Nutrient in a Circular Economy Summit 2022

First summit

Organised by

Australian Research Council

Nutrient in a Circular Economy Research Hub

University of Technology Sydney

8th July 2022

Summit programme

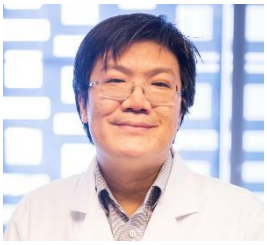
Time	Speakers	Presentation title
Session 1		
2:00 PM	All CIs and Hub team	Brief introduction
2:10 PM	Hokyong Shon, NiCE Hub Director, UTS	Nutrients in a Circular Economy: welcome and Hub update
2:40 PM	Stefano Freguia, University of Melbourne	A circular economy of nutrients through direct urine bioconversion to fertilisers with microbial electro-concentration (Ugold)
2:55 PM	Cara Beal, Griffith University	A NICE systems thinking approach: understanding the health, economics, regulatory and public acceptance aspects of urine recycling for fertilisers
3:10 PM	Mikel Duke, Victoria University	Innovative process development and demonstration for nutrient recovery from complex industrial solutions
3:25 PM	Discussion	
3:40 PM	10 min short break	
Session 2		
3:50 PM	Jason Prior, University of Technology Sydney	Markets and governance for a thriving circular nutrient value chain
4:05 PM	Jeff Powell, Western Sydney University	Context-dependence of fertiliser end-use benefits
4:20 PM	Bernadette McCabe, University of Southern Queensland	Optimisation of urine-derived and biosolids-derived biofertilisers
4:35 PM	Liu Ye, University of Queensland	The impact of sustainable nitrogen management on carbon footprint for water utilities
4:50 PM	Discussion	
5:00 PM	Meeting closes	

Nutrients in a Circular Economy

Ho Kyong Shon, Sherub Phuntsho, Leonard Tijing and Ibrahim El-Saliby

University of Technology Sydney

Brief bio of lead CI/presenter



Professor Hokyong Shon is **a Head of Discipline, Environmental & Water Engineering,** a Director of ARC Research Hub for Nutrients in a Circular Economy at the School of Civil and Environmental Engineering, **University of Technology Sydney, and an ARC College of Experts member**. His research interests include a circular economy, sustainability, resource recovery, desalination and water treatment since 2000.

Abstract

Increasing population growth and rapid urbanisation is placing increasing pressure on existing water infrastrucuture and agricultural food productivity to meet future supply and demand. The World Bank predicts that by 2050, the global population will be nine billion, placing a 50% increase in agricultural food productivity and 15% increase in water withdrawals. With these fertilise shortages, there is a strong market driver for bioavailable nutrients through a renewable approach. Decentralising the treatment of our wastes is especially interesting as it has the potential of making an industry, notoriously thirsts in energy, water and raw materials, a net producer. It was also demonstrated that the integration of source-separation of urine, faeces and greywater would help to achieve this goal, while also opening new opportunities for building a more flexible and resilient urban wastewater network. Urine valorisation is attractive due to its low volume, high nitrogen (N) and phosphorus (P) concentrations (80% of N and 50% of P inputs into sewers), and relative ease of collection and storage. As such, it has often proven to be a suitable raw material from the production of fertiliser, energy and water (this last one mainly on board of the International Space Station). However, conventional technologies often struggle in dealing with urine alkalinity, high NH_3 and dissolved organic carbon concentration (i.e. 5 to 10 g.L-1) and high salinity (i.e. 4 to 9%). That is why, the strong chemical resistance, small footprint, tuneable selectivity and versatility in the operation of processes makes them an ideal technology to extract value from human urine. As such, this presentation will cover four main research themes from the ARC Research Hub for Nutrients in a Circular Economy (ARC NiCE Hub) in terms of economic, commercial, environmental and societal benefits.

A circular economy of nutrients through direct urine bioconversion to fertilisers with microbial electro-concentration (Ugold)

Stefano Freguia

University of Melbourne

Brief bio of lead CI/presenter

Stefano Freguia is a Senior Lecturer at the Department of Chemical Engineering, University of Melbourne. Italian born, he obtained his PhD in 2008 from the University of Queensland, and later received a fellowship from the Japan Society for the Promotion of Science (JSPS) to undertake his post-doctoral studies at Kyoto University (2008-10). From 2010 to 2019 he was an academic at the Advanced Water Management Centre at the University of Queensland. Stefano's research focuses on the development of novel bio-electrochemical processes to transform waste into resources, and to deliver resilience and flexibility to urban water and wastewater services and infrastructure.

Abstract

Establishing the circular economies of the future requires the development of innovative concepts and solutions that will allow for the continuous removal and recovery of valuable resources – including nutrients from wastewater – so that they can be reused continuously rather than linearly. Urine separation and collection at the source has shown enormous potential to increase the resilience of urban wastewater management, while also providing a route for nutrient recovery for reuse in fertilisers. This talk will cover previous achievements and future goals for Ugold, a novel bioelectrochemical technology for the on-site processing of urine to produce fertilisers that are safe, effective and competitive in the existing markets. Through NiCE, the aims are to field-test, improve, commercialise and mainstream this technology.

A NICE systems thinking approach: understanding the health, economics, regulatory aspects of urine recycling for fertilisers

Cara Beal, Sayed Iftekhar, Anne Roiko

Affiliation: Griffith University

Brief bio of lead CI/presenter

Associate Professor Cara Beal is an internationally recognised researcher in the water and wastewater sector, particularly community-led, socio-technical approaches to water management. A/Prof Beal designed and managed the socio-cultural, regulatory and technical aspects of the first Australian urine separation project (Qld ecovillage). She worked with the plumbing industry, health and science regulatory agencies to enable novel trials of urine separation, collection, storage and treatment. Throughout her career, her research has won her industry and peer-recognition including a GU Sciences Research Innovation Award, a Women in Technology Award and AWA Research Innovation finalist.

Abstract

The team at Griffith University, together with other researchers and industry partners across Australia will be asking some critical questions that need to be understood in order to achieve a successful circular economy for recycling of nutrients via urine collection and reuse. These are: 1) what are the risks to human health from urine reuse as a fertiliser? 2) Is it economically feasible and attractive to relevant industry partners? 3) Will it be allowed by the government regulators?

In collaboration with local government and service providers in Brisbane, the Health-based Risk Assessment component will assess the microbiological health risks to help answer question 1. There will be a whole-of-system economics project, in collaboration with the Qldwater Directorate will tackle question 2 by assessing the economic feasibility of urine-sourced fertiliser including logistics—storage and movement of urine/fertiliser; integration with existing plumbing and know-how; effectiveness of new fertiliser compared to market standard. To address question 3 Regulatory mainstreaming project will investigate how to positively engage regulatory authorities around the safety and efficacy of the nutrient extraction technology and fertiliser application

This presentation will detail the key research focus and methods for each of these subprojects along with information on the collaborating partners and stakeholders. It will conclude with the expected outputs and benefits of the work to the overall NICE Hub research goals.

Innovative process development and demonstration for nutrient recovery from complex industrial solutions

Mikel Duke[1] and Bahay Ozcakmak[2].

1 – Institute for Sustainable Industries and Liveable Cities, Victoria University, Werribee Campus, Hoppers Lane, Victoria, Australia.

2 – Parkway Process Solutions (subsidiary of Parkway Corporate Limited, ASX:PWN), 5/45 Bunnett St, Sunshine North, Victoria, Australia.

Brief bio of lead CI/presenter

Prof. Duke has worked for 22 years in materials and applications research of membrane technology for sustainable foods processing, resource recovery and water/energy saving applications at the University of Queensland, Johnson Matthey Technology Centre (UK), Arizona State University (USA) and Fudan University (China). In 2007, Prof Duke received a Linkage International Fellowship from the Australian Research Council, and then in 2010 he received an Endeavour Executive Award and the Victoria University Vice Chancellors Peak Award for Excellence in Research and Research Training. In 2016 he received the inaugural Anthony Fane Award for his outstanding contributions in membrane science and technology from the Membrane Society of Australasia. Prof Duke is a former panel member of the Australian Research Council College of Experts, the founding President of the Membrane Society of Australasia and currently co-editor of the international journal Desalination. He is also the President of the World Association of Membrane Societies.

Abstract

This project will research a range of processes, including innovative aeration and membrane based technologies, as well as aMES® which has been developed to enable the effective processing of typically highly concentrated solutions which occur either naturally or as a result of industrial processes such as desalination, mining and industrial refinery operations (https://pwnps.com/collections/next-generation-technologies). The specific aims are to investigate, evaluate and potentially optimise a number of important steps within the technology portfolio (including innovations developed through prior research by the project partners). In working towards a circular nutrient economy, a key focus of the research project is to recover a range of products from the waste streams, including fertilizer products (including potassium and organic based), as well as the potential to produce other critical products such as lithium. The project will feature a series of tests using bench and pilot scale equipment, including membrane and non-membrane equipment located at Victoria University, Werribee campus and Parkway's operating facilities, in Melbourne. These tests will have defined objectives related to demonstrating various key performance indicators such as solution chemistry, product yield and purity, byproduct formation and energy usage. Additional objectives of the tests include investigation and assessment of physical and biological properties.

Markets and governance for a thriving circular nutrient value chain

Professor Jason Prior, Associate Professor Dana Cordell, Associate Professor Brent Jacobs.

Affiliation: Institute for Sustainable Futures, University of Technology Sydney

Brief bio of lead CI

Jason Prior is Professor of Planning, Health and Environment at the Institute for Sustainable Futures, UTS. As an architect, planner, and geographer, Jason's research program focuses on the environment, planning, and human and planetary health. Jason has attracted over $9.5M in competitive external funding through this research program. He has led 45 national and international research projects through productive collaborations with research organisations, government, industry, NGOs, communities and the professions. Jason's transdisciplinary research has been published widely in various journals, edited collections, and through public reports and interactive tools. Jason is the Program Lead of the Higher Degree-by-Research (HDR) Program at ISF and a Responsible Academic Officer. He is currently the principal supervisor of 5 HDR students. Jason is Deputy Director of the cross-university Healthy Urban Environments (HUE) Clinical Academic Group in Maridulu Budyari Gumal: Sydney Partnership for Health, Education, Research and Enterprise (SPHERE).

Abstract

‘Integration’ across markets and through governance is a cross theme within the ARC Research Hub for Nutrients in a Circular Economy (NiCE) and is being led by the Institute for Sustainable Futures, UTS. A thriving circular nutrient value chain requires circular markets, knowledge flows, social connections and governance. However, these dimensions are often not given the same attention as material and waste flows.

In the second half of 2022, ISF will commence two 4-year research projects.

The first project, titled ‘Circular markets for a thriving circular nutrient value chain: A market feasibility and perception study’, will focus on understanding and overcoming the barriers for forming a circular market that supports a viable circular nutrient value chain. This will be achieved through employing co-design and knowledge co-production principles to engage value chain stakeholders, from toilet manufacturers through to farmers and other market end-users, to identify and learn about material availability and bottlenecks affecting stakeholders across the value chain, providing guidance that supports a sustainable marketplace for a circular nutrient value chain. For example, fertiliser companies from Australia to Africa advise researchers that a barrier to using organic waste in fertiliser production is the lack of sufficient raw material at scale.

The second project, titled ‘Governance for a thriving circular nutrient value chain: An integration study’, will identify effective governance frameworks that allow diverse stakeholders to integrate well into a circular nutrient economy. This will be achieved by employing co-design and knowledge co-production principles to engage stakeholders, from toilet users through to end-users, to identify and learn how: international leading governance structures for nutrient and non-nutrient circular economies may be adapted to the Australian context; understand regulatory and other governance barriers within the Australian context that currently limit how stakeholders can integrate well in nutrient circular economics; and how perceptions of stakeholders in the circular nutrient value chain enable or impede the effective governance of nutrient circular economics.

Context-dependence of fertiliser end-use benefits

Jeff Powell, Jason Reynolds.

Affiliation: Western Sydney University

Brief bio of lead CI/presenter

Jeff Powell has been conducting world-class research on soil biological fertility and plant-soil-microbe interactions for more than fifteen years. Since joining WSU in 2011, Jeff has worked with several industry partners with the aim of improving outcomes for vegetation in agricultural systems (Meat and Livestock Australia, Dairy Australia, Sugar Research Australia) and in ecosystem restoration and species conservation (NSW DPE, Sydney Royal Botanic Gardens, South32). A current ARC Future Fellow, in 2012 he received a Science and Innovation Award for Young People in Agriculture, Fisheries and Forestry for his work on microbial inoculants for improving crop nutrition. Together with Jason Reynolds, he is currently working with Sydney Water to evaluate the extent that wastewater and biosolids can improve the biological fertility of soils across Sydney.

Abstract

To understand and quantify the potential benefits (and risks) of urine-derived fertilisers, we need to know the behaviour of these fertilisers and their derivatives in the soil-plant-atmosphere continuum across the diversity of soils in which they will be applied. Our first objective is to predict behaviour of urine-based fertilisers in different soils to evaluate their potential agronomic benefits and environmental impacts. We will measure the behaviour of Ugold, Urval and their derivatives in soils with different structural and chemical characteristics. Key parameters to investigate will relate to nutrient adsorption/desorption behaviour, nutrient losses via leaching and emissions, salinisation and pH changes. We also need to know how urine-based fertilisers compare to conventional fertilisers for their ability to promote healthy plants and produce other desired outcomes, including carbon farming and reduced environmental losses, as well as identifying options to maximise use-efficiency and minimise impacts of salinisation and changes of pH. Key parameters to investigate will relate to plant productivity and nutrient recovery in plant biomass (relative to nutrient input), soil biological fertility and changes in soil chemistry. We will also investigate additional interventions that may mediate salinisation or nutrient losses associated with urine-based fertilisers in some contexts. These include application timing, soil incorporation, application rate optimisation, further organic amendments, denitrification inhibitors and microbial inoculants. This synthesis will be used to assess conditions that provide maximum benefits while also minimising negative impacts.

Optimisation of urine-derived and biosolids-derived biofertilisers

Professor Bernadette McCabe[1], Dr Dio Antille[1, 2], Dr Serhiy Marchuk[1], Ms Aline Dos Passos Silva[1]

[1] Centre for Agricultural Engineering, University of Southern Queensland; Bernadette.McCabe@usq.edu.au; Serhiy.Marchuk@usq.edu.au; Aline Dos Passos Silva u1138584@umail.usq.edu.au

[2] CSIRO Agriculture and Food, Canberra, Australian Capital Territory, Australia; Dio.Antille@csiro.au

Brief bio of lead CI/presenter

Professor Bernadette McCabe is Director at the University of Southern Queensland's (UniSQ) Centre for Agricultural Engineering (CAE). Bernadette has a background in agricultural biotechnology and has over 25 years' experience as an academic and researcher. Her research investigates technologies to enable intensive Australian farming and food-processing industries to turn their commercial waste into a valuable commodity. She works with these industries to be more profitable by using organic waste to produce biogas, clean recycled water and biofertiliser. Her research has been applied to the livestock and cropping sectors (both on and off farm) and water utilities.

Bernadette collaborates at an international level as Australia's National Team Leader for the International Energy Agency (IEA) Bioenergy program Task 37: Energy from Biogas. Bernadette was a Director on the Board of Bioenergy Australia from 2017-2019 and is an active member of the Bioenergy Australia Renewable Gas Alliance and Circular Economy Committee. Bernadette sits on the Queensland Government's Department of State Development, Infrastructure, Local Government and Planning, Biofutures Industry Advisory Group. She is also a member of the Australian Research Council (ARC) College of Experts (CoE).

Abstract

Disposal of biodegradable wastes through sewer or landfill is regarded as non-sustainable both from the environmental and resource-recovery perspectives. The team at the University of Southern Queensland's (UniSQ) Centre for Agricultural Engineering will undertake two work packages related to the assessment of biofertilisers derived from urine and biosolids. Work Package 1 (WP!) will evaluate and demonstrate Ugold and Urval efficacy in field trials. Ugold and derivatives will be applied to soils at trial sites near Brisbane (including UniSQ sites and City Parklands). Two areas of investigation will be focussed on: 1.The development of specifications for novel urine-derived biofertiliser products that (a) meet the requirements for field application (physical properties) and (b) nutritional needs of plants (chemical composition) and 2. The experimental evaluation of the proposed formulation(s) and product format, determine the fertiliser replacement value (FRV) of urine-derived biofertiliser products and develop guidelines for use on crops and parklands. Multiple application methods will be trialled where appropriate, including surface application, drip feeding and injection. Comparisons will be made with conventional fertiliser treatments for each system.

Work package 2 (WP2) will be optimising biosolids-derived biochar as a biofertiliser and aims to 1. Understand the effect of conversion technology on heavy metals content and mobility in the by-product and 2. Determine the suitability of the by-product as a biofertiliser. This will be performed by assessing:

- Potential risk due to heavy metals (Zn, Cr, Cu, Ni and Pb);
- Nutrient (N and P) leaching in soil treated with by-product;
- Nutrient availability of N, P and K from by-product to soil;
- The by-product as a potential fertiliser with respect to plant yield by determining the agronomic response in glasshouse and field experiments.

The industry benefits include for both work packages include a) Potential income stream through sales of the product and licensing of the technology, or enabling for reduced (avoidance) of costs associated with disposal by increasing agricultural recycling, b) Reduce farmers' reliance on mineral fertilisers, which are likely to go up in price, with the associated benefits in terms of nutrient and organic matter recovery and c) A monetary value in relation to the sale of the product based on the overall urea fertiliser market in Australia which is estimated at AUD1 billion.

The impact of sustainable nitrogen management on carbon footprint for water utilities

Liu Ye

School of Chemical Engineering, University of Queensland

Brief Bio

Dr Liu Ye is an Associate Professor at The University of Queensland (UQ) in the School of Chemical Engineering. Dr Ye's research is focused on sustainable environmental engineering and is dedicated to finding innovative and practical solutions to tackle challenges in achieving net zero emissions, climate resilience, and sustainability. She is the Greenhouse Gas (GHG) research program leader at UQ urban water engineering. She has an established national and international leadership in the research field of net-zero emissions from urban wastewater systems. Dr Ye has more than 120 publications, including 1 edited book (as lead editor), 2 book chapters and over 80 fully refereed journal papers (with 90% journal paper published in Q1). Her work has received over 4200 citation and she an h-index of 36.