Chemical Engineering Impact in Australia

VOLUME 2

The Institution of Chemical Engineers (IChemE) is a not-for-profit, member-led qualifying body and learned society for chemical, biochemical and process engineers, and the only organisation permitted to award the widely-recognised Chartered Chemical Engineer title and Professional Process Safety Engineer registration.

IChemE sets the standard for chemical engineering and process safety through a range of membership grades, registrations, publications and training for those seeking to improve their professional status, enhance their learning and network with peers.

Founded in 1922, IChemE has grown to around 35,000 members in over 100 countries who are supported by a team of professional staff based in Australia, Malaysia, New Zealand, Singapore and the UK.

Australia represents 10% of IChemE's global membership base, making it the third largest on the international membership table.

Formation of a local IChemE association was established in the early 1960s. The Victorian Group of IChemE was formed in December 1962 and was closely followed by the establishment of the New South Wales and South Australian groups. In May 1967, the Australian State groups agreed to form the Australian National Committee, giving birth to the Institution of Chemical Engineers in Australia.

With this document we are pleased to present some recent highlights on chemical engineering research in Australia and its positive impact on the way we live.

Foreword

When asked about our motivation to become chemical engineering researchers, many of us respond with the same, simple answer. To improve things. Once it was about optimising a chemical process on a production line and ultimately the balance sheet of the enterprise. While this is still at the core of the profession, in research we innovate and look for ways to improve the lives of people and our environment.

Chemical engineers are constantly creating new ways of doing things. We are a creative profession and this creativity is showcased in our second edition of our case studies booklet.

In 2019 we aimed to highlight the contribution of our research to the great challenges facing our society. In 2020 wicked problems abound. From climate change, to world poverty and malnutrition, to water shortages and plastic waste. Although the COVID-19 pandemic has dominated everything in 2020, all these other challenges remain.

Some of the research presented here is a direct response to the COVID-19 pandemic. Other research illustrates how chemical engineering know-how can be applied to find solutions in energy, water management, medicine, food technology and risk management – issues which still need our attention.

I am very proud that despite the extremely difficult conditions of 2020, with extended periods of isolation, limits on our laboratory and field work, and the cancellation of all conferences, as a group of researchers, we have continued to make progress towards some of these challenges.

Each case study in this booklet showcases the research in the context of the broader problem, and highlights the impact chemical engineers are making to provide tangible and viable solutions to pressing environmental, social, and medical challenges.

In Australia, chemical engineering continually optimises and shapes the industries and needs of the day. This has never been more apparent this year, with the response to the COVID-19 pandemic. We hope this booklet delivers in its objective to highlight these wonderful research outcomes, and contributes to the improved public understanding of our discipline.

I would like to take this opportunity to thank all the IChemE Research Committee members, Mr Peter Slane (IChemE) for driving this project and IChemE for supporting the initiative.

Professor Cordelia Selomulya
Chair, IChemE Australia Research Committee

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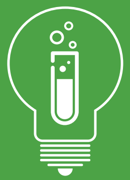
Energy



The transition to new and sustainable energy and manufacturing relies heavily on the innovation of novel green chemical technologies.

Chemical engineering researchers across Australia enable new technologies that can push the energy transformation required to maintain long term sustainability of many industries.

The features presented here showcase research from Monash University into green fuels and work from the University of New South Wales that focuses on optimising processes for a viable H_2 economy.

- Green fuel - closing the CO_2 loop
- Design and optimisation of hydrogen production and utilisation processes

Green fuel - closing the CO_2 loop

Monash University chemical engineering researchers have reported very promising results to covert CO_2 to new green fuel.

Energy

Closing the CO_2 loop - using CO_2 to replace conventional diesel with new green fuel

What is the challenge?

Anthropogenic carbon dioxide emissions are responsible for climate change, with Australia one of the highest green house gas emitters on a per capita basis (15.4 tonne CO_2-equivalent per annum). At the current rate of reductions in CO_2 emissions, the world is unlikely to meet its COP21 targets of less than 2°C warming above pre-industrial levels. Therefore, capturing CO_2 at the source or Direct Air Capture, and converting it into fuels and chemicals, is an essential step in closing the carbon loop and eliminating excess CO_2.

Captured CO_2 can be used as a feedstock to produce fuels and chemicals via catalytic hydrogenation processes, thus reducing or reversing net CO_2 emissions. Hydrogen required for such processes could be supplied by solar powered water electrolysis (called green hydrogen) – resulting in completely renewable products with a net-zero carbon footprint.

How do chemical engineers contribute?

Associate Professor Akshat Tanksale is leading a project at Monash University that aims to produce a new liquid fuel to replace diesel. The new liquid fuel is produced via the direct conversion of CO_2 and H_2. The fuel is a second-generation fuel component–oxymethylene dimethyl ether (OME), which will also drastically reduce soot emission from diesel engines because of its low vapour pressure, high viscosity, high oxygen content, and high cetane number.

The team have recently investigated the production of OME via a cascade reaction of hydrogenation of carbon dioxide into formaldehyde, followed by a reaction with methanol in a liquid phase high pressure slurry reactor (first report in the world). This one-pot approach to synthesise OME eliminates the need for multistep/reactors synthesis, which may potentially reduce capital costs and energy consumption, making the process green and commercially viable. Methanol itself can be produced from CO_2 and green hydrogen, therefore, the feedstocks are completely renewable (www.doi.org/10.1016/j.apcatb.2020.118765 and www.doi.org/10.1021/acssuschemeng.9b06913)

What is the impact?

The research at Monash University has led to the highest yield of OME at the fastest rate ever reported.

Associate Professor Tanksale has the opportunity to take his research further as a Theme Leader for the *Carbon Capture, Conversion and Utilisation* theme of the Woodside Monash Energy Partnership. Woodside Energy and Monash University are jointly investing more than $40 million towards this partnership with three broad themes – 1) New Energy Technologies, 2) Carbon Capture, Conversion and Utilisation, and 3) Energy Leadership. This partnership will support several projects focusing on the use of CO_2 as a feedstock to produce chemicals and fuels, thereby reducing the net CO_2 emissions in the atmosphere.

The team are currently in negotiation with an international industry partner to undertake pre-commercialisation research and development for CO_2 conversion into OME.

At a time when the global pandemic has shifted the focus of a lot of Australian political discussion away from climate change mitigation, Monash University and its industry partners have the challenge firm in focus and are engaging closely with the sector to solve this complex problem.

"The biggest role of chemical engineering in the current global scenario and over the next five years is to leverage our research strengths to engage industry, governments and communities to bring transformational change in the renewable energy and manufacturing sectors. COVID-19 has brought researchers closer to the governments for public health policy implementation, which must extend towards solving the climate change problem", Associate Professor Tanksale said.

"One solution is to retrain our existing workforce in the conventional energy sector and offer micro-credentials to the workforce displaced by the current economic downturn and upskill them for the future energy market."

The research at Monash University has led to the highest yield of oxymethylene dimethyl ether at the fastest rate ever reported.

Contributor:
Associate Professor Akshat Tanksale
(Monash University)

Design and optimisation of hydrogen production, storage and utilisation processes

Combining Computational Fluid Dynamics and laboratory experiments, a group at the University of New South Wales aims to develop a series of highly efficient and optimised designs and processes of hydrogen generation, storage and utilisation for a full-loop hydrogen economy.

Design and optimisation of hydrogen production, storage and utilisation processes

What is the challenge?

Process design and control play significant roles in modern and emerging industries and are the corner stones of chemical engineering. Most processes and reactions are very complex, involving multiphase flows, and heat and mass transfer during their chemical reaction processes. Chemical engineers are concerned with optimising these processes to improve both economic and environmental sustainability.

Hydrogen is a promising next generation renewable and carbon neutral energy source, but any sustained and viable advancement in the hydrogen economy is reliant on the design and optimisation of hydrogen generation, storage and utilisation processes and reactor design, in addition to R&D in materials design.

Currently, key challenges for a full-loop hydrogen economy include hydrogen production, storage and utilisation. Water electrolysis is one favoured route to produce hydrogen; a solid-state hydrogen tank is a sustainable storage method; and hydrogen utilisation in a carbon-intensive industry like the steel industry is the promising route to a full-loop hydrogen economy. However, these processes are yet to be well designed and optimised.

The main obstacles to these processes include reducing the capital costs, sustaining process stability and improving energy efficiency in these processes.

How do chemical engineers contribute?

Dr Yansong Shen is an Associate Professor and ARC Future Fellow at the University of New South Wales. Dr Shen and his group focus on process design and modelling of reacting flows and the applications to a range of complex processes and reactors in conventional and emerging industries. (Dr Shen's research group is the ProMO group, www.promo.unsw.edu.au).

One of his recent research areas investigates hydrogen processes including electrolysis hydrogen generation, hydrogen tank design and hydrogen utilisation in the steel industry, also known as hydrogen metallurgy. Combining Computational Fluid Dynamics and laboratory experiments, the group aims to develop a series of highly-efficient, low-cost and sustainable systems and technologies to optimise design, configuration and productivity for a full-loop hydrogen economy.

The group's work is supported by the Australian Research Council (ARC) and Australian Renewable Energy Agency (ARENA). For example, the team develops new design tools to design and optimise the process of novel electrolysis in terms of, for example, bubbles resistance or new membrane design in the electrolyser. Subsequently, the optimisation can be applied to increase electrolyser efficiency. The team is also developing an innovative solid-state hydrogen storage tank design, and developing innovative hydrogen-based metallurgy processes to a enable carbon-free steel industry.

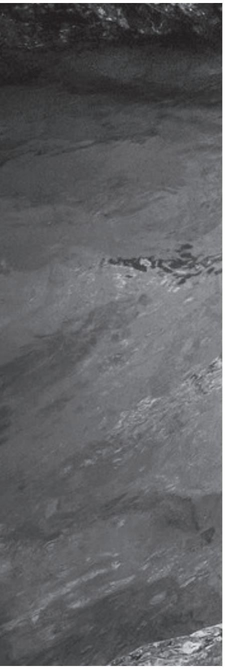
They collaborate (and look forward to further collaborations) with materials/chemistry-focused hydrogen researchers.

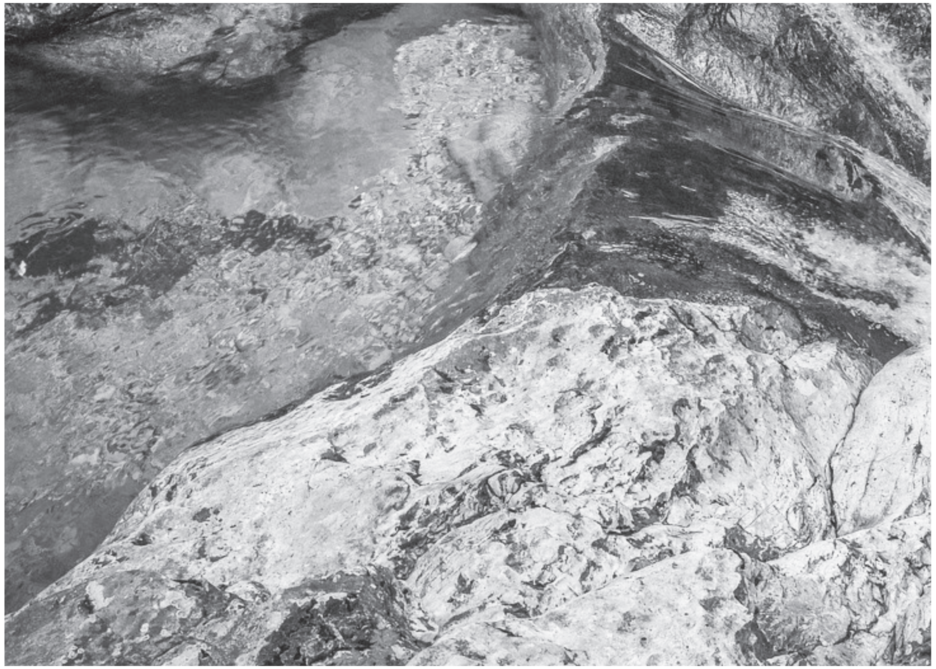
What is the impact?

The process-focused hydrogen research theme, including hydrogen generation, storage and utilisation, will develop a series of comprehensive electrolysers, hydrogen storage tanks and sustainable hydrogen utilisation technology in steel industry for a complete hydrogen economy in Australia and globally.

We want to optimise complex processes to improve both economic and environmental sustainability.

Contributor:
Associate Professor Yansong Shen
(University of New South Wales)





Water

Chemical engineers have long known that water is a precious resource that needs to be managed effectively.

Water scarcity is no longer only affecting developing countries; in the summer of 2019/2020 it arrived on our doorstep, with a number of towns completely running out of water, relying on cartage for months on end.

The features that follow highlight the contribution of researchers to national guidelines for safe water re-use and the application of nanotechnology to improve water remediation.

- Water re-use practices
- Applying nanotechnology to water remediation and treatment

Water re-use practices

Chemical engineering researchers at the University of New South Wales have contributed to national guidelines for the validation of processes used for the treatment and re-use of wastewater, securing safe pathogen removal.

Water

Increasing water re-use practices through improved risk management – the development of national guidelines

What is the challenge?

Australia's usual water supply system – mostly reliant on the capture and delivery of rain water - is under ever increasing pressure. Rising population in urban centres combined with unreliable rainfall means that many areas of Australia are facing a serious water shortage unless safe and reliable alternative water sources can be secured.

The re-use of water, including storm water, grey water and treated sewage, could become part of the nation's water supply. However, in any water re-use applications, a thorough understanding of pathogen removal mechanisms and treatment performance is essential.

Moreover, if pathogen removal is compromised for any reason, it is vital that the breach is immediately detected, quantified and corrected.

How do chemical engineers contribute?

Membrane bioreactors (MBRs) have been developed as an efficient wastewater treatment for re-use in non-potable applications. However, the potential loss of containment of pathogens by MBRs has limited their application.

MBRs combine biological treatment (activated sludge) and membrane filtration, such as microfiltration or ultrafiltration, to reduce the concentration of pathogens in wastewater. A number of influencing factors contribute to the efficiency of the system, resulting in a complex validation approach.

No single mechanism is responsible for the reduction of pathogens through an MBR. Depending on the target pathogen, a combination of size exclusion, adsorption and biodegradation will be responsible for inactivating or removing pathogens.

Responding to the Australian water sector's request for a more cost-effective application of technologies, chemical engineering researchers from the University of New South Wales and the Australian Water Recycling Centre of Excellence, in collaboration with regulators, water utilities and the private sector, developed a way to achieve national consistency in the validation of treatment technologies.

To better justify and demonstrate the reliability of MBRs in removing pathogens, the researchers, including Associate Professor Pierre Le-Clech and colleagues from the University of New South Wales' UNESCO Centre for Membrane Science and Technology, conducted a number of studies leading to the development of a series of critical recommendations to health regulators and practitioners for the development of validation guidelines, which is now available in Australia.

As part of their research, the impact of eight hazardous events on key bulk water quality parameters, on trace organic chemical removal, and on removal of indicator microorganisms during MBR operation, has been systematically assessed. Study results demonstrated that monitoring of membrane integrity will assure a majority of log removal capability.

How has this made an impact?

As a result of this work, a milestone 3-part scientific report has been published in the highly ranked Journal of Membrane Science. For the first time, the impact of a series of hazardous events on (1) water quality, (2) removal of trace organic contaminants and (3) microorganisms log removal efficiency was fully characterised and demonstrated the reliability of MBRs to produce safe water, even when operated under challenging conditions. These results are expected to support practitioners to operate their wastewater treatment processes more appropriately.

This work provided detailed quantitative evidence to support the creation of more appropriate and streamlined national validation guidelines for MBRs in Australia (freely available at www.waterra.com.au/waterval), and, in doing so, has furthered the knowledge to support health risk management of MBRs internationally.

"Although the detection of viruses in sewage does not present any significant direct health risk to the community, our recent work can be used to further demonstrate the efficiency of wastewater processes in removing a range of pathogens of concern", Associate Professor Le-Clech said.

"Our current collaborations with public health and epidemiology experts will help us to develop a new set of recommendations for safer and more appropriate operation and monitoring of other water treatment technologies".

Membrane bioreactors have been developed as an efficient wastewater treatment for re-use in non-potable applications.

Contributor:
Associate Professor Pierre Le-Clech
(University of New South Wales)

Applying nanotechnology to water remediation and treatment

Researchers at Edith Cowan University are using environmental catalysis to carry out the catalytic oxidation of organic pollutants in water, including dyes, phenolics, and emerging contaminants.

Water

Applying nanotechnology to water remediation and treatment

What is the challenge?

Of the vast quantity of water on Earth, only 2.5% is fresh, and of that only 0.4% is accessible from lakes and rivers, with the remaining coming from groundwater (30.9%) and snow and ice (68.7%).

With over seven billion people worldwide in need of safe and clean water for drinking, agriculture and sanitation, we are rapidly entering a water security crisis. Despite the advances being made in water treatment technologies, there are some estimates that within the next ten years, roughly 50% of the planet's population will suffer from water shortage.

The small amount of water that is available to us is at constant risk of pollution, with up to 80% of pollution caused by domestic sewage. This poses a risk to both public and environmental health, and greatly impacts an already scarce resource.

How do chemical engineers contribute?

Professor Hongqi Sun from Edith Cowan University is tackling this problem by applying novel nanotechnology to water remediation processes. In particular, he has employed environmental catalysis to carry out the catalytic oxidation of organic pollutants in water, including dyes, phenolics, and emerging contaminants.

Municipal wastewater is mainly treated by biological processes, however, for toxic chemicals/drugs/pharmaceuticals, the bacteria in activated sludge is rendered ineffective and can thus no longer drive the biological processes. Hence, to degrade or decompose emerging contaminations, advanced oxidation processes are required. The Fenton reaction using hydroxyl radicals has been popular, but it only works in acidic conditions.

Professor Sun's research employs sulphate radicals-based advanced oxidation processes (SR-AOPs) for the decomposition of toxic compounds in wastewater. Compared to the hydroxyl radicals in the Fenton reaction, sulphate radicals here have a higher degradation ability, and better flexibility for acidic, neutral and alkaline conditions.

The research focuses on the generation of sulphate radicals using novel catalyst materials, including metal-free materials, which completely avoid secondary contamination by metal leaching, if using metal-based materials.

Recently, membrane technology was also adopted in this field to achieve the integrated remediation of wastewater with both degradation and membrane separation.

What is the impact?

This technology can be extended beyond the decomposition of toxic chemicals in wastewater to the elimination of bacteria, germs, and viruses in other water sources. This includes the potential to eliminate the COVID-19 virus in water, which is extremely important for treating wastewater in hot-spot and high-risk areas. It is also foreseeable, that through advancing the technology further, it can be readily applied to purify air of airborne viruses.

With over seven billion people worldwide in need of safe and clean water for drinking, agriculture and sanitation, we are rapidly entering a water security crisis.

Contributor:
Professor Hongqi Sun
(Edith Cowan University)



Bioengineering

Bioengineering applies the design principles of engineering to biology and biomedicine. The potential outcomes of this crossover are extraordinary.

Medical science is increasingly looking toward bioengineering for disease treatment, prevention and diagnostics.

Work from chemical engineers at the University of Adelaide has provided the perfect example of what bioengineering can achieve in a crisis situation.

Other research from the University of New South Wales could provide a major breakthrough to the early diagnostic of deadly diseases.

- From biowaste to COVID-19 test
- Colourimetric tests for easy detection of deadly diseases

From biowaste to COVID-19 test

When SA Pathology put an urgent call out for diagnostic materials for their COVID-19 testing, South Australian chemical engineering researchers responded with a novel solution.

Bioengineering

From biowaste to COVID-19 test - chemical engineering research meeting an urgent demand in testing diagnostics

What is the challenge?

As the COVID-19 pandemic lingers, The World Health Organization is urging countries to increase the number of COVID-19 tests to help control the spread of the pandemic, but many countries are struggling with a shortage of diagnostics capacity.

The current globally accepted method to diagnose COVID-19 involves a real-time reverse transcription polymerase chain reaction (RT-PCR) using swab samples from the patient. However, the method is protracted, requires special laboratory equipment, trained technical staff and several reagents including magnetic nanoparticles (MNPs), used to extract RNA genetic material from the collected swab samples.

Unsurprisingly, the supply of MNP reagents from major global manufacturers cannot meet the high demand, leading to capability constraints for COVID-19 testing for many countries including Australia. These conventional MNPs are manufactured by complex and low capacity synthetic methods that make them very expensive. Their global market is valuated over $5 billion and the main suppliers are located outside Australia with limited or restricted imports.

How do chemical engineers contribute?

In April 2020 SA Pathology experienced a shortage of MNPs for COVID-19 testing in South Australia and made an urgent request to local universities to synthesise MNPs within the state. Professor Dusan Losic's team from the School of Chemical Engineering and Advanced Materials at the University of Adelaide accepted the challenge and decided to try a different route, namely a synthetic approach by producing MNPs from biowaste. The enthusiastic group, including many PhD students (volunteering their time during lockdown and working very long hours) developed a scalable method of production to allow continued testing by SA Pathology.

After two months of extensive trials with several hundreds of tests by local and interstate pathology laboratories, the novel biowaste MNPs proved to have similar or better performance compared with commercial MNPs. Moreover, compared with conventional manufacturing technologies, the new process developed by Professor Losic's team is distinctively different and has many competitive advantages, being economic, as it uses waste materials not chemicals; efficient, with production capacity of kilograms per day; and innovative as it produces unique MNPs with a high surface area and different shapes, improving efficiency for extraction of genetic material.

What is the impact?

This invention attracted local and interstate industry partners interested in commercialising the technology to make COVID-19 testing kits. This new product, even at the current laboratory scale production level, will allow Australia to secure enough of this reagent for the millions of tests needed for the whole country without needing to import this expensive reagent. Prototype scale up of manufacturing to increase production capacity to several hundred kilograms per year will enable the reagent to be exported to supply COVID-19 testing kits to other countries, which is a key element in the global effort to fight the pandemic.

This is an excellent example illustrating how chemical engineers can quickly and willingly respond to societal needs and provide a very fast and efficient solution to an urgent problem. Overcoming a shortage of one of the key reagents for testing COVID-19 has significant national and global impacts.

Chemical engineers can quickly and willingly respond to societal needs and provide a very fast and efficient solution to an urgent problem.

Contributor:
Professor Dusan Losic
(University of Adelaide)

Colourimetric tests for easy detection of deadly diseases

Researchers at the University of New South Wales are showing us a future whereby we can detect deadly diseases simply by monitoring the colourimetric signals in response to the molecular signatures of humans.

Bioengineering

Colourimetric tests for easy detection of deadly diseases

What is the challenge?

Despite significant improvements in treatment and survival rates, point-of-care tests for the early detection of life-threatening diseases such as cancer and respiratory illness (including COVID-19) are not yet available.

Currently screenings for cancer, heart disease, and viral infections are mostly performed in hospitals requiring specialised and expensive diagnostic equipment.

In contrast, when a woman suspects she is pregnant, she can purchase an over-the-counter test kit and confirm (or otherwise) pregnancy in the comfort of her own home. This begs the question, if a test kit can detect pregnancy in a few minutes at home, could we create a similar test for deadly diseases?

How do chemical engineers contribute?

Scientia Associate Professor and NHMRC Emerging Leadership Fellow Dr Rona Chandrawati from the University of New South Wales School of Chemical Engineering believes this is possible. Her vision is a future in which practical, low-cost, and easy-to-use sensor technology can be used to detect and monitor disease biomarkers in bodily fluids and in exhaled breath. Early diagnosis has the potential to radically improve the chances of patient survival.

In her quest to create fast, reliable, economic and simple tests that are easy-to-use, Dr Chandrawati's research team has developed a simple detection test based on lipid and polymer nanoparticles that change colour in response to the levels of molecular signatures in human blood. Nanoparticles with unique optical properties are conjugated with biomolecules that can rapidly sense and specifically respond to an array of analytes, including biomarkers for cancer, FLU, inflammation, and thrombosis. The colourimetric signal is related to the concentration of biomarker directly correlated with a certain health condition. Colourimetric mode offers easy readout without specialised equipment and it can be coupled with a smartphone for data processing of the colourimetric analysis.

This technology has proved to be effective at detecting cancer and FLU biomarkers, blood clotting factors, toxins, and toxic heavy metal ions at clinically relevant levels. These assays will be valuable in prompt identification and early intervention for controlling potential life-threatening diseases.

What is the impact?

The technology developed from this research has reached beyond medical diagnostics.

Using the same building blocks, Dr Chandrawati has also developed colourimetric food spoilage indicators that can be attached onto food packaging. The sensor displays blue-to-red colour changes in response to bacteria by-products, informing consumers that the food is no longer safe to be consumed thereby helping to reduce the incidence of food poisoning.

When these colourimetric 'stickers' are attached to food packaging, they can track food quality in real time; changing colour from blue to red, informing consumers when the food is no longer safe.

Cheap and easy early stage cancer detection will have an enormous impact on the cancer survival rates, whereby early detection is key. Likewise, if the early stages of cardiovascular disease could be detected by a simple colourimetric test kit following a routine blood or urine test.

"Quick and easy testing kits, applied in a pandemic situation such as what we are now experiencing, would have dramatic impacts on testing rates, contact tracing and virus containment", Dr Chandrawati said.

If a test kit can detect pregnancy in a few minutes at home, could we create a similar test for deadly diseases?

Contributor:
Associate Professor Rona Chandrawati
(University of New South Wales)

Food technology

Food technology provides another great example of crossover expertise, combining the knowledge of agricultural and food science with engineering.

Applications of food technology have real implications to an equitable and sustainable society, whereby functional foods can address malnutrition in poorer populations and smart packaging can help to minimise food waste.

The case studies presented here showcase research in the dairy industry and the potential of 'food as medicine'

- **Membrane separation technologies to improve dairy manufacture**
- **The untapped potential of natural antiviral compounds and nutraceuticals**

Membrane separation technologies to improve dairy manufacture

Researchers from the University of Melbourne's ARC Dairy Innovation Hub have developed electrically driven membrane separation technologies to facilitate the re-utilisation of dairy by-products.

Food technology

Membrane separation technologies to improve dairy manufacture

What is the challenge?

Acid whey and salt, both by-products of cheese and dairy production, present a major disposal issue for the dairy industry. With a high lactic acid concentration, whey becomes sticky, causing problems during downstream spray drying operations.

Salty whey is produced during the cheese salting process, with approximately half of the added salt ending up in the waste stream, presenting a major environmental challenge if not treated appropriately. As the costs of salt disposal to sewer systems are increasing in Australia, this is also becoming an economic burden to the dairy industry.

Currently, the removal of salts, often referred to as demineralisation (an essential step for example in the production of infant formula and baby foods) is typically achieved by passing dairy products through a bed of ion exchange resins, which bind strongly with salt ions to produce a demineralised stream. The regeneration of these resins, however, requires the use of additional chemicals that end up in waste streams and lead to high treatment costs.

How do chemical engineers contribute?

The research team led by Professor Sandra Kentish at the ARC Dairy Innovation Hub, University of Melbourne, have developed a new technique to separate the different components of whey from milk, allowing them to select the beneficial parts and leave behind the unwanted lactic acid using an electrically-driven membrane process.

The by-products can then potentially be used to make ingredients for other desirable products, such as baby formula, energy bars, drinks and desserts. Once this technology is adopted, it could reduce disposal costs and allow recovery and use of protein and sugars in this by-product stream, generating ~$26 million per annum across the industry.

The researchers have demonstrated the feasibility of using membrane technologies to treat acid whey to produce high quality whey powder at the pilot scale. Three process combinations were tested, namely, (1) ultrafiltration and electrodialysis; (2) ultrafiltration, nanofiltration, and electrodialysis; and (3) ultrafiltration, dia-nanofiltration, and electrodialysis. All three combinations were successful in reducing the levels of lactic acid and minerals in acid whey. However, the lowest ratio between lactic acid and lactose (0.017g lactic acid/g of lactose) was obtained with the process that utilised dia-nanofiltration. This process used a similar amount of energy to the other two, but resulted in a permeate that was 3.5 times more concentrated, and thus over the course of the year will greatly reduce energy consumption and capital investment.

Different to conventional pressure-driven filtration processes that are widely employed, the suite of innovative membrane technologies developed within the ARC Dairy Innovation Hub can provide solutions to processors not only in the dairy industry, but also the broader food and beverage industries.

What is the impact?

These technologies help address technical and environmental challenges that limit productivity and constrain the growth of business.

This work has shown the feasibility of combining different membrane processes to produce demineralized whey powders from acid whey, with a special focus on the electrodialysis process.

The ability to produce consumable products from acid whey not only increases profitability but also reduces waste, leading to a more sustainable dairy industry.

By applying a combination of separation technologies, chemical engineering researchers are bringing innovation to the dairy industry by reducing waste and recycling valuable by-products of cheese making.

Contributors:
Dr George Chen, Dr Sahar Talebi, Ms Qiuyue Wang, Professor Sandra Kentish (University of Melbourne)

The untapped potential of natural antiviral compounds and nutraceuticals

The University of Sydney researchers are computationally screening over 600,000 natural compounds for their binding affinity to the capsid proteins of COVID-19, herpesvirus (HSV), norovirus (NoV) and influenza (FLU).

Food technology

The untapped potential of natural antiviral compounds and nutraceuticals

What is the challenge?

The COVID-19 pandemic is having a significant impact on public health and the global economy. Based on the latest data, the virus has infected more than 35 million people and caused more than one million deaths since the beginning of the pandemic. There is a push to develop vaccines and therapies to reduce transmission and mortality associated with COVID-19, but this is balanced by the need to validate any treatments as both safe and effective.

While there is a current focus on coronavirus infection, other viruses such as influenza, herpesvirus (HSV), norovirus (NoV), and human immunodeficiency virus (HIV) are all major human pathogens. According to the World Health Organization, Influenza (FLU) still causes 3-5 million cases of severe illness and 650,000 deaths per year. HSV is amongst the most prevalent viruses, causing 'cold sores' and other lesions, but can also lead to keratitis, meningitis, and encephalitis. In some cases, it can even be lethal in immunocompromised individuals. HSV lesions can also facilitate the invasion of other highly virulent pathogens, including HIV. NoV is the leading cause of gastroenteritis (vomiting and diarrhea) and features in over 60% of cases. NoV infects about 684 million people every year, resulting in 200,000 deaths and economic costs exceeding US $60 billion. Approaches being used to develop therapeutics for these viruses may be adapted to the context of COVID-19 research and development.

How do chemical engineers contribute?

Chemical engineers are utilising a broad range of strategies and technologies to fight the COVID-19 pandemic. It may be possible to engineer surfaces that are antiviral and antimicrobial, and if deployed via a spray this could be used to reduce transmission associated by physical contact. The design of biosensors is another area where chemical engineering may impact on disease management, creating improved and simple to use devices for COVID-19 diagnostics. Another promising avenue is the untapped potential of natural antiviral compounds that could be purified by chemical engineers from plant or fungal sources.

As a specific example, the research team of Prof Fariba Dehghani is currently screening libraries of natural compounds for candidates with antiviral activity against Sars-Cov2 (the COVID-19 virus). Initial screening can be performed using in silico molecular interaction software, to create a short-list of compounds for laboratory testing. Such techniques have been previously employed for other viruses, such as HSV and FLU, and Prof Dehghani's team has previously established plaque assays to measure cellular infection for these viruses. A strong evidence base founded on experimental data will be required in order to promote any products that may reduce susceptibility to COVID-19.

What is the impact?

Chemical engineers are poised to have significant impact on the COVID-19 pandemic, should some of these research avenues yield positive findings. Surface treatments and biosensors are technologies that could have major applications in public health programs, yet they still need considerable development and validation. Increased accessibility to rapid and affordable screening tools could improve timing and rates of self-isolating, which would in turn reduce disease transmission within the population.

To date, pharmaceutical development has focused on prevention using safe, validated vaccines. While the world waits for vaccine that might take a long time to be available globally, research into alternative preventative measures may yield surprising and beneficial outcomes. For example, it may be possible to reduce infection incidence and severity at a low cost using naturally derived products. This could include functional foods fortified with plant extracts purified by chemical engineers. Such products have the potential to reduce transmission and ameliorate the symptoms of COVID-19 infection. This could greatly reduce the risk of fatality in vulnerable communities such as the aged.

The identification of natural compounds able to significantly reduce the infection rates and clinical impact of viral infection will have dramatic benefits to human health.

Contributor:
Professor Fariba Dehghani
(University of Sydney)

System HACKED

Risk

Major disruptive events, whether biological, environmental or man-made, are becoming increasingly frequent and severe due to the increasing interconnected sociotechnical environment within which we live.

Chemical engineering research on risk brings together knowledge from the disciplines of engineering, humanities, science and business to help industry practitioners detect, identify, assess, respond to and recover from major disruptive events.

Managing risk in a volatile world

Managing risk in a volatile world

UQ R!SK works with industry to create evidence-based, user-centred industry 4.0 informed, systemic risk management approaches that deliver safe, operational, environmental, commercial and reputational performance.

Risk

Managing risk in a volatile world

What is the challenge?

Major disruptive events are those infrequently occurring events that have widespread, significant and long-lasting impacts. The causes can be biological, environmental or man-made. Examples include COVID-19 and mad cow disease (biological), the Christchurch earthquakes and the Indian Ocean Tsunami (environmental), catastrophic industrial accidents (e.g. the 2020 Beirut ammonium nitrate blast, the 2010 Deepwater horizon disaster and the 1986 Chernobyl nuclear disaster), or cyber security and terrorist events (e.g. 2020 Garmin ransomware attack). These events are becoming more prevalent and severe due to the increasing interconnected sociotechnical environment within which we work and live.

Major disruptive events can pose significant operational, safety and strategic risks to high hazard industries and their supply chains. These disruptive risks can be dealt with through risk management and/or crisis management approaches. However, this is becoming more challenging due to the ever-changing risks and uncertainties that make the future more difficult to predict, and the rapid rate of change that gives business less time to respond (Elahi, 2010, Withers et al., 2015).

In addition, there has not been significant innovation in risk management techniques for the last decade. Risk management tools have not been developed to reflect not only the fact that systems have become more digitalised, more complex and more integrated, but also that stakeholders have increasing expectations and changing demands. There also seems to be no training or education program focused on developing evidence-based, industry-validated risk approaches needed to sustain high hazard and other process industry operations before, during and after major disruptive events. Thus, there is a gap between contemporary risk management practices and the integrated, systemic, evidence-based risk optimisation approaches needed to successfully detect and manage the range of major disruptive event risks faced by industry in a manner that sustains their prosperity and competitiveness.

How do chemical engineers contribute?

To address this gap, UQ R!SK has been established by the School of Chemical Engineering at The University of Queensland (UQ). UQ R!SK is a collaborative research group that works with industry to create evidence-based, user-centred industry 4.0 informed, systemic risk management approaches that seek to integrate and optimise safety, operational, environmental, commercial and reputational risks and performance.

The research carried out at UQ R!SK draws from the disciplines of engineering, human factors, science and business to help industry practitioners detect, identify, assess, respond to and recover from major disruptive events.

Current research activities include, investigating and developing human factors approaches to enhance risk-based decision making processes at all organisational levels, and assesses the ability of technological and methodological advancements - including digital twins, artificial intelligence, wearable technologies, data analytics etc - to improve the effectiveness of risk management endeavours.

Other work includes advancing incident investigation and risk assurance processes as well as meta-analysing industry and incident reports within and between industries and countries to identify insights about strengths, weaknesses, opportunities and threats for improvements.

What is the impact?

An important outcome of UQ R!SK is the development of competencies. PhDs, Masters and undergraduates who engage with UQ R!SK leave the university with the competencies to implement and continuously improve leading-edge risk management approaches in a manner that helps industry effectively manage current and future disruptive challenges.

The team are developing commercial software comprising a body of knowledge on the catastrophic risks and risk controls needed to maintain safe operations in high hazard industries. A book is also being published outlining the considerations and approaches that underpin the type of integrated, risk-based thinking required to manage risks in modern industrial contexts.

Post-COVID vision

COVID-19 has been a major disruptive event. It has highlighted and continues to highlight the complex social, political, technical and economic interconnections that underpin modern life, and the known and emergent opportunities and threats associated with major disruptive events. COVID-19 has also revealed the strengths and weaknesses that exist in our ability to identify, assess, prepare for, respond and recover from such events.

"During and post-COVID-19 we aim to work collaboratively with industry to capture the lessons learned from COVID-19, specifically those associated with maintaining healthy, safe and productive people, operations and supply chains", Dr Hassall said.

"In doing so we can leverage the fundamentals of chemical engineering that focus on understanding systems, their components and associated capabilities, and how these interact to deliver functions that transform inputs to output or produce deviations from the desired states."

This type of systems and process thinking is a unique characteristic of chemical engineering that is crucial in unravelling, assessing and managing the interlinkages that exist to produce optimal outcomes.

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