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75 YEAR ANNIVERSARY

CSIR
Touching lives through innovation

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FOREWORD

KEEPING OUR EYES ON THE OPPORTUNITIES, WHILE ADDRESSING THE CHALLENGES

The world has now been going through the devastating consequences of Covid-19 for more than a year. Our scientists continue to search for long-lasting solutions and interventions to keep us safe from the disease, as well as develop other innovations that will reinvigorate our economy.

When we formulated our strategic intent over two years ago in 2018, we did not foresee a pandemic that would grind the world to a halt and then refuse to let it out of its grip. One of the positive outcomes of the Covid-19 pandemic is the fact that it has emphasised the relevance of our strategic intent – we need our science, engineering and technology capabilities, and industrial development endeavours to become force multipliers that contribute to the recovery of South Africa's economy, which has contracted sharply, like other economies.

We have a powerful contribution to make to government's goal of reversing the decline of the local manufacturing sector and to promote re-industrialisation through deeper levels of localisation and exports of technologies, in sectors such as high-value goods manufacturing, agro-processing and health care. We also have innovations and interventions in locally made materials, including steel, cements, bricks and other components, which government identified as a priority. Furthermore, we are optimistic about growing the impact of industrialisation that focuses on small, medium and micro enterprises.

In line with our strategy, we continue to invest in and build our competences in the high-impact sectors that we have identified and in which we believe the country could carve out a competitive advantage. We are keeping our eyes on the opportunities, while working to address the immediate challenges.

The past year has demanded that we adapt, along with the rest of the world – and adapt we did. Our adaptation was made possible by an incredible team with a common set of values. In the *Our People* section of this edition, we highlight a few of the people who represent different aspects of our values and who were recognised at our Excellence Awards last year. Team CSIR pursues **E**xcellence, celebrates **P**eople, personifies **I**ntegrity and welcomes **C**ollaboration. We believe that, as our stakeholders, you will associate with and benefit from an organisation with EPIC behaviours, beliefs and principles.

We also highlight some key issues that will be of significance as we start to implement the country's fourth industrial revolution (4IR) strategy. Read about issues around the regulatory environment for information and communications technology, as well as a data policy that will allow us to unlock 4IR opportunities; how a field like the humanities is changing; and how mining hopes to capitalise on the benefits of 4IR.

Finally, in the section on infrastructure, read about investments in facilities for advanced manufacturing, nano-micro manufacturing and photonics – investments aimed at driving economic growth in a variety of industry sectors.

Dr Thulani Dlamini
CSIR Chief Executive Officer

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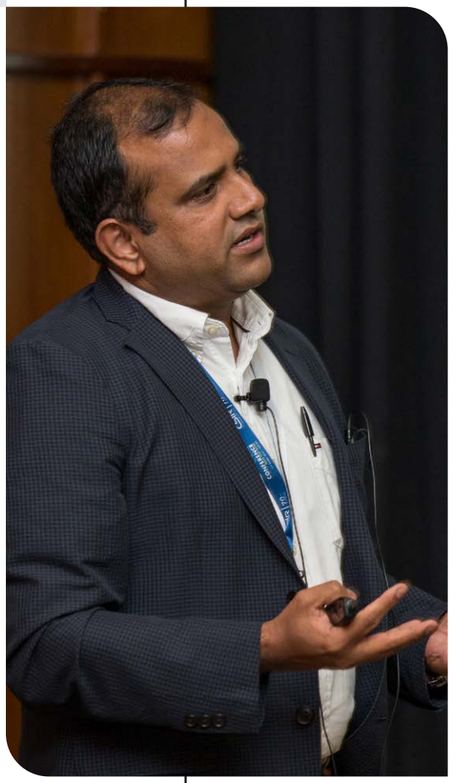

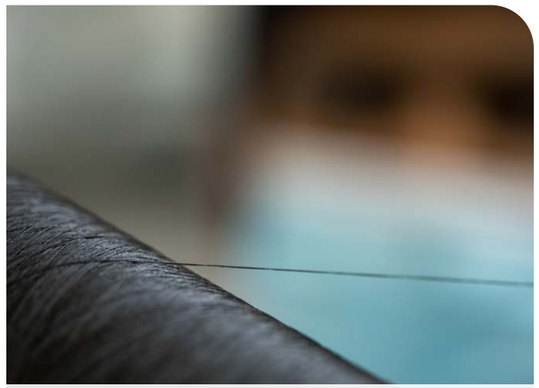

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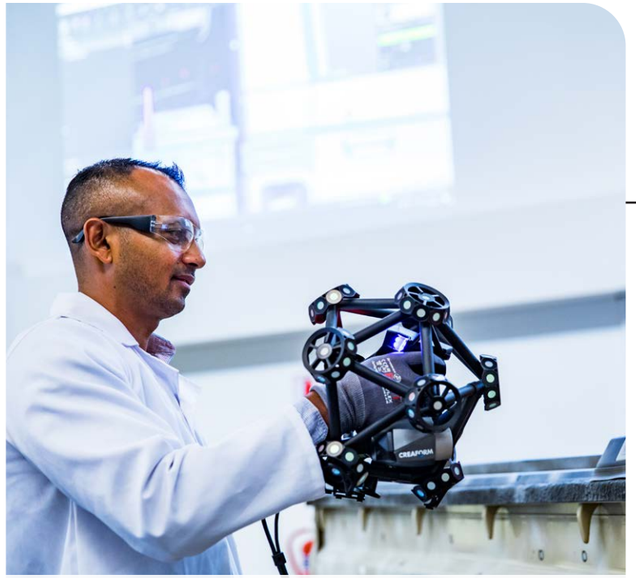

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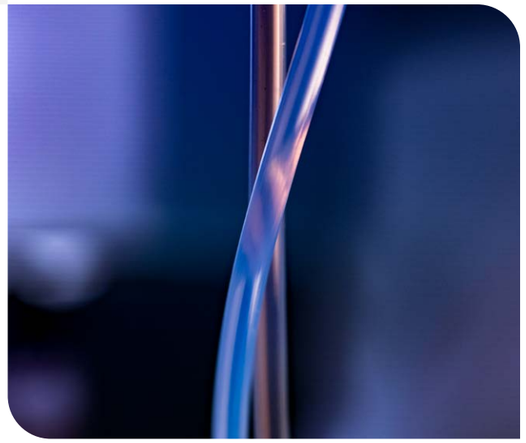


ON THE COVER

Through recent investment from the Department of Science and Innovation and National Treasury, the CSIR is working towards an open innovation facility integrating molecular engineering and continuous pharmaceutical manufacturing for Africa. The expanded facility will focus on the local production of active pharmaceutical ingredients using modern manufacturing technology. Pictured is a close-up of polytetrafluoroethylene tubing that is being used to transfer the reagent from the pump unit to the reactor unit on one of the commercial flow reactors housed at the CSIR in Pretoria. Read more on page 32.

OUR PEOPLE

The CSIR's **Alyssa Ramwell**, a junior mechatronic engineer, is a graduate from the University of Cape Town. She was a CSIR bursary holder from 2016 to 2018 and joined the CSIR in 2019 as a graduate-in-training. She was part of a research and development team who developed and manufactured medical-quality protective facial shields at the start of the Covid-19 pandemic.
The shields are manufactured from materials strictly specified as suitable for medical use. Read more about the CSIR's capabilities in advanced manufacturing on page 62.

CSIR chief researcher Prof. Suprakas Ray.

How an expert on **nanostructured materials** stayed at the top of his game for a **decade**

Professor Suprakas Sinha Ray has put more than 122 640 hours into his work at the CSIR. His passion for research in small particle structures, or nano science, has earned him a formidable reputation in the nanotechnology space, and, at the end of 2020, it secured him the CSIR's Career Achievement Award. Professor Ray was included in the Top 1% of the most impactful and influential scientists (chemistry, materials science and 22 science disciplines) in the Thomson Reuters Essential Science Indicators in 2014.

Professor Suprakas Ray is a chief researcher and research centre manager at the CSIR's Centre for Nanostructures and Advanced Materials, DSI-CSIR Nanotechnology Innovation Centre. His illustrious career at the organisation began in 2006, where he has over the years built an imposing research and human capital development track record.

He has authored four books, co-authored three (with him as lead author) and co-edited five, and has 30 book chapters on various aspects of nanostructured materials and their applications. He has also authored and co-authored more than 350 articles in high-impact international journals, as well as 30 articles in national and international conference proceedings. He has shared (as lead author and co-author) a number of patents and demonstrated technologies (seven already commercialised) with colleagues, collaborators and industrial partners. He is one of the most active and highly cited authors in the field of polymer nanocomposite materials.

With all these accolades and achievements, Ray remains humbled by it all, "Our job is a never-ending, tiring, frustrating, sleep-depriving one. It requires an enormous amount of hard work and sacrifice. But it is also the most rewarding job. The satisfaction you get when that material we developed finally goes to industry for production and commercialisation is indescribable – similarly, when our scientific article is cited by other researchers. So if you are aiming to join the science field, the first step is to make sure you are actually willing to commit to pursuing this career. Focus on excellence, not on success."

> "The first step is to make sure you are actually willing to commit to pursuing this career. Focus on excellence, not on success."

> "Our job is a never-ending, tiring, frustrating, sleep-depriving one… But it is also the most rewarding job."
>
> - Prof. Suprakas Ray, CSIR

The next decade of nanotechnology research

Ray is now working on grooming the next generation of nanotechnology experts and exploring the various aspects of nanotechnology based advanced materials and their applications. His team is working on several projects, such as developing advanced and smart packaging materials to improve the shelf-life of food and monitor food spoilage; controlling the release of drugs over time by improving advanced nano-drug delivery systems; developing green cosmetics, and finally, two-dimensional materials to make materials tougher and electrically conductive.

About the CSIR Nano Centre

The Centre for Nanostructures and Advanced Materials was established in 2007 as part of the implementation of government's National Nanotechnology Strategy. The centre is hosted by the CSIR. It is one of two national innovation centres in nanotechnology, created by government to play a leading role in the development of this research area in the country, as well as the development of skilled South African nanotechnology researchers and scientists.

Academic qualifications

PhD (Physical Chemistry), *University of Calcutta, India, 2001*

MSc (Physical Chemistry) (first class), *University of Calcutta, India, 1996*

CSIR principal researcher Dr Tsepo Tsekoa.

Dr Tsepo Tsekoa advocates for science with a real-world **impact**

Dr Tsepo Tsekoa, principal researcher in CSIR Future Production: Chemicals, has earned a reputation of undertaking and leading research that results in technology demonstrators and solving real-life problems using his skills in applied biochemistry, enzymology and structural biology. This secured him the recognition within the CSIR, when he received the Established Researcher Award during the organisation's Excellence Awards in 2020.

> With the limited resources we have and a constrained economy, we must provide value and benefits to improve people's lives.
>
> - Dr Tsepo Tsekoa, CSIR

Dr Tsepo Tsekoa is the CSIR research group leader for bio-manufacturing technology demonstration. While his responsibilities include training students, Tsekoa's work focuses on developing technologies to produce biopharmaceuticals and enzymes using recombinant techniques. He completed his postdoctoral training in infectious disease and molecular medicine at the University of Cape Town prior to joining the CSIR.

"In our region, so many people are underserved where healthcare provision is concerned. The two-tier health system means that the majority of our population do not have access to advanced biological medicines like recombinant insulins or monoclonal antibodies. The prospects of making an impact in this field by developing cost-effective biopharmaceuticals, are therefore huge."

In recent years, Tsekoa's focus has been on developing production processes for manufacturing biologics at bench and pilot scale. An expert in the recovery and purification of drug substances using natural sources such as bacteria, yeast and tobacco expression hosts, his main tangible output is in the form of technology demonstrators at a technology maturity readiness level of five to six. He also pursues research seeking to solve practical real-life problems using his skills in applied biochemistry, enzymology and structural biology, specifically how these can respond to biomanufacturing challenges.

"The combination of these disciplines enables us to readily engineer expression hosts to produce large amounts of specific biopharmaceuticals with properties that facilitate their manufacture. For example, we are able to make plants produce potent and safe antibodies for HIV, and extract and purify them very economically. These cost-effective processes in turn allow more accessible pricing of these advanced medicines for poor communities."

Tsekoa is no stranger to media engagements and is recognised as an advisor on various national and international organisations' committees. About this role he says, "I find that it is beneficial to us as scientists to engage the public and media regularly to inform them about our work. It's not only great marketing for our capabilities, but doing this also allows us to get feedback and improve our relevance as scientists."

Not satisfied with science staying in the laboratory, Tsekoa is a champion for science that has real-world impact. "I have transferred four technologies to industry thus far, and I am now helping three companies to develop and localise mature technologies for commercial implementation in South Africa.

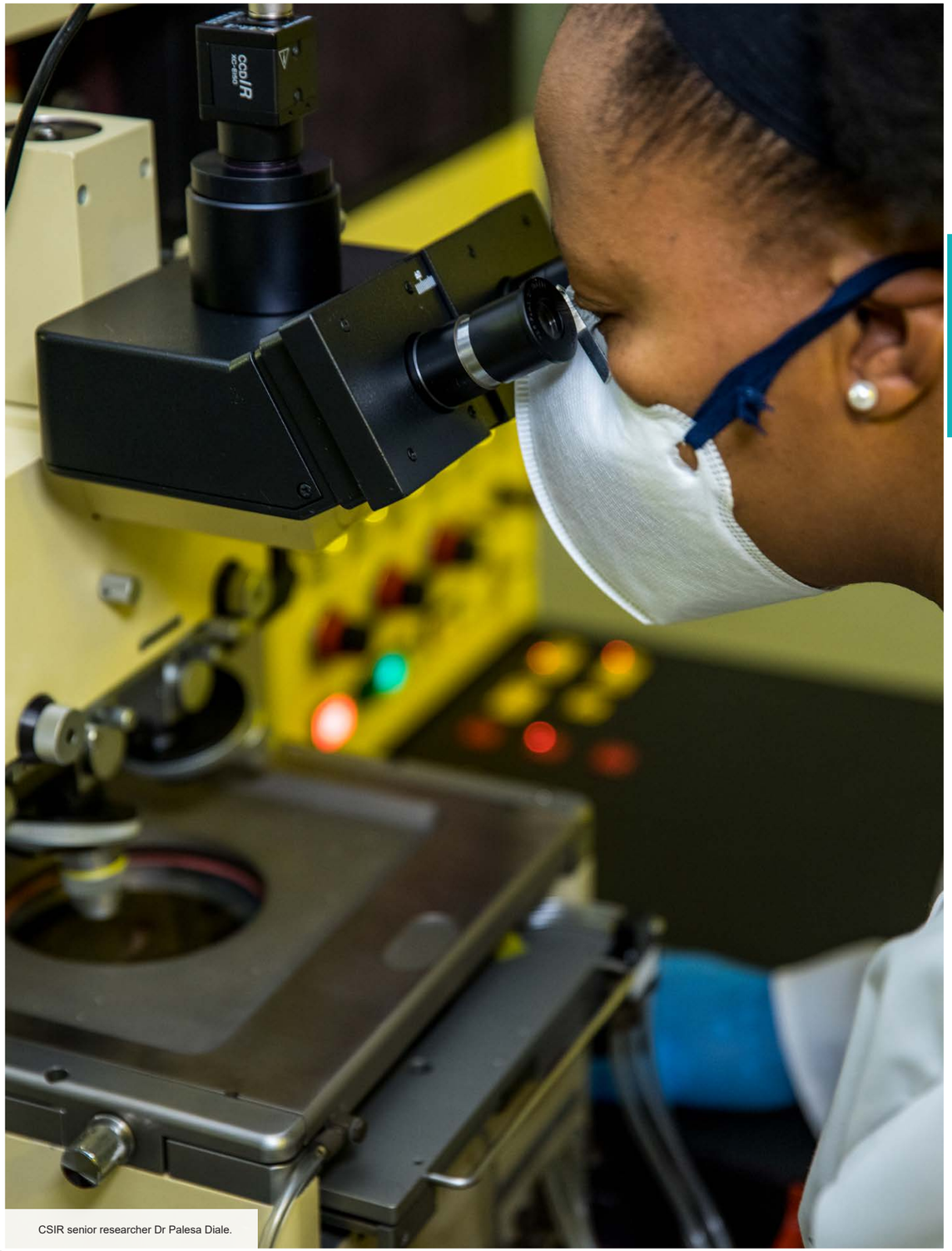
It is important for scientists to commit to translating their work towards impact in society. With the limited resources we have and a constrained economy, we must provide value and benefits to improve people's lives. Of course, at the same time, we must create a pipeline of ideas through some fundamental work that can benefit society in the future. So different parts of the innovation system have a role to play."

Academic qualifications

BSc (Honours) (Biochemistry), *University College London – University of London, United Kingdom, 1998*

MSc (Biochemistry), *University of Cape Town, 2001*

PhD (Applied Biotechnology), *University of Western Cape, 2005*



CSIR senior researcher Dr Palesa Diale.

Dr Palesa Diale, aspiring to leadership **excellence**

Dr Palesa Diale, winner of the Emerging Leader Award at the CSIR's Excellence Awards in 2020, is a bioprocess engineer with extensive mathematical modelling experience, specifically to study the use of indigenous microalgae for the removal of heavy metals from mine waste water through biosorption. The use of mathematical modelling in this context can provide clues on integrated material design, process chemistry, adsorption kinetics and understanding fundamental properties of the biomass, such as mass transfer and hydrodynamics.

Diale is a senior researcher in the CSIR's chemicals cluster. Since joining the organisation, her focus has been on commercialising research on the development of lab-on-a-chip miniaturisation of chemical or biological assays for rapid testing. The development of such point-of-care diagnostic devices enables continuous environmental, human and veterinary monitoring.

She demonstrated her leadership excellence in her role as Manager of the Nano-Micro Device Manufacturing Facility when she joined the CSIR in April 2019. She contributed to improvements in governance and use of the facility. Among others, she developed an online equipment booking system and website, and collaborated with internal, external and industry users to ensure the sustainability of the facility, while also enforcing strict laboratory and equipment management. (Read more about this facility on page 64.)

She says, "My goal was to enable South African innovation in micro-, bio- and nano-fabrication by providing an open-access design, build, test and scale-up pipeline facility, underpinned by cutting-edge capabilities, equipment and expertise."

Leading a team of CSIR researchers in developing a strategy for the facility, she identified important research areas that required further development, and in response is developing capacity for technology support. The strategy serves the entire South African research community.

Bioprocess engineering is a specialisation of chemical engineering, which deals with the design and development of equipment and processes for the manufacturing of products such as agriculture, food, feed, pharmaceuticals, nutraceuticals, chemicals and polymers and paper from biological material and treatment of waste water.

> "I have always aspired to be involved in research with societal impact and was always looking for avenues to be involved in such programmes. The CSIR's strategy and my aspirations are aligned. To young researchers, I want to say that your dreams are valid and the path to your dreams might not always be what you planned. Continue to aim for excellence and do everything with the utmost integrity, no matter how hard it gets.
>
> - Dr Palesa Diale, CSIR

Subsequently, Diale's proposal to the Department of Science and Innovation's South African Research Infrastructures Roadmap programme, compiled with other research leaders in the CSIR, was successful. It led to the CSIR's nomination as one of five nodes in the country, responsible for capacity building, supporting innovation and helping technology reach the market, with the aim to improve South Africa's economy and general public health in the nano-microfabrication domain.

Diale's colleagues sees her mentoring style as inspirational and motivational, as she supervises them with their career growth in mind. One accolade reveals that, "She has motivated her colleagues and clients with her high level of integrity to ensure that they follow a shared organisational vision, and to ensure the effectiveness and success of their areas of research."

Academic qualifications

Certificate, Operations Management, *University of Cape Town, 2018*

Certificate, *River Basins, Power and Law, Natural Resources Law Enforcement and Protective Services, University of Bergen, Norway, 2016*

PhD (Chemical Engineering [Biotechnology/ Bioprocessing Engineering]), *University of the Witwatersrand, 2015*

MSc (Chemical Engineering) *with distinction, University of Johannesburg, 2011*

Dr Ntombi Mathe, trailblazer for additive **manufacturing**

CSIR senior researcher Dr Ntombi Mathe.

> The most rewarding part of my work is my interaction with postgraduate students. To be able to assist them in reaching their full potential and see them grow into competent researchers within their fields mean more to me than anything else.
>
> - Dr Ntombi Mathe, CSIR

She has rapidly built her skills in the additive manufacturing of metal alloys and her colleagues and managers singled her out as having "a highly promising research career", an accolade sufficiently substantiated to earn her the Emerging Researcher Award at the CSIR's Excellence Awards in 2020. **Dr Ntombi Mathe** has been a senior researcher since 2016, working in the laser enabled manufacturing research group.

Dr Ntombi Mathe is a principal investigator on numerous projects that focus on the additive manufacturing of metal alloys and has proven to be highly successful in attracting funding to this specialised field.

"It was a great honour to receive the Emerging Researcher Award. I was excited as this was on my wish list of achievements for my career at the CSIR. The organisation raised me as a researcher. I am what I am today because of the people and environment that helped me grow. I came to the CSIR in 2007 on a Master's studentship and subsequently completed my doctoral degree. To be recognised in such a huge way is still surreal to me," she exudes.

Current focus

She currently leads five projects, two of which are externally focused. One is a collaboration with a local industrial partner where the research group is assisting with prototyping aluminium parts using CSIR-built additive manufacturing machines. "The success of the project will lead to the use of additive manufactured parts in industrial applications using locally built machines. The aim is to localise the technology."

The second is a three-year National Research Foundation-funded collaboration between three Mexican universities and two South African universities, involving more than 10 researchers and focusing on additive manufacturing. Mathe says, "To have obtained this funding as a young researcher has been one of the highlights of my career."

About additive manufacturing

"This is a technology that has taken the world by storm. I believe it has a very bright future, both locally and globally. Increasingly, companies approach the CSIR with projects to determine the feasibility of additive manufacturing for their manufacturing and production facilities. Especially now, where the global pandemic has resulted in many companies shutting down, companies are looking for technologies that will make them sustainable and competitive.

"Additive manufacturing has proven to be a versatile technology that allows for on-site print-on-demand for industries such as aerospace, transportation, mining and others that would usually depend on external suppliers for parts and services."

Seen as a Fourth Industrial Revolution (4IR) technology, it is important for the country to invest in it to bolster the future of the manufacturing industry. Mathe adds, "The CSIR has competencies and capabilities in building metal 3D printers for research and industrial applications. The aim is to create new industries for machine manufacturing and part manufacturing as a service. This technology enables more complex parts to be produced locally, which can position South Africa as a global manufacturing hub for the production of additive manufacturing parts."

Supervising students

Mathe describes her supervision style as 'laid back'. Students have their own strengths and weaknesses according to which she adapts her leadership style. "In the end, I want them to succeed in whatever they do. I let them lead the research and my role is to guide and advise. I tell them, 'This is your work, no one will ever know it as well as you do. Put your best into it and the rest will follow'."

She counsels young researchers to choose a career path that they love, and to be consistent and intentional with their purpose. In a world that can be cruel, she emphasises that it is important to be kind to oneself. "Some days are good and others are not, but always know and remember why you were put on this earth. Take each day as it comes and take a break if you have to, this research life is a journey and it is different for all of us."

Academic qualifications

PhD (Chemistry), *University of the Witwatersrand, 2015*

MSc (Physics), *University of Cape Town, 2010*

BSc Honours (Materials Science), *University of Cape Town, 2004*

BSc (Chemistry), *University of Cape Town, 2003*

The tale of two **doctoral students** who pushed **beyond** their scope

When the Covid-19 wave disrupted the research activities of Drs Katekani Shingange and Ntsoaki Mathabathe, adjusting to the new normal required them to tap into their resilient natures. The pair have managed to use the lockdown period to add to their body of work and reset their strategies. They share the ability to adjust and produce high-quality research, which earned them a joint CSIR Excellence Award for the Best Doctoral Student at the end of 2020. Although they are pursing research in different fields, the budding researchers have a lot in common.

> Over the years, I have learnt how to conduct research and got training on most of the characterisation instruments required for my research.
>
> - Dr Katekani Shingange

> I am honoured and delighted to have won the best doctoral studentship award. The award means a lot to me, for it brings motivation and encouragement to accomplish even more.
>
> - Dr Ntsoaki Mathabathe

Recognition for excellence in specialised research fields

Dr Katekani Shingange is a postdoctoral researcher who specialises in nanosensors for food quality monitoring. She has published more than 10 papers in peer-reviewed international journals with a high impact factor of more than two. Of these 10 publications, three are directly from her MSc, where the focus of her research was on the structural, magnetic and optical properties displayed by zinc oxide nanostructures, in order to link those properties to the gas-sensing mechanism or behaviour of the material towards toxic and combustible gases such as ammonia, methane, hydrogen sulphide and nitrogen dioxide. Five are directly from her PhD research work as a first author, in which her focus was on exploring lanthanum complexes as gas-sensing material. Gas sensing is an important area in the nanomaterials sciences, considering the high demand for gas sensors for food safety, environmental monitoring, as well as disease diagnosis.

“My career at the CSIR began in 2014 on an MSc studentship under the supervision of Prof. Gugu Mhlongo. All I had at the time was my BSc Hons qualification, self-motivation, the drive to acquire knowledge and my obsession over nanomaterials research. Over the years, I have learnt how to conduct research and got training on most of the characterisation instruments required for my research,” says Shingange.

Some of her journals have been published in high-impact factor journals, such as *Sensors and Actuators* (impact factor of 7.100) and *Journal of Alloys and Compounds* (impact factor of 4.560). At the South African Women in Science Awards, held in 2019, Shingange walked away with the TATA Doctoral Fellowship Award and was selected to form part of the delegation of female scientists who attended the 69th Lindau Nobel Laureate Meeting, held in Lindau, Germany.

Shingange is currently working on a project focused on nano-sensors for food quality monitoring.

Carving a niche as a successful researcher

Dr Ntsoaki Mathabathe, a CSIR senior researcher in advanced materials engineering, works on projects that focus on aluminium-joining techniques for manufacturing and the quality assurance of hospital beds.

She has published 12 journal papers in high-impact journals as the main author or a co-author. Nine of the papers relate to her PhD studies, where she looked at the microstructure characterisation of as-cast gamma-titanium aluminide-based intermetallic alloy.

Her performance on the development of high temperature-based titanium aluminides resulted in a degree that was initially a Master’s, but was then converted to a PhD in 2018.

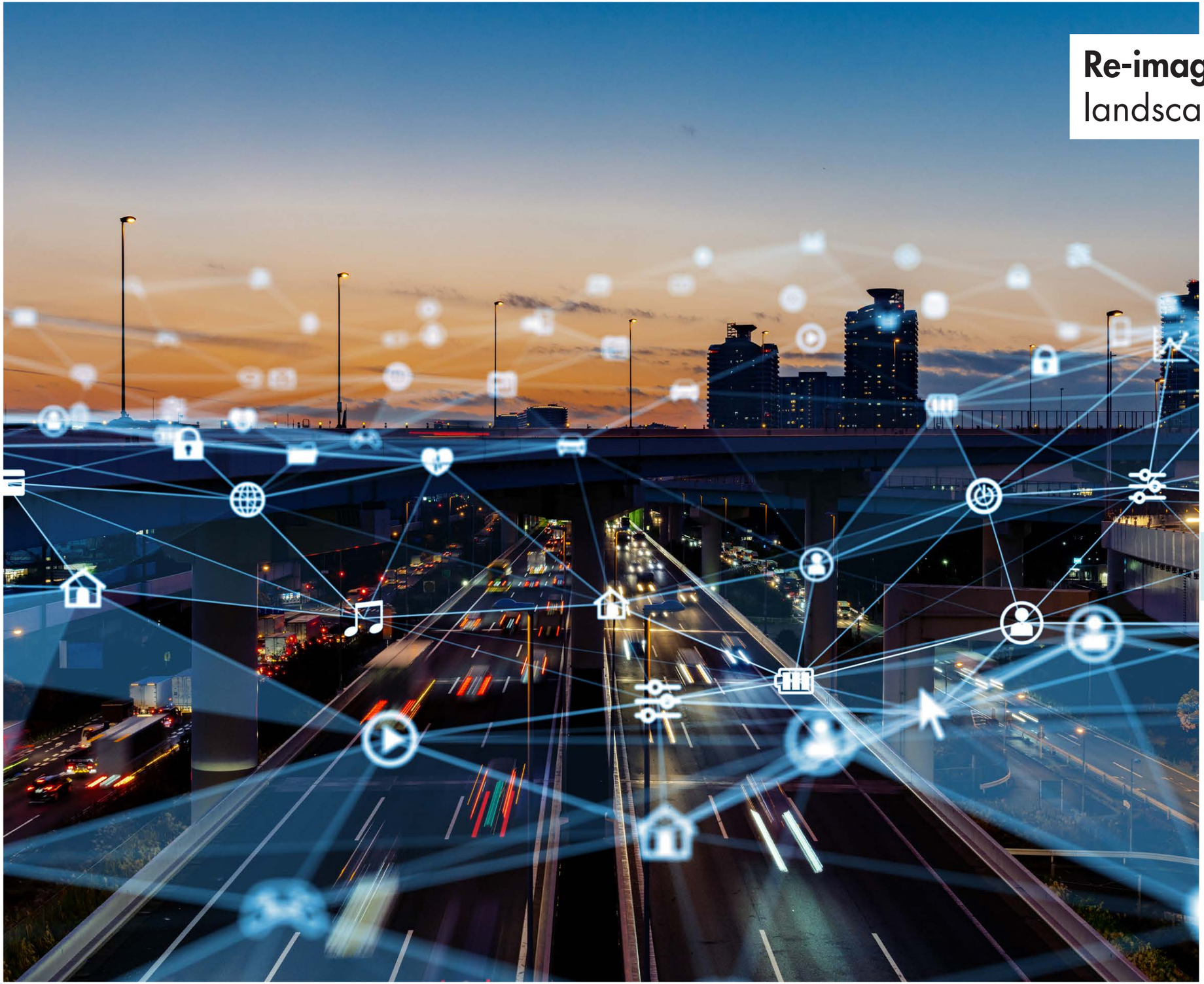
She has contributed to three book chapters – one has been accepted for publication (Elsevier Books) and two are under review (Springer).

After receiving her CSIR Excellence Award, Mathabathe said, “I am honoured and delighted to have won the Best Doctoral Studentship Award. The award means a lot to me, for it brings motivation and encouragement to accomplish even more.” She hopes to develop her profile as an emerging researcher in physical metallurgy and the crystallography of phase domains.

OUR WORK

CSIR postdoctoral researcher, **Dr Valerie Maswanganyi** sets up a reactor used in research aimed at driving technology development for active pharmaceutical ingredient manufacturing in South Africa.

The key differentiator and competitive advantage for a successful African pharmaceutical manufacturing industry is the integration of state-of-the-art chemistry, emerging green and disruptive continuous production, and smart technology for process monitoring and intelligent process optimisation, all of which are required to increase efficiencies across the pharmaceutical production value chain. Read all about it on page 32.



Re-imagining the ICT regulatory landscape in the **4IR era**

> The Fourth Industrial Revolution is an era where people are using smart, connected and converged cyber, physical and biological systems and smart business models to define and reshape the social, economic and political spheres.
>
> - The South African definition of the 4IR.

An opinion piece by

Dr Ntsibane Ntlatlapa

A paper titled “The Fourth Industrial Revolution: what it means, how to respond” by the Founder and Executive Director of the World Economic Forum, Prof Klaus Schwab in January 2016 (World Economic Forum, 2016), put the topic of the fourth industrial revolution (4IR) centre stage in the debate about the impact of technology on socioeconomic development. In that article he declared, “We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before”.

South Africa launched its journey towards developing its strategy on the 4IR in February 2018, when President Cyril Ramaphosa announced in a State of the Nation address that he will be appointing a Presidential Commission on the 4IR (PC4IR) to lead the development of the country’s strategy on 4IR. The PC4IR released its report in October 2020 (PC4IR, 2020). For more details, view https://www.gov.za/sites/default/files/gcis_document/201904/42388gen209.pdf

The commission made eight key recommendations that determine the priorities of the country in the 4IR era. The report recognises the need to update the regulatory environment to enable the desired progress. It is understood that the regulatory environment envisaged covers all sectors of the economy. This article re-imagines the digital ecosystem regulatory landscape that is required to drive the digital transformation in the 4IR era. It touches on two areas that are dealt with in detail in the PC4IR report; building 4IR infrastructure, and securing data for both the government and citizens and making it accessible for innovation.

Regulating the 4IR Infrastructure

The current information, communication and technology (ICT) regulatory landscape covers the communication infrastructure aspect of the 4IR infrastructure. It places the regulation of telecommunications and broadcasting under one communications regulator, the Independent Communications Authority of South Africa (ICASA). This includes almost all aspects on communication infrastructure and services regulations. Some aspects of Internet regulation are regulated by the .za Domain Name Authority (.ZADNA)

Industry sources are in agreement that data centres are not currently licensed and regulated by ICASA; similarly cloud services offered through these data centres are also not regulated by ICASA or by .ZADNA. This is also confirmed by the absence of reporting on the data centres in the *State of the ICT sector report* published by ICASA annually.

However, one opinion is that a data centre could be regulated as a physical electronic communications facility as it is specifically mentioned under the definition of “electronic communications facilities” in section 1 of the Electronic Communications Act. Similarly, the co-location space offered within the data centre would be electronic communications facility. The offering of physical cross-connect services could probably bring a data centre within the definition of a licence-exempt small electronic communications network or a licence-exempt private electronic communications network.

The PC4IR report recommendations are explicit about data sovereignty, but not as clear on data residency. If data residency is assumed within data sovereignty, there is a need to update the regulations to cover the data centre infrastructure as well as the cloud services offered through these data centres.

Regulating the digital ecosystem beyond the infrastructure

The explosion of data generated by digitisation is widely documented in literature. The techniques used to sift through this data, draw insights and conclusions such as data analytics and artificial intelligence and the monetisation thereof, are also well documented. This has led to data being referred to as the new oil by Schwab and Davis in their 2019 book, *Shaping the future of the Fourth Industrial Revolution*. Prof Schwabb says this is not a bad analogy in that:

- It is a significant and untapped asset;
- It must be refined to be useful in most applications; and
- Its use requires both strategic decision-making and technical infrastructure that can help categorise, store, distribute and analyse diverse flows of data.

He further indicates that just like oil, a leak of data can be catastrophic. Therefore, as with oil, there are important reasons to protect data, but to make the most of it, we must find a way to treat it as a collective asset to be used for the common good.

Current regulations are clearer on the protection of personal data, through the Protection of Personal Information Act that is enforced through the Information Regulator. Other than personal data, data is a largely privatised resource that is transferrable and exploited by a few powerful organisations. The regulatory environment must therefore be updated to avoid potential catastrophic leaks, but also to enable refinement and usage in the wider digital transformation of many sectors of the economy and society at large.

It is therefore fitting that one of the PC4IR recommendations is to secure the data of both the government and citizens, and make it available to enable innovation.

Digital regulations best practices

The year 2020 marked the 20th edition of the Global Symposium for Regulators (GSR) under the International Telecommunications Union banner. The regulators re-affirmed the core policy design principles published at the end of the 2019 edition of the GSR. These core principles are to guide regulators to respond to new technology paradigms and business models stemming from collaborative regulation. They further recognise and recommend many tools that can improve the digital market outcome, to form the core of collaborative regulation best practice.

The other organisations that have published best practices for regulating the digital transformation, are the World Economic Forum (WEF) and the Organisation for Economic Co-operation and Development (OECD). The WEF has developed an agile governance framework as an adaptive, human-centred, inclusive and sustainable policy-making tool, which acknowledges that policy development is no longer limited to governments, but rather is an increasingly multi-stakeholder effort. A key element put forward as part of agile governance, is to include innovators in the process from the onset. It brings with it a shift from planning and controlling, to piloting and implementing policies to get rapid feedback and iteration and hence encourage innovators to engage proactively with policy-makers to co-design the governance ecosystem for their inventions.

The OECD has studied a number of use cases of initiatives by regulators across several sectors to deal with disruptions brought about by emerging technologies. A key conclusion from this assessment is that as emerging technologies evolve, regulators need to rethink their approaches and adapt their internal governance towards becoming more agile, iterative and collaborative, so that they are equipped to face the challenges brought about by the 4IR.

Based on the key principles, primarily from the ITU and supported by WEF and OECD, as well as noting the current South African ICT regulatory framework, the following recommendations can be made:

1. Adopt an agile approach – This is highly recommended by the three organisations mentioned above to adapt to the pace of technological development in the 4IR era. This would call for a change in the internal governance of the regulatory authorities to include prototyping, test and iterate cycles in their regulatory development processes.
2. Maximise the potential of public-private collaboration. All the methodologies call for collaboration between policy makers, regulators and industry players. When applied together with the prototype-test-iterate cycles of the agile approach, this enables the innovators to provide early feedback on the impact of the regulatory system on the innovation and investment.
3. Collaborate with other regulators – Digital transformation is a game changer, it can dramatically transform education, health care, environmental management, agriculture, trade and entrepreneurship, as well as the provision of government services. Collaboration that goes beyond memorandums of understandings between ICT regulator and other sector regulators, as well as competition, data protection and consumer protection, are critical. Further collaboration with regulators and players in other economic sectors would be required to co-create regulations to drive digital transformation of those sectors.
4. Use data and digital tools to improve regulation. Adopt data-driven regulation to complement existing mechanisms.
5. Adopt an experimental approach through establishment of a digital transformation regulatory sandbox. Regulators at the core of digital transformation are ICASA, the Competition Commission, Information Regulator and Consumer Commission. A regulatory sandbox that will incorporate the key principles of agility, collaboration with private and other sector regulators as well as adoption of data-driven regulation would bring the required agility to digitally transform all sectors of the economy in the 4IR era. It is recommended that the regulatory sandbox be established by the four core regulators mentioned above. Other sector regulators such as those in energy, finance, transport, mining should be incorporated in projects in their respective sectors.

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Mining 4.0 – Modernisation of mining in the **fourth** industrial revolution

By ***Bongi Ntsoelengoe***,
CSIR Cluster Executive Manager: Mining

The phrase 'the new normal' was coined when the Covid-19 pandemic first struck. But what does 'the new normal' mean for mining and how will the sector become more open and inclined to rapidly adopt digital technology? Can the sector's leaders differentiate themselves from managers by pursuing innovative and appropriate solutions to ensure the sustainability of their business?

Over the years, the mining industry has faced a number of challenges and an immense amount of pressure to change the way it operates – think of resource restrictions, environmental impacts, health and safety standards, and complex social and community interlinkages.

Currently, it is facing an even bigger challenge. No organisation or industry can ignore the impact of the fourth industrial revolution (4IR) and the importance of making technology a strategic priority across every aspect of a business operation.

The modern mine will have to act nimbly in integrating advanced technologies into every step of the value chain – from detecting and exploring minerals, to advanced extraction and real-time digitalised procedures that are overseen by an empowered workforce. The buzzwords 'digitalisation' and 'people-centred modernisation' have also been adopted in this sector. Many of us have seen the gradual implementation of, for example, automated vehicles and drone application with many use cases; the harnessing of radar technologies in prospecting and safety; data-driven process optimisation, a quest for connected workers and driving productivity through leveraging the value of connectivity or digital ecosystems. But there is still a long way to go.

Too often, when one talks of modernisation or automation in mining, the immediate response is a suspicion of job losses and machines replacing humans. The 4IR is characterised by technologies and the combination of technologies, such as artificial intelligence, analytics, cloud computing, the Internet of Things, and other dynamic attributes, all of which have enormous potential to grow the industry while improving workplace safety. Yet, we know, of all the natural resources utilised in mining, people are the most important. The Minerals Council's policy is unequivocal in its emphasis on people-centred modernisation. Employment and skills development are the cornerstones of the industry, and resource wealth and the talent pool are equal drivers in the quest for growth and economic prosperity.

Herein lies the opportunity – the 4IR, which had been ushered in by ever-evolving digital improvements and demands, is inevitably permeating every sphere of industry. The mining industry is no exception to this revolution and sector players understand that, in order to touch lives, the South African mining industry needs to be more innovative. The alignment of the mining industry to the requirements and demands of the 4IR has become a crucial focus for the industry.

The sustainability of the mining industry in South Africa is under threat due to pressures such as high production cost, low profit margins, labour unrest and rising demands by government. Added local challenges have further limited economic recovery for the industry as seen in job losses and the exiting of multinational players. Modernisation of the mining industry can lead to the required transformation and return to productivity. However, financial restrictions and cost-saving attempts have affected investment in research and technology innovation. Studies have demonstrated that research, development and innovation are essential components of modernisation by enabling the testing, development and demonstration of suitable technology solutions. The mining industry continues to drive efforts and facilitate discourses that will enable the development of strong research and development programmes in the sector.

> "In the 4IR, the expanses of technologies available to the mining sector create an immense scope for new skills and new careers in many more new fields – fields that, for one, create the space for more women to enter into the sector."
>
> - Bongi Ntsoelengoe, CSIR

Collectively plotting the **4IR way** for **South African** mining

As the discourse on the unfolding 4IR takes place across sectors globally, the CSIR continues to facilitate rigorous discussions, covering all facets of the phenomenon with experts and key stakeholders.

In a recent CSIR-initiated discussion, mining experts deliberated on factors that can improve the mining sector in South Africa, in light of the 4IR. This discussion touched on a number of aspects, including how innovation in mines would improve global competitiveness and the livelihoods of South Africans through job creation and the eradication of the inequality that still characterises mining.

Sietse van der Woude, a senior executive at the Minerals Council South Africa, stated that it is important for the 4IR to be a friend to the people of South Africa, instead of a threat to their livelihoods.

"Mining exploration through exploration technology is one of the principal focus areas that will play an integral part in the modernisation of mining," says South African mining leadership expert, Bernard Swanepoel.

Mining experts assert that the use of drones with machine learning has the potential to improve exploration accuracy by up to 90%. In addition to this, embedding Internet of Things devices inside mining equipment can improve efficiency by up to 20%. These objectives will be attainable as the sector enhances the skills of its employees, an aspect that the sector will be intentional about, going forward. "It is imperative that employees in the sector be upskilled and reskilled to be able to use the technologies that will be adopted in the mining space," says Van der Woude.

The CSIR is recognised as a key partner in the 4IR in the country. To this end, the Mining Qualification Authority has commissioned the CSIR to undertake a research project in the area of mining innovation. The project examines the envisaged extent of technological innovation and associated impacts in the mining sector. Various aspects of 4IR and mining are prioritised. These include process improvement, mechanisation, robotics, remote-controlled mining, autonomous mining, local power generation and sensor-based real-time information systems management. The CSIR will continue to work with local and international partners to help ensure that 4IR objectives in the mining sector are realised.

It is important for the mining sector to adopt a collaborative approach and synergies to meet the demands of the 4IR. The successful implementation of the National Exploration Plan, which is a key initiative of the Department of Mineral Resources and Energy, will require intentional partnership with all players in the ecosystem. Collaboration with the international mining sector to achieve 4IR objectives will also be beneficial, as intensive research takes places at an international level.

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Data policy to unlock 4IR opportunities for **socioeconomic development** in South Africa

Dr Ntsibane Ntlatlapa, Head of the Centre for Fourth Industrial Revolution (C4IR SA) hosted at the CSIR in South Africa.

> South Africa is in an advantageous position because it has already passed the Protection of Personal Information Act.
>
> - Dr Ntsibane Ntlatlapa, Centre for the Fourth Industrial Revolution South Africa

Data is described as the new oil; it is increasingly generated and collected globally, forcing businesses and governments to have clearer and more practical data governance protocols. For South Africa, embracing open data – particularly the releasing of public data for use by entrepreneurs and developing infrastructure and skills – can enable the country to become a data economy hub in Africa and globally.

Data policy in the South African landscape

In the current digital or fourth industrial revolution (4IR), it is critical that an overarching data policy is developed to govern the sharing, use and protection of data. A number of data sharing frameworks have been developed for the effective management of data sharing from public repositories or between public and private data sources. Sharing of information from diverse sources, including publicly available, personal and business confidential data, is increasingly important when requiring data for public good, such as the response to the Covid-19 pandemic, for service delivery or for economic activity.

"South Africa is in an advantageous position because it has already passed the Protection of Personal Information Act, which addressed the use of personal information. The act, however, does not address the use of public information, either for public good or for economic activity, nor the principles of data sharing between non-public data sources (such as business-to-business and machine-to-machine. Realising this gap, government, through the Department of Communications and Digital Technologies, is developing an overarching data policy for South Africa.

The benefits of such a policy include that it will assist in creating a conducive environment for investment such as the ease of doing business in a data economy, and policy certainty; creating a capable state that deals decisively with ills such as crime and corruption, as well as inequality and transformation; and creating a social compact to develop and co-create policy. At the same time, policymakers need better tools to develop future-oriented and agile frameworks for data regulation that will allow for innovation, but protect individual privacy; promote inclusion; securing data against cybercriminals; and enable data sharing in public service.

4IR best practices and the role for collaboration

The 4IR has already had a profound impact on global trade, economic growth and social progress. On one hand, the ability of data to move across borders underpins new business models, boosting the global gross domestic product by 10% in the last decade alone. However, digital trade barriers, including outdated regulations, fragmented governance and strict data localisation policies could potentially hamper these gains.

The South African government through the Department of Science and Innovation has established a Centre for the Fourth Industrial Revolution (C4IR SA) to lead the process of developing quality governance protocols to maximise the benefits of the South African economy. The C4IR SA is managed and operated by the CSIR. It is affiliated to the World Economic Forum's Fourth Industrial Revolution Network (C4IR Global Network) to tap into the expertise available within the C4IR Global Network.

Data policy in the C4IR SA portfolio focuses on policy implementation protocols that are aimed at maximising the humanitarian and beneficial uses of data, while seeking to develop practical solutions using a multi-stakeholder approach to policymaking. It is a cross-cutting platform; therefore, the governance protocols that can be put in place in this platform may have an impact on other platforms in the C4IR SA, particularly the Internet of Things, artificial intelligence and blockchain.

Projects being explored at the C4IR SA include the models and ownership and the monetisation thereof; and data access models, including open data model for societal value.

Dr Ntsibane Ntlatlapa heads the Centre for the Fourth Industrial Revolution South Africa

Dr Ntsibane Ntlatlapa has been appointed as Centre Head for the Centre for the Fourth Industrial South Africa Revolution (C4IR SA) hosted at the CSIR.

Ntsibane has been at the CSIR for almost 15 years and has held various leadership roles within CSIR management structures. His most recent position was as NextGen Enterprises and Institutions Cluster Impact Area Manager: Networked Systems and Applications.

He is an experienced computer scientist and digital strategist, with a focus on communication technology ecosystems, from digital content generation across the value chain to user interface devices. He has worked closely with ICASA over the past eight years to develop new regulations and technologies to enable Television White Space commercial operations in South Africa.

The C4IR SA was established to support government and industry with developing and piloting the policy protocols, standards and other regulatory instruments necessary for the implementation of the 4IR technologies prioritised by key stakeholders. As the host, the CSIR is optimally positioned to support the implementation of the country's 4IR strategy, which has been developed through the Presidential Commission on 4IR.

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Digital humanities: Reshaping humanities in the **fourth** industrial revolution

Dr Karen Calteaux, CSIR Research Group Leader: Voice Computing

The fourth industrial revolution (4IR) is expected to not only significantly influence the way we live and work, but also how scientists conduct research. The humanities field is one that is being revitalised by the adoption of computational techniques to answer research questions.

Data: The new commodity

Computational techniques make it possible to find meaning in big datasets. The CSIR, University of South Africa (UNISA), and the South African Centre for Digital Language Resources (SADiLaR), hosted by the North-West University, collaboratively explore language and big data. For language, the likely impact of the 4IR is a 'social revolution', as shared linguistic (human) information will greatly expand the accessible information on human nature.

Computational tools to help with communication already exist; some examples are spell checkers, speech recognition, text-to-speech technology and machine translation. However, more linguistic data is required to improve, develop and localise these tools. SADiLaR pursues the long-term curation and dissemination of existing and new language-related datasets and supports the creation of new such sets and tools.

Involving communities

Crowdsourcing supports focused participatory research and ethical co-creation of datasets and tools, enabling communities to take more responsibility as part of data collection and creation processes.

A local example is the 'Spraakatlas' ('Speechatlas'), developed by the Virtual Institute for Afrikaans, where users can read and record a given story for researchers to do phonological research. Users of the platform learn how different people use different dialects around the country.

Next steps include looking at what additional infrastructure is needed to collect, curate and distribute data; how communities can become involved; and what reskilling and upskilling are necessary.

Learning from interconnectedness

Close and distant reading of texts is another example of how the capturing and analysing of large quantities of data enable research. These methodologies aim to reveal relationships and unspoken rules in literature.

First using story books, researchers mapped the interactions of each character to confirm what kind of relational insights can be gleaned. Doing the same for history books, computational analysis might uncover additional relations, for example what power relations were at play, as well as how different books interpreted human communication and interaction over the years.

Indigenous knowledge information as never before

The United Nations Educational, Scientific and Cultural Organization states that preserving knowledge stored in local traditions and practices is necessary to produce new knowledge and responses to emerging challenges.

A 'wordnet' can be used as a large digital repository to capture indigenous knowledge. A wordnet is a semantic dictionary designed as a network. This interrelated system of words and concepts seems to be consistent with how speakers organise their thoughts.

The African Wordnet Project is a multilingual and freely available lexical database of South Africa's nine official African languages. The project resorts under UNISA's African Languages node of SADiLaR.

A wordnet presents the data in a manner that is accessible to other applications in the 4IR. The multilingual nature of a wordnet binds sociocultural phenomena together, while allowing space to explore differences.

Technology solutions to address problems

The upsurge in online meetings and e-learning in the last year, against the backdrop of the Covid-19 pandemic, demonstrated how quickly the world can change and how technology can respond. The interconnectedness of humans was also illustrated, as information could rapidly spread through social media. Also highlighted, was the real danger of a widening digital divide and its impact on a society with existing socioeconomic challenges and high levels of inequality. Technology is a solution to these challenges and the only way to ensure higher levels of social inclusion.

The Awezamed mobile app enables communication between healthcare providers and patients who do not speak the same language.

The CSIR developed and deployed speech technologies used in a speech-to-speech translation application developed by Aweza, a small, medium and micro enterprise. AwezaMed is Android-based and used during interactions between healthcare providers and patients. The first implementation was designed for the midwifery and obstetrics domain in Afrikaans, English, isiXhosa and isiZulu. A Covid-19 version modified some of the content for screening and triage situations, and is available in all 11 official languages.

The augmented ebooks application, Qfrency ebooks, is a modular software system that automatically ingests content in selected formats and outputs this as an augmented ebook. The bespoke reader, of particular benefit to dyslexic users, was built for accessibility and mainstream use and, for the first time, a listener can search for an audio word. It runs on a Windows desktop and Android mobile.

The growth in digital humanities, leveraging what the 4IR has to offer, does not only give the research community and end-users enhanced insight into our 'humanness' and interdependence, but it can also be applied to solve social and economic problems.

This article was compiled following a webinar titled "Hallo Digital Humanities: A reshaping of the humanities in the fourth industrial revolution" at the 7th CSIR Biennial Conference. Its participants were Dr Karen Calteaux, CSIR Research Group Leader: Voice Computing; Prof. Menno van Zaanen, Professor in Digital Humanities, SADiLaR; Prof. Sonja Bosch, Professor in African Languages, University of South Africa; and Mr Juan Steyn, Project Manager, SADILaR.

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The significance of **biocatalysis** in the **fourth industrial revolution**

Could biocatalysis become one of the big players in the fourth industrial revolution? Evidence would suggest so – specifically when its reduced environmental impact, reduced cost and increased yields are considered.

Biocatalysis refers to the process of using natural materials to speed up chemical reactions. Professor Roger Sheldon, Distinguished Professor of Biocatalysis Engineering at the University of the Witwatersrand (Wits), explains, “Enzymes are derived from renewable resources and are biodegradable. Also, they avoid the use of and product contamination by scarce precious metals, which is important in the pharmaceutical industry. This also means that enzyme prices tend to be stable. Biocatalysis requires mild conditions that are less energy intensive, as it is carried out largely in water, which is an environmentally friendly solvent. One does not really need any special equipment; it is high in selectivity, and offers a higher quality product than what most of the chemical methods render.”

“The lower cost and shorter development time have really spurred on the revolution in biocatalysis,” Sheldon adds.

Traditional enzyme applications:

- Detergents
- Food
- Beverages
- Pharmaceuticals

Bio-based economic applications:

- Biofuels
- Chemicals
- Polymers – from plants to plastics

The fourth industrial revolution

Fourth industrial revolution (4IR) technologies expand the scope of biocatalysis from simple hydrolases to much more complicated enzymes. Enzymes are used in continuous flow processing, where there are no time, sequence or substance interruptions, thus saving time, energy and costs, while also reducing waste.

With the progression of synthetic biology, researchers can come up with microorganisms and enzymes that have a large number of application in areas such as food, flavours, fragrances, veterinary products, pharmaceuticals and cosmetics. But for that, they need big data, supported by 4IR technologies, such as artificial intelligence. Large-scale use of biocatalysis can make a big impact on treating plastic pollution, for example. Biocatalysis, and making use of what the 4IR can offer, is a tool that can unlock the production of products that are difficult to manufacture synthetically.

Industry perspective

“Natural aromatic compounds have increased in value compared to synthetic compounds,” says Dr Matthias Esterhuysen, Researcher Fellow at Puris Natural Aroma Chemicals. “The flavour and fragrance industry has been moving towards the use of natural chemicals. These would normally have to be extracted from essential oils or through distillation methods, but now, with biocatalysis, we are able to manufacture these on a large scale, using biotechnology.”

He explains, “Typically, the focus has been on the manufacturing of high-value flavour and fragrance compounds, things like vanillin, which is limited in its natural form and expensive to extract, but has a huge market demand. This has led to the manufacture of natural vanillin through biocatalysis. There are many examples of where the use of natural raw materials adds significant value, using a biocatalytic process to get a natural product. Working with the CSIR, we have had many successes using commercially available enzymes.”

Chemist’s view

Dr Chris van der Westhuyzen, CSIR research chemist, explains that from a chemist’s perspective, “biocatalysis uses two different toolboxes”. He says, “There are a lot of things that chemistry can do that biology can’t do and is not designed to do; and then there’s a huge amount of selectivity and specificity that biocatalysis can do, for which chemistry would need up to 25 steps and biology does in a breeze.”

Many chemical reactions are hazardous, for example hydrogenation, oxidation and halogenation. Increasingly, biocatalysis is used to alleviate this particular problem.”

At the CSIR

CSIR principal researcher, Dr Lucia Steenkamp, says one of the biggest examples of what biocatalysis can do is illustrated in the CSIR’s work on ambrafuran, also known as Ambrox. This is used as a fixative for very expensive perfumes. People initially got it from ambra, an excrement from sperm whales, which floats on the sea and which, when oxidised, forms a specific fragrance.

“People started to kill the sperm whales to get this excrement before they excrete it into the sea, but the whales are now protected, and the chemists came up with an eight-step synthesis to make ambrafuran. We found an organism that can eliminate seven of the chemical steps and then we came up with the final benign zeolite step. Using biocatalysis, we create 40 litres of waste for every kilogram we make, which is easily discarded. The normal chemistry process creates 207 kg of hazardous waste for every kilogram of product produced.”

Other CSIR products made using biocatalysis include:

- Naproxen, an over-the-shelf anti-inflammatory drug known as Naprosyn or Aleve
- L-menthol, the main component of peppermint oil responsible for the cooling sensation
- Monatin, a natural sweetener
- Aloesin, a natural skin whitener
- Four flavour compounds, developed and licensed to Puris for commercialisation
- A number of flavour and fragrance products for Clive Teubes Africa, such as ambrafuran, irones and nootkatone
- Thymidene, used as an anti-retroviral, patented and sold to Arvir
- A number of patents from epoxide hydrolases patented and sold to Oxyrane in the United Kingdom
- A range of veterinary products
- A biocide for Biodx.

More robust enzymes

Prof. Dean Brady, head of Wits’ School of Chemistry recounts, “Islativir is an HIV-treating drug currently under development. We’ve put together nine enzymes in a system, they all work together, one after the other; it is only separated in two separate actions, all of them work in water, which means they don’t have to be worked up each time, resulting in huge savings. Merck has managed to reduce the process from 16 separate steps to three, and pushed up the yield from only 16% of what they have put in, to 80%.”

The CSIR has a sound track record in the field of biocatalysis, with numerous patents and technology demonstrators having resulted from ground work in enzymology and biocatalysis.

Perspective from government

Speaking on behalf of the Department of Science and Innovation, Dr Konanani Rashamuse, Director for Industrial Bioeconomy, says that biocatalysis is important on a number of fronts.

It contributes to a sustainable future by responding to various Sustainable Development Goals. “We see it as central to achieving the targets of our bioeconomy strategy. Firstly, we created the National Biocatalysis Initiative. The next phase saw improvements in productivity, and phase three aims to show socioeconomic impact in the form of jobs, contribution to the gross domestic product and competitive advantage.”

Rashamuse says the intent is to increase support for and collaboration with the business sector, including supporting research and development needs, specific support to small and micro enterprises, as well as emerging industries. “‘Greening of the economy’ is an apt description where biocatalysis is concerned,” he says.

This article was compiled following a webinar titled, “The significance of biocatalysis in the fourth industrial revolution” at the 7th CSIR Biennial Conference.

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Developing essential **medicines** for Africa, **by Africa**

Globally, South Africa has the fifth highest pharmaceutical expenditure per capita. Yet, regional pharmaceutical production has not taken off. The South African pharmaceutical industry is import driven, contributing the fifth largest trade deficit in the country. Local active pharmaceutical ingredient and drug manufacturing is being hindered by various factors, ranging from a lack of skills, to the high cost of production setup, regulatory challenges and the small local market.

A Uniqsis FlowSyn Maxi reactor, highlighting the microfluidic mixing chip.

The challenge

It is estimated that around two billion people globally do not have access to critical medicines. In South Africa, the heavy reliance on the importation of finished drugs, or the active pharmaceutical ingredient (API) itself, places a security-of-supply risk on the country. The centralised nature of international pharmaceutical manufacturing and supply chains has been clearly highlighted through the recent international drug shortages linked to the global Covid-19 shutdowns.

Dr Jenny-Lee Panayides, CSIR principal researcher and research group leader for pharmaceutical technologies, says, “Apart from the interdependence of the pharmaceutical supply chain, reasons of cost, infrastructure challenges and geopolitical instability also have an effect on the availability of drugs within the region. South Africa is one of the biggest buyers of antiretroviral drugs in the world, yet we frequently experience drug shortages. The reality is that for many patients who walk or travel long distances to local clinics, only to be told their medicine is out of stock, the extensive financial burden compounds the devastating effects of HIV/AIDS and they ultimately stop taking their medicine regiments.”

In addition to drug availability, there are growing concerns around drug quality – with the World Health Organization recently reporting that in low- and middle-income countries more than 10% of medicines are counterfeit or of substandard quality. In South Africa, the figure is estimated at one in five.

The opportunity

The pharmaceutical industry is undergoing a revolutionary change in manufacturing, with the potential to switch from batch manufacturing to continuous flow processing. The possibility of applying these leap-frogging technologies in emerging markets will open the door for dramatic changes in regional commercial pharmaceutical manufacturing.

What could be the result of democratised pharmaceutical production, except decreasing costs and increasing availability? “For South Africa, with its high disease burden, it would mean overtaking an outdated manufacturing system, creating huge opportunities to establish and grow a regional pharmaceutical industry,” Panayides says.

Simply put

API factories for pharmaceutical manufacturing are usually multi-purpose facilities that employ batch operations for each step in discrete processes. Specific production campaigns are approached on a batch-by-batch basis, with production runs of the same product often running consecutively within a dedicated campaign – often as multiple consecutive batches. An emerging trend in the industry is to use continuous production, also referred to as flow chemistry technology.

Although continuous chemical processing has been extensively used in large-scale industrial chemical production (such as in Fischer-Tropsch processes in the petrochemical industry), its use in API manufacture has been limited due to the complexities inherent in multistep processes and the existing investment in batch plants by the pharmaceutical industry. Over the last decade, however, continuous flow production has gained interest in the pharmaceutical manufacturing industry. The principal advantages of continuous processes include improved reactor efficiency and reproducibility, improved process safety, and more economical solvent and reagent usage, making the technology attractive from an environmental point of view.

The technology at this stage is disruptive in nature and, as a result, buy-in from countries with established pharmaceutical manufacturing sectors has been slow, despite the advantages afforded by the technology. South Africa has a unique position in that the country has limited existing pharmaceutical manufacturing infrastructure, obviating many of the issues facing established international pharmaceutical companies that would hinder the adoption of a new technology. This affords Africa the opportunity to leapfrog the existing batch manufacturing technology and move directly into the modern continuous flow manufacturing approaches. It could mean independence from the global pharmaceutical market and contributing to South Africa’s economy.

Birthing a regional pharmaceutical industry

The CSIR has collaborated extensively with the University of Pretoria Flow Chemistry Facility and the Center for Rapid Online Analysis of Reactions at Imperial College London to establish a complementary offering that will drive technology development and the commercialisation of API manufacturing in South Africa. Through recent investment from the Department of Science and Innovation and National Treasury, the CSIR is expanding this platform to include an open innovation facility integrating molecular engineering and continuous pharmaceutical manufacturing for Africa. The expanded facility will focus on the production of APIs using modern manufacturing technology that blurs the lines between the physical and the digital worlds, solving complex real-world problems for the local pharmaceutical industry, and making production more automated, modular, cost-effective and responsive.

A high-performance liquid chromatography pumping unit transferring reagent into the reactor.

By working in partnership with industry to apply forward-looking business models, measurable impact will be realised through cost-competitive and improved end-to-end API production technology scaled-up into commercial API ‘micro-factories’ and other facilities. Researchers estimate that industry will be supported to obtain approval for production process implementation within the next five years, heralding a much-awaited era where Africa can produce the drugs it needs, increasing access to good health for millions.

Touching lives through innovation

Panayides says, “With our collaborating partners at the University of Pretoria and Imperial College London, we are currently targeting oncology APIs of social importance in South Africa. To date, we have developed an improved batch-, flow-hybrid process route for a key breast cancer drug that is currently only available in the private sector due, in part, to the high cost of the drug treatment regime. The manufacturing process has been improved by reducing the total number of steps required to make the API, improving the ‘greenness’ by modifying the profile of materials used, and increasing the overall yield of the final product. Scale-up is currently underway at the CSIR facility.”

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Above: Researchers have developed influenza candidate veterinary virus-like particle vaccines produced in tobacco plants **(below)**.

> These new-generation plant-produced virus-like particle vaccines aim to offer safe and efficacious biobetters to traditional vaccine platforms.

Vaccines and **biologics** for veterinary health produced in plants

Vaccination still remains the most effective way of controlling, preventing and eradicating infectious diseases. During the last two decades, a plant-based platform for the production of vaccines for human health emerged, and candidate vaccines are already in advanced clinical trials.

The production of pharmaceutical products in plants is recognised for its scalability, speed, versatility and low production costs. Global leaders based in Canada, Europe and the United States of America claim to produce millions of doses within six weeks of the identification of the latest circulating stains. The potential for the African continent needs to be unlocked and the opportunities to develop highly efficacious vaccines for animal health are vastly untapped.

The CSIR, in collaboration with the University of Pretoria (UP) (through Professor Celia Abolnik, incumbent of the SA Poultry Association's Research Chair in Poultry Health) developed a number of influenza candidate veterinary virus-like particle (VLP) vaccines produced in *Nicotiana benthamiana* (tobacco) plants. A VLP is a synthetic protein shell of the virus that is not infective (due to the lack of the viral genome) and cannot replicate in the mammal, but elicits neutralising antibodies to effectively protect when confronted with the live virus.

The CSIR-UP team demonstrated the superior effectiveness of the plant-produced H6 subtype influenza (VLP) vaccine in chickens when compared to a traditional inactivated egg-grown virus vaccine. Conservatively estimated, up to 10 000 chickens could be vaccinated with the H6 VLP vaccine from just 1 kg of leaf material. There is a minimum effective dose study underway to determine the minimal dose for effective protection against influenza and it might significantly increase the number of chickens that can be vaccinated with 1 kg of plant leave tissue. The efficacy of the plant-produced vaccine products even makes a compelling case for the protection of endangered wildlife birds in future.

The CSIR, in collaboration with its research associates at the University of Cape Town and Onderstepoort Biological Products, also filed a patent for their proprietary VLP vaccine candidates against African horse sickness and the Bluetongue virus, and published the work in acclaimed international journals. A market-driven approach determines the pipeline of candidate vaccines to be produced in plants to protect flocks and herds, whether domesticated or wildlife.

The major advantage of the transient plant-based expression is the short production time (a few days) and this translates into prompt updates of the vaccine to ensure ultimate protection against the latest circulating pathogenic strains or subtypes. As VLPs comprise only the outer protein shell of the virus, the vaccines are DIVA compliant (differentiate between infected and vaccinated animals), which is highly sought after in industry and can assist in disease surveillance and outbreak management of highly pathogenic animal diseases with zoonotic potential (animal-infectious diseases spreading to humans). These new-generation plant-produced VLP vaccines aim to offer safe and efficacious biobetters to the traditional vaccine platforms and will pave the way to highly competitive, commercially viable vaccine products for all economic environments.

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THE TEAM

From left, top to bottom: Postdoctoral fellows Drs Agatha Kola and Tanja Smith, senior researcher Dr Essa Suleman, technician Gugu Mkhize, technician Albert Mabetha, senior researcher Dr Daria Rutkowska, PhD student Kamogelo Sepotokele (University of Pretoria), research group leader for molecular diagnostics and omics, Dr Yolandy Lemmer and senior researcher Dr Maretha O'Kennedy.

The CSIR co-developed a baobab-based instant maize porridge and snack bar with VIDA Pharmaceuticals, an SMME that uses biodiverse resources to create nutritious food products.

Assisting **SMMEs** in developing nutritious **food products**

The CSIR, through its Biomanufacturing Industry Development Centre, has been collaborating with small, medium and micro enterprises (SMMEs) in the chemicals, agro-processing and biotechnology industry to translate research into market-ready products. To date, the organisation has transferred 104 products to 35 SMMEs. One of these SMMEs is VIDA Pharmaceuticals, with female entrepreneur and owner Patricia Mathivha at the helm. The SMME uses biodiversity to create nutritional products that bring sustainable and transformative solutions to communities.

"I was inspired to start VIDA because of the persistent challenges of inaccessible life-saving and life-enhancing healthy food technologies in under-resourced communities in the country and continent. As part of my journey to expanding and improving VIDA products, I worked with the CSIR to develop two product lines from Baobab fruit pulp, a maize porridge and snack bar," says Mathivha.

VIDA Pharmaceuticals is one of 35 SMMEs that have benefitted from the BIDC programme. The company works with communities in Limpopo, specifically in the Vhembe district, where the women of the community collect baobab fruit from the wild, whereafter the pulp is processed to a powder, which is of commercial value due to its use as a food and nutraceutical ingredient.

BIDC Programme Manager Lara Kotze-Jacobs, who has been leading the programme since its inception in 2013, says the success of projects like VIDA Pharmaceuticals lies in the co-development of these innovative products and processes.

"The biggest gaps we have seen when it comes to SMMEs in South Africa are the lack of access to scale-up facilities and expertise in scaling up biotech processes, validation of products, and ensuring the quality of the products. In response to these challenges, the CSIR has proven its capability to assist SMMEs in not only translating concepts into quality products, but also providing a platform that allows SMMEs to network with some of our partners, and access financial resources," says Kotze-Jacobs.

The CSIR's agro-processing technical team, led by Dr Nomusa Dlamini, met with VIDA Pharmaceuticals to brainstorm ideas to design a product and formulate a specification brief that outlined the kind of work that needed to be done, the type of ingredients to be used, as well as packaging and labelling requirements, as regulated by the Department of Health. As part of this process, CSIR engineers also looked at the techno-economic feasibility of producing products at a price that is consistent with the market's expectation, while still resulting in a good return for the company.

> "The CSIR team is very proud of its work. We are not only strengthening South Africa's biomanufacturing industry but also enabling small businesses to productise their unique and novel concepts."
>
> - Lara Kotze-Jacobs, CSIR

"The interactive sessions we had with VIDA provided valuable information regarding the direction the work should take, especially on the taste and look and feel of the products, as these aspects determine consumer acceptance or rejection of the product. During the formulation process, we had to make sure we had incorporated a sufficient amount of ingredients to provide enough nutrients to enable nutritional claims on the products. The safety and shelf stability of the products were also very important," says Dlamini.

After the final formulation process was completed by the CSIR technical team, the product was analysed by an accredited laboratory for nutritional content, microbial safety and shelf stability. Additionally, the manufacturing process was handled by accredited facilities that produced market samples for market testing. Based on the nutritional content analysis and feedback received from the market, VIDA's instant maize porridge could prove its claims of being nutritious, with no added sugar or preservatives. The company's snack bar is naturally sweetened through the addition of honey, and is high in vitamin c, magnesium, iron, zinc and dietary fibre.

VIDA's range of products is specifically tailored in such a way that they are accessible, affordable and have all the nutritional requirements needed to maintain a healthy diet without spending copious amounts of money.

"The CSIR team is very proud of its work. We are not only strengthening South Africa's biomanufacturing industry but also enabling small businesses to productise their unique and novel concepts through science and innovation, combined with access to world-class facilities," says Kotze-Jacobs.

VIDA Pharmaceuticals has manufactured its production equipment and plans are underway to distribute their Baobab-based instant maize porridge and snack bar at local retail stores and wholesalers.

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Helping SMMEs develop safer and more effective **beauty products**

Marple Skin Care products is one of the enterprises supported by the BIDC in the cosmetic sector.

Over the years, the beauty industry worldwide has experienced significant changes, brought about by diverse representations of beauty in the market, consumer concerns on environmental sustainability and the health benefits of using organic products. This has had a ripple effect on the South African market over the last couple of years, which has led to a considerable number of small-scale entrepreneurs entering the beauty market to provide skin and hair care products for a niche market. Assisting some of these small, medium and micro enterprises with the process and product development are CSIR technologist Vivey Phasha and senior researcher Phatheka Ndzotoyi.

The CSIR's Biomanufacturing Industrial Development Centre (BIDC) was established to translate biomanufacturing concepts and technologies into market-ready products and services. The facility offers competencies throughout the value chain, from laboratory-scale validation through to technology prototyping and pilot manufacture.

CSIR technologist Vivey Phasha has, for the past five years, been developing and improving products tailored to meet the needs of small, medium and micro enterprises (SMMEs) incubated at the BIDC. Her experience in scientific research of biological resources and indigenous knowledge has helped her build a track record of transforming raw materials into final products – a skill that ensures budding local SMMEs and industry stay ahead of the curve with new and improved products that meet the ever-changing needs of their customers.

Having worked with entrepreneurs in the agricultural sector who hold indigenous knowledge of raw materials that have been traditionally used for centuries, and are known for their benefits to human hair and skin, Phasha has been able to assist in the development of product concepts for more than 10 entrepreneurs, translating these concepts into tangible products for market use.

"Before kick-starting the formulation development process, our team discusses a range of issues with the SMME, including product requirements, which will determine the type of raw materials to be used, where to source them and what kind of product tests should be conducted based on available research reports and the cosmetic industry regulatory requirements. Thereafter, we have our own information sharing session which guides how I go about formulating the products for the SMME", says Phasha.

A technologist by training, Phasha describes the formulation process as one that cannot be done overnight. "It can take up to a year or more, depending on the availability of the key ingredients and raw materials, and the type of product to be formulated with associated claims. Furthermore, the important steps in between, such as literature review studies, formulation of the products, followed by a process of evaluation and testing, all form part of a lengthy process that guarantees the development of safe, effective and efficient product concepts."

Some of the products that Phasha has formulated for SMMEs to date are:

- **Yivani Naturals** – A face care range that includes face wash, toner, day cream SPF20 and night cream;
- **Marple Skincare** – A body care product range that includes body wash, body lotion, body cream and hand cream; and
- **K2 Group** – An ethnic hair care range formulated with plant-based ingredients. Their hair care range consists of a shampoo, scalp treatment cream and hair butter.

The cosmetic product development process is overseen by CSIR senior researcher, Phatheka Ndzotoyi. With over 20 years' experience in the cosmetic industry, she ensures that product formulation is carried out according to the SMME's needs and requirements, from the type of ingredients used to develop product concepts, the approval of product concepts, meeting of packaging specifications, test requirements, labelling and design, and pilot-scale manufacturing for consumer acceptance in line with the cosmetic regulations.

"I have developed a keen interest in the industry's interest in the use of plant-based ingredients and the use of indigenous plant oils and extracts for formulation development. The principles involved in formulating plant-based ingredients and those with synthetic ingredients are similar, and the biggest lesson lies in stabilising plant-based ingredients in emulsion systems, which requires much alliteration at the concept development stage to meet the customer needs with respect to the colour, texture and odour of the end products. Plant extracts and oils are rich in both colour and odour, hence prior knowledge and expertise in formulation development is required to formulate with them," says Ndzotoyi.

With consumers becoming more health-conscious and the use of natural ingredients in cosmetics continuing to expand, Ndzotoyi asserts it is becoming increasingly important to establish collaborations between research institutions and industry.

"The key to developing effective products is understanding the blending and mixing of chemical molecules in a way that they do not react, but interact, in the final product. This is the kind of knowledge that research institutions can provide to industry to ensure innovative, safe and usable products are consumed by the market," Phasha says.

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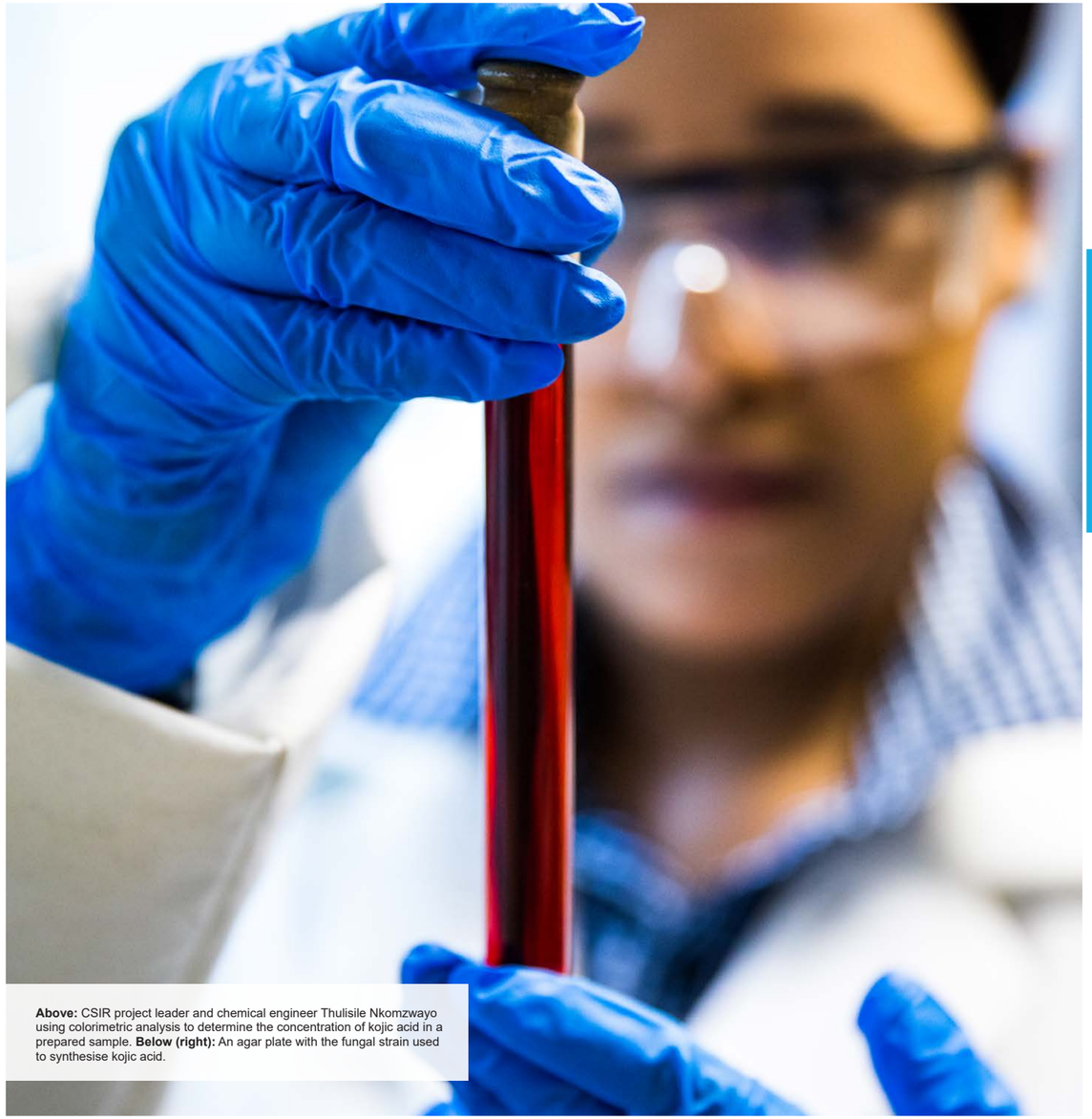
CSIR technologist Vivey Phasha.

CSIR senior researcher Phatheka Ndzotoyi.



Above: CSIR project leader and chemical engineer Thulisile Nkomzwayo using colorimetric analysis to determine the concentration of kojic acid in a prepared sample. **Below (right):** An agar plate with the fungal strain used to synthesise kojic acid.

Homegrown compound to **boost** local cosmetic and personal care industry

A compound with an unconventional start as a waste by-product of one project, is expected to turn into a technological winner that opens the local market for the cost-effective production of international calibre kojic acid, offering a high quality product that is stable and suitable for local dermatology and cosmetic markets, and an easily up-scalable manufacturing process to be licensed to an African female-led SMME.

The CSIR has identified localised kojic acid manufacturing as an ideal starting point to enter the organic skin care market while also promoting the growth of SMMEs in the South African cosmetic sector.

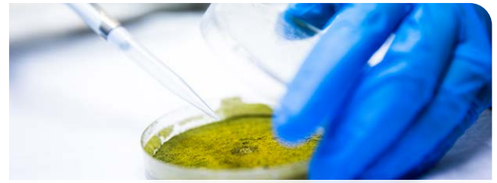
Kojic acid is a natural metabolite produced by fungi that has the ability to inhibit the production of melanin. This is good news for people with skin colour disorders such as those caused by excessive exposure to sunlight, aging, hormonal imbalances, or some medications, among others. Kojic acid can act as an ultra violet protector, and can suppress hyperpigmentation and restrain melanin from forming.

Other star qualities of this compound, which is currently only available from international suppliers, include being biocompatible, antimicrobial and antiviral, anti-inflammatory, antidiabetic, anticancer, antiparasitic, as well as offering pesticidal and insecticidal properties. It is used in skin creams, lotions, soaps and dental care products. The nano-carrier system prepared from kojic acid shows effective deliveries of anti-cancer drugs, significantly inhibits cell proliferation and also reduces tumour growth. Thus, apart from its benefits to the cosmetic and personal care industry and the agricultural and food industry, kojic acid's vast biological activities provide an excellent structure in medicinal chemistry research.

Kojic acid has been proven to be a natural metabolite that is produced in large quantities as a by-product of fungal growth; as such, there is no need to invest in cultivating, producing or extracting the compound, resulting in production cost benefits.

The demand of the compound is also set to increase as global cosmetic manufacturers are seeking replacements for hydroquinone, a skin-lightening ingredient banned by the United States Food and Drug Administration in 2006.

Currently at a technology readiness level of between four and five, the CSIR envisages that the product will be a local replacement of imported kojic acid, benefiting from an optimised manufacturing process and yielding similar or higher product purity and quality with a reduced delivery time. This organic acid produced using CSIR extraction processes has been shown to be at 97% purity using nuclear magnetic resonance. Scientists developed the product purification method using reverse-phase with higher efficacy and product recovery than the recrystallisation method currently used industrially.



An agar plate with an *Aspergillus oryzae* fungal strain used to synthesise kojic acid.

The raw ingredient will now be applied in cosmetic formulations to validate dermal safety and efficacy. The product or prototype will then be offered to dermatologists or suppliers of cosmetic products for uptake to replace imports and support locally produced cosmetic products.

CSIR project leader and chemical engineer Thulisile Nkomzwayo is passionate about process design and optimisation. This research, she believes, will touch lives through innovation by introducing world-class locally produced alternatives, and supporting SMMEs in the cost-effective manufacturing of niche dermatological ingredients.

She says, "Because the CSIR is the incubator of the optimised process, the transfer of the technology to an SMME means the enterprise would not have to grapple with the high investment cost that comes with initial start-up research and development."

Thumbs up to the Kojic acid project for:

- Establishing the CSIR as local manufacturer of kojic acid, replacing imports and increasing economic competitiveness.
- Direct and indirect job creation.
- Improving infrastructure and demonstration of the CSIR's capability to produce high efficacy kojic acid products.
- Contributing to skills development.

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Extracted dagga oil, **left**, and dried dagga leaves, **right**. The CSIR is undertaking research and development into simple extraction technologies that can be used in rural communities to add value to the crops of small farmers.

Emerging **cannabis** industry requires **fertile soil**

> We seem to miss the bigger picture. We waste time by looking at the small things like recreational use.
>
> - Professor Motlalepula G Matsabisa, University of the Free State

Africa produces more than 38 000 tonnes of cannabis annually. However, of the over 50 countries around the world that have legalised some form of cannabis for medicinal use, only three are from Africa. Many African governments are looking to leverage the opportunities from the legalisation of cannabis and the international demand for the continent's legally produced cannabis.

Lost opportunity?

Professor Motlalepula G Matsabisa, from the School of Medicine at the University of the Free State, is concerned that South Africa might be missing the boat in terms of local medicinal cannabis research.

"We seem to miss the bigger picture. We waste time by looking at the small things like recreational use."

The numbers are impressive. The global legal marijuana size is expected to reach $66.3 billion by 2025, and the medical cannabis market $82.19 billion by 2027. "The market is huge and awareness about the advantages of cannabis is increasing. In 2019, *Business Insider SA* projected that the South African dagga industry could be worth R27 billion within four years, although export-quality cannabis may be a problem. South Africa could be a world leader in this emerging industry, but rather than being bold, we fiddle with incremental changes to legislation."

Matsabisa cautioned that cannabis will not be going away, but without proper regulation, illicit trade will increase; formal economic value will diminish; and poverty, dependency and lawlessness will surge.

"We must innovate and not just follow others. We have our own unique environment and do not need to settle for a plug-and-play solution," he concluded.

Regulations

If cannabis has such health benefits, why is it so regulated?

Daphney Mokgadi Fafudi, a Medicine Control Officer with the South African Health Products Regulatory Authority (SAHPRA), said, “We need evidence – solid evidence-based data – to ensure that these products are of good quality, safe and effective.”

> We have collected massive amounts of research data across different elements of cannabis production. We are now in the process of registering some of those products.
>
> - Cian McClelland, CEO, Druids Garden

“We enable research by issuing licences and permits. For the past two years, we have been working with various departments, such as Agriculture, Justice and Police, to make sure that the emerging cannabis industry can grow while adhering to the Medicines Act,” she said.

In 2018, a Constitutional Court judgement required adjustments to the Act. That ruling released hemp, which is a low-THC cannabis (cannabis that contains a small amount of tetrahydrocannabinol), from regulation. However, CBD – cannabidiol, another natural compound found in the cannabis genus – is still regulated as a cannabinoid under the Act.

SAHPRA also removed the cannabis inscription from the Act and from schedule 7 (banned substances). THC now falls under schedule 6 if it contains over 0.2% of the compound, but processed products made from cannabis containing 0,001% or less of THC are exempted from the Act.

“CBD remains in schedule 4. However, we made an exception in terms of complementary products. If these contain less than 600 mg of CBD of the total sales pack and they provide a maximum daily dose of less than 20 mg without making any health claims, we will allow it for complementary medicines as per schedule 0,” Fafudi explained.

Processed products, intended for ingestion, made from the raw cannabis plant, containing less than 0,0075% of the naturally carrying quantity of the CBD, also fall under schedule 0.

Agriculture’s role

Cannabis falls in the industrial crop category. Thabo Ramashala, Director: Plant Production at the Department of Agriculture, Land Reform and Rural Development, said, “During 2019, Cabinet decided that the country must diversify its economy by, among others, commercialising cannabis.

“Thus my department was tasked to lead the drafting of the Cannabis Master Plan for South Africa together with other government and private sector stakeholders. Our approach is that the regulatory issues must be sorted out for us to succeed in deriving the economic, social and environmental benefits from this commodity. The Masterplan provides the framework to commercialise cannabis – dagga and hemp.”

The department looks at various aspects besides coordination. “There are issues around seed, because without proper seed and a formal seed industry, the cannabis industry will not be sustainable. We must also mobilise the farmers to participate. South Africa shall have a cannabis industry. But, it is up to us to define how we want this industry to be and ensure all other restraints are removed responsibly, to diversify the economy and create jobs,” Ramashala said.

Vukile Nkabinde, the Director: Policy Unit within the Department of Small Business Development, added, “We want to ensure that small enterprises are capacitated and competitive so that, as our National Development Plan says, we can peg our economic growth and job creation through small enterprises. Research is a must. Especially around our medical and commercial imports. We must advance this entrepreneurial state to enable these jobs we envisage from the cannabis industry.”

Indigenous knowledge

Dr Hlupheka Chabalala, National Director of the Indigenous Knowledge-Based Technology Innovation Unit of the Department of Science and Innovation, said that the department’s work is backed by the necessity to acknowledge the importance of indigenous knowledge systems and technology-based innovation.

“We use the entire value chain as the framework that guides our work. We call it the Ubuntu-based Bio-Innovation Model. ‘Ubuntu’, because when it comes to cannabis in particular, injustices were visited upon our people, especially the wisdom keepers, like African medicine practitioners. Our work seeks to mainstream the use of cannabis, whether it’s for medicinal purposes, or for cosmeceuticals, nutraceuticals, or health infusions.”

He explained that innovation should be inclusive, saying that the holders of the knowledge, the primary researchers, must be consulted and receive fair recognition. “We need to think about enterprise development and conscious commercialisation. Access and benefit sharing should accrue to the wisdom keepers who are actually informing the researchers. But at the same time, research must empower our people so that they own the means of production; they need not be passive recipients of what emerges out of research.”

Those responsible for various forms of legislation and regulation must use evidence, not only scientific research, but also evidence that comes from these communities, he said.

Cian McClelland, the CEO of Druids Garden, a wellness company that specialises in the cultivation and production of traditional medicines from Africa representing the private sector, reported that, “We have collected massive amounts of research data across different elements of cannabis production. We are now in the process of registering some of those products. We believe that cannabis can revolutionise the economy and social development in South Africa. But it is critical that it is done with community-based structures and with a social development ethos.”

Research and development at the CSIR

High-quality germplasm, drying, downstream processing, analysis and product formulation are bottlenecks in the industry, especially for smallholder farmers and enterprises, explained Dr Blessed Okole, CSIR research group leader for agro-processing. The CSIR is taking the lead in finding affordable solutions to these bottlenecks by developing technologies and processes that can be easily adapted by small and big enterprises. This can only be achieved by working in consortiums to fast-track the process, and putting proudly South African products on the market.

The CSIR received three permits to work on cannabis. One group is developing simple extraction technologies that can be used in rural communities to add value to the crops. The second group is in Durban and is focusing on a high-technology carbon-dioxide extraction method, while the third permit is used by the nanotechnology team in Pretoria, working on improving drug formulations.

*This article was compiled following a webinar titled, ‘**Cannabis: Opportunities for research, product development and job creation**’ at the 7th CSIR Biennial Conference. Its participants were Dr Blessed Okole, CSIR Research Group Leader: Agro-processing; Dr Hlupheka Chabalala, National Director of the Indigenous Knowledge-Based Technology Innovation Unit of the Department of Science and Innovation; Cian McClelland, Chief Executive Officer of Druids Garden; Prof. Motlalepula G Matsabisa, Professor of Pharmacology and Director: Research and Teaching, University of the Free-State; Vukile Nkabinde, Director: National Small Enterprise Development Masterplan, Department of Small Business Development; Ms Daphney Mokgadi Fafudi, Medicine Control Officer, South African Health Products Regulatory Authority; and Thabo Ramashala, Director: Plant Production, Department of Agriculture, Land Reform and Rural Development.*

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CSIR-DSI collaboration yields results for **six** traditional health practitioners

The CSIR assisted six traditional health practitioners to develop safe and standardised traditional medicines for commercialisation in a project funded by the Department of Science and Innovation.

Above: The CSIR assisted Prijap Biolife™ with the development of a safe and standardised 100% natural herbal liquid remedy that has the potential to strengthen the immune system and increase energy levels.
Below (left): Lenong tissue oil is suitable for the treatment of wounds and arthritis. **Below (right):** The CSIR provided in vitro data on a herbal tea called Moshumasekgwa™, which has the potential to regulate type 2 diabetes mellitus. It also treats ailments like high blood pressure and urinary problems.

> It is important for us to valorise and create safer products that will produce jobs for women and youth. It is against this backdrop that the DSI established the IK-based Bio-Innovation Programme.
>
> - Dr Hlupheka Chabalala, Department of Science and Innovation

Mainstreaming indigenous knowledge (IK) within the national systems of innovation can improve the quality of life for thriving societies through wealth creation initiatives. Elaborating on this view, is Dr Hlupheka Chabalala, Director General of Indigenous Knowledge System Technology Innovation at the Department of Science and Innovation (DSI).

“It is important for us to valorise and create safer products that will produce jobs for women and youth. It is against this backdrop that the DSI established the IK-based Bio-Innovation Programme,” he says.

A common challenge for traditional health practitioners in South Africa has been the inability to expand their market reach due to lack of resources and skills to develop traditional medicine products that conform to acceptable standards of safety and quality.

In an effort to improve the safety and quality of their current products, the DSI-led consortium selected six products following a call for expression of interest to traditional health practitioners across the country. The products have been used historically by the traditional health practitioners for specific remedies. The products improved were *Umphetha*, an iced tea used to treat internal ulcers, blood cleansing and immune boosting; *Moshumasekgwa*, a tea that treats high blood pressure, diabetes and urinary problems; *Lenong*, a tissue oil to treat wounds and arthritis; *Kgopa*™, a petroleum jelly to treat sores, skin problems and stomach ache; *Prijap Biolife*™, a herbal liquid with anti-viral and anti-inflammatory properties that strengthens the immune system and increases energy levels and appetite; as well as *Areka Ya Makgoma*™, a herbal sachet that facilitates the healing process of opportunistic infections and improves appetite.

“The CSIR, in conjunction with the University of Pretoria, utilised science, technology and innovation in identifying the active mixtures, carried out in vitro tests to confirm the activity of the ingredients or products, re-formulated the mixtures in consultation with the traditional health practitioners and carried out dermal safety studies, as well as microbial, shelf life and stability studies of the new products,” says CSIR senior researcher, Dr Greg Gordan.

Additionally, the programme provided the selected traditional health practitioners with relevant skills and knowledge on how to start a business and commercialise indigenous products. To provide the training, the Innovation Hub, BioPark and the CoachLab Entrepreneurship Programme shared content on business, finance, marketing, leadership and operations skills. The programme also explored the trademark of product logos in South Africa and, through the South African Bureau of Standards Design Institute, introduced the subject of branding and commercialisation of natural products in South Africa.

Traditional health practitioners and Prijap product owner, Prince Msomi, says: “I am so grateful for this programme. It has played a significant role in shaping my journey, which started in 2005. Much of my knowledge today and the product I have developed to this point, come from my grandfather. This traditional medicine has been in the family since 1914. With the help of the CSIR, in vitro studies were done and proved that the product has the ability to perform three of the five activities tested for. I also want to thank the DSI for their continued support. The Prijap brand has grown since participating in the programme, and now houses four interns who are completing their national diploma.”

The final products, dossiers (technology package) and trademark were handed over to the traditional health practitioners in a formal ceremony arranged by the DSI and the CSIR at the end of 2020.

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Above: A graphene polypropylene nanocomposite formulation produced at the CSIR. **Below, left and right:** Graphene powder produced at the CSIR.

Stimulating **South African** industry to adopt **graphene technologies**

*By **Drs Mike Masukume**, CSIR principal technologist and **Manfred Scriba**, principal technologist, Nanomaterials Industrial Development Group, CSIR*

Graphene has become a buzz-word commonly used in in conversations and popular articles, but many do not quite know what it is and why advanced manufacturers are excited about it. The answer can be found in its properties. Graphene, a black powder, is highly electrically conducting, 200 times stronger than steel and a very good heat conductor. It is thus not surprising that it can be found as an ingredient in many advanced applications.

Unlike graphite, which has been used for centuries and which consists of tightly packed carbon layers, graphene is described as sheets of single carbon layers – a million times thinner than a human hair. Interestingly, the discovery of graphene has very simple origins. In 2004, Professors Andre Geim and Konstantin Novoselov of the University of Manchester obtained a flake of graphene by sticking regular adhesive tape to graphite and then pulling it off. Since then, there has been an explosion in research around its production and application in commercial products to the extent that the global graphene market is projected to reach $2.1 billion by 2025.

In order to stay competitive, South Africa cannot fall back to the position of simply importing graphene technologies, the country has to develop its own capabilities, technologies and products based on graphene.

It is for this reason that the CSIR has established the Graphene Platform within its Centre for Nanostructured and Advanced Materials (CeNAM), which aims to make use of the vast nanotechnology capabilities already established to, jointly with industry, develop graphene-based technologies and products. One of the key focus areas of the platform is polymer nanocomposites, in which CeNAM has considerable expertise as well as special equipment for the characterisation of these materials. In one project, the CSIR has already produced conducting polyethylene fibres for anti-static and electromagnetic shielding applications.

The graphene programme invites progressive enterprises to partner with the CSIR to investigate graphene-based opportunities. For instance, by adding graphene in an epoxy such as those used in fibre glass components, the toughness of that component can be increased multiple time. Such developments allow for the construction of revolutionary aircraft and helicopter structures as well as prosthetic limbs. Graphene is even assisting in the fight against Covid-19, where its anti-viral properties are harnessed in face masks. It has also contributed to major breakthroughs in battery technology and super capacitors, where it enabled faster charge cycles and capacity. Finally, graphene also finds application in sensors, water treatment, coatings, displays and conductive inks.

While the development of local technologies is important, the CSIR is also establishing collaborations with international leaders to set up routes to the possible licensing or localising of graphene-based technologies.

The CSIR Graphene Platform is available to address technical challenges in a wide range of industries and encourages industry to contact us to explore the opportunities.

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CSIR principal technologist Dr Manfred Scriba.

Top: Multispectral surveillance cameras are used for day and night operations. **Bottom (left):** Data from smart cameras are extracted for analysis to perform automatic number plate recognition. **Bottom (right):** Long or medium-range cameras can be employed for small target detection.

Smart surveillance for **safer** correctional services facilities

The CSIR has developed a new camera-based imaging and alerting system that provides wide-area surveillance and intrusion detection. The Smart Physical Security System draws on numerous technologies, from sensor technology to artificial intelligence.

The Smart Physical Security System (SPYSS) has been piloted at a Department of Correctional Services (DCS) facility in the Eastern Cape. The facility had been experiencing robberies at their chicken farming area, with farm-stock being stolen regularly. Dr Gugulethu Mabuza-Hocquet, CSIR research group leader for surveillance and counter measure systems says, “The DCS needed an intervention that would improve security at various facilities, starting with this particular one.” The two parties signed a Memorandum of Understanding to guide their collaboration.

The new security system was developed and deployed at the facility to detect intrusions and strengthen physical security. A computer vision application aids the situational awareness of guards throughout the day, thus improving their confidence and morale.

Guards at different locations can receive the alerts concurrently via SMS or the mobile application and rapidly respond to intrusions. The software application performs instance segmentation from live security cameras in real-time. Feature-pyramid networks are employed to detect small targets on images. The software architecture supports a cascade of classifiers, which act as a second opinion when predicting whether a target is a threat or not, says CSIR researcher Dumisani Kunene.

Drawing on complementary CSIR command and control technology, the system detects and sends alerts about intrusions at the monitored area. The platform is able send alerts to mobile phones within two to five seconds. “Recorded events can be used as evidence to study intrusion patterns to lessen incidents in future,” Kunene adds.

The deployment of the system has helped to not only protect the chicken farm area, but also guide the specification development process for a permanent solution through research and development experiments with artificial intelligence techniques for object recognition at the site.

“In addition to the detection and early warning capabilities of the SPYSS, we plan to expand the system to perform human recognition, vehicle number plate recognition and face recognition to offer a holistic security intervention at DCS facilities,” says Dr Mabuza-Hocquet.

> “Recorded events can be used as evidence to study intrusion patterns to lessen incidents in future.”
>
> - Dumisani Kunene, CSIR

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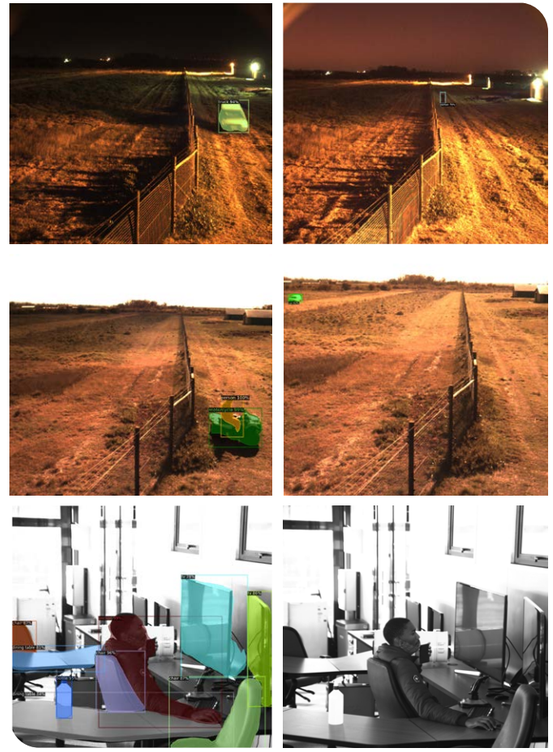
SCREENSHOTS



Top: Intrusion detections. Autonomous intrusion detection can be performed in sufficient lighting conditions during the day and night. **Bottom:** Instance segmentation of objects.

Faster time to market: Digital product lifecycle management gets **Covid-19 ventilators** to pandemic pressure points around the country

A priority for South Africa's fight against the Covid-19 pandemic was to ensure the optimal strength of its full health system. As local infection numbers started to climb, health care workers, facilities and equipment were placed under duress. One aspect that already had local innovators at the drawing board, was devising a key piece of life-saving equipment: easy-to-use, ready and simple ventilators.

Work on the South African ventilators commenced towards the end of May 2020 and what would have taken 18 months using traditional processes, took three months using digital technologies to be ready for what specialists indicated would be the Covid-19 peak. By November, 10 000 units were distributed to between 60 and 70 hospitals in South Africa, and a further 8 000 were already in production. Not only were the systems South African made, they also passed testing by the SA Health Products Regulatory Authority. More requests were received during the second wave of the pandemic – notably via Gift of the Givers, who became instrumental in getting more ventilators out to patients.

The CSIR Lung Inspiratory Flow Enabler (L.I.F.E.) uses standard, hospital-grade oxygen supply, and features easy-to-use, on-device flow gauges to adjust the fraction of inspired oxygen (oxygen-enriched air) in steps of 10% oxygenation.

The development formed part of government's National Ventilator Programme under the auspices of the Department of Trade, Industry and Competition, and is supported by the Solidarity Fund.

About the units

The ventilators are based on the so-called *continuous positive airway pressure* (CPAP) design that provides a mild level of oxygenated air pressure to keep the airways open and, thus, assist with those in respiratory distress. The units are non-invasive (applied to the face and not intubated), easy to attach to oxygen sources and easy to apply to patients.

The device can be used in both high-tech clinical environments and temporary settings, such as field hospitals and quarantine facilities such as those that were established around the country to handle rising Covid-19 cases.

> While ensuring that we achieve this in a short period of time, we had to ensure that we follow a rigorous product lifecycle methodology that would ensure scalable manufacturing, as well as compliance and licensing under the South African Health Products Regulatory Authority and guidelines of the World Health Organization Systems.
>
> Riaan Coetzee - CSIR

Collaborators and support

CSIR virtual collaborators covered five provinces, and included assistance from Siemens in Italy and the United States of America.

- ***Digital platforms:*** Siemens (SA), Simera.
- ***Manufacturing partners:*** Black Capital Systems, Andani Futuretech, Akacia Medical, Endless Summer, Central University of Technology, UV Tooling, Wagner Systems.
- ***Regulatory support:*** Integrated Management Systems, the University of Cape Town Medical Devices Laboratory.
- ***Product support:*** Quali Health provides telephonic and virtual consulting services to medical professionals. Health professionals can also request technical support through a WhatsApp platform.

Virtual factory

An obvious prerequisite for the design and manufacturing approach was that the capability had to be scalable to respond to the high numbers of ventilators needed. Tight timelines amid lockdown regulations and complex contracting and procurement procedures meant that the team had its work cut out. Also, this meant that many designs, testing and manufacturing processes which would normally run sequentially, had to run in parallel. Global flight restrictions impacted the global supply chain, creating an opportunity to localise the manufacturing of a large percentage of the required parts.

Digital lifecycle management addressed the time challenges presented by the many processes and linkages between processes to understand influencing factors and the reality of multiple planning iterations. All planning, mapping, and even simulation and testing were done digitally before developing the physical product. Cost savings were possible because the digital methodology obviated the need to set up a plant first, and all production optimisation could be done virtually. Digital lifecycle management also allowed the team to identify which other entities to bring on board to speed up design, manufacturing and the regulatory approval process – resulting in a virtual factory.

In the end, only two factory visits were necessary, and more than 1 000 teleconferences during the 60 to 80-hour work weeks, served to emphasise the importance of digital transformation.

Human aspect

In November 2020, at its 7th Conference marking the 75th year of its existence, the CSIR explained that digital transformation is about the data flow from and between employees, customers, and the product in the market, to improve decision-making. It means that growing and upskilling employees feature high on the agenda, as does the opportunity for improving the customer's experience to enable direct and immediate feedback that ultimately transforms the product.

The team behind the ventilator project was acknowledged when they received a CSIR Excellence Award in 2020. In addition, the team was heartened by the many messages and feedback from health practitioners about the effectiveness of the ventilators and the lives they were able to save through its use.

Going forward

With the learning from the CPAP project, the CSIR is working on a bi-level positive airway pressure ventilator with a local partner to develop a solution for patients with more severe symptoms. These units assist with both inhalation and exhalation, either in fixed pressure modes or by sensing the oxygen supply required by a patient and adjusting the pressure accordingly.

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Monitoring surface and ground water in the Cradle of Humankind World Heritage Site for effective **water resources management**

The CSIR has established a detailed water resources database for the Cradle of Humankind World Heritage Site. Researchers have, for the last eight years, assisted the heritage site with monitoring of its surface and groundwater. Water quality is a major concern for the delicate nature of the fossil sites in the area, but also for the downstream agricultural and recreational activities that are almost wholly dependent on groundwater for human and business uses.

The Cradle of Humankind World Heritage Site is a world-renowned South African tourist attraction with scientific, cultural and environmental significance. The site is known for palaeo-anthropological discoveries of fossil hominids – early ancestors of modern humans such as *Mrs Ples and Homo Naledi* – dated at about 2.3 million years old. It is reported that about 40% of the world's known hominid remains have been unearthed in and around the caves of the site. Hence the declaration of the area by the United Nations Education, Scientific and Cultural Organisation (UNESCO) as a World Heritage Site in 1999.

The CSIR led the multidisciplinary surface water and groundwater monitoring programme for the management authority of the site since 2012. The programme served as a baseline for establishing the extent to which surface water and groundwater resources across the property compare against various water quality and quantity targets. The major focus was wastewater sources, particularly acid mine water or rock drainage arising in the West Rand basin in Gauteng, and municipal effluent discharged from wastewater treatment works in Krugersdorp. Key aspects of the monitoring programme included the analyses of the physical and chemical properties of the water; surface water-groundwater interactions; and the assessment of aquatic health along several sites of the Bloubank Spruit and Skeerpoort rivers that flow through the heritage site.

Quarterly monitoring and sampling of surface water and groundwater quality and quantity was undertaken at various carefully chosen locations in the study area through a collaboration between the CSIR and the Department of Water and Sanitation. An industry stakeholder, Sibanye-Stillwater, provided rainfall data that were analysed to provide a comprehensive account of the quality of the water resources in the region. Groundwater quality and quantity monitoring was undertaken at 18 dedicated monitoring boreholes. Across the property, a total of 10 springs were monitored bi-annually to provide an indication of the volume and quality of groundwater discharged from the karst landscape that defines the dolomitic footprint of the property. All water samples collected were submitted to the CSIR laboratories for microbiological, ecotoxicity and chemical analyses. The monitoring schedule is informed by a soundly designed monitoring system manual.

CSIR candidate researcher Vuyelwa Mvandaba says the monitoring of the surface water and groundwater environments has contributed to an improved understanding of the hydrophysical and hydrochemical response of the water resources to possible pollutants. "Recent monitoring activities have confirmed pollution of several surface water sites and a general deterioration of river health relating to bacteriological contamination. By collecting and collating historical and newly generated data, we've managed to establish a detailed water resources database for the Cradle of Humankind World Heritage Site," she says.

Since its inception, the monitoring programme has generated 17 bi-annual status quo reports that inform the current situation, trends of change and rising issues related to the site's water resources. Given the increasing water security issues, such knowledge forms the basis for sound options for responsible and effective water resources management. The content of these reports has contributed to the compilation of three State of Conservation reports submitted to UNESCO's World Heritage Centre for examination by its World Heritage Committee. All these reports have been accepted with high recommendations for their quality and detail.

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THE TEAM

From left: CSIR researcher Justinus Shadung, CSIR candidate researcher Vuyelwa Mvandaba and CSIR senior researcher Dr Evison Kapangaziwiri.

Protecting and benefiting from indigenous knowledge: The National Indigenous Knowledge Management System

The use of medicinal plants is a fundamental aspect of African traditional healthcare systems.

Touching lives

Without NIKMAS enabling and maintaining a secure and accessible national repository for the protection and beneficiation of indigenous knowledge, cultural treasures such as the Khomani San's unique knowledge of nature, the land, the plants and their healing properties would be lost to future generations. Similarly, in uMhlabuyalingana, KwaZulu-Natal, the community has made jam and beverages from marula fruit for centuries. NIKMAS helps this community, and many others, to protect their knowledge to further develop and eventually commercialise their products

Indigenous knowledge (IK) holds significant value – it emboldens cultural heritage and identity, and offers valuable economic and environmental benefits. However, changing lifestyles in the form of urbanisation, commercialisation, marginalisation and rapid technological changes heralded the decline of indigenous knowledge, and its possible demise, unless something was done to protect this useful resource.

A solution to this challenge was presented by the Department of Science and Innovation in the form of the National Recordal System (NRS) in collaboration with the CSIR, with the implementation and national rollout of the National Indigenous Knowledge Management System (NIKMAS).

The NRS records, preserves, protects and promotes South Africa's wealth of indigenous knowledge, and helps communities to develop and responsibly disseminate their products. NIKMAS is the backbone of this digital repository and was created to detail traditional medicine, ethnobiology, indigenous environmental knowledge and intangible cultural heritage. Both the initiative and the system give expression to the Protection, Promotion, Development and Management of Indigenous Knowledge Act, No. 6 of 2019.

Key collaborators include the South African National Biodiversity Institute; the Department of Environment, Forestry and Fisheries; the Data Intensive Research Initiative of South Africa; the South African National Research Network; the universities of KwaZulu-Natal, Free State, Fort Hare, Zululand and Venda; and traditional authorities.

Since its inception in 2013, networks have been established across all nine provinces where 90 rural communities record their IK on NIKMAS. Continuous refinements to the system provide an innovative security model for the protection of holdings as well as an advanced search engine and cataloguing facility. More than 80 youths (regional representatives) have been employed, trained and equipped with computers and cameras to facilitate the recording of IK in their communities. Under the core themes of 'Food' and 'African Traditional Medicine', more than 14 750 IK entries have been documented and more than 2 070 IK holders recorded.

In addition, positive acknowledgement of the progress and impact of the initiative by stakeholders such as the Parliamentary Portfolio Committee and resultant legislation, firmly entrenched the importance of capturing IK and helping communities benefit from that knowledge for posterity.

The process includes the Department of Science and Innovation training the regional representatives, who then find the community members who have the indigenous knowledge, and then record and document such in the communities. The recordings are submitted to the Indigenous Knowledge System Documentation Centres across the country in the form of videos, audio recordings, transcriptions and photos. From the documentation stations the information is sent to central NIKMAS, where it is classified to national and international standards, and the necessary security access levels set to strict criteria. The plants used in the indigenous knowledge application are collected for scientific authentication, to ensure legal defensibility.

While the initiative focuses on indigenous knowledge with a scientific base, it considers its holistic nature. It acknowledges the limitations of intellectual property regimes, while being considerate of current copyrights, trademarks, biodiversity and related legislation.

The wealth of information is shared under sound protocols with the South African public, especially the scientific, research and academic communities for consumption, dissemination and further development. Further, the legal frameworks supporting the NRS ensure that the original holders of the IK in communities are not compromised.

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NIKMAS and Covid-19

Decision-makers and researchers consulted the CSIR during the Covid-19 pandemic. The Minister of Higher Education, Science and Technology, Dr Blade Nzimande, requested insights on respiratory ailments and traditional medicines generally associated with respiratory distress. The CSIR, through the NRS initiative, supported an Indigenous Knowledge Covid-19 Research Task Team to find indigenous knowledge-based solutions to Covid-19 and associated respiratory challenges. Thus far, 20 plants are guiding the team's scientific research.

Above: The eutrophication of river systems, resulting from nutrient enrichment, is a serious threat to South African's freshwater ecosystems. On this image of the Lower Orange River, eutrophication is clearly visible. *Image courtesy Dr Lindie Smith Adao.* **Below (left):** The key output report of the National Biodiversity Assessment 2018. **Below (right):** The CSIR team who worked on the freshwater component of the NBA 2018, from left Drs Chantel Petersen, Lindie Smith-Adao and Heidi van Deventer.

Experts highlight the worrying picture of South Africa's **freshwater ecosystems**

The latest assessment of the state of South Africa's biodiversity has found that of the 135 inland wetlands, 79% are threatened and less than 10% are protected. For rivers, 64% of the 222 river ecosystem types are threatened, while only 13% are well protected and 42% not protected. These findings are part of the National Biodiversity Assessment 2018. A National Biodiversity Assessment is produced every five years. It details the status, key pressures such as: habitat loss, pollution and climate change as well as protection levels of the country's ecosystems in order to inform policy and behavioural change.

Wetlands and rivers: Scarce natural capital

South Africa is one of the world's 17 megadiverse nations on account of its diversity and the uniqueness of its ecosystems. The country is ranked in the top three nations globally when it comes to plant and marine species found nowhere else on earth, and has a wide array of ecosystem types across the landscape and seascape. Inland wetlands are considered valuable to the ecosystem because they clean the water, recharge water supplies, reduce flood risks, and provide fish and wildlife habitat. In addition, wetlands and rivers provide recreational opportunities, aesthetic benefits, sites for research and education, and commercial fishery benefits.

The National Biodiversity Assessment (NBA) is led by the South African National Biodiversity Institute (SANBI) as part of their mandate to monitor the status of South Africa's biodiversity. Researchers from the CSIR led the freshwater component of the NBA 2018 in collaboration with SANBI – research for the assessment was undertaken between 2015 and 2019 and officially launched in October 2019.

CSIR senior researcher Dr Heidi van Deventer, who led the freshwater component of the NBA 2018, says, "The findings of the NBA 2011 and 2018 showed that wetlands remained poorly represented, highly threatened and poorly protected. Significant effort was invested to also improve the latest version of the National Wetland Maps (NWM) 5, to better represent the areal extent of wetlands. The updated map showed improvement by 25% in the areal extent of inland wetlands, while reducing errors by an estimated 30%."

Despite the concerted effort, Van Deventer notes that some stakeholders in the country were not entirely convinced that the map represented the areal extent and type of wetland ecosystem accurately. Therefore, SANBI is leading a further update of the NWM to its sixth version.

The picture of the country's rivers is similar, with the majority of rivers being degraded and poorly protected. Most of these threatened river ecosystem types are lowland and lower foothill rivers linked to the pressures accumulating and increasing from river source to sea. Tributaries are however less impacted than main stem rivers. CSIR senior researcher Dr Lindie Smith-Adao, who led the rivers sub-component of the NBA 2018 says, "The decline in ecological conditions between 2011 and 2018 also resulted in 14 of the 62 free-flowing rivers which were identified during the National Freshwater Ecosystem Priority Areas study, losing their status. Of these free-flowing rivers 19 flagship rivers remained intact over the last seven years."

Preserving South Africa's diverse ecosystems

The NBA is the primary tool for reporting on the state of biodiversity in South Africa. It is used to inform policies, strategies and activities for managing and conserving biodiversity more effectively. The freshwater component alone, took more than 22 000 person hours that was spent by at least 121 individuals from approximately 35 institutions during the period April 2015 to March 2019. The NBA 2018 also involved extensive collaboration from over 470 individuals representing about 90 organisations. The reports and data will inform policies that will raise awareness on how the environment can play an important role in growing South Africa's economy.

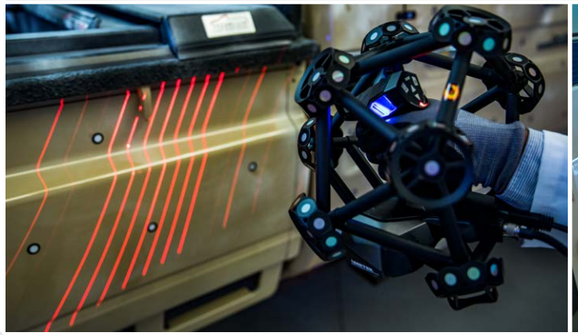
The CSIR and the NBA

The CSIR has a rich history with the NBA and has given inputs in the first assessment of biodiversity, the National Spatial Biodiversity Assessment of 2004, primarily covering rivers, while the NBA 2011 and 2018 included the National Wetland Maps versions four and five, respectively, generated under leadership of the CSIR.

The full suite of NBA products, which include a synthesis report, seven technical reports, datasets, maps, supplementary materials, and popular products has been packaged for decision makers and is available from: *http://biodiversityadvisor.sanbi.org/planning-and-assessment/national-biodiversity-assessment-nba-2018/.*

OUR INFRASTRUCTURE

The CSIR has set up a state-of-the-art prototyping facility, the Advanced Design and Manufacturing Innovation Centre, where equipment such as this 3D scanner, is used to scan various parts and surface finishes in real time for each stage of the manufacturing process. Read more on pages 62 and 63.



Above: CSIR senior technologist Sudesh Budram using the MetraScan 750 Optical elite scanner to scan a Toyota Land Cruiser. **Below (left):** The MetraScan 750 Optical elite scanner. **Below (right):** A bird's eye view of the Advanced Design and Manufacturing Innovation Centre.

A twist to **advanced manufacturing**

The CSIR, in its efforts to help improve the competitiveness of South African industries, has set up a-state-of-the-art prototyping facility, the Advanced Design and Manufacturing Innovation Centre. This additive manufacturing centre is one of the firsts of its kind, providing ongoing research into new manufacturing techniques, technologies and materials, as well as specialised design and manufacturing training for local and international industries.

> Unlike many other 3-D printing facilities, ADMIC operates using a precise methodology that takes into consideration the complete product lifecycle – from concept to final product.
>
> - Sudesh Budram, CSIR

The Advanced Design and Manufacturing Innovation Centre (ADMIC) offers unique capabilities to clients and industry. These include additive manufacturing using polymers and powders, 3D scanning and product life cycle management. "Unlike many other 3-D printing facilities, ADMIC operates using a precise methodology that takes into consideration the complete product lifecycle – from concept to final product," says Sudesh Budram, CSIR senior technologist.

The centre is dedicated to the complete process, from conceptualising or designing a solution, through to material selection, prototyping, testing, manufacturing and delivery. Firm security measures are in place at the centre, making it ideal to serve defence clients, as well as companies performing pre-competitive prototyping, conceptual design and low-volume manufacturing of new products for testing. This ensures the security of clients' intellectual property and confidentiality.

ADMIC provides its users with access to advanced machinery. The MetraScan 750 Optical Elite CMM scanner generates high-accuracy dimensional data, regardless of part size, finish, material and complexity. It is therefore ideal for inspection and reverse engineering applications. The centre is also home to a powerful fused-deposition modelling – or FDM 900 – printer. This printer uses a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three-dimensional object. This makes it ideal for the production of high-accuracy thermoplastic parts used in, for example, approved aircraft, automotive and medical grade materials.

A number of projects have been initiated for the defence industry in the development of customised tools or once-off items. "At the onset of the Covid-19 national state of disaster in South Africa, the centre was used for the rapid design and production of face shields for use by soldiers deployed to infection hot spots," Budram says.

Clients from other sectors, such as aerospace, automotive, agricultural, maritime and medical domains have also benefitted from the technologies at the centre.

The objectives of the Advanced Design and Manufacturing Innovation Centre are to:

- Reduce the cost of the development of any product;
- Reduce the time-to-market of new ideas (including functional products, prototypes and niche solutions);
- Minimise material waste;
- Reduce delivery time frames;
- Offer knowledge and expertise sharing related to advanced manufacturing; and
- Offer a complete life cycle process.

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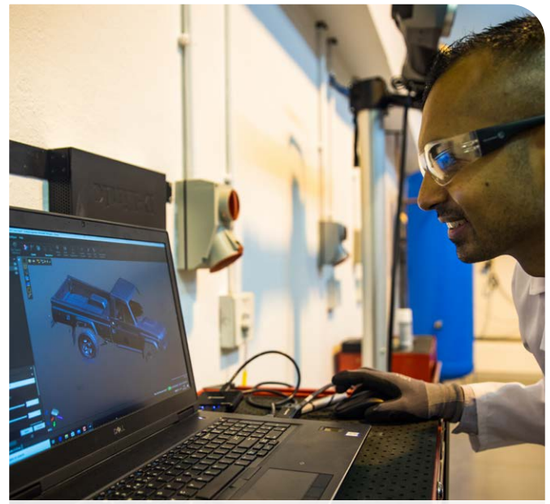
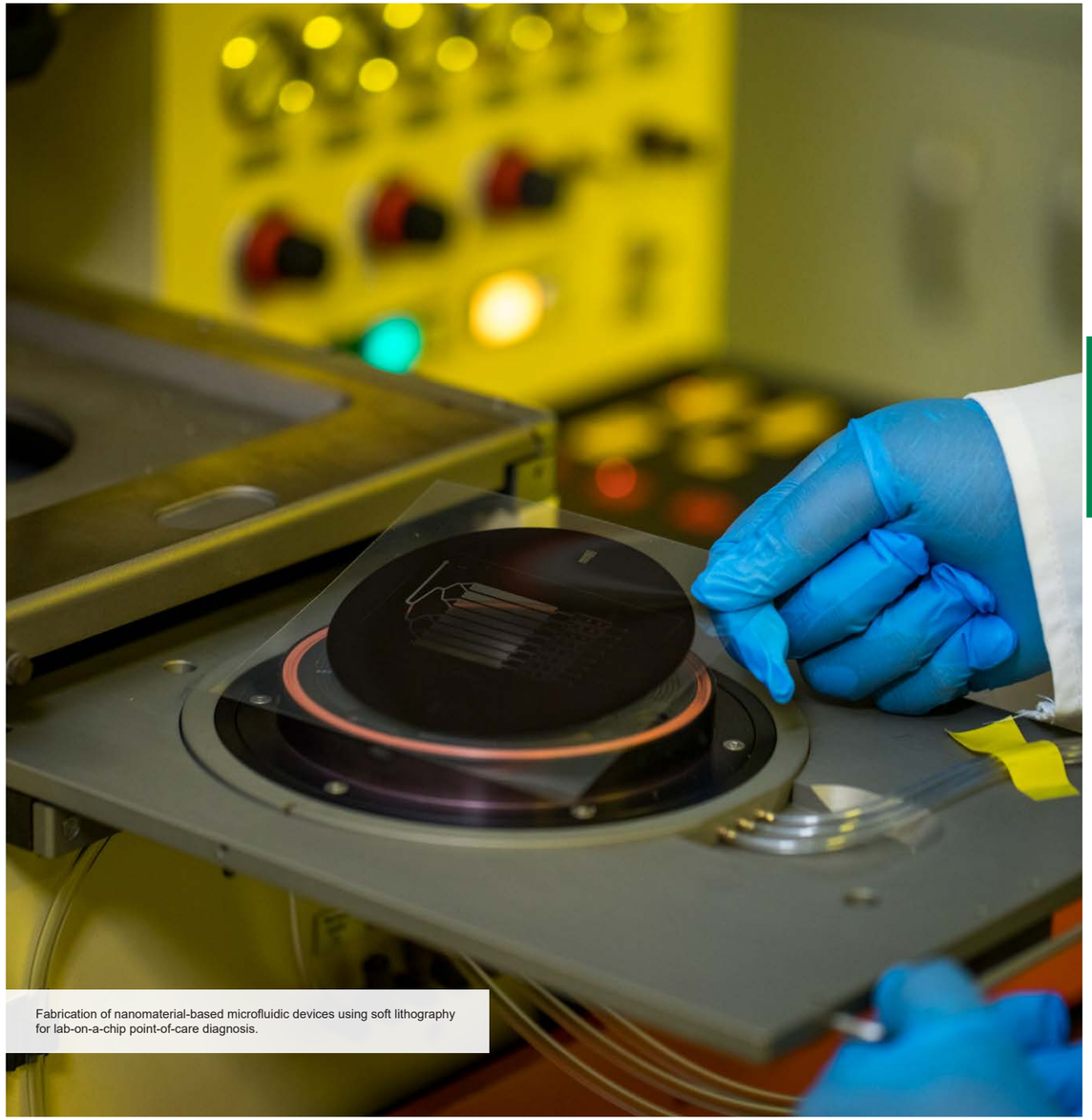
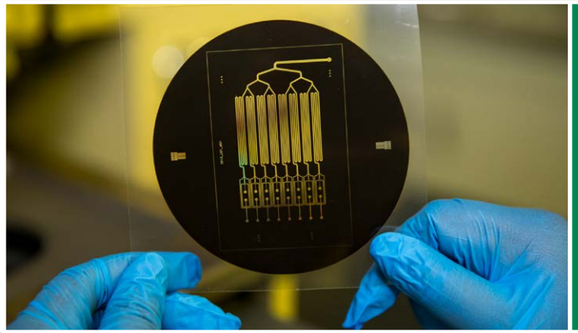


CSIR senior technologist Sudesh Budram verifies and validates the data from the screening process.



Fabrication of nanomaterial-based microfluidic devices using soft lithography for lab-on-a-chip point-of-care diagnosis.



> The CSIR node will be involved in integrated nano-micro manufacturing efforts to develop novel devices and applications, helping to pioneer the nano-micro devices market in South Africa.
>
> -Dr Palesa Diale

Helping to pioneer the **nano-micro devices** market in **South Africa**

Strategic importance of CSIR facility recognised

The South African Research Infrastructure Roadmap of the Department of Science and Innovation selected the CSIR's Nano-Micro Device Manufacturing Facility as one of five national nodes that will support research and development in nano-micro manufacturing technologies at a national level.

The Nano-Micro Device Manufacturing Facility was established as a hub for the development of breakthrough technologies that harness micro- and nanofabrication – the making of super small materials in powder or fluid form which is used in high-precision technologies such as laser ablation, among others.

The facility will focus on assisting researchers from academia and industry to apply microfluidics, advanced materials and additive manufacturing in developing lab-on-chip point-of-care prototypes that will impact human and animal health as well as the environment. The CSIR node aims to further strengthen its impact in capacity building of the lab-on-chip point-of-care technology platform for veterinary, human and environmental applications to encourage interdisciplinary collaboration and communication on health at the human-animal-environmental interface, popularly referred to as the One Health approach.

CSIR Facility Manager, Dr Palesa Diale says, "What excites me about the facility is the challenge to integrate a suite of advanced technologies such as microfluidics, nanosensors, micro-electronics, biochemistry, fluid dynamics and electronics to develop lab-on-chip point-of-care devices. While some research groups are already active in the development of micro-manufactured devices and systems, there is a general lack of capabilities to integrate available technologies in fabricated devices for market development. The SARIR programme, therefore, offers the CSIR an opportunity to be in a distributed model that comprises five technical nodes and one coordinating hub.

"The CSIR node will be involved in integrated nano-micro manufacturing efforts to develop novel devices and applications, helping to pioneer the nano-micro devices market in South Africa."

Success

The CSIR facility has assisted a number of projects – one relating to a rapid test kit development by Mintek researchers, led by Dr Amanda Skepu – to join the fight against the Covid-19 pandemic. The CSIR node assisted the team to develop two types of rapid tests for Covid-19 for antibody and antigen tests. Skepu says, "The antibody test detects SARS-Cov-2 antibodies (the body's response to the virus) from finger-prick blood, whereas the antigen tests detect part of the virus (antigen) from a swab taken from the nose or back of the throat." The CSIR facility made it possible to complete this task by providing access to cutting-edge nano-micro fabrication equipment.

"We aim to further improve the capability to establish and develop lab-on-chip diagnostic devices. Currently we are working on an assay approach that simultaneously meets the requirements of a lab-on-chip point-of-care assay through the combined use of plasmonic nanoparticle tags, and an imaging-based optical biosensor embedded in a microfluidic cartridge. Further, the facility is set to have research contracts with internal clients as well as other research institutions in South Africa from 2021," Diale concludes.

About the South African Infrastructure roadmap

Access to adequate and relevant research infrastructure is essential to promote the outcomes and quality of research, as are adequate levels of funding for such infrastructure. A collaboration between South Africa and the European Union led to the South African Research Infrastructure Roadmap (SARIR) framework, and prioritises the development and provision of national research infrastructure needs across the whole public research system. The roadmap guides the Department of Science and Innovation (DSI) as to the strategic development, acquisition and deployment of research infrastructure as a necessary enabler for research, development and innovation.

On offer

The Nano-Micro Device Manufacturing Facility has research, design, development and prototyping capabilities. Equipment include: optical microscopes; an automated dispensing system; a sputter deposition system; advanced printing; a clean room facility; chemical laboratories; and equipment for cell culturing/ incubation and cell counting.

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Above: Prototype laser ranging product for industrial applications.
Below: A wide range of opto-mechanical equipment is available to support prototype development work.

South Africa launches its first **Photonics Prototyping Facility**

The CSIR, in partnership with the Department of Science and Innovation, has launched its Photonics Prototyping Facility in March 2021. The facility was established to support the development and industrialisation of photonics products in South Africa by providing world-class, specialised photonics facilities, technical support, equipment as well as scarce skills.

The photonics market can be a significant driver for South Africa's economic growth, leading to job creation, skills development and increased revenue. However, the country currently has a small market share of the global photonics industry. The major contributing factors to this local innovation challenge are the fragmented research, development and innovation value chain, low levels of local technology transfer, and perceived low levels of collaboration between stakeholders in the industry, higher education and research communities.

The Department of Science and Innovation-CSIR Photonics Prototyping Facility (PPF) is addressing this innovation chasm by providing world-class facilities, technical support, equipment, and scarce skills to assist in industrialising the untapped potential. The facility supports the development of photonics-based products, specifically the prototype-development phase, to test the market for acceptance of the planned product.

Photonics applications are pervasive in all branches of 21st-century science and engineering, including defence and security, sensing and imaging, quantum optics and metrology, illumination and displays, energy, photo-voltaic systems, materials and manufacturing, as well as information processing and communications. This signifies not only the economic importance of photonics but its potential to address many of the current societal challenges in South Africa. Through this programme, the CSIR makes a range of expertise and skills available to support the development of these prototypes.

Since its establishment, the CSIR has recorded several applications. One of the projects focuses on optical coherence tomography for the 3D extraction of finger-prints. The novelty of this fingerprint acquisition device is that it is capable of extracting both the internal (sub-dermal) and external (surface) fingerprint, thus removing the possibility of spoofing the detection system. It also offers a non-contact approach. The technology has applications in banks, mortuaries and forensic service facilities. The prototype has been developed and the team has received positive feedback from the trials. Other examples include a laser distance measurement system for Kutleng Engineering Technologies and the characterisation of a laser and laser beam delivery system for a locally developed 3D printer for metal materials.

The PPF invites scientists, researchers and engineers from science councils, higher education institutes, small, medium and micro enterprises and industries, as well as entrepreneurs and investors, to propose and participate in photonic-related prototype development.

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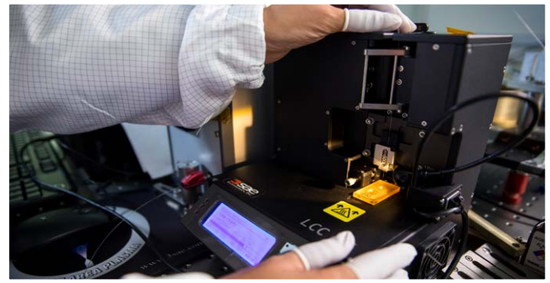
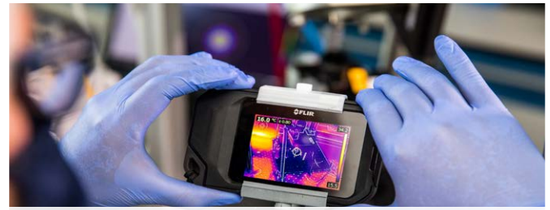
Above and below: The Photonics Prototyping Facility has access to a range of equipment to support the splicing of standard to large diameter optical fibres for laser transmission and high power fibre laser fabrication.





Above: Thermal imaging systems assist engineers to verify opto-mechanical designs and fibre splices for high power laser applications.

ScienceScope

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