ScienceScope

PUBLICATION OF THE CSIR

VOLUME 15 | NUMBER 2 OF 2019

CSIR

our future through science

CONTACT

CSIR
enquiries@csir.co.za
+ 27 (0)12 841 2911

CSIR CLUSTERS

> **CSIR NextGen Health**
cndlazi@csir.co.za

> **CSIR Advanced Agriculture and Food**
tmophosho@csir.co.za

> **CSIR Future Production: Chemicals**
cndlazi@csir.co.za

> **CSIR Future Production: Manufacturing**
ljeanmichel@csir.co.za

> **CSIR Future Production: Mining**
bmtamzeli@csir.co.za

> **CSIR Defence and Security**
cvanderm@csir.co.za

> **CSIR Smart Mobility**
bsikwane@csir.co.za

> **CSIR NextGen Enterprises and Institutions**
ndyosop@csir.co.za

> **CSIR Smart Places**
aabritz@csir.co.za

Compiled by
CSIR Communication
CSIRComms@csir.co.za

Design and production
Janine Smit Editorial Services (JSES)

www.csir.co.za

Printed on **Hi-Q™** art paper. Manufactured from TCF (Totally Chlorine Free) and ECF (Elemental Chlorine Free) pulp. Only wood from sustainable forests is used. ISO 1 4001 certification. Hansol Paper Co. Ltd. complies with the Chain of Custody principles as set out by the Forest Stewardship Council in all areas in which Hansol operates.

ORGANISATIONAL VALUES MATTER

The CSIR has adopted a new vision and strategy to accelerate socioeconomic prosperity by ensuring that the work it does contributes to industrial development. Underpinning the decisions we take daily to implement this new strategy, are our values. Values are often described as the true north of an organisation's brand compass – regardless of the direction that the organisation takes, they remain true. Allow me to introduce the values that serve as the guide for every CSIR employee, operation and activity.

Excellence

We excel in research, development and industrial innovation that address South Africa's challenges. Efficient and novel thinking, as well as high-quality systems and processes, enable the necessary agility to change course when required. We are unashamedly passionate about the impact that we make and pursue excellence in every facet of CSIR life.

In this edition of *ScienceScope*, you get a sense of how central this value is to us. See the faces of the many staff members who excelled by obtaining doctoral or master's level qualifications (pages 13 and 14) and read about the world-class research undertaken.

People-centred

We care about people – our impact through innovation aims to improve lives. We respect diversity and uphold the dignity of every person, regardless of culture or belief system. We treat our stakeholders the way we would like to be treated.

On pages 15 and 16, read about our dedication to ensuring that the youth enrol in the fields of science, technology, engineering and mathematics to ensure that we have a future generation of people who will continue to help improve the lives of their fellow citizens. In reading about our research, you will realise that our work is always about the betterment of our society and strengthening our economy.

Integrity

We value integrity – in ourselves and in others. We are honest and fair in how we work and how we engage the world around us. We respect the trust that our colleagues and stakeholders place in us and commit to ethical decision-making, delivery and governance. In this context, we are proud to have received a clean audit for the 2018/19 financial year, and we have also implemented an ethics hotline for anonymous reporting of ethical transgressions.

Collaboration

We are keen to learn from one another and collaborate across the organisation, and with external partners, to ensure that our work has the best chance of contributing to a better future for South Africans. We actively share our knowledge and expertise so that we can make an impact at a large scale.

In this edition, read about how the collaboration between the CSIR and the Durban University of Technology resulted in new technology to produce an organism suitable for use as an abalone probiotic (page 3). We work closely with the Department of Trade, Industry and Competition to support the South African aerospace industry to improve its competitiveness (pages 17 to 24). We also collaborate internationally, as is evident from our participation in an international study, conducted over a 30-year period, that documents the link between air pollution and increased cardiovascular and respiratory death rates (page 39).

> **Dr Thulani Dlamini**
CSIR Chief Executive Officer

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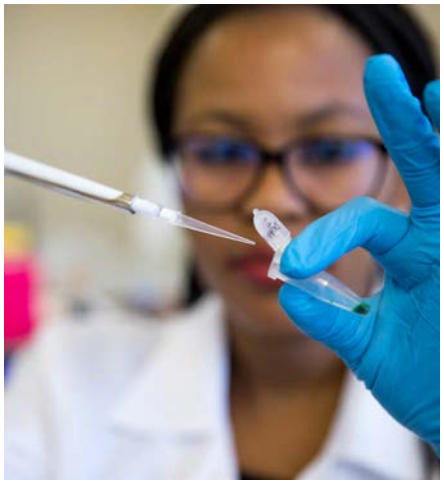
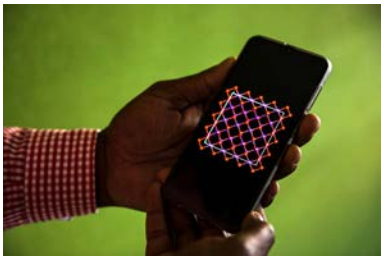
OUR PEOPLE



FOCUS ON PhD STUDIES

OUR WORK



THE AEROSPACE INDUSTRY SUPPORT INITIATIVE

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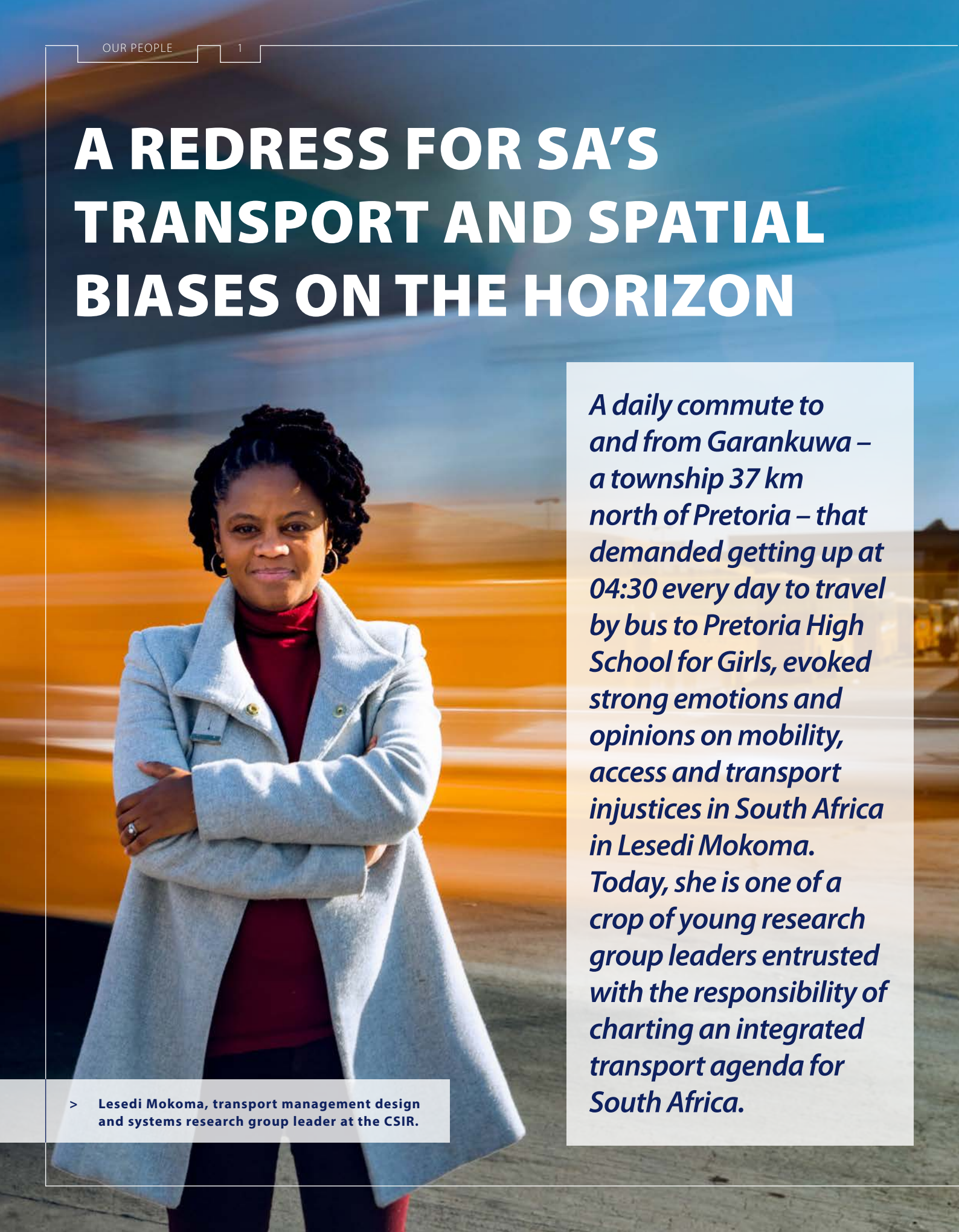
ON THE COVER

Aquatic plants exposed to product-released engineered nanomaterials as part of studies on the risk of nanopollution. Story on page 33.

A REDRESS FOR SA'S TRANSPORT AND SPATIAL BIASES ON THE HORIZON

A daily commute to and from Garankuwa – a township 37 km north of Pretoria – that demanded getting up at 04:30 every day to travel by bus to Pretoria High School for Girls, evoked strong emotions and opinions on mobility, access and transport injustices in South Africa in Lesedi Mokoma. Today, she is one of a crop of young research group leaders entrusted with the responsibility of charting an integrated transport agenda for South Africa.



> **Lesedi Mokoma, transport management design and systems research group leader at the CSIR.**

Lesedi Mokoma says the reason she does what she does, lies in her own struggles with public transport growing up.
"My daily commute from the north to school was not a pleasant one," she says. "My mother wanted me to get the best education, but could not afford the school boarding fees."

It was the exasperation from those four-hour daily bus trips that planted a seed in Mokoma that led to her enrolling for an undergraduate degree in civil engineering at the University of Cape Town.

"Sometimes the bus would break down; I would get to school very late and being late meant detention for something that was not in my control," she says. "I found the whole situation very unfair."

Her mission was, and still is, to change how South Africa's transport is structured.

Mokoma's public transport experience is not unique, as many working South Africans shuttle between their homes and work every day to earn a living. This, in her opinion, is largely because most South African cities are still highly spatially fragmented as a result of segregated and class-based colonial planning systems. But, Mokoma feels that the South African dream of efficient, affordable and integrated public transportation systems is achievable.

"I may not be a major decision-maker, but, through my research, I now have the potential to make a difference in terms of addressing this challenge which affects us all," she says.

Mokoma is transport management design and systems research group leader at the CSIR. Her group works on optimising transport systems in Gauteng through interventions such as assisting the Gauteng Department of Roads and Transport with the General Household Travel Surveys to determine travel needs and patterns within the province. The survey comprises interviews with a sample of 37 000 households to establish their travel patterns within Gauteng.

"We collect data from different modes of transport, such as buses and minibus taxis, so that we can understand how these systems operate and also collect data from the users to understand why things are the way they are," she says.

"The current public transport system is not helping poor citizens and, quite frankly, could be enhancing existing inefficiencies. There needs to be wide-ranging planning that increases accessibility and provides an integrated transport system for people located in the townships and in rural areas. The objective is to transform urban spaces by reducing travel costs and distances.

"Look at cities like New York, Paris and London, for instance, there was a point when they realised that the spaces were not working for them and cities had to be redesigned to reduce some of the challenges they had, like distance.

"We need to find solutions that are African. We need to put emphasis on research to understand how a taxi operator and the taxi business work and what the core issues are. Only then will we be able to design systems that cater for our needs.

"New systems such as bus rapid transit systems are great, but they work in densely populated cities and not over long distances between townships and cities. Outside of the cities, we have this inefficient space to deal with in terms of transport."

She makes an impassioned plea to decision-makers in the public and private sectors, "Invest in research and understand what the issues really are."

The impact of the fourth industrial revolution on transport in South Africa

The transportation of goods, commodities and people is an important factor in the transformation of any nation's economy. This knowledge encourages Mokoma and her colleagues to ensure effective and efficient transport systems in South Africa.

"The essence of transport revolves around economic purposes, spatial interaction and social integration. The fourth industrial revolution brings with it ample opportunities to address these challenges," she says. "Imagine the impact of ride-sharing apps on the minibus taxi industry, as an example. Drivers would know where people are so they would not have to be in a rush looking for passengers and people would start using public transport more. Clearly e-hailing is another way of managing demand for public transport systems," says Mokoma.

She says that her group is investigating how they can facilitate growth in the public transport industry by mapping the full value chain, including manufacturing, financing, policy and regulation.

"We need to empower the public transport industry to embrace aspects of the fourth industrial revolution," she says.

Mommy called it

Mokoma credits her mother for her career success. "She always instilled this thinking that I must be able to stand on my own two feet, no matter what happens; that I should get an education."

"At the time, she said that if I wanted to be an independent woman, I should study science," she says. "Given the almost obscurity of science careers, and specifically women in science, it's pretty remarkable that I ended up at one of Africa's biggest science, engineering and technology organisations."

She is currently reading towards her PhD at the University of Pretoria.

ENQUIRIES

> **Lesedi Mokoma**
lmokoma@csir.co.za

RESEARCHER DEVELOPS PROBIOTIC PRODUCTION PROCESS TO BOOST ABALONE AQUACULTURE

Dr Ghaneshree Moonsamy has tailor-made a bioprocess technology to produce a probiotic used in abalone aquaculture. What began as a Master's study was converted into a Doctoral thesis, a first at the Durban University of Technology (DUT).

Dr Ghaneshree Moonsamy's Master's study focused on the development of an upstream process for *Vibro midae*, an organism identified for use as an abalone probiotic. Abalone, commonly known as perlemoen, is a common name for marine snails and its flesh is a delicacy for many food lovers around the world. Probiotics can be used in abalone production as a mechanism to boost growth rate and limit disease proliferation.

During a progress meeting with her supervisors, Dr Raj Lalloo from the CSIR and Prof Suren Singh from the DUT, the team decided to extend the scope of the study to include aspects of downstream process. As a result, an entire production process was developed, from a proof of concept technology to a commercial-scale production process development.

The amount of work had been doubled and the task at hand was daunting, but the senior researcher who came to the CSIR as an in-service trainee in 2006 has always been curious and eager to grow and expand her skill set, and was ready to take on the task ahead.

Impact on industry

The demonstration of the technology at full manufacturing scale resulted in a patented technology, and has highlighted the attractiveness and commercial feasibility of this production process.

Moonsamy works in the CSIR's bioprocess development group and has worked on a number of interesting industrial biotechnology-based projects. These include development of bioprocesses for biological agents in aquaculture, animal and human probiotics, and biological control agents for use in agriculture as well as wastewater and effluent remediation.

These processes are designed to provide an optimum cultivation environment for these organisms and thereafter either the entire organism or the product made by the organism is extracted. This is then formulated into biological products. Each research project is unique and entails a specific set of conditions, and research and development must occur in order to develop individual, high-efficiency production processes for each application.

Pioneering since primary school

Moonsamy says her parents encouraged and instilled a keen passion for the sciences, and education in general. "Instead of playing with dolls, I wanted to know what was inside the doll," she recalls. When it was time to learn science in school she always punched above her weight, "I used to do science experiments for my show and tell and always did higher level science projects. Once, my science teacher in primary school found it hard to believe that I did a particular electricity-based project on my own, as it was way above the standard in my grade. I then took it apart and rebuilt it in front of him to prove my capability. He was really impressed."

Today, Moonsamy assists students and interns who join the team to gain on-the-job training in the bioprocessing field.

Upstream processing refers to the first step in which microorganisms are grown in bioreactors. When they reach the desired density, they are harvested and moved to the downstream section of the bioprocess. Downstream is the opposite end, where products of interest are formulated as per the user's requirement. Dr Ghaneshree Moonsamy's study focused on upstream and downstream processing of a probiotic for abalone aquaculture.

ENQUIRIES

> **Dr Ghaneshree Moonsamy**
gmoonsamy@csir.co.za

> **CSIR senior researcher Dr Ghaneshree Moonsamy.**

MEDICINE MADE FIT FOR AFRICA: YOUNG CELLULAR BIOLOGIST ADDS HER SKILLS TO THE MIX

Only a handful of people in South Africa have mastered stem cell reprogramming and Dimakatso Gumede is one of them. As a candidate researcher in the CSIR's bioengineering and integrated genomics research group, she works on creating disease models of the innate immune system to study unique African gene variants that lead to elite controllers that naturally control viral load levels without antiretroviral therapy.

By using induced pluripotent stem cell technology, the CSIR also creates 'mini liver' models in order to determine adverse drug reactions in the South African population.

"The African population is known for its genetic variation, which often affects the way in which an individual responds to particular medication. For example, while an aspirin may work effectively for 70% of the population, it is possible that the remaining 30% may experience adverse effects. Therefore, the CSIR is looking to create effective and personalised medication for those who do not respond positively to the drugs that have been distributed for the general population," says Gumede.

Gumede, who is a PhD scholar of the University of Cape Town (UCT), recently submitted her doctoral thesis. She studied the role of a gene mutation that causes skin and lung fibrosis, using a scientific method called induced pluripotent stem cells. This approach produces any cell type in the body, such as skin or lung cells, which, in this case, provides insight into how an inherited dermatological condition is associated with lung fibrosis – a condition caused by uncontrolled scar formation that affects the organ and air sacks.

However, this was not Gumede's original project. Initially, her PhD project was on cardio genetics, and she was working with the late Prof. Bongani Mayosi and Dr Gasnat Shabooden at the UCT Hatter Institute for Cardiovascular Research in Africa.

"While I was busy with my initial research project, the late Prof. Mayosi suggested that I shift the focus of my project to the study of a rare genetic condition that is associated with lung, skin and muscle fibrosis. I was excited because not only was it a ground-breaking research project that would serve as a massive breakthrough for the South African medical science sector, but it would also provide me with the opportunity to apply my cell biology expertise," says Gumede.

With the assistance of Prof. Susan Kidson and Dr Robea Ballo, Gumede

> **CSIR candidate researcher Dimakatso Gumede.**

ENQUIRIES

> **Dimakatso Gumede**
dgumede@csir.co.za

focused mainly on the cell biology of the rare skin condition in question. She learnt a great deal about reprogramming skin cells into pluripotent cells to understand what causes this gene mutation, how this rare skin condition develops at cellular level and how or why it affects organs such as the lungs and muscles and prevents them from functioning properly.

"I discovered that the gene mutation that causes this condition accelerates cell division, which contributes to fibrosis in the affected individuals and is also associated with cancer progression," says Gumede.

Further, according to Gumede's principal investigator at the CSIR, Dr Janine Scholefield, her ability to not only master, but explain highly technical and advanced science in isiZulu and Sesotho is what makes her so highly prized at the CSIR.

"She has mastered the craft of communicating her work fluently in isiZulu, Sesotho and English, which is so important. With science and technology shaping our lives daily, it ought to be accessible to all, especially young people wanting to pursue a career in science. Having a young black woman who is at the top of her game and is able to make the work we do relatable, is what will continue to inspire young girls entering the science field. It also makes her even more invaluable to the CSIR and the scientific community at large," adds Scholefield.

With the skills that she has gained, she aims to use her PhD to further establish the stem cell platform for precision medicine and drug screening and, possibly, commercialisation in the CSIR. She also intends to use the stem cell and genome engineering platforms to find new approaches to eliminate HIV reservoirs in infected persons and, hopefully, also contribute to finding key therapeutic strategies that resolve excessive scar formation in heart and lung conditions, which are a great burden of disease worldwide.

USING LASER TECHNIQUES FOR THE DIAGNOSIS AND TREATMENT OF HIV-INFECTED CELLS

CSIR PhD student Masixole Lugongolo is researching how laser applications can be used to detect and control HIV infection in cells, with the aim of simplifying HIV treatment and diagnosis. Lugongolo is part of the CSIR's biophotonics group that is working towards the development of laser-based point-of-care devices that can assist health care practitioners in diagnosing and treating patients in resource-limited settings.

In her PhD thesis, titled *Optical Micro-manipulation in HIV-1 Infected Cells for Improved HIV-1 Treatment and Diagnosis*, Lugongolo looks at the use of low-level laser therapy, optical trapping, transmission spectroscopy and luminescence spectroscopy, and the impact that these techniques have on HIV-infected cells.

In low-level laser therapy, she uses a red laser beam at attenuated doses to irradiate HIV-1-infected TZM-bl cells in the presence of antiretroviral drugs (ARVs) to assess the effect of combining laser light and ARVs for potentially treating HIV-1. The results showed how laser therapy, in conjunction with current antiretroviral therapy, could reduce HIV-1 infection to undetectable levels in the TZM-bl cells. In her research, Lugongolo also uses luminescence spectroscopy to detect HIV-1 infection in TZM-bl cells. HIV infected TZM-bl cells emit light (produce luminescence), whereas the uninfected ones have no luminescence. The research also found that, by coupling optical trapping and transmission spectroscopy, label-free diagnosis of HIV in infected TZM-bl cells was possible. Finally, to confirm that TZM-bl cells were indeed infected, a conventional system, structured illumination microscopy, was used to detect HIV-1 infection in TZM-bl cells. Here, the data obtained confirmed that, in infected cells, viral molecules were detected, while these were undetectable in uninfected cells.

Intended impact of the research

Lugongolo says the research still needs to be applied to infected blood cells (laser diagnosis) and/or animal models, but the group believes that the results will be favourable and have the ability to revolutionise current diagnosis and treatment methods, as laser exposure will decrease the side effects associated with ARV treatment. In future studies, super resolution microscopy will be integrated with optical trapping to verify that each trapped cell is infected or uninfected, so as to improve HIV diagnosis.

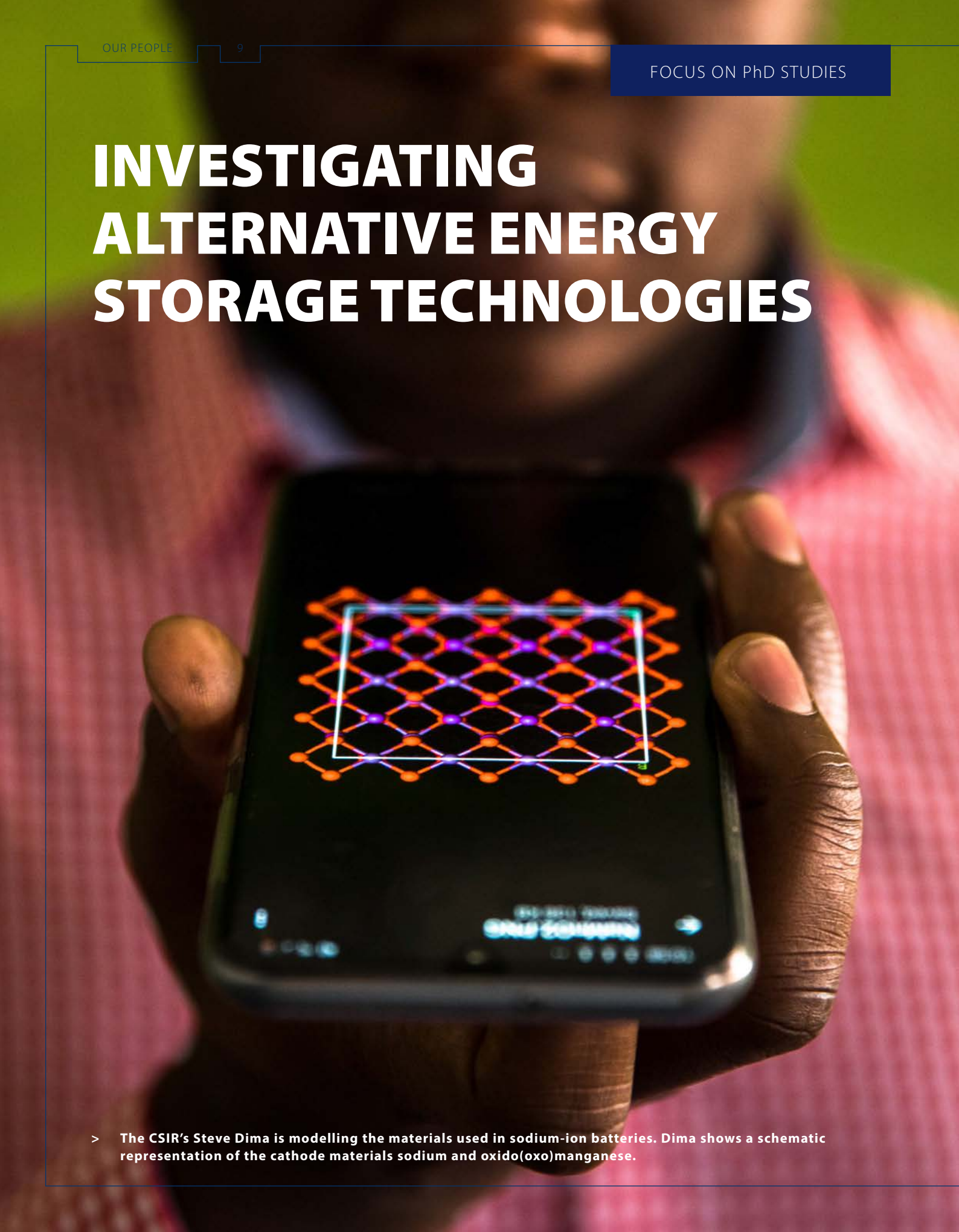
Biophotonics is the science of generating and using photons or light to image, identify and engineer biological materials.

Optical trapping is the process of securely holding and moving microscopic material using a tightly focused laser beam.

TZM-bl cell line is an indicator cell line that enables simple and quantitative analysis of HIV using either β-gal or luciferase as a reporter.

> **Lugongolo analysing HIV-1 infected cells in a cell culture dish using the optical trapping and transmission spectroscopy system for label-free detection of HIV-1 infection in TZM-bl cells.**

INVESTIGATING ALTERNATIVE ENERGY STORAGE TECHNOLOGIES



> **The CSIR's Steve Dima is modelling the materials used in sodium-ion batteries. Dima shows a schematic representation of the cathode materials sodium and oxido(oxo)manganese.**

Ratshilumela Steve Dima is a CSIR student pursuing a PhD in physics at the University of Venda. He is investigating the optimal design of sodium-ion battery materials using advanced multiscale modelling.

The world's energy consumption increases from year to year due to the ever-increasing global population. Climate change and the decreasing availability of cost-effective fossil fuels further contribute to the global concern regarding energy and sustainable energy solutions. With this comes concerns about energy storage, leading towards a collective effort to find alternative energy storage technologies. Key in the quest for energy storage solutions is the need to develop new materials with improved properties to use in energy storage devices.

One of the leading technologies in energy storage currently is the lithium-ion battery, which is a type of rechargeable battery that is well-equipped for portable electronic devices, such as laptops, cameras and mobile phones, and this has made these systems some of the most used technologies in the past two decades. However, due to its low power density, using these batteries in large-scale applications, such as smart grids and aerospace applications with high power, is still a challenge. Furthermore, lithium's low abundance in the earth's crust and the continued demands for electrical energy storage can also lead to the overall depletion in lithium reserves.

"All these challenges make sodium-ion batteries an attractive alternative to lithium-ion batteries. The battery components and the electrical storage mechanism of the two types of batteries are basically the same, with the exception of their ion carriers," says Dima.

He aims to use multiscale modelling investigations to improve the intrinsic properties of the high-energy density sodium intercalation electrode material. "Traditional approaches to modelling focus on one scale. The multiscale opens unprecedented opportunities for materials modelling. The method allows us to connect engineering applications with basic science. It offers a more unified view to modelling, by focusing on different levels of physical laws and the relationships between them," he says.

Dima joined the CSIR in 2019 on a PhD studentship. On completion of his PhD he wants to make an impact in the field of materials modelling, focusing on renewable energy materials.

ENQUIRIES

> **Ratshilumela Steve Dima**
sdima@csir.co.za

> **Steve Dima is on a PhD studentship at the CSIR. He uses modelling to help design better sodium-ion battery materials.**

STUDYING BLAST EFFECTS ON THE HUMAN BODY

CSIR student Zelldra Schutte is investigating how the seat of a vehicle affects the occupant's spine and pelvis during a blast. Schutte is pursuing her PhD in trauma biomechanics through the University of Cape Town in a study titled "Determining the load paths from seat to occupant during under-body blasts."

Trauma biomechanics uses the principles of mechanics to study the response and tolerance levels of biological tissues – the human body – under extreme loading conditions. Schutte attempts to understand and mechanically explain the effect that an under-body blast, below armoured vehicles, has on the spine of the soldier or crew member inside the vehicle. Part of her research aims to more precisely predict the mechanisms of injury to ultimately mitigate spinal injuries during under-body blasts. "Put simply, we blow up things, and from the data derived, we try to prevent people from getting hurt from similar threats in the future."

Schutte holds a Bachelor of Mechanical Engineering and a Master's of Mechanical Engineering from North-West University. She joined the CSIR on a studentship in 2016. "I was interested in the human body and biomechanics and wanted to work for the CSIR. I work in a great team and we get a lot of practical experience working for the CSIR," says Schutte.

CSIR researchers specialise in studying the effects of various blast devices at the detonics, ballistics and explosive laboratory. The facility caters for the testing and evaluation of vehicles and other protective gear that aim to reduce the damage done to people exposed to explosive events. Crash test dummies (anthropomorphic test devices or ATDs) are used as surrogates for vehicle occupants and are fitted with data-collecting sensors that measure how the impact or shockwave of the explosion travels through the ATD. Data collected indicate where forces and accelerations generated by an explosion do the most damage and where better protection is needed.

"Schutte is demonstrating exceptional technical competency, strength of character and determination in pursuit of her end objectives in a highly challenging work environment," says Dr Ajith Gopal, manager at the CSIR Landward Sciences impact area.

ENQUIRIES

> **Zelldra Schutte**
zschutte@csir.co.za

Schutte attempts to understand and mechanically explain the effects that an under-body blast, below armoured vehicles, has on the spine of the soldier or crew member inside the vehicle. Part of her research aims to more precisely predict the mechanisms of injury, to ultimately mitigate spinal injuries during under-body blasts.

> **The CSIR's Zelldra Schutte sets up a test to gather data to develop protection solutions for ground soldiers, as well as military personnel, subjected to blast events. Improvised explosive devices can cause multidimensional injuries, impairing numerous physiological systems and organs.**

THE CLASS OF 2018

The CSIR is committed to supporting the academic development and transformation of its staff, both in the science, engineering and technology and support bases. In line with the organisation's values, the organisation pursues excellence and celebrates its people.

Below are some of the employees who obtained doctoral or master's-level qualifications in 2018.

Dr Sindisiwe Buthelezi,
CSIR researcher
PhD (Biochemistry and Cell Biology), University of the Witwatersrand

Dr Varsha Chhiba,
CSIR senior researcher
PhD (Chemistry), University of the Witwatersrand

Dr Jacques Cilliers,
CSIR principal researcher
PhD (Electronic Engineering), University College London

Dr Pranitha Dawlal,
CSIR researcher
PhD (Microbiology), University of Pretoria

Dr Christoper de Saxe,
CSIR senior engineer
PhD (Engineering), Cambridge University

Precilla Dimpe,
CSIR systems administrator
MTech (Information Technology), Tshwane University of Technology

Babalo Dlulane,
CSIR financial administrative officer, MTech (Cost and Management Accounting), Tshwane University of Technology

Zimbini Faniso,
CSIR engineer
MSc (Physics), University of Fort Hare

Marlene Jivan,
CSIR senior project coordinator
MCom (Programme and Project Management), Cranefield College

Dr Hlabishi Kobo,
CSIR senior researcher
PhD (Computer Engineering), University of Pretoria

Tichaona Kumirai,
CSIR senior technician
MSc (Applied Science: Mechanical Engineering), University of Pretoria

Lehlo Ledwaba,
Candidate engineer
MSc (Applied Science), University of Pretoria

Qualifications obtained but not available for a photograph:
Amos Akande, Kirodh Boodhraj, Johnny Botha, OJ Botlhoko, Nwabisa Budaza, Gawie Croeser, Steve Dima, Ross Holder, Gugu Khalala, Thokozani Khwela, Dimakatso Makwakwa, Prettier Maleka, Ipfi Matoho, Lindokuhle Mdletshe, Rory Meyer, Tladi Mofokeng,

Dr Gugulethu Mabuza-Hocquet,
CSIR engineer
DPhil (Electrical and Electronic Engineering), University of Johannesburg

Dr Sabelo Madonsela,
CSIR postdoctorate
PhD (Geography), University of KwaZulu-Natal

Washington Makoana,
CSIR researcher
MEng (Mechanical Engineering), Central University of Technology

Victor Manavhela,
Regional Manager: National Cleaner Production Centre
MSc (Environmental Management), University of the Free State

Nthabiseng Mokoena,
CSIR engineer
MSc (Computer and Electrical Engineering), North-West University

Vuyelwa Mvandaba,
CSIR candidate researcher
MSc (Hydrology), Rhodes University

Dr Suliman Ridhwaan,
CSIR senior researcher
PhD (Applied Mathematics), University of Cambridge

Dr Delphia Skosana,
Project Management Manager
D (Philosophy), University of South Africa

Dr Andrew Smith,
CSIR senior researcher
PhD (Computer Science), University of South Africa

Mr Oscar Sono,
CSIR technician
MEng (Mechanical Engineering), University of the Witwatersrand

Mayur Tikam,
CSIR engineer
MEng (Mechanical Engineering), University of Pretoria

Sibongile Tshabalala,
Studentship
MSc (Medicine), University of the Witwatersrand

Christo Fourie,
CSIR research group leader
MEng (Engineering Management)
University of Pretoria

Dr Laven Naidoo,
CSIR senior researcher
PhD (Geoinformatics), University of Pretoria

Mahlatse Ratsoma,
CSIR engineer
MSc (Computer and Electronic Engineering), North-West University

Dr Elsona van Huyssteen,
CSIR principal researcher
PhD (Town and Regional Planning), University of Pretoria

Dr Lara van Niekerk,
CSIR senior researcher
PhD (Botany), Nelson Mandela University

Madumetja Moselakgomo, Nilesh Moti, Abesach Motlatle, Sibongile Mtimka, Nthambeleni Mukwevho, Gculisile Mvelase, Laven Naidoo, Andre Page, Treshan Pillay, Nomasonto Rapulenyane, Colin Schwegmann, Stanley Semelane, Justice Shaku, Hester Van Greuning, Corney Van Rooyen, Nqobile Xaba

BRINGING SCIENCE, ENGINEERING AND TECHNOLOGY TO THE PUBLIC

The CSIR undertakes engagement activities such as career days at schools and universities, exhibitions, as well as outreach programmes to raise awareness about science, engineering and technology. The CSIR's science engagement is informed by the vision of the Department of Science and Innovation (DSI) to promote science through the involvement of citizens, particularly the youth.

Science engagement in the CSIR context refers to all the organisation's efforts to engage or interact with the public about its research, development and innovation. It includes programmes to attract the youth to enrol in the fields of science, technology, engineering and mathematics (STEM), sharing of knowledge and expertise between CSIR researchers and other African scientists or organisations, as well as outreach and awareness activities. The CSIR takes guidance in respect of thematic interventions and national initiatives from the DSI and the South African Agency for Science and Technology Advancement.

Science engagement for a younger audience

The CSIR hosts career days that focus on grade 10-12 students. CSIR researchers showcase their work and share their experiences with students and their teachers at tailored exhibitions and visits to laboratories.

> **The CSIR hosted a career day for grade 10 to 12 students at its International Convention Centre in 2018.**

> **Laique Djeutchouang, a PhD student associated with the Southern Ocean Carbon and Climate Observatory, explaining the ocean-climate link to learners at the 2019 National Science Week events hosted by the CSIR.**

Grooming young scientists in communicating about their research

The CSIR's Emerging Researchers' Symposium is a platform for young researchers to showcase their research to peers and potential collaborators. The researchers also participate in other science events across the country.

CSIR senior events practitioner Bonang Tselane travels with CSIR interns to outreach programmes where students in higher education institutions get first-hand information about choosing a career in science. Tselane has experienced the rewards first-hand, saying that a student in Venda took up a career in laser technology after engaging with the CSIR during an outreach programme.

The CSIR partners with public and private organisations to showcase its work, promote science and engineering generally, and STEM careers in particular. Exhibitions and workshops are prominent features of this programme. The organisation participates at exhibitions that are relevant to its areas of focus, to showcase its work to stakeholders and potential partners or collaborators.

"My goal is to try and make sure that no child is left behind, especially now that the fourth industrial revolution is on our doorsteps."

Bonang Tselane,
CSIR senior events practitioner

SOME OF THE CSIR'S PUBLIC ENGAGEMENT ACTIVITIES IN 2018/19

CSIR-hosted events

> Black Science, Technology and Engineering Professionals student chapter visit, Pretoria, Gauteng
> Emerging Researchers Symposium, Pretoria, Gauteng
> Career Day, Pretoria, Gauteng

Outreach activities

> Science Beyond Borders, Thohoyandou, Limpopo and Kimberley, Northern Cape
> Soshanguve Crossing Centre, Pretoria, Gauteng
> Father Smangaliso Mkhatshwa Centre, Pretoria, Gauteng

Exhibition participation

> Bio-Africa Convention, Durban, KwaZulu-Natal
> Scifest Africa – South Africa's National Science Festival, Makhanda, Eastern Cape
> Sasol TechnoX Science, Maths and Technology Exhibition, Sasolburg, Free State
> Eding International Science Festival, Polokwane, Limpopo and Klerksdorp, North West
> Parliamentary exhibit following State of the Nation address, Cape Town, Western Cape
> National Science Week Launch, Mpumalanga
> Africa Aerospace and Defence Expo, Pretoria, Gauteng
> Science Forum South Africa, Pretoria, Gauteng
> Gauteng Youth Expo, Johannesburg, Gauteng
> South African Local Government Association Municipal Managers Forum, Mbombela, Mpumalanga

> **Learning more about trauma biomechanics at the CSIR exhibition during National Science Week 2019.**

THE AISI: IMPROVING COMPETITIVENESS IN THE AEROSPACE INDUSTRY

The Department of Trade and Industry established the Aerospace Industry Support Initiative (AISI) to help the South African industry to improve its competitiveness. This in response to government objectives such as the industrialisation of technologies, job creation and industry transformation.

Rapid technological advances, as well as increased globalisation, present significant challenges to SMMEs in the South African aerospace industry. Substantial investment is required to keep abreast of technological developments such as additive manufacturing, Industry 4.0, advanced materials, including composites, and product refinement to match market needs. The AISI supports these SMMEs by 'de-risking' technologies through technology transfer, validation and the provision of product development support. This gives the SMMEs access to new market opportunities and technological advances that would otherwise be unattainable.

> **Infrared thermography was effective in pinpointing the precise location of identified defects on the surface of a sandwich-construction panel such as this one.**

IDENTIFYING DEFECTS IN AEROSPACE COMPOSITES USING INFRARED THERMOGRAPHY

Denel Aeronautics, supported by the Aerospace Industry Support Initiative (AISI), has proved the usefulness of infrared thermography in providing additional information on defects in composite parts used in aircraft.

Infrared thermography detects infrared energy emitted from an object, converts it to temperature, and displays an image of temperature distribution.

> **A carbon fibre sandwich test panel with built-in defects used in tests to show how infrared thermography can detect these defects.**

The integrity of composite panels in aircraft is important for the safety of the aircraft and its passengers. Such parts have to be replaced on time and are costly to repair.

As a tier one supplier to major aerospace original equipment manufacturers, Denel Aeronautics is an advanced aerospace manufacturing organisation, supplying both metallic and composite components to their final assembly lines. One of the programmes experienced challenges in identifying defects in honeycomb-type composite structures, with resultant expensive repairs and even scrapping of structural components.

"It is important to understand why composite parts are crucial in aerospace. Weight is everything when it comes to heavier-than-air machines, and designers work continuously to improve lift-to-weight ratios. Composite materials have played a major part in weight reduction. They also have some remarkable properties. Each type has different mechanical properties and is used in different areas of aircraft construction," says Marié Botha, AISI Programme Manager.

Denel Aeronautics uses two types of non-destructing testing methods – through-transmission ultrasonic testing for sandwich regions; and pulse-echo for monolithic parts. However, at best, these technologies deliver indications of regions and depths at which defects occur, and do not help in identifying the type of defect.

Denel Aeronautics worked with the CSIR to assess how well infrared thermography worked. Panels identical to real parts were built at Denel Aeronautics, but with known defects incorporated. Infrared thermography was effective in pinpointing the precise location of identified defects on the inner or outer surface of a sandwich-construction panel. It is also effective when used on monolithic composite material. Based on these findings, the standard operating procedure for infrared thermography inspection (documenting all steps in the process), which has been developed, could be of great value to the aerospace and industrial manufacturing sectors.

"In the Denel context, the correct identification and location of the defects in honeycomb core structures provide considerable cost and time savings. The rejection of defective components, which would otherwise not be detectable using conventional methods, is possible," says Cardoso.

"This will contribute to improved efficiencies, productivity and on-time delivery. Infrared thermography also makes it possible to better classify and categorise defects, opening the way for Denel Aeronautics to work with Airbus on a qualification programme for parts supplied."

ENQUIRIES

> **Marié Botha**
mbotha1@csir.co.za

A SMALL GAS TURBINE TAKES TO THE MARKET

Cape Aerospace Technologies, an SMME based in Cape Town, completed the design, integration and manufacture of a new 250 N micro gas turbine and has received the first orders for it. The company, supported by the Aerospace Industry Support Initiative (AISI), is set to contribute to the aerospace sector in the Western Cape and take its place in the global aerospace market.

Made in South Africa: Jet engines in micro and small sizes

Small gas turbines are much in demand by hobbyists for use in model aircraft, by sailplane manufacturers as the mechanical backup or range extender, and by the military for weapon propulsion systems. As there are no South African aerospace companies in this field, Cape Aerospace Technologies set out to capture the local market to manufacture high-precision micro to small gas turbines. The recently completed 250 N micro gas turbine, a type of jet engine, has become sought after by the defence industry.

Cape Aerospace Technologies' David Krige is passionate about his work. "My childhood dream was to fly," he says. While he has not yet realised this dream of human flight, he and co-founder Andre Baird run a small, but thriving, business established in 2013, manufacturing a range of gas turbines: 120 N, 250 N, 400 N and larger.

Cape Aerospace Technologies developed a roadmap for the developmental process of the 250 N gas turbine. With support from the AISI, the 250 N micro gas turbine was taken from design to market through different stages. "Stage 1 was strictly numerical design, utilising computational fluid dynamics and computer-aided design computer programmes. This is all about assembling parts on the computer in an optimised environment to see how well they work together and where we can improve on our design," he says.

Turbomachinery engineering of this nature is a niche skill, and Krige drew on his relationships with Stellenbosch University and the CSIR for expert advice.

"Stage 2 involved the use of computational fluid dynamics to match the compressor and turbine to determine if the turbine could drive the compressor. This stage optimised the compressor and diffuser (to extract pressure) design to match the turbine characteristics.

> **The CAT 400 turbine, which produces 400 N thrust at sea-level static conditions.**

"In stage 3, the final engine design and all components related to the newly designed gas turbine were assembled, using computer-aided design, and checked; thereafter they were manufactured. Once the manufactured parts had cleared the quality control checkpoint, they were assembled in the 250 N turbine," he says.

In stage 4, experimental testing was done on the 250 N gas turbine in the on-site laboratory, and experimental and numerical results were compared. Stage 5 involved the upgrade of the previous turbine control unit and user interface. In stage 6, intelligent design and investigation of processes helped to streamline the design-to-manufacture process to minimise the wastage of material and time.

Krige highlights some challenges encountered during the process. "We learnt through experience that industrialisation for the market, which involved stages 5 and 6, is neither simple nor quick. We're still working on market readiness and will continue to market our products at upcoming trade shows in Brazil and London this year."

ENQUIRIES

> **Marié Botha**
mbotha1@csir.co.za

REGAINING BEST-IN-CLASS STATUS WITH A NEW SAILPLANE

The Aerospace Industry Support Initiative (AISI) is supporting world-renowned sailplane manufacturer, Jonker Sailplanes, in adding a new sailplane model to its product portfolio.

> **A computer-aided design illustration of the extended wingspan from the current 21 m to the new 24 m.**

Jonker Sailplanes: Getting back to best in class

For many years Jonker Sailplanes has had an unassailable market position as the only manufacturer of sailplanes outside Germany. Its sailplanes are rated as the best in the world and are in demand for recreational purposes. They are sought-after products, flown by leading pilots from Czech Republic, Denmark, France, Germany, Great Britain, Hungary, the Netherlands, New Zealand, Poland, South Africa and the United States of America.

In the 2018 World Gliding Championships, the EB29R took the top three positions in the Open Class, pushing Jonker Sailplanes' JS1C-21 off the podium. Uys Jonker, Chief Executive Officer of Jonker Sailplanes says, "Since then, we have received many requests from clients to develop a sailplane to match this competitor."

The decision to add the JS2-24 to its portfolio to regain its market position has been boosted by support from the AISI for three years.

Advantages for Jonker Sailplanes include the capabilities of its formidable design team, Dr Johan Bosman and Dr Attie Jonker, whose approach is to focus on numerical modelling first before using computer-aided design for structural development. In addition, the well-established design and production

***Sailplane*: An unpowered aircraft, using naturally occurring currents of rising air in the atmosphere to remain airborne. Also known as a glider.**

> **The Jonker Sailplanes production and assembly plant in Potchefstroom employs 115 local people in an otherwise economically depressed area.**

facility in Potchefstroom has lower costs than its overseas competitors.

As a start, the Jonker Sailplanes design team used its expertise to model and optimise the envisaged sailplane design by factoring in the variables of wingspan, twisting of wings and structure strength.

Using the Jonker Sailplanes numerical model, various parameters were drawn on to interrogate different design options and the resulting effect on performance. Bosman explains, "Of particular interest for sailplane efficiency is speed versus rate of descent for a particular wingspan length and structural design. We regard the favourable modelling result for JS2-24 as a reliable indicator of superior performance for this new Jonker Sailplanes product."

The team has identified 24 m as the optimal wingspan for the new product (hence the designation, JS2-**24**) and is confident that predictions will match performance.

ENQUIRIES

> **Marié Botha**
mbotha1@csir.co.za

LASER SHOCK PROCESSING FOR STRAIGHTENING OF MACHINED ALUMINIUM SPARS

Denel Aeronautics successfully used laser shock processing to modify a machine part – a machined aluminium spar – that had been scrapped. The component is particularly prone to post-machining distortion (bending). With the support of the Aerospace Industry Support Initiative (AISI), a laser shock processing technology that made it possible to reverse the undesirable distortion was developed and the shape of the component was modified to acceptable deviations.

> Measuring the distortion on an aluminium spar.

Using laser technology to correct distortion in aerospace components

Denel Aeronautics manufactures a significant number of structural components for the global aerospace industry by precision machining of aluminium. One of the challenges of manufacturing thin-walled structures is the resulting post-machining distortion. A number of machined components are scrapped due to this distortion problem as the components fail the geometric tolerance specifications – they are out of shape and unusable.

The aluminium spar in question is a component in the winglet of a business jet, which takes the bending load. It is manufactured to tight tolerance, which is measured in percentages. Less than 2% is acceptably 'in shape'; more than 2% is deemed 'out of shape' and will be scrapped. This distortion is thought to result from residual stress in the aluminium billets (semi-finished casting products), which are used in the machining process.

Through support from the AISI, Denel Aeronautics embarked on a process to see if laser shock processing technology could be used to straighten the spars that were found to be out of shape. Denel chief engineer Alcino Cardoso says that neither material properties nor structural integrity could be compromised through this process. "We had to find the right range in which to use laser shock processing, so that we did not inflict more damage on the component." Testing for fatigue damage was done to conform to the standard, ASTM E466-15.

Another challenge was the fact that each of the machined aluminium spars had a different distortion. A specialised jig (a type of custom-made tool used to control the location and/or motion of parts or other tools) was designed and manufactured. It includes a precision laser displacement sensor that can be positioned along the length of the component for in-process verification, and therefore effective handling of different distortion requirements during laser shock processing.

Three promising findings emanated from the project. Firstly, the microstructure of material was not damaged, as was shown by the images from a scanning electron microscope. Secondly, laser shock processing parameters (range) were identified, which would not make the material susceptible to breaking; and thirdly, machine-induced distortions could be fixed within an acceptable level.

Cardoso points out, "Given the stringent requirements placed on original equipment manufacturers, Denel Aeronautics required the development of a detailed list of activities for aerostructural component-forming by laser shock processing."

He concludes, "It would seem that this process has the potential for commercial application in aerospace. It is expensive, but then it would be used on high-value components. It would do away with scrapping, which is a big waste in material and productivity and a concern for manufacturers."

"This successful demonstration of the technology sets the stage for the following act, which is to certify and qualify the process according to the original equipment manufacturer's requirements."

Laser shock processing acts as a precision hammer to provide highly engineered distortions into high-end components for high performance applications. The technology utilises a pulsed laser that improves metal fatigue life and damage tolerance.

ENQUIRIES

> **Marié Botha**
mbotha1@csir.co.za

> The CSIR developed a protection package that acts as a shield against deadly explosive threats. The device can be installed on vehicles that carry personnel, equipment or supplies.

INNOVATIVE ADD-ON ARMOUR PACKAGE FOR MILITARY VEHICLES

The CSIR has drawn on its skills in materials manufacturing as well as detonics and ballistics to develop a novel, cost-effective protection solution against the threat of improvised explosive devices.

Protection against improvised explosive devices is a necessity for defence forces engaged in peacekeeping missions or deployment, especially when patrolling strife-torn regions.

Armoured personnel carriers are particularly vulnerable to improvised explosively formed projectiles due to the formidable penetration capability of such devices into armoured steel. These carriers cannot be 'up-armoured' above certain weight limits as the thickness of additional conventional steel armour on the vehicles has a negative impact on their manoeuvrability and mobility. Many sophisticated lighter weight solutions have been developed to mitigate threats, however, they are costly and difficult to implement. This leaves armed forces with a constant demand for lighter and more cost-effective solutions against continually evolving threats from improvised explosive devices.

Experts in the CSIR's clusters for defence and security and manufacturing pooled their expertise to investigate the challenge and develop a solution. Manufacturing experts focused on the material possibilities in the solution, while defence experts analysed the threat

The team succeeded in developing a bespoke solution that can be fielded against explosive threats.

and provided the infrastructure for field experiments. The team succeeded in developing a bespoke solution that can be fielded against explosive threats.

Such a solution can be deployed in an add-on manner on vehicles, without unduly compromising the vehicle's mobility. This is especially necessary for deployments of the South African National Defence Force on peacekeeping missions.

The final solution utilises specific manufacturing techniques for the consolidation of a combination of light-weight off-the-shelf materials that are used in specific layouts against the threat. The optimisation of the layout was made possible by expert post-test analysis of the fracture modes in the materials and the analysis of high-speed photographic data obtained from the impact experiments. The manufacturing techniques and layouts were optimised in such a way that materials not usually effective against this threat on their own, could be combined cost-effectively in a passive layup. The current mass of the protection layup compares well with those in the field which uses more sophisticated and costly materials.

> **The CSIR's improvised explosive device protection package was developed through scientifically proven methods and offers protection equal to that of 50 mm thick conventional steel armour.**

> **The CSIR detonics, ballistics and explosives laboratory is a national research facility for the testing, measurement and evaluation of explosive events and their effects on infrastructure, vehicles and surroundings.**

ENQUIRIES

> **Gary Corderley**
gcorderl@csir.co.za

CSIR-DEVELOPED GRAVEL ROAD TEST KIT ADDS VALUE TO AFRICA'S ROADS

A CSIR-developed gravel road test kit is changing how low-volume unsealed roads and unsealed road building materials in Africa can be rapidly characterised.

The gravel road test kit has been widely adopted by the African market. To date, the CSIR has sold over 250 units, mainly to roads authorities and agencies in African countries like Liberia and Tanzania, but also in countries like Afghanistan and the Republic of Kosovo.

The materials laboratory manager at the Tanzania Rural and Urban Roads Agency, Vincent Lwanda, says, "The equipment is beginning to make an impact on low-volume road improvement in the councils that first received and put the equipment into use."

"Generally speaking, wherever the equipment has been used, there is a remarkable improvement in the quality of executed works," Lwanda continues.

The test kit is a result of a joint effort between the CSIR and the International Labour Organisation, in which the team developed the field test kit to evaluate borrow pit materials for use as wearing course on unsealed roads and to ensure that the quality of the construction is appropriate. Borrow pits are areas close to major construction projects where soil, gravel and sand are dug up for use in the construction.

Simply put, the field test kit is a ubiquitous soils testing kit, tucked in two 1 m x 60 cm x 50 cm steel trunks, weighing about 56 kg and 45 kg each.

At first glance, the mobile materials testing kit, with its components neatly arranged in a wooden framework inside these trunks, looks old fashioned. However, CSIR workshop supervisor, Alan Crawford says, "The genius of it lies in its simplicity."

"The challenge with CSIR technologies has always been understanding industry needs and providing solutions that are value for money. These kits are a perfect example of value addition and innovation guided by the need for a simple solution," adds Crawford.

The idea was to design and develop a simple technology that could be operated independently of resources like energy and water – which are scarce in some parts of the continent – and by someone with relatively modest training.

> **A drop cone for liquid limit data.**

> **The main kit (inset top) and the solar oven (inset bottom). Dr Martin Mgangira and Isaac Maselela from the CSIR demonstrating the kit items.**

In the case of the field test, simple means reliable – and reliable can mean the difference between having a machine that functions and having one that requires regular maintenance.

One of the main contributors to the performance of gravel roads is the material selected, including testing and control of constructed layer work.

The test kits are manufactured at the CSIR. The ability to provide this specialised support to the roads construction industry, especially in rural areas, is rooted in a first-rate workshop facility, specialised equipment and highly skilled technicians.

CSIR senior researcher and manager of the CSIR Advanced Material Testing Laboratories, Georges Mturi, says that this technology has now proven its viability.

"Given that the continent is largely rural, with limited access to electricity and water, these kits are ideal. We are hoping that, as more countries are introduced to the technology, the demand will increase and an environment more suitable for mass production will become a requirement," Mturi says. "This will create opportunities for South African small, medium and micro enterprises to manufacture the kits under licence to the CSIR."

The technology allows material grading, as well as determining cohesion (liquid limit and linear shrinkage), compacted strength and aggregate strength of the borrowed material. A thickness probe, included in the kit, is used to determine layer thickness at the time of construction, ensuring that the correct layer depth is compacted. A rapid compaction control device, also contained in the kit, ensures that the layers are compacted to the correct density for construction quality assurance.

The kit is designed to make use of local water and solar energy, and contains a solar oven and calculator, as well as a battery-powered balance. Therefore, it does not require electricity and running water. A manual describing the step-by-step test methods, with worksheets for test results and practical guidelines, is supplied with every kit. The manual also assists in the analysis and interpretation of the collected data.

ENQUIRIES

> **Georges Mturi**
gmturi@csir.co.za

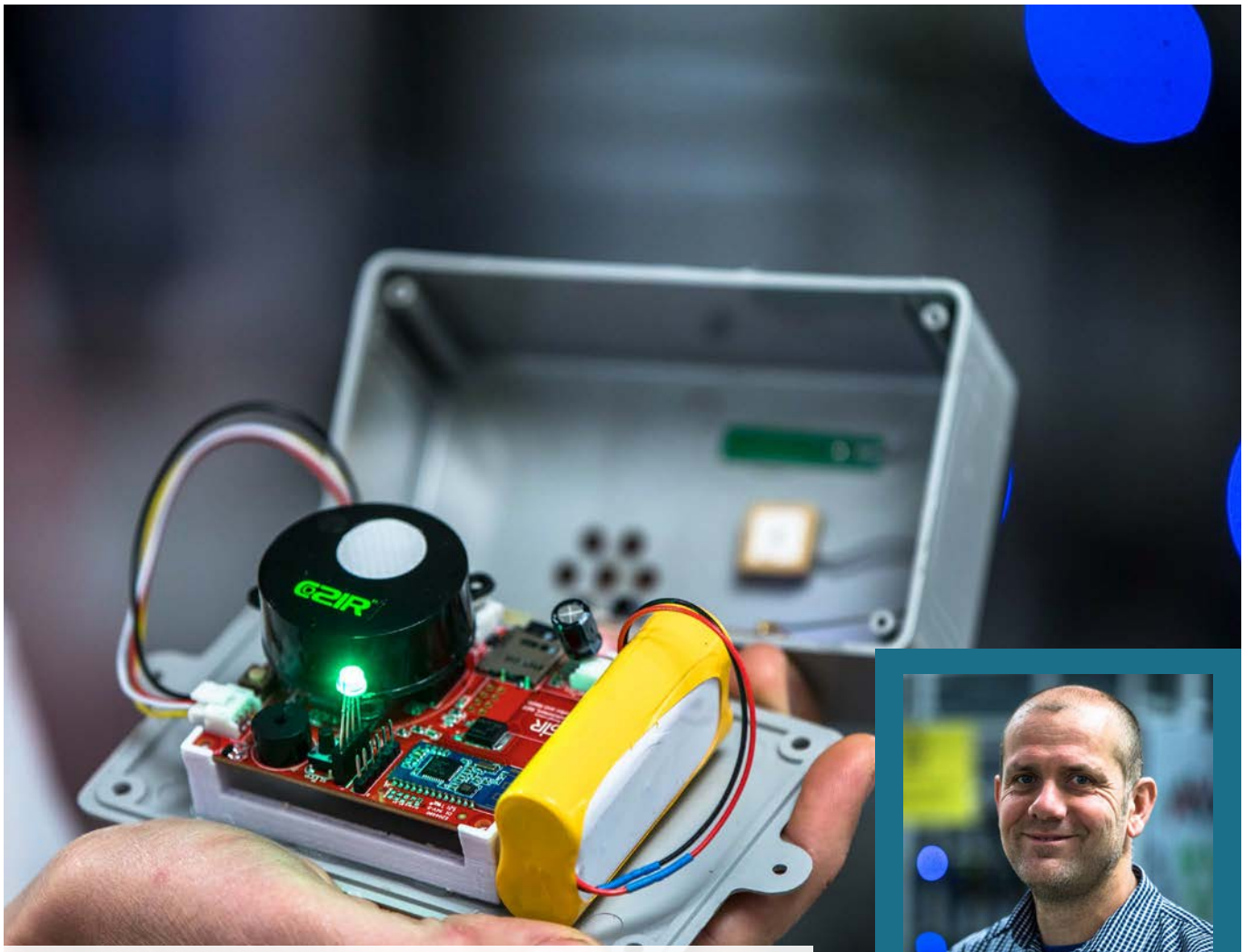
SENSOR PLATFORM FOR INDOOR ENVIRONMENTAL QUALITY DEPLOYED IN PUBLIC HEALTH FACILITIES

The CSIR has developed and deployed electronic devices that can estimate airborne disease transmission risk in real time. The devices generate an alarm when corrective action is needed. Together with its project partners, CSIR researchers have installed nearly 40 devices at various public health facilities across the country, mainly in suspected high tuberculosis risk areas, such as pharmacies, emergency centres and outpatient departments.

> Device configuration and testing at the CSIR in Pretoria.

The CSIR is evaluating the performance of newly developed electronic devices in efforts to minimise the risk of tuberculosis transmission in public health facilities and improve awareness and appropriate responses in health-care workers.

The device estimates the infection risk in real time, using exhaled carbon dioxide as a proxy for the transmission risk.



> **The CSIR-developed electronic device that can help manage the risk of tuberculosis transmission in public health facilities.**

> **CSIR senior engineer Tobias van Reenen is leading the project, which has now progressed to deployment of the devices to health facilies.**

The device determines the differential between indoor and outdoor carbon dioxide and indicates when ventilation has to be improved or the number of occupants in an indoor area reduced. This is indicated directly by a flashing light turning from green to red. CSIR researcher Tobias van Reenen says while the device was initially installed with the patient in mind, data collected show the critical need to reduce exposure of health workers who operate in highly congested areas for long periods of time.

Tuberculosis spreads from person to person through the air. The risk of contracting the disease is influenced by the duration of exposure and the indoor air quality, which, in turn, is dependent on the building ventilation rate and occupancy levels. Settings with high airborne disease transmission risk are typically found in the congregate areas of social infrastructure, such as hospital and clinic waiting rooms, licensing departments, home affairs and correctional centres.

The CSIR has, via its project partners, submitted a proposal to the Department of Health based on the findings, advocating for a scale-up of the network of devices for greater facility coverage and improved risk management.

ENQUIRIES

> **Tobias van Reenen**
tvreenen@csir.co.za

PARTNERING WITH RIGHT ePHARMACY FOR THE LOCALISATION OF A MEDICINE-DISPENSING ROBOT

> The sachet dispensing robotic system.

The CSIR is collaborating with Right ePharmacy to design and develop a robotic pharmaceutical dispensing unit containing electronic and robotic technology to support the dispensing of medication to patients. Researchers have also helped the pharmaceutical firm to optimise its electronic locker systems to improve patient access to pre-dispensed medication parcels.

Dispensing robotic system

Up to 30% of medicines in South Africa and 80% in Africa are dispensed in medicine sachets. Current robotic dispensing systems do not support the handling of these sachets. Right ePharmacy, a leading pharmaceutical product developer focusing on optimising the pharmaceutical supply chain, was in search of an innovative, easy-access medicine-dispensing solution with quality controls and measures that support the pharmaceutical staff and improve quality and control around medicine dispensing. Right ePharmacy currently supports 18 medicine-dispensing locations at five shopping centres in South Africa.

The dispensing robot's picking speed is 900 sachets per hour and it can apply labels to medicine sachets. The robot scans and verifies each product before dispensing it.

The current prototype dispensing robot is incubated in the CSIR Industry 4.0 Product Lifecycle Management Centre of Technologies to focus on the localisation and manufacturing of the technology. The CSIR's product lifecycle management supports the private and public sectors to help bridge the gap between research and product development. The localisation of technology will optimise the local supply chain and product manufacturing industry in South Africa.

Prescription collection unit

Right ePharmacy customises and utilises electronic locker systems for prescription collection. The lockers are temperature-controlled, secure and also integrated with cloud-based technology. The cloud-based information system is mobile application enabled, guiding logistics of parcel distribution and loading, including reverse logistics.

The cloud's SMS system keeps users informed about parcels ready to collect and their next collection dates. This promotes patient retention, supports parcel collection rates by patients and enables early identification and intervention for patients at risk of non-adherence. The system contributes to positive clinical outcomes and effective patient data management. The project is directly aligned with the priority need of South Africa's Department of Health to decant stable patients out of facilities and enable more convenient chronic medication collection.

The CSIR was contracted by Right ePharmacy to design and develop a solution with some key intervention areas. The interventions focused on optimal airflow design in the lockers, battery backup capabilities, as well as modular plug-and-play deployment innovations.

"The development of a local (South African-based) supply chain with emphasis on local manufacturing is key for Right ePharmacy," says Andre van Biljon, Chief Technology Officer of Right ePharmacy. "The focus on fit-for-purpose, and our assistance in optimising technologies for deployment in local conditions, enable Right ePharmacy to serve the South African market, as well as regions in Africa," he says.

The CSIR's product lifecycle management supports the private and public sectors to help bridge the gap between research and product development. The localisation of technology such as Right ePharmacy will optimise the local supply chain and product manufacturing industry in South Africa.

ENQUIRIES

> **Pieter Roux**
proux@csir.co.za

SCIENTISTS AND INDUSTRIALISTS NEED TO COLLABORATE TO REDUCE NANOPOLLUTION RISKS

Some of the most common household products, including sunscreens, hair relaxers, body lotions and cleaning detergents, contain engineered nanomaterial ingredients that, when released into the environment, have the potential to cause nanopollution, warn studies by local environmental and nanotechnology scientists.

A recent study identified sunscreens as a main concern, due to the likelihood of the product releasing engineered nanomaterials into water systems during bathing and/or swimming.

Sunscreens recorded a release factor above 90%. The release factor refers to the fraction of the engineered nanomaterials contained in the product that can be released, in comparison to the amount of product used. This was the first time that nano-enabled products were identified and prioritised (qualitatively and quantitatively) according to their likelihood for nanopollution in Africa. The studies were conducted by a team of nanotechnology scientists from the CSIR, the University of Johannesburg, the Nelson Mandela University and the Sefako Makgatho Health Sciences University.

> **CSIR researchers investigated the physical and chemical characteristics of engineered nanomaterials in sunscreens.**

Nano simply means small, and nanopollution describes an introduction of nano-sized contaminants into the natural environment, which causes instability, possibly harming the ecosystem.

"Engineered nanomaterials are considered a case of contaminants of emerging concern because their environmental behaviour differs from their larger-sized counterparts and, thus, their risk management does not fit well into the existing environmental risk assessment frameworks," explains CSIR senior researcher and study leader, Dr Melusi Thwala.

Due to their prevalence in the market, sunscreens were analytically examined and their applications were simulated, showing that South African wastewater systems are vulnerable to nanopollution.

In the study, researchers also express concern over 90% of the identified products exhibiting a medium to high potential for nanopollution. It is recommended that South African authorities in the environmental regulation sector establish the means to identify sources of nanopollution and their extant. Where considerable environmental risks are identified, scientists and industrialists need to formulate mechanisms for risk reduction, for instance through safety-by-design approaches for the development of nano-enabled products, where hazardous characteristics of engineered nanomaterials are altered or replaced with greener alternatives. The ultimate goal would be to retain or even maximise the nano-induced superior performance of the products while reducing potential environmental harm.

The studies were conducted to improve an understanding of the potential sources of engineered nanomaterials into the environment, under a consortium funded by the Department of Science and Innovation.

> **CSIR senior researcher Dr Melusi Thwala examining the health state of aquatic plants that were exposed to product-released engineered nanomaterials.**

ENQUIRIES

> **Dr Melusi Thwala**
mthwala@csir.co.za

THE KNYSNA FIRES OF 2017: MINIMISING THE RISK AND IMPACT OF ANOTHER MEGA FIRE IN SOUTH AFRICA

In the recent report on the Knysna fires of 2017, researchers point out an increase in extreme fire danger days – on the scale of the Knysna fires – that threaten to compromise infrastructure, people and the environment, if government, industry and the public are not adequately prepared. Researchers warn that the risk of mega fires is increasing.

Climate change is extending the fire season in Southern Africa and, primarily due to rising temperatures, increasing the number of high and extreme fire danger days. Fires are also becoming more difficult to control.

This year, 2019, marks the second anniversary of the worst wildfire disaster in South Africa's history – the Knysna Fires of 2017. Santam commissioned the CSIR, the Research Alliance for Disaster and Risk Reduction and the Fire Engineering Research Unit at Stellenbosch University to prepare a report to improve the understanding of the pre-fire situation, the incident itself and the post-fire recovery efforts. The report makes several recommendations to government, the insurance sector, communities and industry on how to better manage wildfires.

"Our goal was to analyse the causes of the Knysna fires and find out why they were so severe; but more importantly, the purpose was to establish how we can reduce the risk of reoccurrence and the severity of such fires should they reoccur," says John Melville, Chief Underwriting Officer at Santam.

Importantly, the report notes that the underlying risk drivers that fuelled the fires are replicated throughout the Western Cape and in other provinces. Despite the ferocity of the fires, the number of people threatened, and a very challenging response environment, the report finds that responders were remarkably successful in saving lives. Nonetheless, critical gaps in responses centred on training for wildfire suppression and incident command, evacuation and response planning, communication and data collection to support strategic resource mobilisation and rationalisation.

"A growing population, coupled with expansion of the urban footprint into flammable natural vegetation, is increasing the likelihood of fires and the number of people in harm's way," warns the CSIR's Greg Forsyth. The Knysna fires exhibited all the characteristics of mega fires that are associated with droughts, heatwaves, low atmospheric humidity and strong winds.

High fuel loads, chiefly associated with invasive alien plants and commercial forests, as well as inadequately managed fynbos played a big role in the initial rapid spread of the fire on 7 June 2017 and its persistence for 12 days. "These findings clearly highlight the need for more effective fuel reduction in the wildland-urban interface and the application of measures aimed at protecting structures, including houses, from fires; and reducing the probability of ignitions and the consequent losses," says Dr David Le Maitre, CSIR principal researcher.

According to CSIR engineer Riaan van den Dool, the indicators used to determine the risk of fires may also have

compromised early warning. The research found that the current National Fire Danger Rating System, which is used to measure and report on the daily fire danger across South Africa, is not well-suited for the Southern Cape and the fynbos biome, and did not adequately signal the exceptionally dangerous conditions preceding and during the fires.

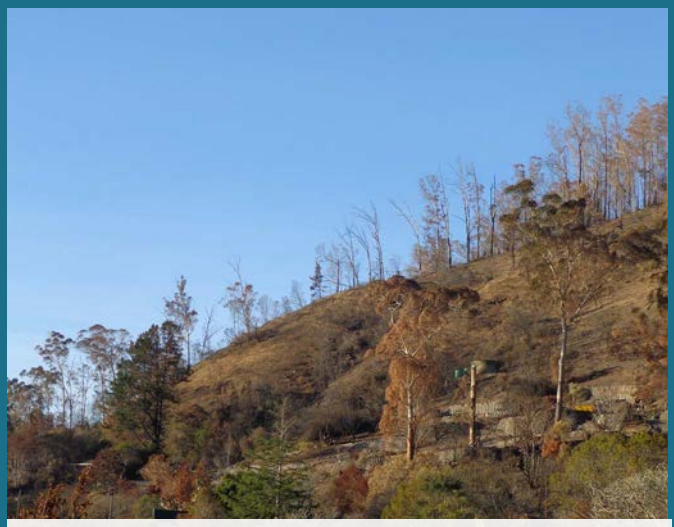
The cost of the Knysna fires to the town and its inhabitants illustrates the importance of implementing measures to reduce risk in the Garden Route and elsewhere in South Africa. The benefits of reducing fuel loads, making homes more fire-resistant and strengthening response capacity far outweigh the costs of these activities.

The consolidated findings of the research and recommendations are presented in the report *The Knysna Fires of 2017: Learning from this disaster*: https://www.santam.co.za/media/2685028/consolidated-knysna-fires-report_28_may_final.pdf

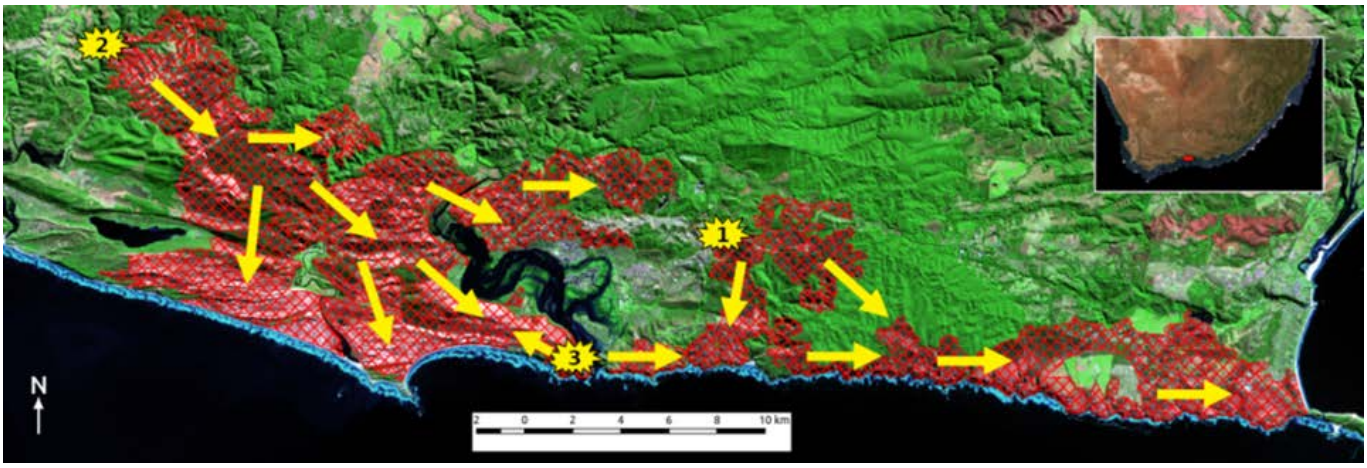
ENQUIRIES

> **Greg Forsyth**
gforsyth@csir.co.za

> **Chalets surrounded by tall trees on a steep slope prior to the Knysna fires.**



> **Remnants of destroyed chalets on the same slope post the Knysna fires.**



> **The general eastward spread of the Knysna fires from a number of ignition points is shown by arrows.**

ECOSYSTEM SERVICES UNDER THREAT AS SA FARMS ARE ABANDONED AMIDST DRY CLIMATE CONDITIONS

In the last two decades, the summer rainfall region of South Africa has experienced frequent droughts, which had a negative impact on crop farming. This has resulted in an increase in farm abandonment in the region - which includes the provinces of North West, Limpopo and the Free State – ensued by an increase in bush encroachment threatening the grazing potential of the savanna system that could cripple food security as livestock lose access to grassy plant species.

CSIR remote sensing specialists studied satellite imagery of South Africa's savanna system over the period 2001 to 2018, which showed that as the climate became drier, farms were abandoned, which, in turn, led to an increase in tree cover.

"The grass-tree co-existence of the savanna is crucial to the provision of important ecosystem services, including grazing and browsing resources to livestock and wildlife; and the provision of food and medicinal plants to the human community," says CSIR remote sensing specialist, Dr Moses Cho.

The Kruger National Park is located in the savanna system and the variability of grass and tree cover is controlled by a number of environmental and human-induced factors. For example, increasing levels of atmospheric carbon dioxide released from industries and other human activities favour tree growth in the savanna, causing bush encroachment.

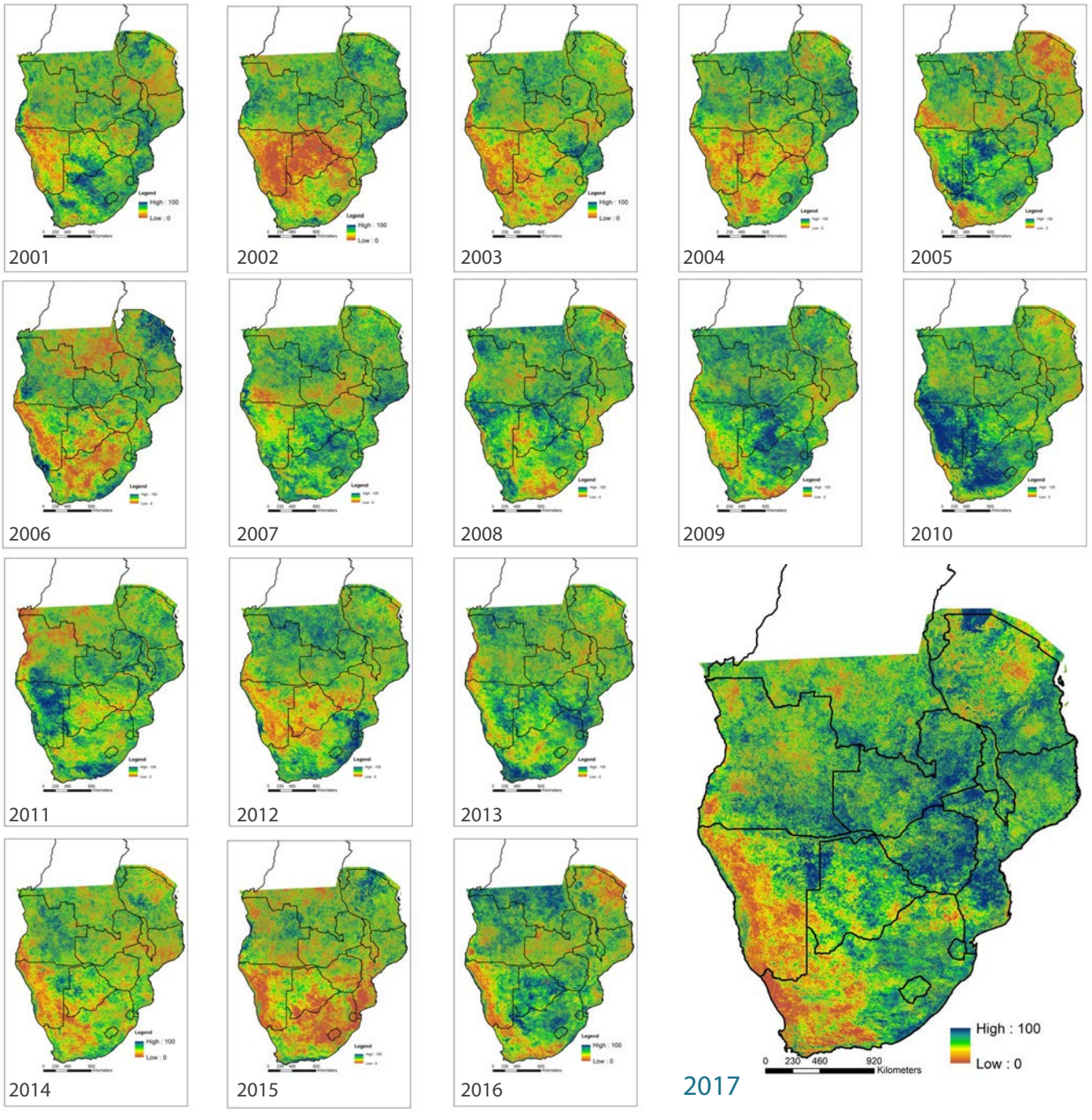
Cho warns that this could lead to the expansion of tree cover at the expense of grassy areas, adding that other activities, such as deforestation, overgrazing and farm abandonment are equally changing the dynamics of tree and grass cover in the region.

While increasing bush density in the savanna reduces land accessibility by wildlife and livestock, the researchers acknowledge that the increase in tree cover has the potential to increase the landscape's resilience to the impacts of droughts.

This research was published in the *International Journal of Applied Earth Observation Geoinformation*.

ENQUIRIES

> **Dr Moses Cho**
mcho@csir.co.za



> **Vegetation cover index over Southern Africa: 2001–2017. Vegetative drought for the month of December. The pervasive droughts in 2002 and 2015 are clear from the yellowish colour indicating low vegetation cover.**

SAVANNA VEGETATION

Over 30% of the land area of South Africa is occupied by savanna vegetation. Savanna vegetation is characterised by a continuous layer of grassy vegetation and varying proportions of tree cover.

Value	Category
90 - 100 %	No Drought
80 – 90 %	No Drought
70 – 80 %	No Drought
60 – 70 %	No Drought
50 – 60 %	No Drought
40 – 50 %	No Drought
30 – 40 %	Light Drought
20 – 30 %	Moderate Drought
10 – 20 %	Severe Drought
0 – 10 %	Extreme Drought

STUDY CONFIRMS LINKS BETWEEN AIR POLLUTION AND CARDIOVASCULAR AND RESPIRATORY DEATH RATES

A new international study has strengthened the evidence base that air pollution is linked to increased cardiovascular and respiratory death rates. The study, conducted over a 30-year period, is the largest of its kind to investigate the short-term impacts of air pollution as a cause of death and, for the first time, included assessments in South Africa. The study analysed data on air pollution and mortality in 24 countries and regions, with the CSIR playing a role in the research.

Air pollution occurs when harmful gases and particles are emitted in the air at concentrations that have an impact on human health or that are harmful to the environment. According to the World Health Organization, air quality is the largest environmental risk to human health in the world. The concentrations of pollutants in ambient (outside) air in South Africa regularly exceed the South African National Ambient Air Quality Standards (NAAQS).

The global study, led by Dr Haidong Kan from Fudan University in China, analysed data on air pollution and mortality in 652 cities across 24 countries and regions. It found that increases in total deaths are linked to exposure to inhalable particles (PM_{10} – particles that have an aerodynamic diameter equal to or less than 10 micrometres) and fine particles ($PM_{2.5}$ – particles that have an aerodynamic diameter equal to or less than 2.5 micrometres) emitted from fires or formed through atmospheric chemical transformation.

CSIR principal researcher and air quality specialist, Prof. Rebecca Garland, was part of the team that focused on South Africa, and analysed the South African air quality data used in the study. Garland says South Africa has different sources of air pollution and concentration levels of $PM_{2.5}$ compared to other parts of the world. As the international study uses ambient air quality, which is a mixture from all sources, the fact that the relationships between mortality and PM concentrations are robust across sites, despite country specific aspects, such as lifestyle contributors, such as indoor/outdoor cooking and heating through domestic fuel (i.e. coal, wood), is interesting.

"We work with different stakeholders to try and raise awareness about the effects of air quality, including particular matter and its impacts. The impact of air quality is a concern in many parts of the country, and much of our recent work has focused on urban pollution. We hope to provide the evidence base to motivate for policies that lead the country to comply with our NAAQS. One of the ways that national government wants to approach this, is by quantifying impacts of poor air quality, including the impact on mortality," she says.

Garland is part of the CSIR's climate and air quality modelling group

We work with different stakeholders to try and raise awareness about the effects of air quality, including particular matter and its impacts.

that simulates the fate, transport and dispersion of pollutants and what impact pollutants have on climate, health, agriculture and ecosystems. Air pollutants can interact with radiation from the sun and have a warming or cooling effect on the earth (pollutant-dependent). The CSIR has also developed an air quality modelling platform with which one can build an emissions scenario and view the likely impacts thereof on air quality, as well as human and ecological health. This modelling platform is linked to the CSIR climate model used to investigate the air quality and its impacts in a changing climate.

The full paper can be found online at https://www.nejm.org/doi/full/10.1056/NEJMoa1817364

> **The concentrations of pollutants in ambient (outside) air in South Africa regularly exceed the National Ambient Air Quality Standards.**

ENQUIRIES

> **Prof. Rebecca Garland**
rgarland@csir.co.za

RESEARCHERS DOCUMENT CLIMATE ADAPTATION MEASURES DEVELOPED BY INDIGENOUS COMMUNITIES

For centuries, the world's indigenous communities have developed climate change mitigation practices that have sustained countless generations. A compendium containing some of these practices was launched during the Stockholm International Water Institute World Water Week earlier this year.

Age-old climate change mitigation practices have the potential to be strengthened through modern science. The CSIR, in collaboration with the Food and Agriculture Organization (FAO) of the United Nations, led the development of a compendium of community and indigenous strategies for climate change adaptation that focuses specifically on addressing water scarcity in agriculture.

"Through our experiences in the field, engaging with stakeholders in the agriculture sector and our extensive research in the sector, we found that indigenous knowledge plays an important role in sustaining the resilience of social-ecological systems and demands some attention," says CSIR principal researcher Dr Jean-Marc Mwenge Kahinda, who led the development of the compendium.

"The community-developed strategies have the potential of being strengthened through modern science and technology and this compendium is regarded as a first step towards providing a comprehensive listing of indigenous strategies for climate change adaptation that focuses on addressing water scarcity in agriculture," he says.

There are between 300 and 500 million self-identified indigenous people worldwide – most of whom live in biodiversity hotspots, indicating their ability to protect biodiversity. And even though indigenous people are the ones most affected by climate change, Mwenge Kahinda explains that they hardly ever cause it.

Case studies

The compendium assimilates case studies from around the world, categorised into six technologies and practices themes: Weather forecasting and early warning systems; grazing and livestock management; soil and water management; water harvesting; forest management; and integrated wetlands and fisheries management.

Some of the case studies, taken from the compendium:

Weather forecasting and early warning systems – In Lushoto, Tanzania, the start of short rains is identified by the existence of large flocks of swallows and swans, roaming from the south to the north during the months of September to November.

Grazing and livestock management – The Wodaabe, also known as the Mbororo, a small subgroup of the Fulani ethnic group, use lunar cycles to schedule livestock movements to new pastures. This leads to moving grazing areas every two to three days.

> **The CSIR's Karen Nortje and Jean-Marc Mwenge Kahinda, in collaboration with the FAO and supported by CSIR students and interns, prepared a compendium of climate change mitigation practices of indigenous communities.**

Soil and water management – In the Gwallek–Keda (Baitadi district, Nepal), farmers plant legume crops in paddy fields. They also intercrop soybean with maize and apply farmyard manure to improve soil fertility.

Water harvesting – In Timor-Leste, local communities dig small holes next to the riverbed to collect clean water. The water seeps through the sand and wells up through the soil.

"Indigenous knowledge is local and specific and the examples highlighted are a reflection of the ability of these communities to cope with the variability of climate change," says Mwenge Kahinda, emphasising the need to strengthen the dissemination of this knowledge and integrate modern approaches that reinforce indigenous knowledge in climate change adaptation and resilience.

The compendium provides a basis for transferring technologies and practices between areas of similar agro-ecology; and the authors recommend that such transfers are pursued and documented in preparation for wider adoption and upscaling.

ENQUIRIES

> **Jean-Marc Mwenge Kahinda**
jmwengekahinda@csir.co.za

ENABLING SMALL BUSINESS TO GROW IN THE BIOMANUFACTURING SECTOR

By Lara Kotze-Jacobs, CSIR Programme Manager of the CSIR Biomanufacturing Industry Development Centre

Access to funding and market remains the main challenges for small, medium and micro enterprises (SMMEs) to grow their revenue and expand their businesses. It is often not the lack of a quality product that hinders their growth, although this may be a contributing factor, but an inability to prioritise the activities that will enable market access, as well as securing funding for business growth.

Despite an abundance of training in entrepreneurship that is on offer from various institutions and platforms, there is a dire need for mentoring of entrepreneurs. Further, the incoherent support instruments currently on offer often cause them to consume valuable time and energy on pursuing too many avenues at once.

SMMEs that have approached us, in many instances stated that they are unaware of the other instruments in the National System of Innovation that are available to provide entrepreneurship support, including funding for business support, purchasing of equipment or conducting product and technology development. The converse is also true where entrepreneurs are being supported by the different facilities on offer, and yet, they still have not capitalised on this support. There is a real need for alignment and engagement between the instruments to maximise the outcomes in the form of successful SMMEs.

We often hear that small businesses must be the engine of our economy and provide employment. In the biomanufacturing sector, there are entrepreneurs that are attempting to do just that. These include the home baker, realising the potential of a humble vegetable and expanding her idea to high-quality processing and analysis for the retail market, to the biotechnology company that has in-licensed international intellectual property and is attempting to validate and scale up that technology for local production.

(continued on page 45)

> **CSIR senior process engineer Prisha Naicker with locally manufactured chemical oxygen demand (COD) test kits, developed for a client. Industry and municipalities are required to adhere to water discharge specifications for COD, and currently imported COD test kits are widely used.**

The CSIR's Biomanufacturing Industry Development Centre (BIDC) has assisted these entrepreneurs by reducing the barriers faced by so many SMMEs, such as access to scientists and engineers, as well as world-class facilities for product and process development.
We are extremely encouraged by initiatives from the United Nations Industrial Development Organization (UNIDO) and GIZ (ABioSA) to provide support for quality and standards development for essential and fixed oils in South Africa and to develop industry and support SMMEs in the natural products sector, with specific focus on indigenous plant ingredients and finished products. These initiatives stimulate the involvement of stakeholders and identify bottlenecks and barriers to SMME success, while devising mechanisms through which these can be overcome.

The biomanufacturing sector continues to be a space where there is plenty of enthusiasm and a high entrepreneurial spirit. Moreover, the multiple support instruments in the sector and support from government departments, such as the Departments of Science and Innovation (DSI); Environment, Forestry and Fisheries; Small Business Development; and Trade and Industry, create an environment where success is not just a possibility for SMMEs in biomanufacturing, but a reality – we have seen real success stories and growth among the SMMEs supported through our programme. Launching products in retail spaces became a reality, as did accessing funds from investors to build manufacturing facilities and purchase equipment.

The CSIR, through the BIDC, will continue to attract support from its stakeholders and funders in support of our sincere desire to develop this industry and strengthen South Africa's economy. This can be done by supporting small businesses in productising their unique and novel concepts in biomanufacturing through the application of science and innovation.

In the six years since the inception of the BIDC, we've seen more than 220 unique applications from SMMEs in the area of biomanufacturing. Products and technologies include speciality chemicals, biotechnology products with applications such as laboratory reagents or eco-friendly cleaning products, nutritional foods, cosmetics with a focus on indigenous natural product-based ingredients and biopharmaceuticals. Most of these companies have been located in Gauteng, with a smaller representation from other provinces, and were mostly in the micro to very small range.

From these applications, the BIDC has, to date, supported 31 companies by developing and validating manufacturing technologies for products, including scale-up, piloting and techno-economic assessment, as well as initial contract manufacture to enable companies to test the market. Examples of these SMMEs include Lighthouse Healthcare, Professional Laboratory Services, Marple Skincare, OptimusBio, JVS Biotech Solutions and Phepisa Natural Products Institute. The support was made possible by funding from the Jobs Fund and the DSI, as part of a national drive towards job creation and achieving sustainable impact through innovation.

As a result of the support provided, 92 products have been developed together with SMMEs, tested and transferred to the SMMEs. These products can be found online, in retail stores, through agent-based sales or are being sold to larger companies for re-packaging and on-selling.

> **Article author: Programme Manager of the CSIR Biomanufacturing Industry Development Centre.**

FOOD INNOVATION FOR WELLNESS

By CSIR principal researcher Dr Nomusa Dlamini, CSIR Advanced Agriculture and Food

Adopting processing technologies to facilitate value addition, increased production, utilisation of edible indigenous and underutilised crops is critical in providing key nutrients and addressing food security in the country.

South Africa, like most developing countries, faces a challenge of undernutrition or malnutrition associated with specific nutrient deficiencies, such as Vitamin A, iron and zinc, especially in children. On the other hand, there is an increase in obesity and related health challenges in adults, such as diabetes, heart disease and certain cancers. The contribution of local edible plants to the reduction of health risks has always been recognised as part of indigenous knowledge, which forms part of the country's multifaceted cultural system.

In addition, there is a growing consumer demand for natural, vegetarian products with health benefits that can be used as food ingredients and nutraceuticals. Researchers at the CSIR are aiming to develop nutraceutical products and identify alternative sources of food ingredients with nutritional and functional properties from South African biodiversity (microbial and plant). The increasing realisation that food can play an important role in maintaining health and in the prevention of lifestyle diseases has shifted the focus to plants and foods with health-promoting phytochemicals, such as carotenoids and flavonoids.

> **Article author: CSIR principal researcher Dr Nomusa Dlamini, CSIR Advanced Agriculture and Food.**

Product development from indigenous and underutilised crops

The CSIR's Advanced Agriculture and Food cluster focuses on developing innovative nutritious food products from indigenous foods with health benefits. The areas that we are currently focusing on are over- and undernutrition in children, developing food ingredients that are used in existing products to increase their value and developing nutraceutical and functional foods for specific disease areas. The research activities contribute to the scientific validation and development of innovative products from indigenous plants, such as leafy vegetables and indigenous grains, such as sorghum, millet and cowpea. The CSIR has done well in converting research and development activities to technology innovations for industrialisation. In the last couple of years, the organisation has investigated and identified nutrients in a number of indigenous and naturalised plants that have a long history of being consumed by rural communities. The plants were formulated into food product concepts and one product, called Nutri-Drink, was formulated to have appropriate levels of nutrients for school children and has been piloted as part of a school feeding scheme in the Eastern Cape in South Africa.

In addition to contributing to industrialisation and the commercialisation of indigenous edible plants, the work in this area contributes to community development through technology and skills transfer, specifically through training programmes in post-harvest technologies and how to reduce crop losses of perishable products, thus improving food security.

During the process of innovation and product development, researchers continually engage with the food and wellness industries to direct and focus research to ensure that products with a high potential of consumer acceptance and market uptake are developed. The food plants that have been promoted and developed into nutritious food products include indigenous cereal grains like sorghum (*Sorghum bicolor*), millets (*Pennisetum glaucum*), the grain legume, cowpea grain (*Vigna unguiculata*), leafy vegetables like *Cleome gynandra*, also known as spider flower, Lerotho (Sesotho/Setswana), uLude (isiZulu) and *Amaranthus cruentus*, also known as Thephe (Sesotho/Setswana), uNomdlomboyi (isiXhosa). Other readily available cereals, like maize, as well as a newly developed provitamin A-biofortified maize and sweet potatoes, have also been used in nutritious food product development.

Research has shown that foods developed from indigenous and underutilised crops are beneficial to health and can help alleviate malnutrition and food insecurity. The indigenous leafy vegetables, in particular, contain health-benefitting provitamin A carotenoids, such as beta carotene, which the body converts to vitamin A on absorption. The leafy vegetables are also good sources of minerals such as calcium (for bone health), as well as iron and zinc (for overall wellness). In addition, the leafy vegetables contain phytochemicals, such as flavonoids, that have been shown to reduce diseases related to inflammation.

An important aspect to note with indigenous grains, such as sorghum, pearl millet and other millets, is that they are gluten free and can be formulated into gluten-free products for improved wellness. Gluten is found in cereal grains, such as wheat, and this affects the health of people with gluten intolerance, such as causing bloating and nutrient malabsorption. Sorghum and millets can be used for the production of gluten-free bakery products, pastas and other commercial products where cereals are needed because of their high carbohydrate content. In addition to being gluten-free, the starch in sorghum and millets is digested slowly, and this makes these grains suitable for producing safe diabetic foods that will avoid sugar spikes after meal consumption.

In developing food products, a database of information is created on nutritional content, the safety of the food, as well the scientifically validated health claims associated with these foods. In addition, working with the South African Bureau of Standards, the CSIR has contributed towards developing standardised processing methods of underutilised and indigenous foods, such as the Mopani worm, which is the larval stage of the Emperor moth.

In conclusion, underutilised indigenous crops and fruits, like Marula, have huge potential as novel food ingredients for both the local and export markets, and the establishment of industries and processing facilities will lead to job creation and poverty alleviation. The indigenous small grains, sorghum and the millets that are more adapted to the generally harsh agro-climatic conditions in the sub-Saharan African countries, including South Africa, have the potential to contribute to food and nutrition security and wellbeing.

> **CSIR researcher Pumeza Melane showcasing a product developed using indigenous ingredients.**

THE CASE FOR SA AS THE NEXT PHARMA HUB

Flow chemistry could drive regional manufacturing in Africa

By CSIR research group leader in pharmaceutical technologies, Dr Jenny-Lee Panayides and senior lecturer at the University of Pretoria, Darren Riley

Chemical synthesis is a century behind its rivals when it comes to manufacturing. While other fields have adopted a continuous production line, the pharmaceutical and fine chemicals industries are still reliant on a stop-start series of steps to complete the necessary reactions. This is because almost any synthetic process requires the use of vastly different chemical and physical conditions between steps, and, to make matters worse, many products also require careful downstream processing and purification to create material of sufficient purity.

For the past two decades, the flow chemistry revolution has been promising an end to this with a 'factory of the future', whereby chemical entities are routinely manufactured continuously. While the idea of flow-based pharmaceutical manufacturing may have seemed far-fetched outside of a few pioneering research groups 20 years ago, today the situation is quite different. Flow chemistry has evolved from a novel synthesis concept into a powerful and versatile platform for continuous manufacturing of active pharmaceutical ingredients (APIs) with high productivity, small manufacturing footprint, and reduced cost and waste.

A new, ambitious goal is now centered on integrating pharmaceutical manufacturing – from raw materials to final dosage forms – into a continuous flow process. Advances in cloud computing, automation and system unification are paving the way for continuous API production with digital connectivity, and the integration of these and other technologies with traditional flow approaches and in-line automation is currently a driving force in the 'synthesis 4.0' revolution.

The technology has now arguably matured to a point where it's only a matter of time before the 'factory of the future' becomes the flow plant of today. This presents the opportunity for a revolutionary change in pharmaceutical manufacturing – and could open the door for dramatic changes in emerging markets.

African landscape

Africa is home to some of the world's fastest growing economies, thanks to the rise of major cities, expansion in healthcare capacity across the continent and a maturing business environment. South Africa, in particular, boasts the fifth-highest worldwide pharmaceutical expenditure per capita. Although its largest killer remains HIV/Aids, the country's evolving demographic and epidemiological profile creates increased revenue opportunities for pharmaceutical companies, particularly those producing non-communicable disease treatments.

In recent years, several private sector companies have considered regional pharmaceutical production in South Africa but almost all have failed to make an investment. This is in stark contrast to the massive growth in API production in the other BRICS (Brazil, Russia, India, China, South Africa) countries. Major constraints for developing the pharmaceutical industry in South Africa include the small local market, lack of skilled workforce, poor infrastructure, long lead times, insufficient regulation and an export-averse culture. Together, these have prevented regional manufacturers from achieving the economies of scale that are essential to survive in a global market while deterring foreign investors.

Yet these same factors could open the door for dramatic changes when the switch from batch manufacturing to continuous flow processing comes. Africa was able to leapfrog traditional fixed-line telecommunications and move straight to cellular networks; in the same way, there is limited existing pharmaceutical infrastructure to hinder the adoption of a new, disruptive technology. As a result, the use of flow technologies has received widespread interest and has been identified as a critical development area at both industrial and government levels within the 16-state Southern African Development Community. This is particularly true for South Africa, where health inequalities hinder much of the population's access to essential medicines and the ability to innovate is critical for development.

There is a clear business case for regional API manufacturing companies to adopt new technologies and embrace digital disruption. These technologies can effectively limit the impact of critical drug shortages, protect against foreign exchange fluctuations and help to generate competitive differentiation. We believe South Africa can initially focus on the implementation of multi-step continuous flow synthesis in newly established API manufacturing facilities. This could also include green chemistry practices, robotics, process automation and continuous monitoring systems to minimise waste and energy consumption.

> **Article author: CSIR research group leader in pharmaceutical technologies Dr Jenny-Lee Panayides.**

However, for this uptake to be successful, regional pharmaceutical companies will need to expand their skill sets and cross the digital divide. If they can make this change, then Africa could be home to one of the most advanced pharmaceutical hubs in the world.

This article first appeared in Chemistry World, April 2019. The link to the full article is: https://pubs.rsc.org/en/content/articlelanding/2019/re/c8re00236c#!divAbstract

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