has successfully been implemented to manage restrictions in existing infrastructure through peak shaving, offering a faster response to growing LNG market demand and supplying to demands that do not reach the minimum volume to justify traditional infrastructure development.

In developing countries, SS-LNG can enable countries to access their own natural gas reserves more independently and is not limited by a lack of infrastructure as SS-LNG is not dependent on transmission lines or large loading and unloading terminals. SS-LNG enables developing countries to access their energy potential in a shorter timeline than traditional LNG. It is motivated that fast access to LNG energy can assist developing countries in their economic growth and aid them in their just energy transition. SS-LNG also offers an alternative to enable the supply of LNG in countries where security issues hinder the development of traditional LNG facilities, even if these would be economically favourable.

Various commercialised technologies for SS-LNG plants exist. This study also provides an overview of the available technologies and technology readiness of proposed technologies. The technologies are discussed based on energy efficiency, cost and complexity of each technology.

Keywords

Small-Scale-LNG, Modular-design, Just energy transition.

23.2 Development of highly durable PEM fuel cell ORR catalysts

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Abstract

PEM fuel cells have received a lot of attention as clean energy production alternatives using hydrogen as the fuel and producing only water as the by-product. These typically use carbon supported Pt nanoparticles as the main catalysts for the anodic and cathodic reactions. However, the durability of these catalysts has hindered their widespread application, due to the corrosion of the support and subsequent loss of electrochemical surface area. Thus, alternative supports have been investigated for superior durability, yet still possessing high conductivity and high surface areas as required for Pt supports. In this work, doped metal oxides and doped carbon supports have been developed to determine their application as fuel cell cathode catalyst supports. Tin oxide was doped with antimony to increase its conductivity by narrowing the band gap, whilst high surface area carbon (Ketjenblack EC300J) was doped with nitrogen to modify the surface structure, hence increasing its durability. The trade-off between the durability of the support and the depressed BET surface area was investigated. It was found that both the supports showed increased durability with an ECSA loss of up to 21% compared to commercial HySA K40 catalysts which show a loss of 34%. However, the catalysts prepared with antimony-doped tin oxide (ATO) displayed very poor ORR activity, thus eliminating ATO as an alternative support. The catalysts prepared with N-doped Ketjenblack showed similar ORR activity to the commercial HySA K40 catalyst, thus qualifying these supports as viable, more durable alternatives.

Keywords

Fuel cell, catalysis, hydrogen

23.3 Application of nanostructured platinum-transition metal alloys to enhance ORR activity in PEMFCs.

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Abstract

Platinum (Pt) nanoparticles on carbon support (Pt/C) are regarded as the most catalytically active materials for oxygen reduction reaction (ORR) activity in proton exchange membrane fuel cells (PEMFCs). However, the main drawback hindering PEMFC commercialization is the cost and scarcity of platinum necessitating low platinum loading into the fuel cell leading to low activity. There has been significant research looking into the synthesis of structured Pt-TM alloys (TM = 3d-transition metals e.g., Ni, Co, Fe, or Cu) to improve catalysis activity and durability with reduced platinum use. These nanostructured or shaped Pt-TM alloys include three dimensional nanocrystals dominated by low index facets, hollow structures rich with Pt, or one-dimensional nanostructures like Pt-TM alloy nanowires.

Hollow structures such as Pt-TM alloy nanoframes and nanowires are more appealing because most of the Pt on the frames contributes to the catalytic activity as opposed to solid nanocrystals with buried Pt. The use of Pt-TM alloy skin or skeleton nanoframes/nanowires is necessary for the reduction of platinum loading to reduce cost but still maintaining high activities and durability, essential for PEMFCs. Here, Pt-Ni alloy nanoframes and nanowires are synthesised through a co-reduction method starting with solid shaped nanostructures and etching the sacrificial nickel to realise nanoframes. The synthesised nanocrystals are characterised via electron microscopy for morphology, crystallinity, and elemental composition; x-ray diffraction for phase identification and crystallinity, and lastly x-ray photoemission spectroscopy to probe oxidation states of the Pt and Ni. The Pt-Ni nanoframes/nanowires are then supported on a high surface area carbon to complete the catalyst and to perform catalytic activity through electrochemical methods using thin-film rotating disc electrolyte (RDE) measurements.

Keywords

Platinum-alloys, Nanostructures, Nanoframes, ORR, PEMFCs

24.1 Heterogeneous Hydrogenations in Flow – Case Studies and Scale-up Considerations

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Abstract

Continuous manufacturing offers a route towards improved process safety, increased productive capacity, and greatly reduced peak energy requirements. Catalytic hydrogenation reactions are prominent in the chemicals sector and often require a heterogeneous precious metal catalyst. A major barrier to flow process development and scale-up is the limitation of versatility at lab-scale when compared with batch. Sufficient mass transfer across a wide range of reaction times, and the ability to perform heterogeneous reactions, especially simultaneous handling of solid, liquid and gas, is limited with existing flow reactor technology. Therefore, multipurpose and scalable flow reactor technology that can handle multiphase chemistry including slurries is required.

Solids handling in flow has presented a significant challenge, with the tendency of particulates to bridge or block flow reactor channels being a major barrier to the widespread adoption of flow at production-scale. Solids handling issues can be mitigated through immobilisation of heterogeneous material on supports, or through tuning solvents and concentrations to avoid solid precipitation. However, for many industrially significant chemical processes, such mitigation methods are either too inefficient or are limiting. Dilution or other solvent alterations can negatively impact reaction kinetics and reduce productivity, and in some cases, precipitation may be required to achieve a favourable reaction equilibrium. Immobilisation can be a useful method for heterogeneous catalytic reactions, but the semi-continuous nature can limit throughput and efficiency when compared to a continuous feed of free-flowing slurry.

Here, we outline recent advances in developing a range of approaches to handle multiphase flow hydrogenations with a versatile and scalable flow reactor system.

Keywords

Flow Chemistry, Hydrogenations, Continuous Manufacturing

24.2 Design and optimization of separation process alternatives for butanediol dehydration for use as a bio-fuel

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Abstract

Butanediols have been identified as suitable drop-in fuels in certain transport applications. A biochemical, renewable, lower energy process can be used to produce butanediols by the fermentation of biomass by certain microorganisms. Low-concentrations of the butanediols in water are produced that must be dehydrated before use. Lower energy dehydration alternatives to conventional distillation include hybrid techniques involving solvent extraction and recovery by distillation to first remove excess water and subsequently concentrate the butanediol product.

In this work, novel isothermal vapour-liquid equilibrium data were measured for the systems of water/butan-1-ol with the butanediol component; butane-1,4-diol/butane-2,3-diol utilizing a dynamic-analytical apparatus. For the systems of water (1)/ butan-1-ol (1) + butane-1,4-diol (2)/butane-2,3-diol (2), measurements were performed at temperatures ranging from 353 – 373 K. The P - T - x - y data was modelled using the γ - Φ approach.

The VLE data were used to design separation alternatives to purify butanediol from the aqueous mixtures that result from the biological process pathways. This was executed by exploring the design potential of a hybrid extraction-assisted distillation separation process in comparison to conventional distillation. The design of the separation process was performed using Aspen Plus® and optimized using standard procedures to reduce duties and costs. The simulation was used to investigate the techno-economic feasibility of the process and included heat-integration. A feed of 20 000 kg/hr aqueous butanediol was considered with a recovery exceeding 90% and a purity exceeding 99%. Conventional distillation was found to be the economically feasible process alternative for the butane-1,4-diol purification, with an estimated total annual cost in the range of \$4,532,846.67 and \$4,635,070.52 for a payback period of 3 years, while extraction assisted distillation with heat integration was found to be the economically viable option for butane-2,3-diol purification with total annual costs in the range of \$2,997,204.58 and \$3,988,868.70 for a payback period of 3 years.

Keywords

Biofuel, hybrid distillation, heat-integration, VLE

24.3 Microwave-assisted pyrolysis of biomass using HZSM-5 catalyst derived from slag waste

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Abstract

The study investigated the microwave-assisted pyrolysis of corn cob waste using a zeolite-based catalyst synthesized from slag waste. The synthesized zeolite-based catalyst (HZSM-5) exhibited textural properties (pore shape and size, morphology, and crystallinity) comparable to the commercial HZSM-5. The bio-oil conversion rate was higher with the synthesized catalyst (43.6 wt%) than the commercial catalyst (41.9 wt%). The bio-oil produced was obtained at fast-heating rates under microwave irradiation conditions (350°C, 1600 kW, and 3 min). The composition of the bio-oil without catalyst primarily consisted of organic acids (26.9%), ketones (19.4%), phenols (20.6%), and alcohols (20.6%). However, the selectivity of the reaction shifted to produce mainly phenols (22.8%) and ketones (29.5%) in the presence of the synthesized catalyst. After upgrading, the phenols and ketones can serve as feedstock for the chemical industry. The product yield for both catalysts was mainly gases composed of CO, H₂, CO₂, CH₄, and light hydrocarbons. The transitional metals occupying the mesoporous structure improved the catalytic activity and selectivity of the synthesized catalyst. Overall, the study demonstrated the valorization of corn cob waste in the presence of HZSM-5 derived from slag waste.

Keywords

Biomass; Bio-oil; Microwave-pyrolysis; Slag; Zeolite.

25.1 Optimizing mixing-assisted oxidative desulfurization: application of sludge-derived ferrate(VI) to dibenzothiophene and pyrolysis oil

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Abstract

In response to the effects of using fossil fuel-derived oils, many countries are investigating methods of energy recovery from waste. Pyrolysis oil from waste tires is explored as an alternative fuel. However, it contains high levels of sulfur compounds, making it unsuitable for direct use. In this study, mixing-assisted oxidative desulfurization was applied in a dibenzothiophene (DBT) model fuel to determine maximum sulfur to sulfone conversion. The oxidant, crude K_2FeO_4 or Fe(VI), was prepared from drinking water treatment sludge using the wet oxidation method. Optimization studies were performed considering the following parameters: Fe(VI) concentration, phase transfer agent (PTA) concentration, mixing speed, and mixing temperature. The optimized MAOD parameters for maximum DBT conversion were determined to be 537 ppm Fe(VI), 114 mg PTA/50-mL model fuel, 8,157 rpm agitation speed, and 41.7 °C, resulting in a sulfur conversion of 99.7%. The optimal parameters were applied to a pyrolysis oil sample with an initial sulfur concentration of 8,804 ppm, and desulfurization was achieved at 53.2%. Results confirm the effectiveness of MAOD in achieving sulfur conversion, as evidenced by the resulting sulfur content aligning with the specifications set by Taiwan EPA and DENR Philippines for industrial heating oils. Moreover, this study demonstrates the potential of using Fe(VI) derived from DWTS in MAOD for effective desulfurization and discusses insights into the effects of operating conditions to enhance desulfurization efficiency. Ultimately, it supports the promising applicability of MAOD in producing cleaner fuels via waste recovery for industrial applications.

Keywords

Oxidative desulfurization; dibenzothiophene; Pyrolysis oil

25.2 Valorisation of Iron-rich Acid Mine Drainage Sludge for Reusability Potential to Extract Valuable Material: The Synthesis of Barium Hexaferrite

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Abstract

Acid mine drainage (AMD) impacted waters in South Africa is effectively treated using lime neutralization, however, this process generates costly and large volumes of sludge. Prior research on utilizing iron-rich wastes to synthesize barium hexaferrite ($\text{BaFe}_{12}\text{O}_{19}$) - (a valuable nano-magnetite), shows promise. However, extracting high-purity iron (III) Oxide (Fe_2O_3) as a precursor for this purpose remains a challenge. This study seeks to address AMD sludge management costs by developing oxidation coupled with an acid-leaching process and selective precipitation technique to isolate iron and obtain pure $\text{BaFe}_{12}\text{O}_{19}$. Oxidation, acid leaching, and selective precipitation techniques were employed to isolate iron (III) hydroxide ($\text{Fe}(\text{OH})_3$) from AMD sludge and produce high-purity $\text{BaFe}_{12}\text{O}_{19}$ through a solid-state reaction. The focus of this study involves evaluating the efficacy of selective precipitation of $\text{Fe}(\text{OH})_3$ through recovery and purity analysis, identifying effective extractants and temperature-pH conditions, and examining how varying nanoparticle sizes affect the magnetic properties of $\text{BaFe}_{12}\text{O}_{19}$. The proposed method aims to enhance the purity of the final product, contributing to efficient sludge recycling. In the preliminary experimental work, acid leaching, and pH gradient manipulation have successfully extracted ($\text{Fe}(\text{OH})_3$) from dry AMD sludge. This was confirmed through qualitative Fe^{3+} analysis as well as atomic absorption spectroscopy (AAS). When using different leaching solutions, the amount of ($\text{Fe}(\text{OH})_3$) recovered ranges from 43% to 85%. These findings establish that Fe_2O_3 (product of ($\text{Fe}(\text{OH})_3$) decomposition) can be obtained from the sludge as a precursor for $\text{BaFe}_{12}\text{O}_{19}$ synthesis. Currently fine-tuning reaction conditions to achieve optimal recovery, aiming for a target recovery rate exceeding 95%. These promising results lay the foundation for the efficient synthesis of high-purity $\text{BaFe}_{12}\text{O}_{19}$ from AMD sludge, offering significant potential for environmental and economic benefits. By successfully extracting ($\text{Fe}(\text{OH})_3$) and optimizing recovery processes, this research contributes to sustainable solutions in AMD management.

Keywords

Acid Mine Drainage (AMD); Acid-Leaching Process; Oxidation; Barium Hexaferrite

25.3 Comparative performance of solvents in post-combustion CO₂ capture using rotating packed bed technology

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Abstract

The most debated issues in today's industrialized world are those that affect the environment, which is often associated with the release of greenhouse gasses. Carbon dioxide emissions, especially from power plants, are considered to be the biggest contributor to global warming. To mitigate the most severe impacts of climate change, such as increases in the frequency and severity of droughts, heat waves and erratic rainfall, it is important to capture CO₂ from large point sources. Due to the significant cost impact of CO₂ capture on the price of electricity, conventional post-combustion CO₂ capture has been repeatedly questioned. Rotating packed bed technology has shown that a reduction in the cost of CO₂ capture is possible. This article summarizes the results of experimental research on a custom built rotating packed bed absorber for capturing CO₂ from a flue gas stream. Different solvents and their mixtures were investigated to compare their performance in terms of CO₂ capture efficiency and overall volumetric mass transfer coefficient. Process parameters such as rotation speed, liquid-to-gas ratio and concentration of the solvents and their mixtures were investigated. The study showed that the CO₂ capture efficiency and the overall volumetric mass transfer coefficient improved proportionally to the increase in rotor speed. This can be attributed to the fact that a higher rotor speed results in the packing being dominated by a droplet flow, which means an increase in the contact area between the flue gas and the solvents. In addition, the CO₂ capture efficiency and overall mass transfer coefficient increased with increasing solvent concentration. This is due to the fact that an increase in concentration leads to an increase in reaction rate. The investigation has shown that a rotating packed bed absorber is an effective unit for CO₂ capture as it improves mass transfer performance compared to conventional packed column

Keywords

Process Intensification, Rotating Packed Bed,

25.4 Decay factor characterisation of paper materials using laboratory- and pilot-scale reactor studies

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Abstract

Organic materials undergo decomposition in landfills, producing greenhouse gases (GHGs), including methane and carbon dioxide. To understand the contribution of components in landfill waste to gas generation, national GHG inventories require the assignment of decay factors to components in organic waste streams to better estimate GHG emissions. The initiative was driven by the Intergovernmental Panel on Climate Change (IPCC) regarding the adoption of country-specific decay values for individual products. South Africa currently lacks data on GHG emissions from these wastes, relying instead on default factors specified by the IPCC. This research aimed to determine decay factors for selected paper materials and, ultimately, update the factors adopted by the National GHG Inventory of South Africa. Eight paper-containing materials were investigated: packaging paper (PP), newsprint (NP), coated paper (CP), office paper (OP), paper sacks (PS), multilayered paper (ML), liquid board packaging (LQ), and label backing paper (LB). The anaerobic biodegradability of these materials was characterised by simulating optimal landfill conditions in bench-top (500 ml) and pilot-scale (30 L) reactors. To simulate organic decay more realistically, leachate from landfills in the Western Cape was used to mimic microbial consortia typically prevalent in landfills. Experiments included fully submerged and packed-bed reactors, which aimed to represent an upper and lower limit of decay, respectively. The study involved an in-depth analysis of methane yields, decay rates, and the decomposition dynamics of cellulose, hemicellulose, and organic carbon content. The compositional data obtained from various scales of experimentation served as parameters used to model and predict decay factors for individual products, extending the findings to a landfill scale. OP, PS, and LB were most recalcitrant to decay with methane yields ranging from 200 to 250 $\text{Nml}_{\text{CH}_4} \text{g}_{\text{VS}}^{-1}$, while CP, ML, and NP exhibited lower yields ranging from 50 to 190 $\text{Nml}_{\text{CH}_4} \text{g}_{\text{VS}}^{-1}$, respectively.

Keywords

Decay, GHGs, Anaerobic, Methane, Paper

25.5 A sensitivity analyses on the cost of production and storage of green ammonia in South Africa

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Abstract

To mitigate the adverse effects of climate change, urgent attention and action is being directed towards the use of renewable energy and the planned production of green hydrogen (carbon free). The conversion of this hydrogen to power fuels, such as methanol, ammonia and other hydrogen derivatives are of interest for safe transportation and storage of energy source. While available open-source models provide economic analyses into the cost calculations of hydrogen and ammonia, there are inherent biases and variables to consider. With hydrogen being generated by electrolysis using renewable energy, the energy mix of solar from photovoltaics, wind turbines or grid, electrolyzer technologies, power/battery backup to electrolyzers, and many other factors feed into the levelized cost of green hydrogen. This study evaluated sustainable ammonia production costs through the development of an evidence-based costing framework. More specifically, it aimed to determine the levelized cost of green ammonia production, specifically tailored to the unique economic and environmental context of South Africa. A bespoke cost model was used, and its outputs were then compared to results from three different open-source costing models. Empirical data relevant to South African production characteristics was considered, such as renewable energy and infrastructure costs. The aim was to create a deterministic model, from which comparisons with other models could be drawn. By doing so, over-and under estimations were evaluated in determining the overall cost of green ammonia production. By comparison, grey ammonia production currently stands at \$300US per ton. Cost reductions and optimization studies were performed in determining configurations for cost competitiveness for the anticipated costs obtainable for clean/green hydrogen and storage.

Keywords

Green hydrogen, Levelised cost, Ammonia

27.2 Phase equilibrium data for CO₂/methane/CO/H₂ + 2-methyl quinoline

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Abstract

Hydrogen plays a major role in the transition to renewable and cleaner energy production. However, there are issues regarding the safe storage and transportation of hydrogen. Various liquid organic hydrogen carriers (LOHC) are reported for safe hydrogen storage and transportation. Storage solutions based on N-heterocycle LOHC systems are more attractive because the nitrogen atom in the ring can lower the dehydrogenation reaction temperature compared to cycloalkanes. Amongst the LOHC, 2 methyl quinoline (quinaldine) with a hydrogen carrying capacity of 6.6 wt.% shows promising potential. The hydrogen release enthalpies that appear to be most appropriate for automobile hydrogen storage lie in the range of 15–25 kJ.mol⁻¹ and correspond to release temperatures in the range of 273 to 373 K. It has been demonstrated that the hydrogenation and dehydrogenation of heterocyclic liquids can be performed at a temperature range of 323 to 470 K and a pressure of around 7.2 MPa. This study investigated the phase equilibria data for CO₂/methane/CO/H₂ + quinaldine and H₂+CO+CO₂ + quinaldine over a temperature range of 298 to 353 K and pressures up to 15 MPa. Experiments were conducted using a combined static analytic/static synthetic apparatus. Previous studies reported phase equilibria data for H₂/CO + quinoline related to the separation of polyaromatic components in coal tar. Methane/CO₂/CO/H₂ are common in coal conversion processes. Quinaldine can be recovered from coal tars. Thermodynamic modelling of the measured data was performed using Aspen Plus V12.1 with the Peng Robinson equation of state incorporating the Wong Sandler mixing rules (PRWS) and the Non-Random Two-Liquid activity coefficient model. The novel data has not been reported in open literature. Such information aids in the generation of a database of phase equilibrium data related to energy storage materials, which forms the backbone for the design of separation and purification units.

Keywords

Quinaldine, Hydrogen storage, Phase-equilibrium data

27.3 Flooded mineshaft compressed air energy storage in the Witwatersrand Goldmine Complex – case study of a proposed novel energy storage method

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Abstract:

With renewable energy sources representing a rapidly-growing share of the global energy mix, their intermittent nature has led to growing interest in mechanisms of storing energy during periods of high availability, for use during times of high demand. Several different types of compressed-air energy storage have been considered, including constant-volume approaches such as salt dome or artificial vessel storage and newer constant-pressure approaches such as submerged cavern storage. This manuscript proposes a novel approach where abandoned, flooded mineshafts are pressurized with air, displacing water downward in the shaft but upward in other hydraulically-linked shafts in the same geological complex. This approach is something of a hybrid between compressed-air storage and pumped storage and is thermodynamically distinct in that neither pressure nor volume are constant. An application to the abandoned goldmine shafts of South Africa's Witwatersrand geological complex is considered, and thermodynamic analysis indicates that this approach offers around 10% greater energy density than conventional compressed air energy storage, and that a single mineshaft could have isothermal storage capacity exceeding 1GWh, with some operational advantages specific to the Witwatersrand context, meriting further research to design processes.

Keywords:

Renewable Energy Storage, Compressed-Air Energy Storage (CAES), Pumped Storage Hybridization, Abandoned Mineshaft Utilization, Thermodynamic Efficiency in Energy Storage

28.2 An economic analysis for the production of food-type products in an integrated sugarcane biorefinery

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Abstract

The excess of crystalline sugar and low prices are posing a challenge to the global sugarcane industry, forcing it to look at diversification options for their product portfolio to mitigate this economic burden. This research examines the economic feasibility of producing various food-type products, including L-tryptophan, erythritol, collagen and short-chain fructooligosaccharides (scFOS) in integrated sugarcane biorefineries from A-molasses. Each production process was simulated in Aspen Plus® using available technical data from published literature, allowing a techno-economic analysis to be completed for each, to determine its economic feasibility in terms of its minimum selling price (MSP) at an acceptable return on investment. In addition, the greenhouse gas (GHG) emissions of each production process were assessed using the Roundtable on Sustainable Biofuels (RSB) tool, for comparison to economic viability. The products scFOS, tryptophan and collagen demonstrated the highest profitability with MSPs that were 51 to 88% their respective market prices, while the MSP for erythritol was very similar to its reported market price. However, the low MSPs for scFOS and tryptophan required production scales that would supply up to 45% of the global market sizes for each product, which is expected to substantially reduce market prices and economic viability, due to oversupply. All the biorefinery scenarios showed low GHG emissions, with the tryptophan manufacturing being the least harmful to the environment due to reduced demands for freshwater and process chemicals. Collagen demonstrated the most attractive trade-off between economic and environmental benefits, having acceptable performances in terms of both financial viability and GHG emissions, despite not having the best performance in individual categories.

Keywords

Technoeconomic, tryptophan, erythritol, collagen, biorefinery

28.3 Soxhlet Extraction of Cinnamon Oil Comparing Particle Size with Different Functional Group Solvents

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Abstract

Cinnamon oil, prized for its diverse applications spanning culinary, agricultural, and pharmaceutical industries, owes its versatility to a combination of flavourful attributes and antioxidant properties. A recent investigation focused on the yield percentage analysis of cinnamon oil extracted through Soxhlet extraction, employing methanol, hexane, and ethyl acetate as solvents, specifically emphasising how particle size influences extraction efficiency.

The experiment utilised different sizes of cinnamon material, including small bark (10-15 mm wide), large bark (65-70 mm wide), and finely crushed bark (0.05 mm length, 0.02 mm width). Each size variant underwent extraction for approximately an hour per solvent, followed by the recovery of solvents via distillation to isolate the oil.

The findings revealed a significant correlation between particle size and oil yield, with smaller particles demonstrating higher extraction rates attributed to increased interfacial contact between the solvent and cinnamon material. Crushed bark exhibited the highest yield across all solvents, followed by small and large bark variants.

Methanol emerged as the most efficient solvent, yielding the highest percentages of oil for all bark sizes: 34.7% for crushed bark, 20.85% for small bark, and 19.77% for large bark. Ethyl acetate ranked as the second-best solvent, yielding 20.5%, 17.38%, and 15.03% oil, respectively, while n-hexane exhibited the lowest efficacy, resulting in 13.8%, 12.21%, and 9.40% oil yields for the respective bark sizes.

This variance in solvent effectiveness can be attributed to their respective polarity indices, with methanol boasting the highest polarity (5.5), followed by ethyl acetate (4.4), and n-hexane (0.1). The polar nature of cinnamon oil renders it more soluble in polar solvents, elucidating methanol's superior performance.

To enhance extraction efficiency, it is recommended to prolong extraction times and pre-dry cinnamon bark to eliminate surface moisture, thereby optimising contact between solvent and particles.

Keywords

Cinnamon-oil, Soxhlet extraction, particle size

29.1 Commercial-scale trial feeding waste activated sludge to a Sasol fixed bed dry bottom gasifier

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Abstract

Global trends and Sasol environmental strategies support the need to move waste streams away from incineration and to proceed up the waste hierarchy. This is what motivated the Sasol research team to develop a process setup, to test on commercial scale, whether one can co-feed high moisture content waste activated sludge (WAS) to the SASOL fixed bed dry bottom gasifiers. This would effectively utilize existing assets to manage the WAS in a more efficient way, deriving synthesis gas from the carbon contained in the sludge. The thickened WAS behaves as a non-Newtonian, shear thinning liquid, which made pump designs for gasifier injection very challenging. To overcome this, thermal hydrolysis pre-treatment of the sludge was included to reduce its viscosity and kill the pathogens associated with the sludge as a process step in the trial run setup. Different operating conditions of the thermal hydrolysis reactor were evaluated to minimize the sludge viscosity. The hydrolysis temperature, as determined by the pressure in the vessel was found to be the governing factor, and optimization of this variable resulted minimized the viscosity. At the gasifier, the thermally treated sludge was injected at specified flow rate into one gasifier, which was operated under otherwise normal conditions with coal, steam and oxygen feedstock. Seven gasifier test conditions were evaluated. The results were compared to baseline tests to quantify the impact of the sludge injection on the gasifier operation and main output streams that were sampled. It was concluded that the sludge injection did not negatively impact the gasifier operating stability. The sludge injection, at a low ratio relative to coal fed to the gasifier, also did not have adverse consequences on the main gasifier product streams. This trial run has proven that it is technically feasible to route WAS to the SASOL FBDB gasifiers.

Keywords

bio-sludge, gasification, co-feeding

29.2 The effect of UV/H₂O₂ pre-treatment on the solubilization of bituminous coal fines waste for the biogenic production of methane gas.

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Abstract

Coal is a complex organic compound, which makes the hydrolysis process the rate-limiting step of the bioconversion of coal. As a result, pre-treatment of the coal fines (CF) using oxidizing agents such as hydrogen peroxide (H₂O₂) under ultraviolet light (UV/H₂O₂) increases the coal availability by producing free radicals that interact with the CF moieties, this is known as photocatalytic oxidation. This study aims to characterize the compositional changes in the CF treated with H₂O₂ and (UV/H₂O₂), to investigate the effect of photolysis. The -300µm CF were oxidized with 3% (v/v) H₂O₂ solution to increase the abundance of solvent-extractable matter in CF. The filtrate of the treated sample was analyzed for the concentration of Total Dissolved Organic carbon (TOC) and the remaining residue was oven dried and analyzed for functional groups. The effect of the oxidation on the CF solubilization was further determined through Thermal Gravimetric Analysis (TGA) to analyze the thermal stability and degradation of the CF. Changes in the weight of the CF were observed with no significant difference. However, the UV/H₂O₂ oxidation has enhanced the solubilization of the CF which resulted in having the highest TOC concentration of 29 mg/L and 17 mg/L for the H₂O₂ oxidized CF. These findings offer a good basis for coal solubilization as a key starting point for biogenic production of methane gas.

Keywords

Coal fines, Photocatalytic oxidation, Bioconversion

29.3 An investigation into the Flocculation and Settling Behaviour of Coal Preparation Plant Tailings

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Abstract

The mineral processing industry generate a huge quantity of coal fine tailings, which present environmental challenges worldwide. This necessitates the adoption of efficient solid–liquid separation technologies. Flocculation technology, by employing flocculants, play an important role in the solid-liquid separation of coal fine tailings. The work aims to investigate the performance of commercially available polyacrylamide flocculant, Magnafloc10, for enhancing the settling performance of coal fine tailings. In this study a coal fine tailing sample (-0.5 mm particle size) was collected from the tailing pond of a coal preparation plant located in the Jharia coalfield, Dhanbad, India. Firstly, the characterization and the flocculation studies were conducted by varying different parameters, i.e., pulp density (6-12% solid w/w), pH (6.5-9.5) and flocculant dosage (4.89-19.56 g/t) with measured responses including settling rate, turbidity, and density of settled slurry carried out. Then, the process optimization was carried out using response surface methodology, which generate a response surface model equation for the responses. These responses were optimally solved, by the optimization problem using the GRG optimization technique. The optimum processing conditions determined were pH 8.5, flocculant dosage 14.6 g/t, and pulp density 7.2% solid m/m. The optimum levels of the process parameters resulted in a maximum settling rate of 174.3 mm/min, minimum turbidity of 22.4 NTU and maximum density of the settled slurry of 40.63 with the desirability of 81.6%. The findings from this study provide a feasible approach and procedure for the mineral processing industry to optimize flocculation of fine particles.

Keywords

Flocculation; Flocculant dosage; Settling rate

29.4 Combustion of mixed waste fuel

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Abstract

The paper addresses increasing world volumes of waste, namely sewage and paper mill sludge, and its use as an alternative fuel either itself or at a co-combustion with coal. The fuel (sewage and paper mill sludge and their blends, with and without coal) in the form of pellets (10 - 15mm, h = 6mm) was combusted in a fluidized bed of sand (pilot plant combustor of I.D. = 140 mm) at a temperature of 800-900°C. After reaching a steady state the flue gas was analysed for Hg, CO, CO₂, NO_x, SO₂, NH₃, CH₄ and HCl. The concentrations of pollutants were below acceptable limits in most EU countries with exceptions of SO₂, HCl, Cl₂, and Cd indicating a need for a downstream flue gas cleaning. The mechanical properties of pelletized fuel (hardness, material and bulk density, moisture content) together with its higher and lower heating values allow its utilization in the storage, transport, and processing. While a usual flue gas cleaning is still necessary, an alternative fuel may be used for fluidised bed combustion.

Keywords

co-combustion, combustion, fluidization, sludge

30.2 On Bubble Deformation and Breakup in Liquids Containing Surface Active Agents

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Abstract

Bubble breaking in the gas-liquid flows is a widespread phenomenon in many industrial applications (biotechnology, waste water treatment, heat and mass transfer intensification, etc.). The knowledge and characterisation of the bubble breakup mechanisms in such flows is essential to improve the modelling of multiphase systems using numerical methods. The stochastic nature of turbulence imposes many limitations and the interpretation of available data can be quite difficult. A possible more deterministic approach simplifying the problem is to study the interaction of a single bubble with a single vortex structure.

One of the effects with a significant impact on the behaviour and breakup of bubbles in multiphase flows is the presence of surface-active agents (surfactants). They are often added to chemical reactors and they alter the bubble dynamics and interfacial properties. By adsorbing to the gas-liquid interface, they create a sublayer and consequently change the interface properties.

The aim of the present study is to experimentally investigate the bubble-vortex interaction in order to find out the effect of surfactants on bubble deformation and possible breakup. The experiments are based on the high-speed visualisation of a single bubble interacting with a single vortex-ring generated in a liquid containing one of two types of surfactants at different concentrations (α -terpineol and Triton X-45). The presence of the surfactant suppresses the deformations of the bubble and more energy is required to deform the bubble sufficiently resulting in its breakage. The surface tension was found to be insufficient to characterise the bubble surface energy and the actual amount of surfactant molecules adsorbed at the gas-liquid interface must be considered when predicting the breakup frequency and mean number of daughters.

Keywords

bubble deformations, bubble breakup, surfactants

30.3 The Potential of Unconventional Statistical Methods in Chemical Engineering

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Abstract

Statistical methods play a crucial role in the analysis and interpretation of complex data in chemical engineering research. However, conventional approaches may not always suffice in addressing the intricacies of engineering challenges within design, process modelling, and process development. This presentation explores the potential of unconventional statistical methods in chemical engineering, drawing upon recent findings from a study conducted on low flux flue gas desulphurisation circulating fluidised beds (FGD-CFBs).

By leveraging unconventional statistical techniques such as Bland-Altman plots and the Kruskal-Wallis test, in conjunction with the one-way ANOVA, an analysis was conducted in this study on the solids flux measurements in a novel low flux CFB system. Based on the statistical analyses of the data a non-isokinetic solids sampling technique for low flux dry and semi-dry flue gas desulfurisation CFBs was validated. Therefore it serves as a case study to showcase the applicability of these statistical methods within chemical engineering applications, even though these methods are more generally known to be used in medical research applications.

Importantly, the focus of this contribution lies not only on the specific findings but on the methodologies employed in the case study. It highlights the broader implications of utilising innovative statistical approaches in addressing practical engineering challenges.

This evaluation emphasises the potential of unconventional statistical methods in providing valuable insights into complex engineering systems, guided by a systematic inquiry aimed at assessing their suitability for different types of data sets. By embracing these methods, chemical engineers can unlock new avenues for research and development, thereby facilitating innovation, sustainability, and advancement in the field.

Keywords

Statistical methods; Bland-Altman; Kruskal-Wallis; FGD-CFB

30.4 Advancing the Understanding of Wet Ball Mill Loads: A Comprehensive Numerical Simulation Framework

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Abstract

The accurate numerical simulation of wet ball mill loads poses a significant challenge, as it necessitates the seamless integration of solid-based and liquid-based computer algorithms within a realistic framework. To address this need, this paper presents the development of a novel computer framework that combines the power of Discrete Element Modelling (DEM) and Computational Fluid Dynamics (CFD). In this framework, the grinding media are modeled using a Lagrangian approach, treating the grinding charge as a collection of distinct particles governed by Newton's laws of motion. The particle-particle collisions are assumed to adhere to the Hertzian contact law. The implementation of this model is realized using the open-source C++ based platform LIGGGTHS. Conversely, the slurry phase is modeled using the Navier-Stokes equation and solved utilizing a finite volume element method. The presence of grinding balls is accounted for by incorporating a solid phase volume fraction in the Navier-Stokes equation. The encoding of this model into a C++ script is achieved using OpenFOAM®. Interaction between the grinding media and the slurry, or the DEM-CFD coupling, is described through buoyancy and drag forces. By conducting a series of simulations, the CFD-DEM framework is validated against published experimental data from selected laboratory and pilot-scale ball mills, with a focus on load positions. Remarkably, the simulated shoulder and toe of the media charge align closely with the published results, displaying a remarkable agreement within a 10% margin. Furthermore, the calibrated CFD-DEM model demonstrates minimal influence of slurry viscosity and material properties on load behavior. Notably, the shoulder position is observed to increase with mill speed. The proposed framework is capable to accurately simulate mill charge motion. However, further refinement is warranted, particularly in the modeling of drag forces. This framework holds significant promise for enhancing our understanding of wet mill loads and optimizing grinding processes.

Keywords

Wet ball milling Numerical Simulation

31.1 Advances in Ion Exchange to Mitigate Climate Change

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Abstract

Ion Exchange has been extensively used over the last 80 years for the treatment and purification of water. The ion exchange process has lent itself to other processes in the fields of hydrometallurgy, chlor-alkali, sugar and sweeteners, and wastewater treatment. Ion exchangers are able to selectively retain elements from dilute solutions that are not amenable to other processes, such as precipitation, membranes and solvent extraction. In concentrated solutions, selective resins are able to remove contaminants down to ppb levels

New developments have been made in the production and recycling of battery materials, including the recovery of lithium from seawater. The development of chelating resins has improved the purity obtained for cathode materials such as cobalt, nickel and manganese.

An interesting application is in the direct capture of carbon dioxide from air, and progress has been made in scaling up these plants in Switzerland and Iceland. The concentrated CO₂ can be stored underground, or reacted with ultramafic minerals to fix the carbon for the long term.

Lastly developments have been made in the treatment of Acid Mine Drainage (AMD), reducing the impact of toxic metals and the recovery of valuable components, such as Rare Earth Elements.

Ion Exchange and ion exchange materials can be considered as an important tool in the Chemical Engineer's toolbox for the solution of environmental problems, and the creation of a circular economy.

Keywords

"Ion Exchange", REE, AMD

31.2 A novel approach to model the environmental impact of wastewater treatment processes: a case study of hydrometallurgical recycling of lithium-ion batteries

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Abstract

The wastewater quality of different industrial effluent streams, produced by various chemical and metallurgical processes, is liable to vary greatly. This makes it difficult to compare the environmental impact of unique industrial wastewater streams. When performing life cycle assessment studies for chemical processes, researchers are often left using generalised wastewater treatment datasets to model their effluent streams. This approach disregards the thermodynamic properties of the effluent streams and only considers the volume of wastewater being treated. The aim of this investigation was to develop a simplified, consistent methodology for modelling the environmental impact of unique industrial wastewater streams.

The proposed method primarily involves calculating the Gibbs free energy of mixing which can then be analysed as either a regular- or a specific energy value, thereby highlighting the importance of both improving wastewater quality and reducing wastewater quantity to minimise the environmental impact of treating industrial effluent. Subsequently, to approximate the actual energy requirement for treating each individual wastewater stream, the Gibbs free energy of mixing may be divided by the exergetic efficiency of the appropriate wastewater treatment technology for that specific effluent stream.

To illustrate the utilisation of this methodology, a case study was performed which compared the environmental impact of wastewater streams produced by different hydrometallurgical lithium-ion battery recycling plants. The process with the lowest specific wastewater impact made use of citric acid as leaching reagent in comparison to a more traditional sulphuric acid-based lithium-ion battery recycling process. However, the citric acid-based process had a larger volume of effluent to treat and ultimately required more energy to achieve complete theoretical separation of the contaminants from the wastewater than the sulphuric acid-based process.

Keywords

Hydrometallurgy; LCA; Wastewater; Batteries; Recycling

31.3 A comparison of economic feasibility and environmental performance of biochemicals, biofuels, biomaterials and food-products as diversification options for the sugar industry

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Abstract

In recent years, the South African government has developed the Sugar Value Chain Master Plan 2030, which aim is to transform the local sugarcane industry to achieve future sustainability for its stakeholders, the bio-economy and the broader society. Diversification of its product portfolio is an essential aspect of future sustainability, which has been under investigation within the Sugarcane Biorefineries Research Chair at Stellenbosch University. Using standardised approaches to process simulations, techno-economic assessment and life cycle analysis, the economic and environmental performances of more than forty (40) potential products that can be derived from sugar, including biochemicals, biofuels, biopolymers and food-type products, could be benchmarked against each other. The production process of each product was simulated in Aspen Plus® based on published technical data for conversion, while economic feasibility was determined by the minimum selling price (MSP) for an acceptable return on investment, compared to its current market price. The greenhouse gas (GHG) emissions associated with each production process were determined using SimaPro® life cycle assessment (LCA) software. The calculated MSPs ranged between almost 0% and 400% of market prices, where 62% of the products had MSPs below 150% of their respective market prices. Comparison of economic feasibility and GHG emissions reductions compared to fossil-based products allowed prioritisation of preferred products for diversification of the South African sugar industry, each showing sufficient potential to justify feasibility studies towards identification of investment opportunities.

Keywords

Technoeconomic analysis, Environmental, benchmarking, bioproducts

32.1 Assessing the water impact of carbon capture technologies

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Abstract

Carbon capture technology has dominated environmental trends in the electric power generation industry, contributing significantly to greenhouse gas emissions and requiring significant amounts of water throughout the cradle to gate life cycle, essential to power generation operations. This work investigates the water impact of carbon capture technologies such as post-combustion solvent-based carbon capture, the integrated gasification combined cycle process, oxyfuel combustion, and solid oxide fuel cells for coal and natural gas power generation.

Water data was interrogated to a consistent basis to enable the creation of a metric that relates water impact to carbon dioxide avoided over the life cycle. The water impact index was used to assess water impact and is a function of water volume, quality, and the water scarcity index.

Gaps in the water data were estimated based on previous meta studies for each technology case. The preliminary results reflect that some carbon capture technology require additional water during operations, especially for cooling for both natural gas and coal fuel types; increasing the water impact per CO₂ avoided. However, technologies based on fuel cells and oxyfuels, have the least water impact per CO₂ avoided. We observe that water impact, when mapped as water withdrawal has similar trend to the WII for certain water qualities. This means that in the absence of quality and WSI data, the metric maintains it's usefulness as a stakeholder decision making tool.

Reducing the global warming potential can have a significant impact on water resources if the technologies are not holistically analyzed. This metric will enable stakeholders to understand the consequences of the adoption of carbon capture technology especially for countries at risk with high water stress indices.

Keywords

water, sustainability, impact, carbon, emissions

32.2 Developing a theoretical predictive fouling model for a Polyethersulfone (PES) Ultrafiltration membrane for wastewater treatment.

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Abstract

There are many ultrafiltration (UF) membrane fouling models that have been developed over the years. Though the basic principles and mechanisms for membrane fouling may be similar, the models are often not transferrable from one UF membrane type to another as each membrane is unique, particularly with the advent of new modified membranes functionalised to improve anti-fouling properties and performance. Even so, the existing models for conventional UF membranes have their weaknesses that need to be addressed. Many of the models are simplified and often loosely based on the classic Hermia models (developed for dead-end filtration applications). Most models focus on one type of foulant/fouling (organic/bio/chemical etc.) and do not account for the fouling types occurring simultaneously as observed under real operating conditions. This limits their use in simulating fouling under real operational environments. The literature demonstrates that there is still a need for more robust models that are adaptable and tuneable to real-life operating conditions. As more suitable models that can realistically simulate fouling are required, this work will address some of the concerns raised above by developing a model based on the characteristics of treated effluent from an industrial wastewater treatment plant. A commercial UF membrane will be fully characterised to determine its performance and fouling features, and the analysis will be used as the basis for building the predictive fouling model. The theoretical model will be validated by comparing it to results obtained from actual fouling experiments.

Keywords

Membrane, Ultrafiltration, Predictive, Model, Wastewater

32.3 Anticipating Environmental Risks: Harnessing Predictive Water Balances for Sustainable Power Generation at Kusile Power Station

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Abstract

Water scarcity in South Africa forces the power-generating sector to explore new, innovative ways to conserve water and to optimise the existing processes that require water. The installation of the Flue Gas Desulphurisation (FGD) system at Kusile, aimed at addressing SO₂ emissions, intensified the need for water management due to its substantial water demand. Fortunately, the FGD is flexible in water quality required for the process. Despite this, the FGD's water demand necessitated the installation of raw water lines to the FGD itself and the pollution control dam (PCD) where the FGD takes suction. Water accumulated in the PCDs as commissioning progressed. Delays in the Wastewater Treatment Plant commissioning led to FGD waste going to the PCDs instead of being treated. This, coupled with ash and oil contamination, resulted in a decline in PCD water quality to a point where it was no longer suitable for FGD consumption.

The FGD's inability to use wastewater from the FGDs, prematurely increased the raw water requirement and increased environmental pollution risks. To address this challenge, the station aimed to shift the FGD's water source back to wastewater, necessitating improvement in PCD water quality. Rather than resorting to costly chemical treatment, the station explored blending raw water and wastewater as a viable option.

Gathering essential information for blending feasibility involved assessing PCD water volume, flow rates, water quality, raw water quality, and FGD water quality requirements. Due to high PCD levels, a diffusion model was developed to estimate the time required for raw water to meet FGD standards. The model revealed that direct blending in the PCDs was unfeasible. Instead, an alternative approach involving blending within the FGD itself demonstrated raw water savings. This not only addressed water scarcity concerns but also showcased a sustainable approach to water management in power generation.

Keywords

Water, Environment

32.4 Zinc Oxide and Silver Doped Zinc Oxide Nanoparticle-Chitosan-PVPP Composite Beads for Immobilization of Laccase Enzyme

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Abstract

The exponential increase in the manufacture of consumer products such as textile, paper, dyes and agrochemicals over the years has resulted in an increased release of polyphenol pollutants and their derivatives. Majority of these phenolic compounds are highly toxic, carcinogenic and not degradable. Once in the water bodies, they also prevent penetration of sunlight into the water which inhibits the development of aquatic life. This necessitates their detection and quantification in the environment when evaluating the total toxicity of an environmental sample. Phenolic compounds are also present in fruits and vegetables and their products such as juices and wines. The polyphenol content in juices and wines affects their quality in terms of colour, flavour, stability, and aging behaviour hence the need for their quantification.

Biosensors modified with laccase have been developed for detection of laccase electron donors (phenolic compounds) and monitoring oxygen and laccase inhibitors. The construction of laccase-based biosensors is relatively simple as it doesn't require hydrogen peroxide as a co-substrate or any other co-factor for its catalytic activity. The biosensors are based on the principle of reduction of oxygen by laccase to water hence monitor the consumption of oxygen during oxidation of the analyte.

In this study we focus on immobilizing laccase enzyme on metal-polyaniline (PANI) composite modified glassy carbon electrode (GCE) for application in the sensing of organic pollutants. Modification of the Ag@ZnO-PANI/GCE electrode with laccase and polypyrrole provided an increased linear range, lower limit of detection up to nM concentrations compared to Ag@ZnO-PANI/GCE electrode alone. The composite material of PANI and polypyrrole offers enzyme stability, reusability, and prevents enzyme leakage while the conductivity of the Ag@ZnONPs enhance electron exchange between the enzyme and pollutant hence providing a highly sensitive biosensor.

Keywords

Laccase; nanoparticles; metal-polymer composite; immobilization.

33.1 Biorefineries for the production of biochemicals, biofuels, biomaterials and food-products as viable diversification options for the sugar cane industry

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Abstract

The global sugarcane industry aims to address challenges and opportunities stemming from the oversupply of international sucrose markets and the evolution of the global bioeconomy. To ensure sustainable prospects for the rural economies dependent on sugarcane, the industry is exploring diversification into bio-based products like chemicals, biomaterials, advanced biofuels, and novel food ingredients.

The Sugarcane Biorefineries Research Chair at Stellenbosch University has identified over 40 potential sugarcane-derived products. Through standardized approaches involving AspenPlus® process simulations, techno-economic assessments, and life cycle analyses, the viability and attractiveness of products and production methods for integration into existing sugarcane mills were evaluated. Minimum selling prices (MSPs) for acceptable returns on investment varied, with 62% of products demonstrating economic feasibility at MSPs below 150% of their market prices.

Diversification strategies include producing low-calorie sweeteners such as isomaltulose, allulose, short-chain fructooligosaccharides, and sweet proteins, which are crucial to the sugar industry. Multiproduct biorefinery scenarios have been developed to efficiently allocate available molasses to various products, providing economies of scale and flexibility in production rates, without oversupplying the global markets for these products.

Valourisation of lignocellulosic residues like harvesting residues and bagasse allows maximum value extraction and environmental benefits in sugarcane biorefineries. Integrated processing of lignocelluloses and molasses in 1G2G scenarios is a unique opportunity for sugarcane, offering technical and economic benefits that can be applied to multiple bioprocessing products. 1G2G bio-ethanol production already provides substantial cost reduction in lignocelluloses bioconversion, still to be applied for valuable products like isobutanol, 2,3-butanediol and bioplastics. Microbial strain development, especially in high-throughput biofoundry facilities, is an essential component for the development of new bioprocessing technologies. The application of synthetic biology, bioprocess development, and standardized tools like process simulations and economic assessments, presents opportunities for rapid progress for diversification in the global sugarcane industry, ensuring a sustainable and economically viable future.

Keywords

biorefineries, biofuels, sugarcane diversification

33.2 The efficient microbial production of cellobiose lipids (CBLs) as novel antifungal agents

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Abstract

Cellobiose lipids (CBLs) are a glycolipid biosurfactant that has grown in popularity due to their excellent antifungal activity towards pathogenic ascomycetes and basidiomycetes belonging to more than 52 different genera. These properties have recommended them for various industrial applications in agriculture, pharmaceutical, cosmetic, and food sectors. These compounds, which consist of a hydrophilic cellobiose disaccharide core glycosidically linked to a hydroxy palmitic acid, are interchangeably produced along with mannosylerythritol lipids (MELs), another glycolipid biosurfactant, by fungi of the family Ustilaginaceae, including *Ustilago maydis* and *Sporisorium scitamineum*. More recently, it has been discovered that these organisms prefer the production of CBLs over MELs under certain operating conditions. This study aimed to identify the effect of certain operating conditions, such as pH and carbon/nitrogen ratio, on the production of these biosurfactants with the aim of developing a bioprocess capable of preferentially producing CBLs from *Ustilago maydis* DSM 4500. Furthermore, This study considered the production of CBLs from a wild strain of *Sporisorium scitamineum* isolated from sugarcane samples originating from Kwa-Zulu Natal obtained from the South African Sugarcane Research Institute (SASRI).

Keywords

Upstream bioprocessing, Biosurfactants, Glycolipids, Antifungals

33.4 Eggshell-Derived Catalysts for Enhancing Biodiesel Synthesis from Waste Cooking Oil

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Abstract

The burgeoning demand for sustainable energy sources has prompted extensive research into biodiesel production as a promising alternative to conventional fossil fuels. As the quest for sustainable energy sources intensifies, the present study delves into an innovative approach for biodiesel synthesis utilizing waste cooking oil and, notably, waste-derived eggshell catalysts. The catalysts under investigation are prepared from eggshells and further modified with TiO_2 , SiO_2 , and Co_2SiO_4 to enhance their catalytic efficiency. This research focuses on elucidating the catalytic mechanisms and synergistic effects arising from the incorporation of TiO_2 , SiO_2 , and Co_2SiO_4 into the waste eggshell-derived catalyst matrix, in addition to catalyst stability. Analysis of physicochemical properties of the catalysts indicate that the modification alters the surface area of the catalyst and hence improves the yield per mass of the catalyst. The increase in the yield can also be related to changes in the basicity upon modification. The study further explores the influence of reaction conditions, in particular the alcohol to oil feed ratio and the reaction temperature on the leaching of CaO out of the catalyst into the product and hence biodiesel quality. Kinetic experiments indicate that the temperature changes affect the transesterification rate constant by changing the pre-exponential factor rather than the activation energy.

By leveraging waste eggshells as a sustainable catalyst precursor material, this research contributes to the circular economy while addressing the need for efficient and eco-friendly catalysts in biodiesel synthesis. The outcomes of this study not only shed light on the viability of waste-derived eggshell catalysts but also offer insights into the potential applications of these catalysts in large-scale biodiesel production. As the world transitions towards cleaner energy sources, the use of waste-derived catalysts in biodiesel synthesis provides a promising avenue for sustainable and environmentally responsible fuel production.

Keywords

Biodiesel, eggshell, cooking oil

36.1 Process Development for Ethanol Production from Cellulose-Rich Furfural Residues Annexed to a Typical South African Sugar Mill

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Abstract

Lignocellulosic biomass is a crucial feedstock for sustainable ethanol production as it is easily accessible in large quantities, does not compete with food supply and shows potential as a base for green chemicals. Furfural may be produced from sugarcane bagasse at around 180-200 °C and 10 bar, leaving behind high-cellulose-rich furfural residues with the potential for green chemical production.

Furfural residues from a furfural production plant annexed to a typical sugar mill were used for ethanol production without pretreatment. The study involved screening three different enzymes cocktails and yeasts for optimal ethanol production using varied fermentation methods, aiming at reducing production costs. Thereafter, the best-performing enzyme and yeast were used for process optimization in a 5-L bioreactor before scaling up to a 150-L bioreactor at optimal enzyme dosage and solid loading.

Furfural residues (FRs) used contained 38.29% cellulose, 31.18% lignin, 11.81% ash, and 18.72% extractives. The highest ethanol produced at an enzyme dosage of 5-10 FPU/g dry FRs and 20% (w/w) solid loading was around 40-45 g/L, using fed-batch simultaneous saccharification and fermentation.

Therefore, pilot ethanol production conducted in this study aids in quantifying the commercial feasibility of ethanol production from FRs. However, a full techno-economic assessment is needed for decision-making and assessing the process's economic feasibility.

Keywords

Furfural residues, Lignocellulosic biomass, fermentation

36.2 The Culturability of Five South African Vaginal Probiotic Lactobacilli in a Low-Cost, Plant-Based Soytone Growth Medium.

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Abstract

A comparatively low-cost, plant-based growth medium was assessed for the culturing of South African lactobacillus isolates intended for application as probiotics to treat bacterial vaginosis. This plant-based growth medium uses soytone as the primary protein source and is proposed as an alternative to the expensive and animal-derived MRS Broth. Though MRS Broth is widely used to isolate and cultivate lactic acid bacteria, it can be unsuitable for products intended for human consumption and its animal derived components lead to expensive bioprocess scale-up and industrial application.

The plant-based medium was constituted to have the same carbon concentration as standard MRS Broth. An analysis of carbon-to-nitrogen ratios revealed that the plant-based medium has a higher C/N ratio than MRS Broth, of 8.1 ± 0.04 versus 6.6 ± 0.06 . The growth of five lactobacillus vaginal isolates were tested in the two media. Four of the five cultures grew better in the plant-based medium than the MRS Broth in terms of average final cell densities and growth rates (49% and 11% higher, respectively). MRS Broth only supported similar growth kinetics upon tripling the concentration of its constituents, making the medium even more expensive. The costs of the proposed plant-based soytone growth medium and MRS Broth were modelled, and the plant-based medium was shown to be 44% less expensive per volume than MRS Broth.

This work thus demonstrates the feasibility and attractiveness of using such a plant-based growth medium for lactobacilli, from an economic and sustainability standpoint, and resolving limitations posed by animal-derived products.

Keywords

Probiotics, NitrogenSource, Lactobacillus, Growth Media.

36.3 Environmental and Economic Benefits from Strain and Bioprocess Improvements for Sustainable Production of 3-Hydroxypropanoic in a Sugarcane Biorefinery

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Abstract

3-Hydroxypropanoic acid (3-HP) is a highly sought-after chemical with significant global demand. Producing 3-HP through microbial conversion of sugars offers a promising alternative to traditional fossil-fuel-derived methods, potentially lowering greenhouse gas (GHG) emissions. Recent advancements in microbial engineering and bioprocess optimization have enhanced 3-HP production metrics, including yields, titres, and production rates. This study evaluates the theoretical maximum performances achievable through these advancements using flux balancing and pathway analysis, presenting a matrix of potential future yields, titres, and volumetric productivities.

The study also examines the financial and environmental implications of these technological improvements by determining the minimum selling price (MSP) required for a viable return on investment and assessing the associated life cycle GHG emissions. Specifically, 3-HP production was modelled in a biorefinery integrated with an existing sugarcane mill, using A-molasses as feedstock. The process was simulated using Aspen Plus® to provide technical data for economic and environmental evaluations.

Flux balance predictions were applied to genome-scale metabolic models for *Saccharomyces cerevisiae* and *Komagataella pastoris*, offering reliable estimates of maximum theoretical yields. The host organism choice significantly impacted 3-HP production, with each having distinct advantages and limitations. Pathway analysis highlighted the importance of precursor availability, competing reactions, and redox and energy balance for efficient 3-HP production. In *S. cerevisiae*, theoretical yields were similar across the Malonyl-CoA, β -alanine, and oxaloacetate pathways (0.77-0.79 g/g glucose). In *K. pastoris*, the oxaloacetate pathway's yield was 16-21% higher than the other pathways (0.99 vs. 0.82-0.85 g/g glucose). Mitochondrial localization of the Malonyl-CoA pathway in *S. cerevisiae* improved yields by 6%, but no improvement was observed in *K. pastoris*.

The potential financial and environmental benefits underscore the motivation to further develop these biotechnologies, aiming for commercially viable microbial 3-HP production.

Keywords

3-hydroxypropanoic acid acid, techno-economic analysis

36.4 Sustainable acrylic acid and propylene glycol production in a sugarcane biorefinery: A Techno-economic and environmental analysis

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Abstract

In response to the unfavourable effects of fossil resource utilization on the environment there is an increasing focus on alternative, sustainable feedstocks for fuels, chemicals, and materials production. This presents an opportunity to revitalize the global sugar industry to diversify its product portfolio by using sugarcane-based feedstock in biorefineries to produce biochemicals, bioplastics or biofuels. In the present study, second generation (2G) lignocellulosic sugarcane resources (bagasse and harvesting residues) as well as first generation (1G) sugar-based resource (A-molasses) produced in the sugar mill are considered as feedstock to produce acrylic acid (AA) and propylene glycol (PG) through lactic acid (LA) platform as intermediate. Platform chemicals are reported to be one of the fastest ways to replace fossil-based chemicals, with LA being one of the common platforms obtained from sugars. AA and PG constitute two of the largest markets of products obtained from LA as a platform. Four process scenarios were assessed in a biorefinery annexed to an existing sugar mill including a 1G AA production scenario, a 1G2G AA production scenario, a 1G PG production scenario and lastly, a 1G2G PG production. Each process was simulated using Aspen Plus® to generate mass and energy data used to determine the economic feasibility (using a discounted cash flow analysis) and conduct a life cycle assessment (LCA) using SimaPro software of each scenario. The 1G and 1G2G scenarios are compared in the context of a sugarcane biorefinery to determine whether the complete utilisation of the biomass resource available in the sugarcane mill yields an added advantage thereby making it competitive. The integrated economic and environmental assessment could identify the preferred bioproduct and feedstock for LA as intermediate in a sugar mill biorefinery.

Keywords

acrylic acid, propylene glycol, biorefinery

36.5 Effect of corncob hydrolysate on yield and productivity during fermentation by *Lactobacillus cereus*

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Abstract

Bacillus cereus can be used as a biological control agent in the agricultural industry because of its ability to help plants fight off certain bacterial pathogens. It is important to develop an efficient bio-manufacturing process of *Bacillus cereus* from industrially-biomass streams, that is cost-competitive with the current petrochemicals route. *Bacillus cereus* can grow on pure sugar feed streams which potentially competes with food resources. Carbon and nitrogen sources are the two biggest components in the fermentation medium, with glucose and yeast extract being the most widely used carbon and nitrogen sources, respectively. The high cost of glucose and yeast extract could be limiting factor for the industrial production of organic acids.

This research aims to identify a microbial production of glycerol and malic acid by *Bacillus cereus* as the biocatalyst, using biomass-derived feed streams. It has been proven by a previous study that *B. cereus* has the ability to utilize xylose, a hemicellulose derived sugar, for cell growth. However, there is limited research data on bio-organic acid production by *B. cereus*.

All fermentations were performed anaerobically, in a stirred reactor. To assess the effect of oxidation reduction potential (ORP) on the system, the ORP was continuously monitored. This research promises to provide much needed insight into the metabolism of *B. cereus* when grown on agricultural wastes and residues which is crucial for the integrated process development and fermentation industrial glycerol and malic acid production. This research further shows how the microbial *B. cereus* grows as a function of changes in the nitrogen and carbon source, the ORP as well as the organic acid concentration in the medium. The information obtained will help in developing methods to produce these organic products in yields and titres at a lower cost to the petroleum-derived route.

Keywords

Bacillus cereus, Xylose, Glucose, ORP

37.2 Novel application of biochar to improve hydrophilicity and the permeability of aramid nanofiber hybrid membrane

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Abstract

Mixed matrix membranes have received more attention due to their high separation performance, taking the advantages of both porous fillers and polymer backbones. This study involves the synthesis and characterization of Kevlar-biochar nanofiltration membrane for wastewater treatment. The hybrid membrane was synthesized by thermo-assisted phase inversion method and Biochar was synthesized from invasive wood species by pyrolysis.

The morphologies of hybrid membranes were inspected using Scanning Electron Microscope. The functional groups were recorded by Fourier transform infrared spectroscopy. The Brunauer-Emmett-Teller method was used to quantify specific surface area and pore volume of the membrane. The contact angles were assessed using a KSV CA meter.

Pyrolysis yield decreased as temperature and time increased (25.5% at 500 °C, 20.9% at 600 °C and 20% at 700 °C). Maximum carbonization was realized in between 500-600 °C. Scanning Electron Microscope images of biochar showed a mesoporous structure at 500 °C for 2 hours and macroporous structure at 700 °C for 1 hour both suitable for membrane synthesis. Fourier transform infrared spectroscopy of biochar revealed the presence of hydroxyl; carboxyl; alkynes and nitriles groups, as pollutants adsorption sites. Fourier transform infrared spectroscopy results of pristine membrane revealed the presence N-H, C=O; C=C, C-N amide II; phenyl-N; carboxylate groups. With the addition of biochar, the N-H and C=O peaks increased in the hybrid membrane as the C-H, alkynes and nitrile peaks disappeared on the biochar. This confirmed biochar's dispersion in the Kevlar matrix and improvement in the membrane hydrophilicity. Scanning Electron Microscope images of pristine membrane showed a dense and smooth surface. However, rougher surface with more peaks and valleys were observed on the hybrid membrane. The obtained membrane with biochar as additives provided extra channels for molecular transfer.

Keywords

biochar; Kevlar; mixed matrix membrane

37.3 Effect of ethanol as a solvent for surfactants in cassiterite ore flotation

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Abstract

Cassiterite is a major source of tin. It is generally found in deposits such as pegmatites usually associated with numerous other minerals. In addition to challenges arising from liberating the cassiterite, its composition as an oxide mineral suggests a poor response to surfactants due to its inherent hydrophilic surface properties. Metal ions, such as lead, are used to activate the mineral surface and complex surfactants are used to selectively float the mineral. Lead ions are not environmentally friendly, and the use of complex reagents makes the procedure relatively uneconomical.

An investigation was conducted to test the possibility of floating cassiterite particles in the presence of ethanol, as a solvent, to overcome the challenge of surface hydration and eliminate the use of lead ions. Benzohydroxamic acid (BHA) and salicylhydroxamic acid (SHA) were used as surfactants both in water and dissolved in ethanol.

Micro-flotation experiments of cassiterite particles were conducted using a modified Hallimond tube with nitrogen gas to generate bubbles for the flotation of particles. After flotation was completed, particles were filtered and dried in an oven for 2 h at a temperature of 130 °C. Dried particles were weighed and flotation recovery was calculated. An improvement in the flotation recovery of cassiterite particles of c.20 % was observed when surfactants were dissolved in ethanol as compared to distilled or de-ionized water. It can be postulated that, when surfactants were dissolved in ethanol, their solubility increased, therefore facilitating higher adsorption onto the mineral surface and thus resulting in improved flotation recovery.

Keywords

Cassiterite, flotation, ethanol solvent, surfactants.

38.1 Inclusion of nano-silver compounds in RO membranes as solutions to fouling by microbes and natural organic matter during seawater desalination

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Abstract

Strategic economic sectors such as agriculture and manufacturing face a threat of contraction due to water scarcity. Water scarcity can be defined as inadequate volumes of fresh water available to meet socioeconomic demands. This may be caused by inappropriate allocation of potable water, infrastructure mismanagement, contamination of natural water bodies, and climate change. Seawater reverse osmosis has proved to be a viable method for desalination and has assisted in addressing challenges associated with freshwater shortages. A limitation to the sustainable use of this technology is membrane fouling; which is often caused by adsorption, accumulation and crystallization of microbial, organic, and inorganic constituents on the feed water-membrane interface. The observed fouling deteriorates membrane integrity, in which decreased permeate flux, salt rejection, permeate quality, and membrane lifetime are apparent. In this study we aim to fabricate polyamide (PA) thin-film composite membranes (TFC) and thin-film nanocomposites (TFN) coalesced with silver sulfide (Ag_2S) nanoparticles (NPs). Reports show that Ag_2S NPs possess photocatalytic and antibacterial properties, which can reduce membrane fouling by organic matter and microbes. XRD patterns matched those of monoclinic Ag_2S NPs. It was determined from UV-Vis that bandgap energy was 2.32 eV, which corroborates with the visible region of electromagnetic radiation. The fabrication of TFN membranes coalesced with Ag_2S NPs (20, 30, and 50 mg) was done via inverse polymerization on a polysulfone support membrane. The pure water flux (J_o) obtained by all TFN membranes was above 25 L/m²h. Moreover, the 30 mg loaded TFN membrane attained the highest J_o of 32.7 L/m²h. Salt rejection of the nanocomposite membranes was above 98%, which deems them suitable materials for seawater desalination.

Keywords

Water-security, desalination, membrane fouling, thin-film-nanocomposites

38.2 Treating Persistent Pollutants, Pesticides, PFAS, with FILTRASORB® Granular Activated Carbon

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Abstract

Providing clean and safe drinking water is fundamental to life and activated carbon is one of the most effective technologies for the purification of water.

Chemviron, European Operations of Calgon Corporation was an original pioneer in widely installing granular activated carbon in European drinking water treatment works against a variety of impurities: taste and odour and compounds of algae metabolism, cyanotoxins, dissolved compounds from organic decay, pesticides and a wide range of principle ingredients, endocrine disruptors and other synthetic toxic molecules found in water sources at trace concentrations, the so-called emerging micro-pollutants. The Chemviron range of FILTRASORB® activated carbons which can be effectively custom recycled by reactivation for reuse provides an effective sustainable treatment solution.

Since the general acknowledgement of perfluorinated compounds (PFAS) in water sources in the early 2,000s, Chemviron, along with Calgon, has systematically tested the ability of its own materials to remove those, and also that of a large variety of commercially available activated carbons. Throughout the R&D group, extensive batch and rapid column tests were conducted in the laboratory. Further, positive experience of use in the field started to accumulate. Today, we are proud of supplying a proven solution to eliminate PFAS from surface and ground water, also in wastes, remediation and water recovered for any purpose, particularly through the family of re-agglomerated carbons FILTRASORB®. We have further gathered evidence that such perfluorinated compounds are destroyed during usual thermal reactivation (this based on our full-scale trials as well as independent, scientific reports), which will make activated carbon a sustainable and effective means to reduce significantly the presence of these objectionable compounds in the environment.

Keywords

#ActivatedCarbon, #PFAS, #Chemviron, #WaterTreatment, #Filtratorb

38.3 A comparison between powdered activated carbon (PAC) and granular activated carbon (GAC) for water treatment

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Abstract

Activated carbon is widely used in industry for both potable and wastewater treatment. It is made from various materials; the most common are wood, coconut and coal. Each has unique features and capabilities. Typically, coal based activated carbon is used for potable and wastewater due to its high efficiency for colour, taste, odour, organic and toxic substances removal.

Activated carbon is produced in powder, granular, pelletised and other forms. Powder and granular are used in liquid phase applications, while pelletised is mostly used for gas phase.

Powdered activated carbon (PAC) has the advantage of seasonal dosage (when necessary), high surface area and fast kinetics; however, handling and dosing is more complicated. The PAC also needs to be filtered from solution and the disposal is expensive.

Granular activated carbon (GAC) is easier to operate, although installed permanently it only loads when contaminants are presents and it also has a longer life span. However, it has slower kinetics and requires larger vessels. Another key advantage of GAC is that it can be reactivated which significantly reduces costs and also reduces the need for waste disposal.

Reactivation of GAC is achieved by high temperature thermal treatment to remove loaded organics and contaminants from the pores. Reactivated carbon exhibits similar performance to virgin activated carbon at about a third to half the cost depending on the carbon and spent condition.

PAC and GAC are effectively used to remove contaminants. The use of each is dependent on infrastructure, cost and treatment objectives.

Keywords

#PACvsGAC, #ActivatedCarbon, #PotableAndWastewater, #Reactivation, #WaterTreatment

39.1 Characterization of corrosion products formed on carbon steel after exposure to a bacterial consortia from a cooling tower

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Abstract

In this study FTIR (Fourier Transform Infrared) with Raman spectroscopic methods were used to analyze carbon steel surfaces with a bacterial biofilm. These methods are rarely used in the petrochemical industry. This study presents insights into multispecies bacterial functioning in forming iron oxides, which may assist the industry in making informed decisions for future steel modifications in cooling water systems. Biofouling is a part of a world-wide problem where a cost of corrosion of US\$2.5 trillion was projected in 2013. Carbon steel pipe material, A106 B was exposed to bacteria from a cooling tower. The bacteria was grown in a batch reactor, under conditions similar to that of the cooling tower in an aerobic environment with a constant temperature of 35°C. Exposure days 3, 6 and 13 were evaluated in this study based on a previously determined growth model. Iron-reducing bacteria (IRB) abundantly attached to the surface of the alloy on day 3 and was determined from previous work. FTIR spectroscopy results showed that the IRB produced acetylenic compounds in the form of acetic acid on days 3 and 6, with an intense peak observed on day 6 in the region of 2500-2000 cm^{-1} , the organic acid is known to aid in equipment failures. Moreover, a unique transition metal carbonyl functional group was evident on day 3, which showed an intensified peak on day 6. The Raman spectroscopy results showed three corrosion products; lepidocrocite, goethite and magnetite, the protective magnetite layer was formed after long-term exposure on day 13. It is imperative to understanding bacterial populations at these stages as they perform important roles in phase transformation impacting the steel in different ways. The determination of the C-Fe bonds provided evidence of possible carbon-metal bonding which may alter the bonds with iron and can be investigated in future work.

Keywords

carbon steel, bacterial consortia, corrosion products, Raman, FTIR

39.2 Physicochemical properties of cellulose nanocrystals (CNCs) extracted from post-consumer cotton/polyester blended fabrics.

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Abstract

The utilization of cotton waste as precursors in the synthesis of nanocrystalline cellulose has gained significant attention. This approach offers a sustainable solution to address the growing concern of textile waste accumulation as it not only contributes to waste management but also provides a potential avenue for the development of new applications in various industries. This study aimed to isolate and characterize cellulose nanocrystals obtained from a mixed post-consumer textile waste stream. The process involved the extraction and separation of cellulose nanocrystals from the waste material, followed by purification. Acid hydrolysis with sulfuric acid followed by ultrasonication was employed to extract CNCs from discarded fabrics composed of cotton and polyester. The obtained CNCs were characterized in terms of yield, crystallinity, morphology, particle size, zeta potential, surface chemistry and thermal stability. The resulting yield, based on cotton content, ranged from 38% to 69% with a high crystallinity ranging from 79% to 86%. The CNCs also demonstrated exceptional purity, resembling similar structural, physical, and chemical characteristics as those extracted from virgin sources. Almost all the polyester fibers present in the original textiles were successfully recovered in a convenient state suitable for efficient recycling.

Keywords

textile waste, cellulose-nanocrystals, acid hydrolysis

39.3 Perspective on Metal-organic Frameworks-based Atmospheric Water Harvesting Systems Towards Universal Adoption

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Abstract

The global water crisis represents one of the most critical challenges faced by humanity today. Traditional sources of freshwater are becoming increasingly scarce due to over-extraction, pollution, and climate change. In response, sorbents-based atmospheric water harvesting (AWH) technologies, particularly those utilizing metal-organic frameworks (MOFs), have emerged as a promising solution. The highly porous features with exceptional water adsorption capacities make MOFs well-suited for AWH applications. This perspective provides a comprehensive overview of MOF-based AWH systems and highlights their potential to address the global water scarcity issue. More specifically, the fundamental principles of sorption-based AWH technologies are discussed focusing on the unique properties of MOFs that facilitate efficient water capture from the atmosphere. Key factors influencing the performance of MOF-based AWH systems including climatic conditions, sorbent properties, and system design are also examined. Furthermore, the recent advancements in MOF development such as the large-scale production, creation of composite sorbents, improvements in mass transport and heat transfer, the engineering of structural defects and the integration of MOFs into functional AWH systems are also explored.

Keywords

Metal-organic Frameworks, Atmospheric water harvesting

40.1 Evaluation of the water treatment plant performance using process capability assessment

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Abstract

To provide the higher quality and stable water to the customers, the water utilities themselves should establish the proper maintenance and management programs to enhance the availability of plant facilities and equipment in the water treatment plant. It is therefore the responsibility of water utilities to conduct a process audit at least annually as prescribed by the national regulator. Within the process audit, one of the most important part is the process capability assessments. The water treatment process capability assessment is a tool that is used to analyse whether the water treatment is operating effectively in terms of producing water that is (1) free of pathogens, free of diseases, and SANS 241 compliant, (2) palatable, (3) does not corrode or scale forming in the distribution system and households, (4) and the potable water is produced at an affordable cost.

The process capability assessment model focuses on the current condition of the water treatment plant (snapshot in time) and the historical performance of the facility taking into account the seasonal variation of the raw water quality versus the overall performance of the facility. Activities undertaken in the water treatment process capability assessment include evaluation of major unit processes, assessment of the plant performance, and prioritization of the performance limiting factors. This paper outlines the approach to water treatment process capability assessment for conventional water treatment processes and the experience over the years in a bulk water utility.

Keywords

process capability, plant evaluation, optimisation

P1: Developing a trickle bed bioreactor for the production of glycolipids biosurfactants

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Abstract

Glycolipid biosurfactants are a class of surface-active compounds of microbial origin that consist of a hydrophilic sugar core attached to various fatty acids that act as hydrophilic tails. This class includes many different structurally unique biosurfactants, such as mannosylerythritol lipids (MELs), cellobiose lipids (CBLs), rhamnolipids, and sophorolipids. Due to their wide structural diversity, combined with their excellent surface-active properties and environmental compatibility, these compounds have found applicability in various industries. Both MELs and CBLs have been extensively studied within our research group and it has been observed that oxygen availability plays a crucial role in their production. Furthermore, increased glycolipids production in shake flasks has been associated with the formation of biofilms in the reactor vessel. Therefore, this study will aim to utilize the results from the aforementioned investigations to design and implement a trickle bed bioreactor to achieve enhanced production of glycolipid biosurfactants. This bioreactor configuration has been identified as a possible route to improve the scalability of glycolipid production since it facilitates biofilm formation while providing high oxygen availability to glycolipid-producing microbes.

Keywords

Biosurfactants; Glycolipids; Bioreactor; Process development

P2: Enhancing anaerobic digestion of organic wastes through micro-aeration

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Abstract

Anaerobic digestion (AD) is a mature technology used to process several types of organic feedstocks while simultaneously producing biogas. The process helps to reduce greenhouse gas (GHG) emissions by capturing the methane produced in the biogas instead of releasing it into the atmosphere. However, the process has several pitfalls, such as a slow hydrolysis rate for lignocellulosic feedstocks, instability at high organic loading rates, and production of hydrogen sulphide in the biogas. These issues can potentially be overcome through micro-aeration, by exposing facultative bacteria to low levels of oxygen, leading to an increase in the growth rate, activity and diversity of the facultative bacteria and the associated production of hydrolytic enzymes. This in turn results in improved hydrolysis rates and biogas yields, a more stable process through controlling volatile fatty acid concentration, and hydrogen sulphide gas scavenging. The project aimed to determine the role that micro-aeration plays in improving the hydrolysis of lignocellulosic biomass and recovering process stability after a volatile fatty acid accumulation occurs during AD of organic waste. This was shown by developing an effective micro-aeration delivery system, assessing the most effective aeration rate, and determining the effectiveness of micro-aeration during co-digestion. Mono-digested corn stover was compared to its co-digestion with food waste based on an optimised carbon-to-nitrogen ratio of 30:1. Three aeration rates of 0.1, 0.6, 0.9 L-O₂/L-reactor/day for corn stover were tested and found to show no improvement. Five additional rates between 0.002 - 0.03 L-O₂/L-reactor/day for corn stover mono-digestion and three aeration rates of 0.02, 0.03, 0.1 L-O₂/L-reactor/day for corn stover with food waste co-digestion was assessed. Improving biogas production using low levels of air further enhances the appeal of anaerobic digestion as an approach to waste diversion and renewable energy production.

Keywords

Anaerobic digestion; Micro-aeration; Hydrolysis; Process-stability

P3: Amino-Functionalized Metal Organic Frameworks (MOFs) For Biogas Purification and Prediction Using Machine Learning (ML)

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Abstract

Anaerobic digestion (AD) generates raw biogas from waste organic materials through biochemical processes. The application of the AD process and utilization of biogas is increasing as a renewable energy source. Raw biogas generated in the AD process contains undesired constituents (H_2S , CO_2 , NH_3 , siloxanes and VOCs). These gases affect the direct application of biogas, and are a concern in biogas utilization. Conventional physico-chemical biogas purification methods are energy-intensive and expensive.

Raw biogas containing H_2S must be treated prior its end-use application, as H_2S is toxic and corrosive. NH_3 , siloxanes and VOCs are unwanted pollutants. NH_3 induces corrosion in engines, siloxanes in silicium deposits causes abrasion, whereas combustion of VOCs such as benzene give an unpleasant odour to biogas, and toxic to human health. Comprehensive biogas purification is required prior to its application, i.e. to generate electricity or biomethane upgrade

To promote sustainable and green technologies, renewable technology such as MOFs have the potential for biogas purification owing to their intriguing characteristics of the great specific surface area, extremely high porosity, post-synthesis modification, significant chemical and structural stability.

The functionalization of MOFs is a primary and effective strategy for altering the interaction between the MOF framework and the guest species to obtain high gas capacity. In this study, MOFs embedded with amino ($-NH_2$) functional groups will be employed for prediction of gas and their efficiency in biogas purification. Moreover, for enhancement of gas adsorption capacity and kinetics.

ML is a valuable tool in chemical engineering with the potential to overcome limitations of mechanistic modelling, as it can learn complex behaviours and adapt to new data. ML algorithms such as random forest, decision tree, linear regression, SVM will be utilized to predict the adsorption capacity of these toxic gases using MOFs. The best performing ML algorithm and MOF materials will be studied.

Keywords

MOFs, ML, Biogas, Anaerobic Digestion

P4: Statistical analysis and optimization of NaBH₄ based hydrogenation process for xylitol production under mild conditions

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Abstract

Xylitol is a sugar alcohol that is commercially produced by hydrogenation of xylose using Raney nickel catalyst, however this method employs high energy and harsh reaction conditions. Herein, a low-cost and environmental-friendly process for the hydrogenation of xylose into xylitol was designed. A Response Surface Methodology (RSM) approach was employed to optimize the hydrogenation process to produce xylitol. A Response Surface Methodology was used to determine the significant effect of independent process variables and to optimize the hydrogenation of xylose into xylitol. Reaction temperature and pH were significant parameters in the hydrogenation process, whereas reaction time variable was insignificant. Increasing the reaction temperature led to a degradation of xylitol, while lowering pH favored the xylitol formation. The experimental data of the fitted quadratic model for optimization, offered a high determination coefficient (R^2) of 0.9407. The optimum process conditions obtained were pH (3.0), reaction temperature (298K), and reaction time (60min), which presented a maximum xylitol yield of 73.78%. The composition of xylitol obtained was quantified by High-Performance Liquid Chromatography (HPLC), and the xylitol in a syrup solution was further identified by Pyrolysis–Gas Chromatography–Mass Spectrometry (Py-CG/MS).

Keywords

Xylitol; Hydrogenation; Process Optimization; Green-Process

P5: A design of multiple process e-waste recycling plant

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Abstract

New, sustainable metal recycling methods should be introduced into the global economy to meet the increasing demands for critical metals used in electronic and electrical devices. Globally, 53,6 million metric tonnes of e-waste was produced in 2019, which increased to 59,4 million in 2022.

According to the United Nations Global E-waste Monitor, 415.5 kilotonnes of e-waste was produced in South Africa in 2019 of which only 14% of the total volume of e-waste is recycled. Limited e-waste collection capacity poses a significant issue regarding a commercial-scale recycling facility.

A multiple-purpose facility is proposed to increase the amount of e-waste processed in a single plant, making it economically feasible in low e-waste collection countries such as South Africa. Neodymium-iron-boron magnets, lithium batteries, luminophore lightbulbs and printed circuit boards were considered as the e-waste sources due to their abundance in the overall volume of e-waste, in addition to the multiple critical metals contained in this waste fraction. In the design, the process can be easily modified to accommodate different waste streams available for processing at a given time without hindering the operation in the long term.

Hydrometallurgical processing utilising leaching, extraction and precipitation stages was chosen as it demands less energy than the pyrometallurgical approach and generates significantly lower greenhouse gas emissions. In this process, different mineral acids in varying conditions selectively leach metals from the e-waste into a solution. This solution is then contacted with an immiscible organic phase containing selective extractants, allowing the separation of different metals, which then can be precipitated, forming final products of high purity.

The feasibility of the process design is an ongoing study. Optimisation and adjustments of the particular stages for the individual e-waste fractions are important for the simplification and transition between processes within a single e-waste processing facility.

Keywords

Sustainability, Recycling, E-waste, hydrometallurgy, design

P6: Design of an engineered model for *in vitro* testing of biotherapeutics for treatment of bacterial vaginosis

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Abstract

Recent years have seen an increase in research into the vaginal microbiome. Bacterial vaginosis (BV) is of particular interest, given its adverse reproductive- and obstetric-related complications in women of child-bearing age. Laboratory vaginal models are being developed not only to explore the aetiology of BV, but also to investigate alternative forms of therapy that reduce its recurrence. In this project, we aim to engineer a laboratory model that is representative of the human vaginal environment, with which the efficacy of potential probiotic vaginal isolates can be tested.

Achieving this aim involved studying two facets: the growth of vaginal bacteria and mammalian vaginal cells under *in vivo*-like conditions – specifically, an acidic, microaerophilic environment with a medium simulating vaginal fluid (MSVF). Data from the *Lactobacillus* growth curves showed decreased maximum specific growth rates (μ_{\max}) for all the strains in use, when subjected to these harsh environments. *L. rhamnosus* GG, *L. crispatus* 70.6PA and *L. mucosae* 90.13PA achieved μ_{\max} values of 0.06/h, 0.04/h and 0.11/h respectively, down from 0.55/h, 0.14/h and 0.24/h under near-neutral, nutrient-replete conditions. VK2/E6E7 vaginal cell viability (determined via a Trypan Blue stain) varied depending on whether the cells were in suspension or in a monolayer. Suspended cells achieved a viability between 70% and 85% when subjected to an acidic but nutrient-replete Keratinocyte Serum-Free Medium (KSFM) in an atmosphere with different CO₂ concentrations. However, no cells survived when suspended in acidic MSVF. In the monolayer case, cells were not viable when exposed to either acidic KSFM or MSVF. Therefore, further model development may require the use of near-neutral KSFM to maintain VK2/E6E7 viability.

Further research is underway to establish a more robust model in which vaginal cells and vaginal bacteria can persist together in these *in vivo*-like conditions, thereby, presenting an opportunity for exploring epithelial integrity under various environments.

Keywords

Probiotics; bacterial vaginosis; vaginal model

P7: Development of environmental specimen bank (ESB) in South Africa with the pursuit of sustainable development goals

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Abstract

Environmental specimen banks (ESBs) play a significant role in preserving and archiving samples from the environment without altering their chemical compositions for future research and monitoring purposes [1]. In the context of South Africa's commitment to sustainability and regenerative practices, establishing an ESB offers a unique opportunity to display their innovative initiatives. South Africa's environmental consciousness has been demonstrated through its sustainability and regeneration methods. By establishing an ESB, the country can enhance its significance in commitments of safeguarding biodiversity, ecosystems, and human health. The ESB will serve as a repository for diverse environmental specimens, including soil, water, air, and biological samples [2,3]. Moving Beyond "Business as Usual", the ESB project represents a break from regular techniques approaches. This involves redesigning procedures, products, and resource utilization. By collecting and storing specimens, South Africa participates in a global effort to understand environmental changes and their impact on human health. The ESB will store a wide range of specimens, reflecting different ecosystems and chemical compositions capturing the intricate web of interactions. Researchers can analyse these specimens to assess pollution levels, monitor emerging contaminants, and track their long-term trends. Addressing Sustainable Development Goals (SDGs), ESB aligns with several SDGs. By monitoring water quality through stored samples following the SDG 6 (clean water and sanitation), ESB can contribute to ensuring clean water availability in South Africa. The ESB indirectly supports energy conservation efforts by promoting responsible resource management responding to SDG 7 (Affordable and Clean Energy). Following the SDG 12 (Responsible Consumption and Production), By studying waste generation patterns, the ESB informs strategies for minimizing environmental impact. Following the SDG 15 (Life on Land), The ESB also aids in biodiversity conservation, preserving genetic diversity for future generations.

Keywords

ESB, SDGs, Environment, Experiments, Africa

P8: Desalination Of Water for Sustainable Development: A Non-Conservative Alternative for Conserving Scarce Water Resources

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Abstract

There is a need for good quality water for domestic, agricultural and industrial purposes all over the world. Traditional sources of water such as groundwater, and water from rivers and lakes are unable to fulfil the water requirements of communities. The population of African countries is growing and the water needs of our people is increasing. So, there is a need to consider non-traditional sources of water such as sea water or recycled or reused water. The considerations as to what type of process to select will depend on the following: required capacity; plant location; type (concentration) of sea water; energy cost and environmental impact.

Keywords

Desalination; Ocean thermocline energy

P9: Solar Desalination by Black TiO₂ and 3D Printed Photocatalysis Mounted on Cellulose Nanocubes as the Support Material

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Abstract

This study aims to apply 3D printed graphene oxide onto a buoyant porous polymeric material to increase the exposure to sunlight and the possibility of fast thermo conductivity leading to heating of water to thermally extract clean water from saline water. The evaporator is to be constructed and its morphology, elemental composition, porosity, broadband solar absorption potential, photothermal performance, and interfacial desalination potential are to be assessed. Solar interfacial evaporation is required to comprise a solar absorber which has efficient broadband solar absorption potential, and adequate thermal insulation system which circumvents the heat loss to the bulk water and localising the solar-to-thermal conversion process at the liquid water interface and is required to be a floating structure which can simultaneously maximise the evaporation rate and transfer of liquid to the evaporative surface. The 3D printing of graphene onto a cellulose nanotube is required to increase the specific surface area and ensure a high level of porosity with a high pore volume and a mesoporous structure.

Traditional solar water evaporation systems produce steam by means of volumetric heating of the bulk water body. Traditional solar-driven desalination is susceptible to low efficiency due to the wastage of solar energy when the non-evaporative bulk water is heated. This form of interfacial solar-driven desalination centres around the localisation of heat at the water-air interface which produces outstanding photothermal conversion potential and evaporation rates. Freshwater is in short supply around the globe, freshwater supplies are being aggravated by rapid economic and population growth, industrialisation, and urbanisation. This study will demonstrate the promising potential of the 3D hybrid composite for real-world application and the properties which make it plausible to utilise unlimited solar energy for the generation of freshwater from copious hypersaline seawater as well as other saline water sources which will overcome global water shortage.

Keywords

Graphene, interfacial, solar absorption, mesoporous

P10: Simulation, Optimization and Economic Evaluation of a Coal -to -Liquid (CTL) process.

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Abstract

The global energy sector is grappling with ensuring both energy and environmental security simultaneously. Energy demand has greatly increased over the years, impelled by rapid population growth and robust economic development. In the transport sector, energy consumption is projected to be 30% higher by 2050. Despite the advent of electric vehicles, liquid transport fuels are expected to play an important role in the future energy mix. However, crude oil, from which they are derived is marred by dwindling reserves and geopolitical instabilities in oil producing regions. So, interest in other hydrocarbon sources such as natural gas and coal has been renewed. Coal is abundant, equally distributed and exhibits more stable supply and prices. Coal – rich countries have embarked on a quest to develop sustainable Coal – to -Liquid (CTL) technologies to bolster their energy security and reduce reliance on imported oil.

CTL is a pivotal avenue for utilising low-grade coal reserves to produce synthetic fuels for the transport sector. It is a mature and commercially deployable technology but the current mainstream processes are challenged by operational inefficiencies, high carbon emissions and high production costs. Studies have been conducted to model the CTL process but mainly focus on a specific unit. Limited work has been done to simulate and optimise the performance of the complete process. This study endeavors to employ Aspen plus software to develop comprehensive models of the complete CTL process with the overarching goal of providing insights into the technical, economic and environmental aspects of the process. The detailed simulation captures the intricate interplay of chemical reactions, mass transfer, and process conditions, laying the foundation for subsequent process optimization. Sensitivity analyses are conducted to evaluate the robustness of the optimized solutions. Economic evaluation is conducted to critically assess the feasibility process.

Keywords

Simulation, CTL, FTS, Polygeneration, CCS

P11: Innovative Coking Coal Blending Model Development and Optimization

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Abstract

The global expansion of the iron and steel industry has had a considerable impact on the international coking coal market in recent years. This modification has resulted in substantial increase in coal costs and presented additional difficulties in obtaining coals that were previously readily available in the market. To increase coal quality and lower expenses, there must be estimated coke quality and optimize the coal blending scheme. In this dissertation, a modelling and optimization approach that is based on the specific characteristics of the coal blending and coking process. Additionally, the consumption of extant coking coal reserves is degrading in quality on a global scale. In conclusion, coal transportation in South Africa is hindered by an inadequately developed infrastructure. On account of these considerations, it is crucial to utilize available raw materials for coke production sparingly and employ proved technologies so as to preserve the iron and steel industry. To enhance the strength of coke by replacing coking coals with non-coking coals or upgrading coking coals, a substantial amount of research has been devoted to examining various technologies and processes, including coal pre-treatment, coal preheating, stamped charging, improved briquetting charging, formed coke, petroleum coke addition, and chemical additives to coal blends, including diesel, oil, and tar. Consequently, the primary aim of this research is to examine the impact of proximate and ultimate analysis of progenitor coking coal on coal blend. Additionally, this study seeks to advance the development of predictive models for coal blending across various scenarios that are taken into account in this research. This will be achieved through the manipulation of the proportions of imported coking coals in the base composition. An exhaustive analysis of the mixture will be conducted employing well established analytical techniques.

Keywords

Coking, Quality, Model, Development, Optimization

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