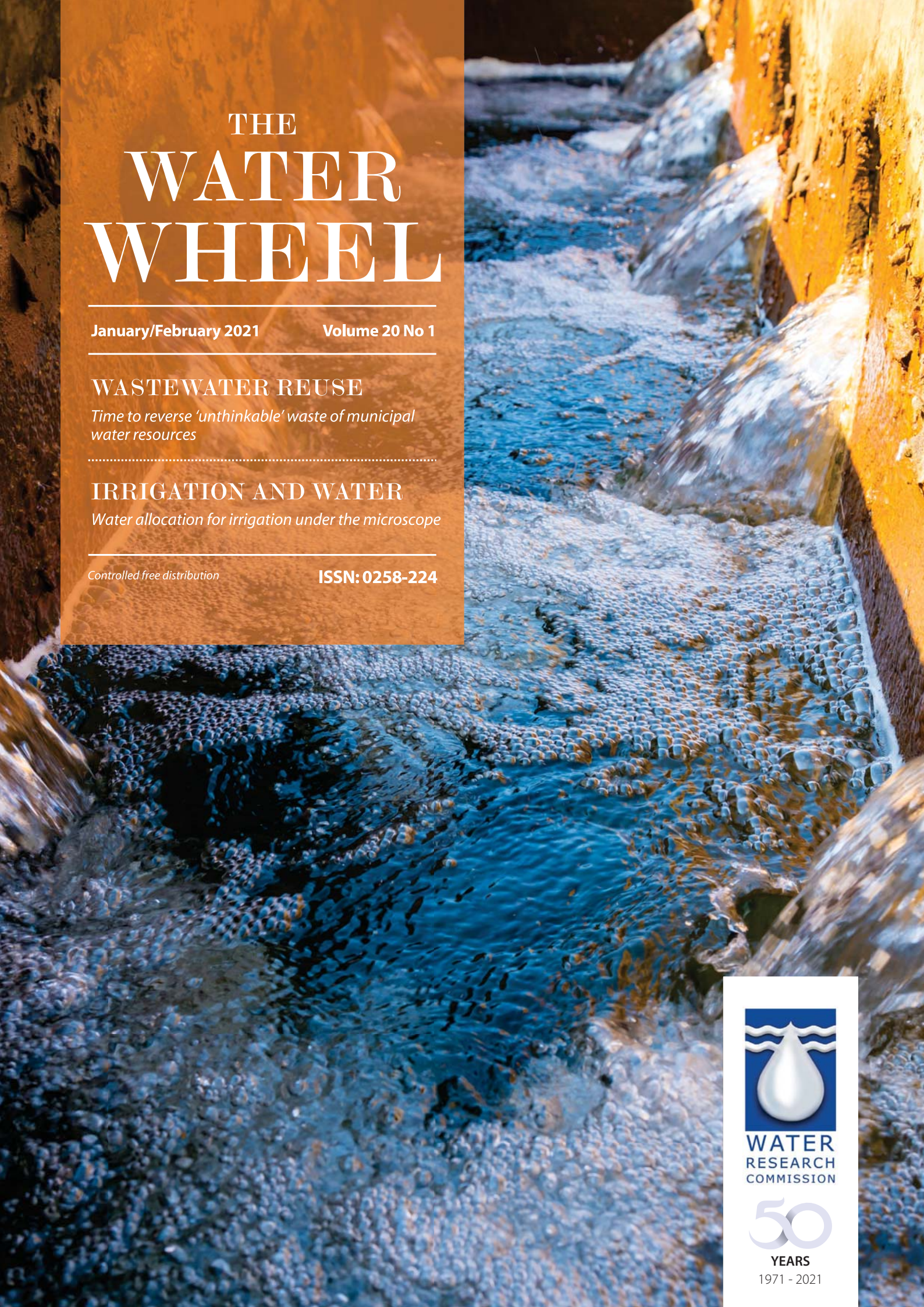

THE WATER WHEEL

January/February 2021 Volume 20 No 1

WASTEWATER REUSE

Time to reverse 'unthinkable' waste of municipal water resources

IRRIGATION AND WATER

Water allocation for irrigation under the microscope

Controlled free distribution

ISSN: 0258-224

WATER RESEARCH COMMISSION

50 YEARS
1971 - 2021

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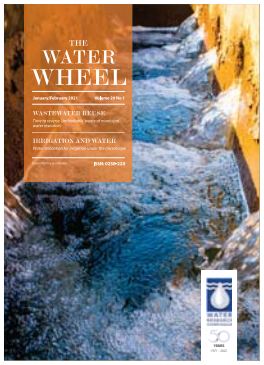

Tony Carnie explores the potential of wastewater reuse as a possible strategy to reduce water stress. See article on page 12.

FLUID THOUGHTS

Gender equality – Past, present and future

WRC CEO, Dhesigen Naidoo

We are once again in the throes of a familiar predicament.

The year 2020 has, unfortunately, yielded even more reason for the 16 Days of Activism against gender-based violence against women and girls, compared to previous years. This is in spite of it being a milestone year for women empowerment.

September 2020 marked the 25th anniversary of the Beijing Declaration and Platform for Action. It was a landmark achievement. Adopted by 189 countries, it is regarded as the most comprehensive global framework for the rights of women and girls. For a one-year-old democratic South Africa, it heralded a beacon of hope for a non-sexist new South Africa, having just emerged from the apartheid era characterised by racial oppression and patriarchy. Globally, it promised a turning point in the quest for gender equality.

Rollercoaster ride for gender equality

But these past 25 years have been a rollercoaster ride with few highs and too many lows for gender equality worldwide. According to United Nations Women Executive Director Phumzile Mlambo-Ngcuka, while political representation of women has doubled since 1995, men still control 75% of parliamentary seats. One billion women and girls, 15 years and older, have no basic reading and writing skills.

In fact, in 2020, 31% of young women are not in education at all. Unsurprisingly, women between the ages of 25-34 are 25% more likely to live in poverty than their male counterparts. The International Planned Parenthood Federation (IPPF) statistics indicate that two thirds of the 1.4 billion people living in extreme poverty today are women.

This is further exacerbated by the fact that even for educated and capacitated women, the gender gap in labour force participation stands at 31%. And when women finally get in, you have to deal with a series of obstacles and glass ceilings. Incredibly, after you have vertically tunnelled through all of those, women will still be paid less for the same job and levels of productivity.

Bias against women

And, even more shocking, people think that this is okay in the 21st century. According to the 2020 UNDP Gender Norms Index, 90% of a combined cohort of men and women have some measure of bias against women and think that they are justified. The data from 75 countries, covering 80% of the world's population, reveal that 50% of people think that men are better political leaders, 40% herald that men make better business executives and, alarmingly, 28% think that men are justified in beating their wives.

We have for the longest time associated gender inequality with levels of development and the poverty of nations. There were several rude awakenings to this clearly false thesis – one of the more vocal being the #MeToo movement. This visualised for the world that education, wealth and talent did not provide enough protection from gender-based violence.

A global malaise

Further indicators come from the World Economic Forum (WEF). The 2020 WEF Global Gender Gap Index ranks the wealthiest nation on Earth, the United States, at a staggeringly unexpected low 53rd ranking. The year 2020 also marks the 50th anniversary of the UK Equal Pay Act, and all the data indicates that this continues to be an elusive target. In fact, the WEF estimates that the gender gap, at the current rate of change, will only be closed by 2133. This is a global malaise.

It is clear that we come from a difficult past and our current statistics are far from good. What does the future hold? Across the world, we are at various stages of entry into the fourth industrial revolution (4IR). We are on the brink of a future defined by technological innovation, digitalisation, artificial intelligence, virtual reality, and big data. There are clearly great opportunities to put a sizable dent into gender inequality.

Anne-Marie Imafodin, founder of STEMettes (women in science, technology, engineering, and mathematics), sees this opportunity. She offers that as virtual work becomes more dominant, many traditional barriers preventing women from certain jobs should disappear. This is also true for jobs that do not invite women in on the basis of physical strength since in a 4IR world, technological solutions should no longer require humans to be beasts of burden.

4IR workforce – males have a head-start

But it can also easily go the other way. First is the historical factor. Success in the 4IR economy will depend on IT skills, technology prowess and entrepreneurship. The 2019 EIGE (European Institute on Gender Equality) report on the 4IR points out the current gender bias in these skills domains. In Europe, women programmers and developers are 9% of this workforce and they constitute only 19% of the IT and communications labour force

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as a whole. Furthermore, women are only 20% of the European technology sector and comprise only 19% of the entrepreneur base. In this 4IR workforce 100 m race, males already have an 80 m head-start.

There are other important challenges. Artificial intelligence and big data rely heavily on historical data sets, almost all of which are biased against women and girls. It has dire consequences as some famous AI HR shortlisting tools automatically exclude women candidates to conform with the current and historical percentages of males in certain jobs. Further threats relate to direct job substitution in women-dominated industries. A 2016 UN International Labour Organization (ILO) report predicts that some Asian nations could lose 80% of their garment industries to 'sewbots', affecting some 9 million working women in the Association of Southeast Asian Nations (ASEAN).

Manase Chiweshe from the South African Institute of International Affairs (SAIIA) makes the case that rural African women have the potential to be the most marginalised in a new digital economy. But, with the right policies, innovator strategies, good support instruments and political will at all levels, a very different future is possible.

Better plan for a better world

In this the centenary anniversary of the final ratification of the 19th Amendment giving women the right to vote in the USA, let us hope that the several nations that go to the polls in 2021 will make the courageous changes needed to take us forward in the struggle of women and the girl child. The US elections has already delivered its first woman vice-president. We have declared ourselves ready to use the opportunity of the current global crisis to emerge from it with a better plan for a better world. Let us indeed work to build back better, build forward greener and build a more gender equal society.

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NEWS

Letter to the Editor: Planning and maintenance key to sustainable water infrastructure

Like so many government schemes we read and hear about, all the new and wonderful projects in the coming, but the defects in the current systems are not seen, mentioned nor rectified.

Why do we want to provide drinking water to everybody, sewerage systems to the furthest outposts while the existing systems are falling apart? Raw sewage is pumped into our rivers every day, millions of litres of treated water is leaking out of delapidated pipe systems and water treatment plants are failing.

Money is spent on water projects and then left unfinished and vandalised by the communities. It is no good painting the house if the walls are collapsing.
I am a pensioned DWA employee and have witnessed how things just got completely ruined due to a lack of planning and maintenance in the last 20 years. I was involved in the refurbishment of the Standerton water treatment plant which was in a total mess due to non-maintenance.

It was refurbished at a cost of close on R20 million to good as new condition, but it was taken back to its prior status within a year because no maintenance was done and the operators had no training on running the plant.

I was involved in the De Hoop dam scheme (Olifants Water Resource Development Project) at a cost of close on R5 trillion which is now lying waste and being vandalised to a state of ruin.

Is it necessary to keep on wasting money on half-breed projects and un-maintained systems?

It sounds great to say we must eradicate the bucket system, but if there is not water available or a sewerage system operational what are we actually saying? Our government is making great sounds hoping to be supported at the election polls with votes, but has made no progress on improving the country.

Can we convince the government to spend money on viable and profitable projects?

Johan van Niekerk

South African to lead global water and agriculture body

Felix Reinders of the Agricultural Research Council's Agricultural Engineering group has been elected as the new Chair of the Global Framework on Water Scarcity in Agriculture (WASAG) for a period of two years (2020 to 2022).

Reinders is a professional engineer with a strong expertise in the field of agriculture and civil engineering. He has been President of the International Commission on Irrigation and Drainage (ICID) since 2017.

Water scarcity is one of the greatest challenges of the twenty-first century and agriculture, encompassing crops, livestock, fisheries, aquaculture and forestry, is both a cause and a victim of water scarcity. It accounts for 70% of the global water withdrawals. With the world's population that is projected to reach 9.7 billion by 2050 and as water stress spreads around the globe, ways have to be found of getting more crop per drop to meet our food needs.

The Global Framework on Water Scarcity in Agriculture (WASAG) was established in 2017. It is designed to bring together key players across the globe and across sectors to tackle the collective challenge of using water better in agriculture to ensure food security for all. It is an initiative for partners from all fields and backgrounds to collaborate in supporting countries and stakeholders in their commitments and plans related to the 2030 Sustainable Development Agenda, the Paris Climate Agreement and other plans and programmes related to agriculture and water.

Following his election, Reinders stated: "We need a water-centric approach to embrace water-energy-food-climate change nexus for global developmental endeavours. I firmly believe WASAG should focus global and regionally on awareness raising, followed by project development, then research and training with an emphasis on sustainable agriculture water use and drought preparedness. WASAG succeeds not because it is big or because it has been long established but because there are people building it, who live it, sleep it, dream it, believe in it and build great future plans for it."

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Criminal case opened against Mpumalanga coal mine

The Department of Water and Sanitation (DWS) has opened a criminal case against Woestalleen Colliery and its business rescue partner following the pollution of water resources in Middelburg, Mpumalanga.

The department has also suspended the mine's water use licence. According to the DWS, the mine was found to be non-compliant with the conditions of the licence, and has also engaged in unlawful water use activities.

Chief Director of Compliance, Monitoring and Evaluation, Siboniso Mkhaliphi, said the department has been inspecting the mine since 2016. The colliery failed to present to the department concrete plans to stop pollution of water resources.

"Following a site inspection at the mine, it was discovered that there is an unlawful discharge of poor quality from the dam into the Woestalleen Spruit. This poor-quality water contaminates the spruit and also impacts negatively on groundwater resources, aquatic life and agricultural users who rely on the spruit for irrigation purposes," said Mkhaliphi.

The DWS is mandated by the National Water Act of 1998 to enforce proper water management and legislation compliance to the mining sector. Mkhaliphi said the department has conducted its administrative enforcement processes, however it did not receive cooperation from the mine.

"All of our enforcement tools have been exhausted and today we are implementing a process of suspending the water use license. We cannot afford to continue focusing on one mine water user that is non-compliant. This matter stops here and will follow the legal processes to enforce the user to comply," noted Mkhaliphi.

The Chief Director emphasised that the department opens a criminal case against any transgressor, as a last resort. "We have engaged the mine on numerous occasions and they failed to present to us a convincing plan that they will sort the situation out. Our interventions are not punitive in nature but when polluters are not responsive, we seek recourse in our law enforcement agencies in line with National Water Act of 1998."

Cabinet approves measures to address threatened biodiversity

Cabinet has approved the updated National Protected Areas Expansion Strategy and the revised National Biodiversity Framework.

The measures are considered important policy instruments for the protection of South African species and ecosystems. Through the release of the National Biodiversity Assessment by the South African National Biodiversity Institute (SANBI) in 2019, the country is able to better target future protected area expansion. The assessment has also assisted with South Africa's national and international reporting obligations, including the state of environment reporting, and the Convention on Biological Diversity Country Report – reporting against Aichi Targets or the Sustainable Development Goals.

The Revised National Biodiversity Framework has been approved for public comment. The sectoral plan addresses the biodiversity threats identified during the scientific assessment of the state of biodiversity and ecosystems in South Africa by SANBI.

The most critical areas in the assessment report related to freshwater ecosystems – with freshwater fish being the most vulnerable of all the species. "South Africa is a water scarce country, and pressures on biodiversity, such as the illegal trade in species, land degradation, habitat loss and exponential population growth are key factors that risk infectious diseases such as COVID-19," said the Department of Environment, Forestry and Fisheries in a statement.

"Continued investment in healthy ecosystems in terms of management, conservation and restoration of ecosystems and biodiversity is crucial for water, food and energy security, disease and natural disaster control, climate change resilience, and for post-COVID-19 recovery. Strong commitment and cooperation across all spheres of government is essential for the implementation of the National Biodiversity Framework (NBF) as one of the National Development Plan's accelerators."

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GLOBAL

Study points to dangers of collecting drinking water

Collecting drinking water in low- and middle-income countries can cause serious injury, particularly for women, according to new research from the University of East Anglia.

The study published in ***BMJ Global Health*** reveals dangers including falls, traffic accidents, animal attacks, and fights, which can result in broken bones, spinal injuries, lacerations, and other physical injuries.

And women are most likely to sustain such injuries – highlighting the social and gender inequities of a hidden global health challenge.

Dr Jo-Anne Geere, from UEA's School of Health Sciences, said: "Millions of people don't have the luxury of clean drinking water at their home, and they face many dangers before the water even touches their lips. Global research on water has largely focused on scarcity and health issues related to what is in the water, but the burden and risks of how water is retrieved and carried has been overlooked until now. We wanted to better understand the true burden of water insecurity."

The new study was led by Northwestern University in the US, in collaboration with UEA, the University of Miami and the Household Water Insecurity Experiences Research Coordination Network (HWISE RCN).

The research team used a large global dataset to understand what factors might predict waterfetching injuries. The work draws on a survey of 6 291 randomly selected households across 24 sites in 21 low- and middle-income countries in Asia, Africa, Latin America, and the Caribbean.

They found that 13% of the respondents reported some sort of injury while collecting water, and that women were twice as likely to be hurt as men.

Dr Sera Young, from Northwestern University, said: "Thirteen percent is a big number, but it is probably an underestimate. It's highly likely that more people would have reported injuries if the survey had more detailed questions."

Prof Paul Hunter, from UEA's Norwich Medical School, said: "This reinforces how the burden of water scarcity disproportionately falls on women, on rural populations, and on those who do not have water sources close to home. It highlights the importance of safe interventions that prioritise personal physical safety alongside traditional global indicators of water, sanitation, and hygiene."

To read the original study, visit: https://gh.bmj.com/content/5/10/e003328

La Niña prediction continues for 2021

The La Niña phenomenon that developed last year is expected to last into 2021, affecting temperatures, precipitation and storm patterns in many parts of the world. This is according to the World Meteorological Organisation (WMO).

This year's La Niña is expected to be moderate to strong. The last time there was a strong event was in 2010/11, followed by a moderate event in 2011/12. La Niña refers to the large-scale cooling of the ocean surface temperatures in the central and eastern equatorial Pacific Ocean, coupled with changes in the tropical atmospheric circulation, namely winds, pressure and rainfall. It usually has the opposite impacts on weather and climate as El Niño, which is the warm phase of the so-called El Niño Southern Oscillation (ENSO).

"El Niño and La Niña are major, naturally occurring drivers of the Earth's climate system. But all naturally occurring climate events now take place against a background of human-induced climate change which is exacerbating extreme weather and affecting the water cycle," said WMO Secretary-General, Prof Petteri Taalas. "La Niña typically has a cooling effect on global temperatures, but this is more than offset by the heat trapped in our atmosphere by greenhouse gases.

"Therefore, 2020 remains on track to be one of the warmest years on record and 2016-2020 is expected to be the warmest five-year period on record," said Prof Taalas. "La Niña years now are warmer even than years with strong El Niño events of the past."

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Scientists identify underground water storage potential in Murray-Darling Basin

Analysis by researchers at CSIRO, Australia's national science agency, have found areas in the Murray-Darling Basin suitable for long-term underground water storage and could help build drought resilience.

Water banking – known more technically as managed aquifer recharging (MAR) – is when water is stored underground for later uses, such as irrigation and town water supply. The study, published in the journal ***Water***, found that across the entire Murray-Darling Basin, there were storage opportunities of between two and four cubic kilometres in underground aquifers close to rivers.

Study co-author Dr Declan Page said the recent announcement of a La Niña weather pattern – indicating a higher likelihood of rainfall – was a timely reminder to regional communities that they had opportunities to secure water supplies before the next drought. "Drought resilience starts well before droughts hit – it's planning and preparing by implementing practices that are water efficient and developing infrastructure that enables water conservation and storage."

"Recharging aquifers at times of higher rainfall, storing the water, and discharging them during droughts is a cost-effective way to manage regional water security," Dr Page said. "Water banking allows communities and their industries to potentially limit the economic impacts of a drought, operating at far less restrictive levels, for far longer."

The paper identified water banking opportunities for regions in the Murray-Darling Basin area, including the Warrego River, Condamine-Culgoa Rivers, Darling River, Macquarie-Bogan Rivers and Namoi River. Each have the potential for more than 200 gigalitres of regional underground storage.

"Dams and more recently water desalination are often seen to be the main option for increasing water security," Dr Page said. "However, in areas where the topography, climate or environmental impacts don't make dams suitable, or towns are too far away from the ocean for desalination, water banking can be a cost-effective opportunity for regional Australian towns to improve their water security against times of drought."

Ancient Maya built sophisticated water filters

Ancient Maya in the once-bustling city of Tikal built sophisticated water filters using natural materials they imported from miles away, according to the University of Cincinnati.

University of Cincinnati (UC) researchers discovered evidence of a fillter system at the Corriental reservoir, an important source of drinking water for the ancient Maya in what is now northern Guatemala.

A multidisciplinary team of UC anthropologists, geographers and biologists identified crystalline quartz and zeolite imported miles from the city. The quartz found in the coarse sand along with zeolite, a crystalline compound consisting of silicon and aluminium, create a natural molecular sieve. Both minerals are used in modern water filtration.

The filters would have removed harmful microbes, nitrogen-rich compounds, heavy metals such as mercury and other toxins from the water, said Kenneth Barnett Tankersley, associate professor of anthropology and lead author of the study.

"What's interesting is this system would still be effective today and the Maya discovered it more than 2 000 years ago," Tankersley said.

UC's discovery was published in the journal ***Scientific Reports. To read the original article, Visit: https://www.nature.com/articles/s41598-020-75023-7***

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THE WATER WHEEL

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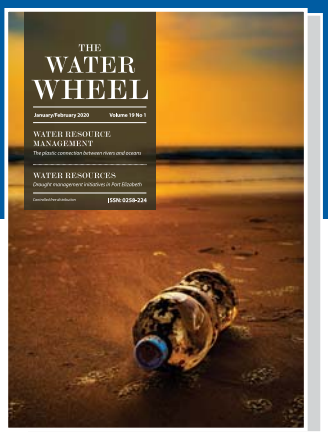

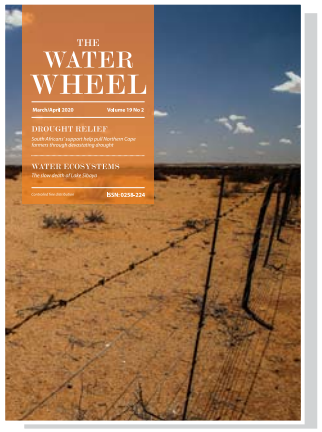

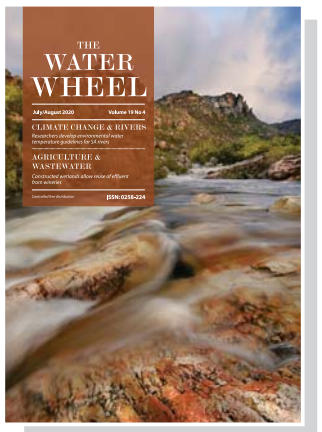

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WATER RESEARCH COMMISSION

WORLD MOURNS PASSING OF SA AQUATIC EXPERT

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Olaf was at his happiest in the field.

Condolences have been pouring in from all over the world following the untimely passing of Prof Olaf Weyl in November. Olaf, a globally recognised expert in inland fisheries, freshwater ecology, and the consequences of alien species introductions in freshwater ecosystems, passed away on 14 November. He was doing what he loved best – chasing fish in mountain streams, and looking for new trout genetics sampling sites.

Olaf was born in 1972 in Giessen, Germany. In 1977 his parents moved to the northwestern province of Zambia as development workers. He obtained his PhD at Rhodes University in 1998. He married Michelle Price in 1999 and was the proud father of twin girls, Philippa and Olivia.

Following a stint as a Fisheries Research Advisor to the Malawi Department of Fisheries, Olaf became a senior lecturer at Rhodes University. In 2009 he joined the South African Institute of Aquatic Biodiversity (SAIAB), initially as Senior Scientist and then as Chief Scientist. Testimony to his great standing and pursuit of excellence in both inland fisheries and aquatic invasion biology, he was awarded the South African Research Chair in Inland Fisheries and Freshwater Ecology in 2017.

Olaf participated in several Water Research Commission (WRC) research projects through the years, first as a young researcher and later as a project leader and mentor to post-graduate students. The WRC joins the world community in mourning this great loss.

"It is almost impossible to talk about Olaf without talking about freshwater fish, students, society and fishermen," said WRC Research Manager, Bonani Madikizela. "His career did not only shape the fish industry in South Africa, but in Africa and globally."

Between 2010 and 2018, Olaf served as the project leader of three projects at the WRC in the strategic area of water management and aquatic ecosystems. These projects covered a highly controversial subject, namely the control of alien and invasive fish species, such as bass, using the chemical rotenone. The WRC worked with Cape Nature in order to pilot test the use of rotenone within the confines of the National Environmental Management: Biodiversity Act and Alien and Invasive Species Regulations, National Water Act and the Conservation of Agricultural Resources Act (CARA). "Only an authoritative figure, such as Olaf, could lead such a sensitive project successfully," noted Madikizela.

Through the years Olaf became a leading figure in the aquatic science sector, and the large number of students that thrived under his mentorship made him a recognised project leader. It was this legacy that earned him a WRC Knowledge Tree award in 2015. "We have lost a great authority on freshwater fish science. Olaf did not only have a big personality with a thunderous voice, he also had a great love of nature and people," said Madikizela.

Should anyone wish to leave a personal message of condolence for Michelle, Olivia and Philippa and their extended family, SAIAB has set up a dedicated email address: condolences.olaf@saiab.ac.za These messages will be redirected to the family. A dedicated memorial page is also available on Memories.net: https://memories.net/timeline/olaf-weyl-69791#.X7GB79ghSWM.link.

To watch Prof Weyl's last presentation, given at the American Fisheries Society Virtual Conference 2020 in September, visit: https://www.youtube.com/watch?v=yx6hi1Cj2QU

Olaf in 2015 with his WRC Knowledge Tree Award.

WASTEWATER REUSE

Time to reverse 'unthinkable' waste of municipal water resources

At a time when freshwater supplies are being depleted by cities and industries across the world, massive volumes of municipal wastewater remain untapped and unmined – and the time has come to change this, writes Tony Carnie.

EU Civil Protection and Humanitarian Aid)

Crazed by thirst, the Ancient Mariner pondered the ocean of water that surrounded him and declared: "Water, water everywhere, Nor any drop to drink. . ."

More than two hundred years after Samuel Taylor Coleridge's grey-bearded sailor lamented the irony of scarcity amid abundance, researchers from the United Nations University in Canada have calculated that 380 billion m^3 of municipal wastewater is generated every year – a massive body of largely untapped organics and liquids that could be mined and recycled into freshwater, nutrients and energy.

To put that volume into context, the researchers note that 380 billion m^3 is roughly equivalent to the annual discharge from the Ganges River in India, five times the amount of water passing over Niagara Falls each year – or enough to fill Africa's Lake Victoria in roughly seven years and Lake Geneva in Switzerland in less than three months.

And the volume of this largely wasted resource keeps growing, with a projected rise of roughly 24% by 2030 and 51% by 2050.

Dr Manzoor Qadir, lead author of a study titled ***Global and regional potential of wastewater as a water, nutrient and energy source***, says freshwater supplies are becoming increasingly stressed in several parts of the world and demand keeps growing. In this scenario, ignoring the opportunities for resource recovery from wastewater "is nothing less than unthinkable," he argues.

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For example, the volume of water potentially recoverable from wastewater could irrigate up to 31 million hectares – equal to almost 20% of the farmland in the European Union. Recovering valuable nutrients such as phosphorous, nitrogen and potassium from wastewater could provide more than 13% of current agricultural demand for such fertilisers – while simultaneously reducing pollution and eutrophication of dams and river systems.

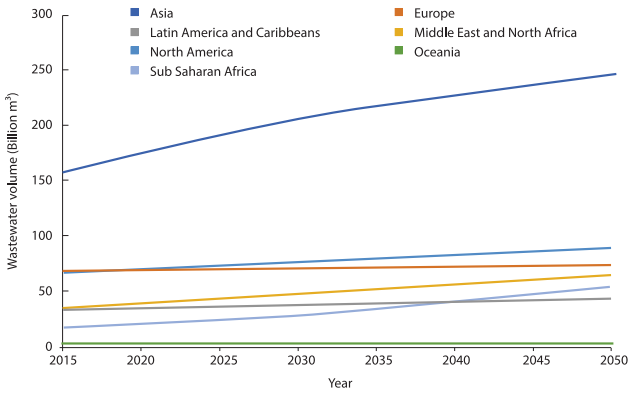
Eutrophication is caused by excessive levels of nutrients in water bodies, which, in turn, leads to the growth of dense mats of algae and other water plants, as well as the death of fish and other aquatic animals due to a lack of oxygen. Hartbeespoort Dam, west of Pretoria, is just one local example of where eutrophication has become a major problem due to excessive municipal sewage and wastewater pollution loads. In KwaZulu-Natal, eutrophication also threatens vital drinking water resources such as the Midmar Dam system.

Qadir, an environmental scientist and assistant director at the United Nations' University's Institute for Water, Environment and Health (UNU-INWEH), also suggests that harvesting the chemical energy embedded in wastewater could provide enough electricity to supply 158 million households – roughly the number of households in the USA and Mexico combined.

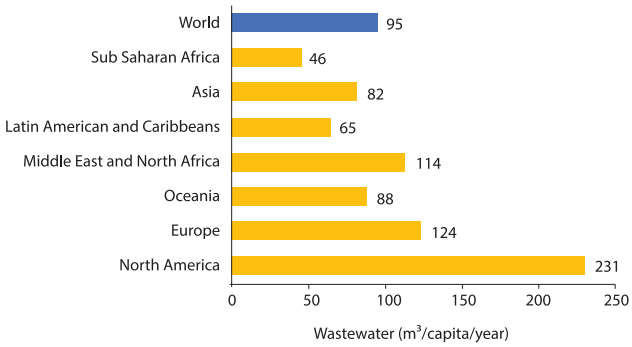
Vladimir Smakhtin, the director of UNU-INWEH, says is it unfortunate that municipal wastewater is often seen as "filth". But the institute believes that attitudes are changing slowly to recognise the potentially enormous economic returns and other environmental benefits that could flow from improved recovery of water, nutrients and energy from wastewater streams.

Some innovative examples from Africa include the Namibian capital, Windhoek, which has been recovering a significant volume of drinking grade water from municipal wastewater for more than 50 years. The first Windhoek plant started to produce drinking water in 1968 – the first such plant in the world – and in 2002 a new direct potable reuse plant was commissioned. This plant is operated by a consortium made up of Veolia and WABAG.

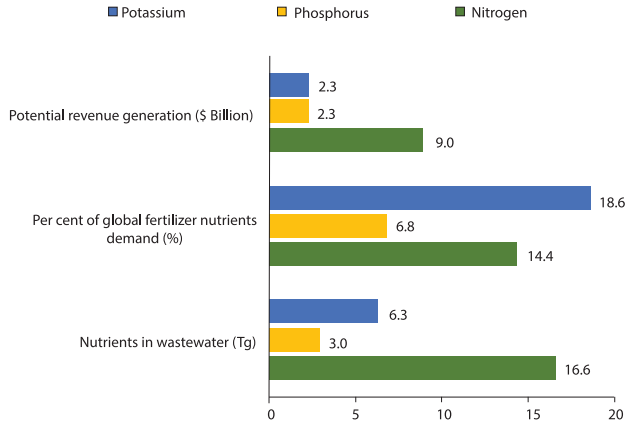
"In Windhoek, every drop of water counts," according to the Windhoek Goreangab Operating Company (WINGOC).



Global wastewater production across regions in 2015 and predicted until 2050. (Source: World Urbanization Prospects, 2018)



Annual volumes of wastewater produced per capita across regions. The world average is based on the total amount of urban wastewater produced and the urban population at the global level in 2015. (Source: UNU-INWEH)



Current levels of nutrients—nitrogen, phosphorus and potassium—embedded in wastewater and the percentage of global fertilizer nutrient supply that can theoretically be supplemented by these nutrients. (Source: UNU-INWEH)

Namibia is one of the most arid countries in Africa. The average rainfall is 250 mm per year, but the heat causes more than 80% to evaporate, allowing only about 1% of rainwater to infiltrate into the ground. Consequently, Windhoek depends mainly on boreholes and three dams, and the growing city had to look for alternative solutions to secure its water supply in a sustainable way.

The water reclamation facility features state-of-the-art 'multi-barrier' technology (ozone treatment, biological activated carbon, granular activated carbon, ultra-membrane filtration and residual chlorination amongst others) that eliminates pollutants and contaminants.

Singapore has also become a world leader in this arena through the development of a multiple-barrier water reclamation process known as NEWater. According to the Singapore PUB National Water Agency, the genesis of NEWater dates back to the 1970s, when the government commissioned a study to determine the feasibility of producing reclaimed water. Although the study found it was technically possible, the high costs and unproven reliability at that point posed insurmountable concerns.

But by the 1990s, the cost and performance of membrane technology had improved considerably and in 1998, PUB set up

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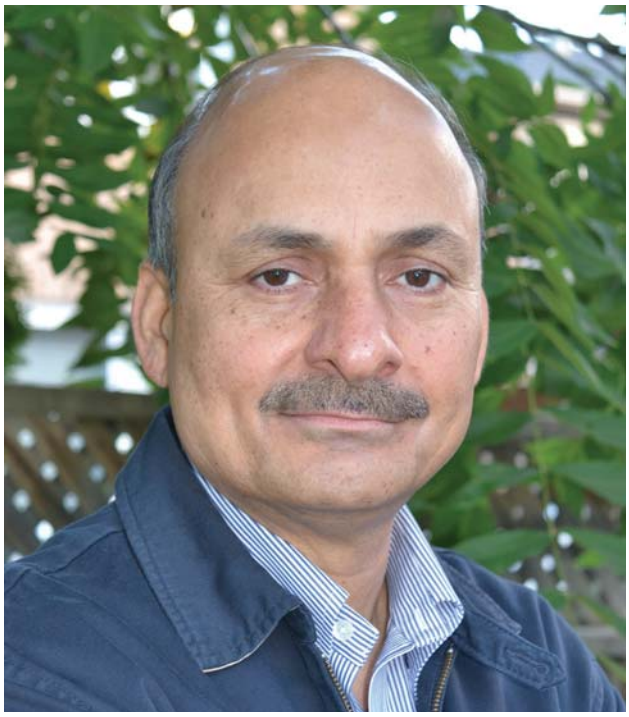
Image: Supplied



Dr Manzoor Qadir believes that it is "unthinkable" to ignore the growing opportunities for resource recovery from wastewater.

a team to test the latest membrane technology for use in water reclamation for potable purposes. In 2000, it commissioned a full-scale demonstration plant that could produce 10 000 m^3 daily and a battery of tests and audits showed it was a safe and sustainable water source. The three-stage process involves microfiltration and ultrafiltration, followed by a second stage of reverse osmosis and a final tertiary stage of ultraviolent disinfection capable of killing both bacteria and viruses.

An international group of experts in engineering, biomedical sciences, chemistry and water technology also found that NEWater's quality was consistently safe and high, and well within the World Health Organisation requirements for drinking water. They recommended it be used for indirect potable use, by introducing it into raw water reservoirs during dry periods. This blended water then undergoes naturalisation and further treatment in conventional waterworks to create drinking water.

Significant quantities are also used for non-potable uses in industry or for air-con cooling at industrial estates and commercial buildings. The biggest users of NEWater are wafer fabrication plants, which require water quality that is even more stringent than water for drinking.

Closer to home, the city of Durban has been a leader in recovering high quality water from municipal waste streams, and over recent decades it has pioneered several exploratory projects to harvest nutrients from both urine and faeces. In 2001, the city established South Africa's first private water recycling plant in Merebank (adjacent to the Southern wastewater treatment works) to recycle more than 10% of the city's total wastewater flows.

The plant is designed to treat up to 47.5 million litres of domestic and industrial wastewater to a near potable standard for sale to a large paper mill and fuel refinery. By reducing the amount of treated tap water used by local industry, the project indirectly frees up more drinking water for up to 300 000 people. It has also reduced the volume of polluted wastewater pumped into the sea via marine pipelines.

Nevertheless, huge volumes of wastewater still end up in municipal treatment works across the world, largely untapped for their water, nutrient or energy potential. Qadir and his research colleagues acknowledge that challenges remain to

Durban recycles more than 10% of the its total wastewater flows for industrial use.

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An aerial view of the Windhoek water reclamation plant and Goreangab dam. The Namibian facility, the first plant of its kind in the world, was established in 1968.

convince some consumers about using reclaimed water for direct potable use, yet it can also be used to irrigate new areas or to replace valuable freshwater where crops are already irrigated.

> *"human urine is known to contain highly concentrated nutrients, including nitrogen and phosphorus - much more than faeces."*

"This is already happening as farmers use treated and untreated wastewater directly for irrigation or indirectly when it is discharged into freshwater bodies where it becomes diluted and diverted to the agricultural farms."

They also note that despite growing tap water constraints, several cities still discharge municipal effluents directly into the sea. So, it could decades to achieve full-scale wastewater collection, treatment and alternative use in irrigation and other purposes, even though natural water supply is limited.

At a global level, Asia is the largest wastewater producer, generating an estimated 42% of the world's urban wastewater. In contrast, Sub-Saharan Africa produces the lowest annual amounts of wastewater per capita, almost five times lower than the volume of wastewater produced per capita in North America.

Quite apart from recovering water, municipal waste streams also contain a virtually untapped source of commercially-viable nutrients such as nitrogen, phosphorus and potassium. Using World Bank commodity data for fertilizers, the study notes that urea has a commercial value of around US$ 249/t, triple superphosphate (US$ 347/t) and potassium chloride (US$ 216/t). Collectively, 25.9 Tg of these three nutrients are embedded in annual wastewater flows, comparable to 78 times the mass of the Empire State Building.

Assuming the recovered nutrients have the same quality and market acceptance as industrial fertilizer, the recovery of these nutrients from wastewater could result in revenue generation of $13.6 billion globally with $9.0 billion from the recovery of nitrogen, $2.3 billion from phosphorus and $2.3 billion from potassium.

Though it is highly diluted by the time it reaches the municipal treatment works, human urine is known to contain highly concentrated nutrients, including nitrogen and phosphorus - much more than faeces.

"It is thus no surprise that human urine is also responsible for 80% of the nitrogen loading and 50% of phosphorus loading to municipal wastewater treatment plants."

If such nutrients could be recovered at source (directly from the toilet using urine-separation technology) this would not only benefit aquatic environments by reducing eutrophication but it would also reduce the cost of municipal wastewater treatment.

The chemical energy in wastewater could provide a third potential revenue stream, or a significant saving in treatment costs, through the recovery of methane-rich biogas. Wastewater is also a source of thermal energy, but this must be reused as close to the source as possible.

Assuming full energy recovery from wastewater, they calculate a current global energy value of around 53.2 billion m^3 methane

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Above and top: Windhoek has been reclaiming potable water from municipal wastewater for over 50 years. The newest plant features multi-barrier technology (ozone treatment, ultra-membrane filtration and residual chlorination) to eliminate pollutants and contaminants.

Veolia

Singapore has been reclaiming high quality water from municipal wastewater for nearly two decades. The biggest users are semiconductor wafer fabrication plants, which require water quality even more stringent than potable water.

with a calorific value of 1,908 billion MJ – enough to provide electricity to around 158 million households.

The researchers conclude that the torrent of "waste" water will continue to grow from rapid urbanisation, population increase and economic development and there is an urgent need to exploit this unmined resource.

"The good news is that a shift in research and practice supporting collection, treatment and fit-for-purpose and productive use of treated municipal wastewater is underway. It is important to note that many innovations are available and are being refined to bridge the gap between current resource recovery levels and resource recovery potential."

"For countries to progress, there is a need to invest in a supportive regulatory and financial environment towards a green economy, and to leverage private capital for resource recovery related business models that are financially feasible and increase cost recovery from municipal wastewater," concludes co-author, Pay Drechsel of the International Water Management Institute in Sri Lanka.

Wastewater – fast facts

- The energy value in 380 billion m^3 of wastewater is estimated to be 53.2 billion m^3 of methane – enough to provide electricity for up to 158 million households (or between 474 million to 632 million people, assuming an average of three to four people per household).
- In agriculture, the volume of water potentially recoverable from wastewater could irrigate up to 31 million hectares – equal to almost 20% of the farmland in the European Union. This reclaimed water can be used to irrigate new areas or to replace valuable freshwater where crops are already irrigated.
- World wastewater production is expected to reach 470 billion m^3 by 2030 – a 24% increase from today. And by 2050, it will reach 574 billion m^3, a 51% increase.
- Asia is the largest wastewater producer, with an estimated 159 billion cubic meters, representing 42% of urban wastewater generated globally.
- Other regions producing large volumes of wastewater: North America (67 billion m^3) and Europe (68 billion $m^{3)}$
- Full recovery from wastewater could, theoretically, offset 14.4% of global demand for nitrogen as a fertilizer nutrient; phosphorus 6.8% and potassium 18.6%.
- The nutrients in wastewater could theoretically generate revenue of US$13.6 billion globally: US$9.0 billion from the recovery of nitrogen, US$2.3 billion from phosphorus, and US$2.3 billion from potassium.
- Human urine is responsible for 80% of the nitrogen and 50% of phosphorus entering municipal wastewater treatment plants.

Source: PUB Singapore National Water Agency

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WASTEWATER-BASED EPIDEMIOLOGY

Harnessing wastewater-based surveillance in the fight against illicit drugs

A Water Research Commission-funded project used wastewater-based epidemiology to assess illicit drug usage in two communities. Article by Sue Matthews.

Wastewater-based epidemiology (WBE) has been in the news a lot recently, because its potential as a Covid-19 monitoring tool and early warning system is being tested in studieds around the world. South Africa's own National Covid-19 Water and Sanitation Surveillance Programme, coordinated by the Water Research Commission (WRC), entered the pilot-scale monitoring phase in November, following the successful completion of the proof-of-concept phase.

The WBE approach was originally proposed 20 years ago, as a means of monitoring not infectious disease, but community-level usage of illicit drugs. In 2001, Christian Daughton, the then head of the United States Environmental Protection Agency's environmental chemistry branch, based in Las Vegas, outlined his idea in the final chapter of a book he co-edited, titled ***Pharmaceuticals and Personal Care Products in the Environment***. He suggested that monitoring illicit drugs in the influents of sewage treatment facilities – known in South Africa as wastewater treatment works (WWTW) – would allow the scale of the drug problem to be assessed in a non-intrusive way, assuring the confidentiality of individuals, while also providing data on the exposure risk to aquatic biota.

The first known application of the approach was by a group of researchers in Italy, led by Ettore Zuccato. In 2005 they published a paper detailing the presence of cocaine and its main urinary

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metabolite, benzoylecgonine, in water samples collected from the River Po and a number of WWTW in medium-sized Italian cities. Five years later, European experts on illicit drug analysis established a network called SCORE – an acronym for Sewage Analysis CORe group Europe – to standardise methodologies and coordinate joint studies. In 2011, the first annual Europe-wide monitoring campaign was conducted, together with an intercalibration exercise that allowed the uncertainties of the approach to be characterised. With the support of the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), participation grew rapidly from the initial 19 cities in 11 countries to 42 cities in 21 countries in 2013. By 2019, when the campaign was conducted during a single week in March, 24-hour composite samples were collected in more than 70 cities in 25 countries, providing a snapshot of the 'drug problem' in Europe.

The first use of the WBE approach on the African continent was by Edward Archer and Gideon Wolfaardt from Stellenbosch University's microbiology department, in collaboration with researchers from the Department of Chemistry at the University of Bath in the United Kingdom (UK). The research formed part of a broader WRC-funded project on micropollutants and endocrine-disrupting contaminants (EDCs) in wastewater treatment systems (**WRC Project No. K5/2733**), but this component of the research was co-funded by the UK's Engineering and Physical Sciences Research Council (EPSRC). The research report for the WRC project was completed in October last year, although the findings of the WBE study on illicit drugs had already been published in ***Science of the Total Environment*** (Archer et al. 2018).

During 2017, sampling was done at seven consecutive days at two WWTW – one in Gauteng and the other in Cape Town. Samples were taken from the influent raw sewage, the final effluent, the return activated sludge, as well as from river water collected upstream and downstream of the WWTW. These samples were screened for various illicit drugs and their metabolites, as well as prescription drugs that are frequently abused. For example, ketamine is a class III schedule drug used as an anaesthetic in hospitals and other medical facilities, but it is also used as a recreational drug because of its hallucinogenic, tranquillising and dissociative effects. Medications for attention-deficit hyperactivity disorder (ADHD), such as Adderall and Ritalin, are similarly abused because their active ingredients – the stimulants amphetamine and methylphenidate, respectively – create feelings of euphoria when a number of the pills are crushed and then either snorted or injected with water.

Rather than considering only the concentration of compounds in the samples, the mass loads (grams per day) were calculated for each to compensate for the variation in daily influent and effluent flow rates, and this was then used to determine the removal of the compounds during wastewater treatment. Population-normalised drug loads (mg per day per 1 000

The research team found that most of the 38 compounds analysed – including medications and human biomarkers like caffeine, nicotine and alcohol as well as illicit drugs – were removed with high efficiency at both treatment plants.

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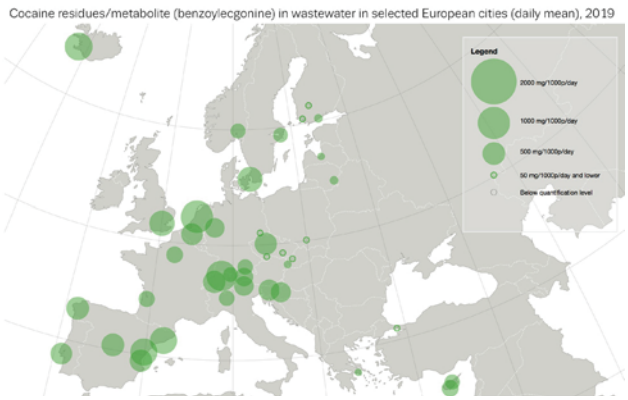
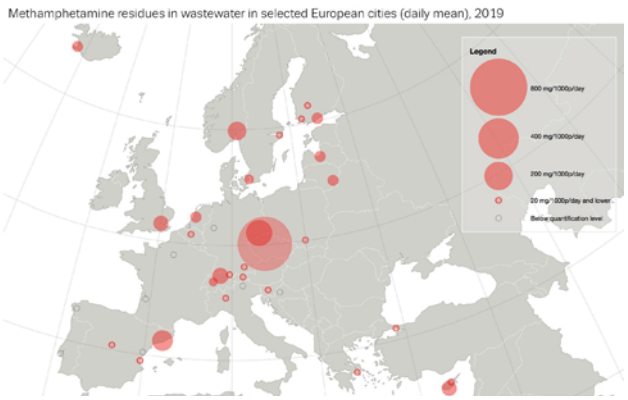


The 2019 SCORE monitoring campaign confirmed that cocaine remains the most widely and heavily abused illicit drug in Europe.



The use of methamphetamine – known in South Africa as 'tik' – was historically restricted to Czechia and Slovakia, but has been steadily increasing in other countries in recent years.

inhabitants), taking into account the population served by each WWTW, were also calculated to estimate drug use patterns in the different communities.

In addition, in order to distinguish between consumption of drugs and their direct disposal into the wastewater system, the researchers quantified urinary metabolites as drug target residues (DTR) and also performed enantiomeric profiling of chiral drugs of abuse. Chiral compounds occur in two mirror-image forms, called enantiomers, which cannot be superimposed on one another, like our left and right hands – indeed, the term chiral is derived from the Greek word for hand. The biological activity of a drug is often related to its 'handedness', with one form sometimes being beneficial and the other inactive or even toxic. The two enantiomers are differentiated by the prefix R or S, and a homogeneous mixture of the two in equal proportions is said to be racemic. However, since the enantiomeric ratio changes after human metabolism, this can be used to determine whether drugs detected in wastewater originated from consumption, rather than direct disposal.

For example, methamphetamine – known in South Africa as 'tik', but as crystal meth, ice or speed in many other parts of the world – was found to be the most prevalent illicit drug at both WWTW. Its mass loads were dominated by S-(+)-methamphetamine, which is known to be the primary enantiomer of illicit use. When the population-normalised loads were compared, it was clear that the scale of methamphetamine use in the community around the WWTW sampled in Cape Town was much higher than that around the Gauteng one. The maximum result of approximately 1 185 mg/day/1 000 inhabitants was the daily mean recorded for the Sunday of the sampling week – as was the case for many of the other drugs included in the study, the results reflect heavier drug use within the community at weekends.

Surprisingly, though, at the Gauteng WWTW the average concentration of S-(+)-methamphetamine at the river sampling station 3.5 km downstream of the final effluent discharge point was 18 times higher than in the upstream river water. Since the enantiomer is removed by the WWTW with relatively high efficiency, it is clearly entering the river from an additional source downstream of the WWTW.

In Europe, methamphetamine use has historically been restricted to Czechia and Slovakia, but there has been an increasing trend in other countries in recent years, and the 2019 SCORE results showed that the drug was also present in wastewater in cities in Cyprus, the east of Germany, Spain and several northern European countries. The highest result was 770 mg/day/1 000 inhabitants for the weekend mean in Prague, which is far exceeded by the 2017 figure for Cape Town. Prague was not part of the SCORE study in 2017, and at that stage the highest results were from Chemnitz and Erfurt in Germany, with weekend means in the 215–230 mg/day/1 000 inhabitants range.

In the case of cocaine, its use was also more prevalent in the community served by the WWTW in Cape Town in 2017, compared to the Gauteng one. Population-normalised mass loads of the metabolite benzoylecgonine ranged from a low of 257 mg/day/1 000 inhabitants on the Thursday to a peak of almost 590 mg/day/1 000 inhabitants on the Sunday. The metabolite cocaethylene, which is formed when cocaine is taken with alcohol, was also detected, and showed a similar spike on weekends.

"The research team found that most of the 38 compounds analysed – including medications and human biomarkers like caffeine, nicotine and alcohol as well as illicit drugs – were removed with high efficiency at both treatment plants."

Cocaine use is considerably higher in Europe, particularly in cities in Belgium and the Netherlands, where the mean population-normalised mass loads of benzoylecgonine for the week exceeded 950 mg/day/1 000 inhabitants in Antwerp and Amsterdam in 2019. Similar maxima were recorded in 2017, although then it was Barcelona and Zurich that had the highest results, and the SCORE data for Europe as a whole have shown an increasing trend for benzoylecgonine since 2016. A 2018 EMCDDA study noted that this could potentially be attributed to more people consuming cocaine, the same people consuming

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more cocaine, increased purity of the drug, or a combination of all three.

The drug known as Ecstasy or Molly is more correctly called MDMA, short for 3,4-methylenedioxy-methamphetamine. There appeared to be negligible use of this drug in the community served by the Gauteng WWTW in 2017, while at the Cape Town WWTW the population-normalised mass loads ranged from 9–62 mg/day/1 000 inhabitants, with these results reflecting the Thursday and Sunday daily means, respectively. In Europe, MDMA use is widely believed to have peaked in the early to mid-2000s, but the SCORE data showed that for 11 out of the 12 cities with data for both 2011 and 2019, MDMA loads were higher in 2019 than in 2011. The highest overall mean for the week was recorded for Antwerp in Belgium and three cities in the Netherlands, all exceeding 100 mg/day/1 000 inhabitants but reaching 287 mg/day/1 000 inhabitants in Amsterdam.

The metabolite of heroin, 6-monoacetylmorphine (6-MAM), was detected in raw effluent of the WWTW in Cape Town, confirming that the drug is used within the surrounding community. However, 6-MAM is known to be unstable in wastewater, so it cannot be used for quantitative estimates, and is omitted from the SCORE data for Europe.

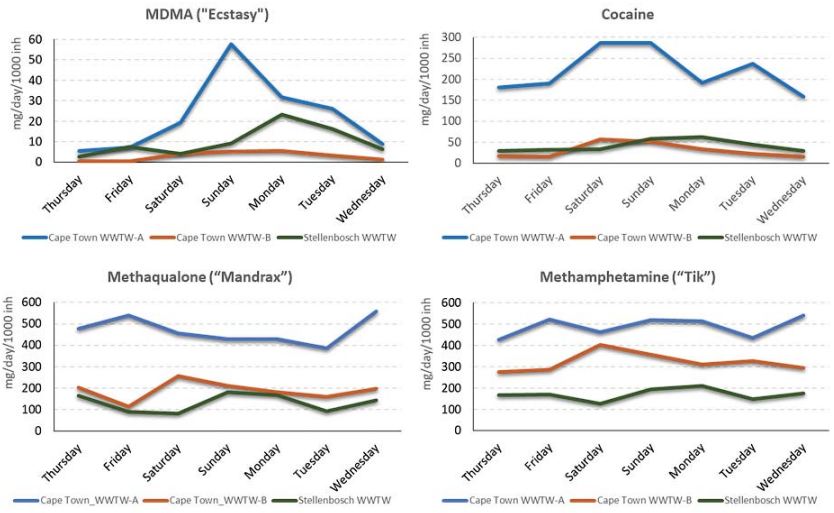
The results of the WRC-funded research provide insight into drug use within the communities served by the particular WWTW included in the study – other WWTW in Cape Town and Gauteng may yield quite different results, depending on the demographics, socio-economic pressures and lifestyles of the surrounding communities. But what are the implications for aquatic biota?

The research team found that most of the 38 compounds analysed – including medications and human biomarkers like caffeine, nicotine and alcohol as well as illicit drugs – were removed with high efficiency at both treatment plants. The exceptions were the opioid pain-reliever tramadol and the antidepressant venlafaxine and their metabolites. A follow-up study at two other WWTW in Cape Town, also conducted as part of the WRC project, likewise found that illicit drugs were well removed, apart from methaqualone – better known as mandrax. The drug had not been included in the 2017 study; in fact, this was the world's first-ever report to show the presence and fate of the drug in a wastewater monitoring study. Methaqualone is not widely used in other parts of the world, with the possible exception of the Indian subcontinent.

In addition to methaqualone, the antibiotic sulfamethoxazole, the NSAID diclofenac, the ARVs emtricitabine and efavirenz, and the anti-convulsant 10,11-dihydro-hydroxycarbamazepine were found in the follow-up study to have moderate to low removal, while carbamazepine had negative removal, being found in higher concentrations in the final effluent than in the influent wastewater. The project team therefore recommended that methaqualone and the medications identified in the two studies should be prioritised for further research on their potential ecological risk, their interaction with various biochemical pathways (potential sub-lethal toxicity responses), as well as the persistence of their breakdown products and bio-accumulation in freshwater biota.

Also of concern, of course, is the fact that illicit drugs were found in river water samples upstream of WWTW, often at concentrations similar to or even higher than those in the final effluent discharged from the WWTW back into the river. This is indicative of sewage reaching the river via leaking sewers or direct disposal by households not connected to the wastewater network, particularly where rivers pass through informal settlements.

An environmental risk assessment conducted by the project team, using Predicted No Effect Concentration (PNEC) acute toxicity data from the literature for algae, cladocerans or fish, showed that the concentrations of illicit drugs both in the final effluent and the river waters posed a low risk, with the exception of morphine in river water in the vicinity of the WWTW in Cape Town. Nevertheless, such PNEC-derived risk values do not



The researchers who conducted the WRC project have been participating in the SCORE monitoring week for the past three years. In 2019, this involved round-the-clock sampling at two WWTW in Cape Town and one in Stellenbosch. The samples were analysed for methaqualone (mandrax) too, although this drug is not included in SCORE because usage is very limited outside southern Africa, East Africa and the Indian subcontinent, where it originated.

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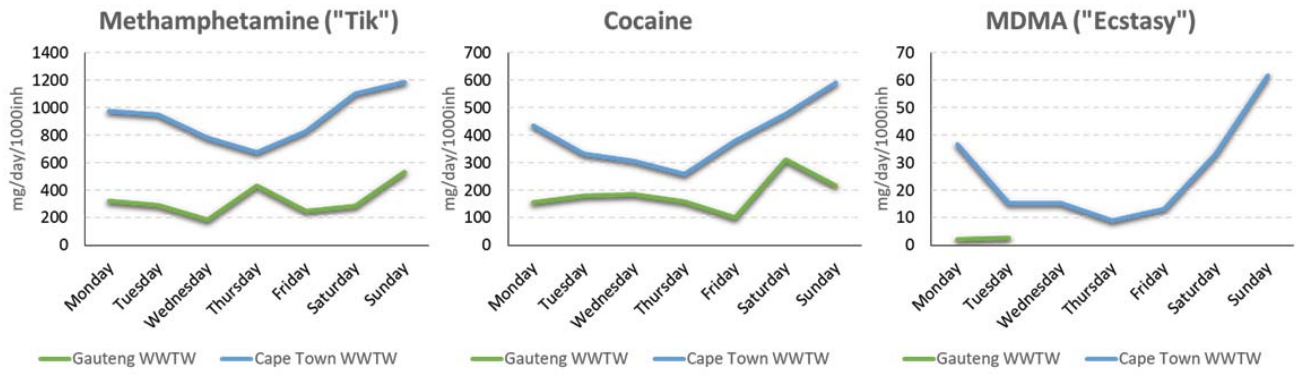

Results of a week-long monitoring exercise at two wastewater treatment works, conducted in 2017 as part of the WRC project, showed higher drug use in the community surrounding the Cape Town one.

consider the long-term health effects of continual exposure to the drugs – either individually or in combination, exerting cumulative impacts – over many generations of aquatic biota.

The researchers note that the broader application of the WBE approach in South Africa can serve as a support system to compare drug use and abuse trends between communities and over periods of time. Currently, collation of such information is largely limited to substance-abuse treatment centres and law-enforcement reports, which may lead to inaccurate estimations of illicit drug use.

The WBE approach can provide near real-time monitoring of a social ill that is closely tied to criminal activity and has a ripple effect on other problems in communities, including high unemployment, gender-based violence, petty theft and gang warfare. And since wastewater samples can be used to monitor a wide variety of other biological and chemical substances, the WRC sees it as a cost-effective approach that should ideally be scaled-up to a nation-wide monitoring programme.

SCORE data and images from SCORE (2020). Wastewater monitoring data 2011-2019. Sewage analysis CORe group Europe, http://score-cost.eu/monitoring2019

To download the WRC report, ***Substances of emerging concern in South African aquatic ecosystems. Volume 1: Fate, environmental health risk characterisation and substance use epidemiology in surrounding communities*** (**Report No. 2733/1/20**), visit: www.wrc.org.za.

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WATER AND THE ENVIRONMENT

New mayfly species discovered in Kruger adding bricks to conservation foundation

Discovery of new mayfly species in the rivers of the Kruger National Parks illustrates how much South Africans still need to learn about their freshwater ecosystems. Article by Petro Kotzé.

All photographs supplied

Project leader, Dr Lizaan de Necker, with fellow postdoctoral fellow Dr Hannes Erasmus and Honours students Nobukhosi Sithole and Herman le Roux conducting field work for the bilharzia research project.

"Mayfly taxonomy is not considered to be a sexy science," Dr Helen Barber-James says. Though not the most popular choice of study field, it is very important. Barber-James would know. A freshwater biologist, she has dedicated much of her career to exactly that – the biodiversity, systematics and biogeography of freshwater invertebrates, especially the Ephemeroptera (mayflies).

Nevertheless, there is still much work to be done. Last year, Barber-James led a team that identified two new mayfly species, and at least seven caddisfly species from the Kruger National Park's rivers. "It's amazing that we are still finding all these new species in such well-studied rivers," she says. The specimens are tiny; the mayflies only 3 to 4 mm long but, in addition to being exceptional finds, they are also an important part of a very large picture. Key to unlocking the messages from the mayflies, is calling each by their name.

An important aquatic inhabitant

The name mayfly refers to the time of year they emerge in the Northern Hemisphere (in spring, typically starting in the month of May). The tiny critters are perhaps commonly best known for the short lifespan of the adults (in many cases not even a day, sometimes only a few hours) and for occasionally emerging in large swarms depending on the species, but there is much more to them.

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Mayflies are one of the oldest groups of insects, and date back to the late Carboniferous or early Permian periods, some 290 million years ago, says Barber-James, who co-published the findings on the two mayflies with international mayfly expert, Dr Peter Malzacher.

They spend the bulk of their lifetimes unseen under water, where, in their developing nymphal stage, they cling to rocks and aquatic plants, feeding on microscopic plants and bacterial growth (periphyton). A few of them burrow in river banks under the water surface and in the sediments. They play an important role in nutrient cycling through the aquatic ecosystem and are a rich source of food to many other species.

All of these functions make them essential to the ecosystem, but they are also very sensitive to changes within it. As such, mayflies are indicators of ecosystem health. Several mayfly families are included as indicators in the South African Scoring System (SASS5) biomonitoring system, which forms the backbone of South Africa's River Health Programme.

Different mayflies have different sensitivities, so their presence or absence can tell a lot about the quality of a freshwater system. "Every single one of them has a slightly different ecological role to play, is adapted to live in a particular area, and has a different sensitivity to change," Barber-James says. Researchers count on them to indicate the state of the rivers, and in this case, the rivers of the Kruger National Park.

KNP game guard, Moffat Mambane, with Lyndall Pereira da Conceicoa and Helen Barber-James.

Counting critters in the water

The researchers conducted detailed surveys of the freshwater macro-invertebrate fauna of selected rivers within the park. With funding from the National Research Foundation (FBIP programme), Rhodes University and the South African Institute of Aquatic Biodiversity (SAIAB), Barber-James led the project in her capacity as head of the Department Freshwater Invertebrates at the Albany Museum, with the help of post-doctoral fellow, Dr Alexandra Holland and several post-graduate students.

It is common practice to record the presence of families of freshwater macro-invertebrates when scoring the health of aquatic ecosystems but, uniquely, this study dug down to species level. Only looking at family level is far too shallow for a biodiversity study, Barber-James says.

So, with the Kruger rivers survey project, they look at species within families of aquatic macro-invertebrates. Documented species richness and distribution is then compared to a similar study carried out in the 1980s (by Moore and Chutter, see reference below), to see how the species complement and abundance has changed.

However, for the species to be documented, they have to be known. "We have to know whether it's a Caenidae mayfly or a Baetidae mayfly and within those families what the species are," she says. "Species identification is the foundation of all ecological studies."

Helen Barber-James finding the best site for sampling.

Walking to a site with some of the KNP colleagues and game guards.

What's in a name?

All living things are named according to a classification system that dates back a long time ago, developed by a Swedish botanist from the 17th century, Linnaeus. With some modifications, this system is still in use today. There are now eight taxonomic ranks, which broadly group similar organisms, starting with the broadest categorisation and going down to the finest (species) level. The levels are domain, kingdom, phylum, class, order, family, genus and species.

To put this in context, the two newly discovered mayflies from Kruger are from the kingdom Animalia, in the phylum Arthropoda (joint-legged animals), in the insect class and part of the order Ephemeroptera, meaning they are winged creatures with a short life (ephemeral wings). More specifically, they belong to the family Caenidae, and are part of the genus ***Caenis***, which is widely distributed in Africa (yet still poorly studied). The adult ***Caenis*** males are characterised by forceps with a tuft of long spines, while the nymphs typically have square gills covering the rest of the gills on the body (hence the common name square-gill mayfly). The two new species have been named ***Caenis albicans*** (referring to the white body) and ***Caenis letabanensis*** (from the Letaba River)**.**

For the sake of comparison, lions and leopards are also part of the Animalia Kingdom, the phylum Chordata, class Mammalia, order Carnivora, the family Felidae and the genus ***Panthera***. It's only at species level that they are classified as lion and leopard. In the aquatic world, ***Caenis albicans*** and ***Caenis letabanensis*** are thus as different and significant as lions and leopards.

However, the classification of the specimens is difficult and time-consuming. Often there's not enough literature or reference papers published as far back as the 1930s or earlier, sometimes written in foreign languages, need to be referenced. "It's a tremendous task," says SANParks aquatic ecologist, Robin Petersen, which is why SANParks needs the help of outside researchers to do it.

Unfortunately, the pool of researchers to fish from, is small. This is work for specialists, Petersen says, of which there are only a small handful with limited networks to call on. Plus, the pool is not growing substantially. "It's totally not seen as trendy," Barber-James says.

A further challenge is ongoing funding for foundational biodiversity research. We are very grateful to the NRF Foundational Biodiversity Information Funding (FBIP) programme for supporting this project for three years, she says. The study happened to coincide with a period of extreme drought and, ideally, should have continued into the period of renewed rainfall after the drought broke. But since their funding came to an end, they have had to move on to other projects.

This challenge is not new. A 2001 Technical Report (Herbert et al. 2001) written to bring critical issues relating to taxonomy and systematics research in South Africa to the attention of the then-Department of Arts, Culture, Science and Technology (DACST) and the NRF, highlighted that much of South Africa's unique and diverse biological heritage remains undocumented, and until it is made known and studied, cannot be conserved or utilised.

The authors warned that capacity for taxonomy and systematics

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Caenis albicans larva

Caenis albicans male

Caenis breviceps larva

Caenis breviceps male

research in South Africa was already in danger of falling below critical mass levels, if it had not already done so. The lack of systematics research has management implications, up to national governmental level and impacts on our country's international commitments.

In Kruger, for example, the project results can advise management strategies. According to the project proposal, "monitoring of the environmental conditions affecting the invertebrate species living in these rivers, and looking beyond the broad family level used in regular biomonitoring, will allow recommendations to be made for reducing the pollution levels from external land use".

Furthermore, if rare species are found these can be placed on the IUCN Red List of Threatened Species, which can help put pressure on organisations responsible for causing pollution. The benefits of creating a suitable freshwater environment to aquatic fauna will also spillover to other megafauna.

Already, the aquatic vertebrate species are telling researchers much about the state of the Kruger rivers.

What the mayflies say

So far, they have sorted, identified and catalogued the samples collected over the three-year period and identified some of the groups to species level, Barber-James says. They focused on Ephemeroptera, Trichoptera and Plecoptera (the so-called EPT indicator species) and Odonata (dragonflies and damselflies). There are two reasons for this, she says. This first is that these groups are well recognised as ecologically sensitive. The second is the expertise available. For some of the other groups, they need additional experts for accurate species-level identification.

While the paper on ***Caenis albicans*** and ***Caenis letabanensis*** was published earlier this year, Dr Alexandra Holland (under the guidance of (retired) caddis expert at the Albany Museum, Dr Ferdy de Moor) is still at work on the mentioned caddisfly species, as part of her post-doc research.

Regardless of the exciting new findings, early results from the surveys also indicated a decline in total mayfly abundance and species diversity over time at some sites. The researchers concluded that this is possibly due to increased effects of mining and other upstream land-use activities affecting some of the rivers, or coinciding with drought periods. Another serious concern is the presence of the alien freshwater snail, ***Tarebia granifera***. This native to Southeast Asia is outcompeting some of the indigenous aquatic macroinvertebrate fauna and could be part of the cause of decline in diversity of the indigenous freshwater macroinvertebrate species.

There is still much more work to be done in these rivers, Petersen says, with different aquatic species in the park that have been studied more than others. Fish and riverine areas in general are well defined, and comprehensive inventories on reptilians and frogs were conducted in the seventies and eighties though few resurveys have been conducted since.

"There's endless work," Barber-James says, "but it's hampered by inadequate expertise to really assess the biodiversity of our systems." Considering the global realisation of massive decline in species diversity and numbers over recent years, this work is timely. What we really need is more people to do this kind of work. Across the continent, she says, we run the risk of losing species quicker than we can record them. Without an efficient baseline of species in place, we cannot measure change effectively. Without this foundation in place, she says, any knowledge is built on shaky ground. We might never know the price that we pay for this gap.

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IRRIGATION AND WATER

Water allocation for irrigation under the microscope

The precarious state of South Africa's water supply is now a well-known fact, and science-based information regarding how this precious resource must best be used is integral. A recent Water Research Commission-funded study investigated if the largest allocated share of the country's water – to irrigated agriculture – is correct, by comparing crops' water use with water quotas. Petro Kotzé writes for the Water Wheel.

Brand South Africa

The results indicate that some water allocations might be erroneous, but experts warn that though the work is "extremely important", it should be seen as the first step in a way forward that calls for more in-depth investigation.

For the purpose of the study, allocated water quotas were compared with crops' water requirements using SAPWAT4, a progam designed with WRC funding to estimate irrigation water needs. The project was led by agronomist Pieter van Heerden, one of the original SAPWAT developers.

A history of water allocation in South Africa

Under the previous Water Act (Act no. 54 of 1956), irrigation areas were given a water use right as a water quota. The amount was expressed in terms of cubic metres per hectare per annum, for a specified number of hectares. Under the new National Water Act (Act no. 38 of 1998), this has been replaced by a water use right, expressed in total cubic metres of water for a farm or property. However, since the first determinations, and review of some allocation in the first half of the twentieth century when

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large-scale irrigation development took place, there has been no, or limited revisions and adaptions.

South Africa's water quotas were thus set in ink before sophisticated methods to determine the water requirements of plants existed. The requirements that were known were available to a limited extent, based on a combination of local experience and some research. Irrigation needs were determined by measuring plants' water use, says van Heerden. By adding trees or maize plants to a plot, for example, and then re-measuring water use, an estimate could be made. "This was timeous and expensive research," he says. These methods resulted in advice such as "two irrigations of 3 inches (75 mm) per cutting for lucerne production in the Great Fish River Valley."

Since then, irrigated agriculture has seen major development. Crop growth characteristics and the major crops grown under irrigation have changed. Through the development of shorter growing maize, cotton and potato cultivars, it is now possible to grow two crops in one season on the same irrigated field. More sophisticated water measuring tools have been developed and farmers have learned how to do more with their available water. Irrigation systems have been revolutionised.

Especially over the last few years, van Heerden says, the technology available to calculate more precise water requirements of irrigated crops has improved by leaps and bounds. The South African-developed SAPWAT, in particular, has gained renown for this purpose. The most recent version, SAPWAT4, is commonly used across all southern African countries (except the DRC) and widely to the north of the continent as well. In South Africa, Nic Knoetze, CEO of the South African Association for Water User Associations, says the model is held in such high regard, it was used for calculations when existing lawful water use was registered and is recommended as backup should actual water metering equipment fail.

The model can incorporate soil water characteristics, evaporation parameters, irrigation system efficiency and crop water requirement with data from weather stations and the climate region that the area is located in, to estimate crop irrigation requirements.

It can be applied to a single crop, a field with multiple cropping, a single farm, a group of farms or Water User Association (WUA), for a group of WUAs, or for river basin and basin sub-units. The results are given, where appropriate, in millimetres and cubic metres.

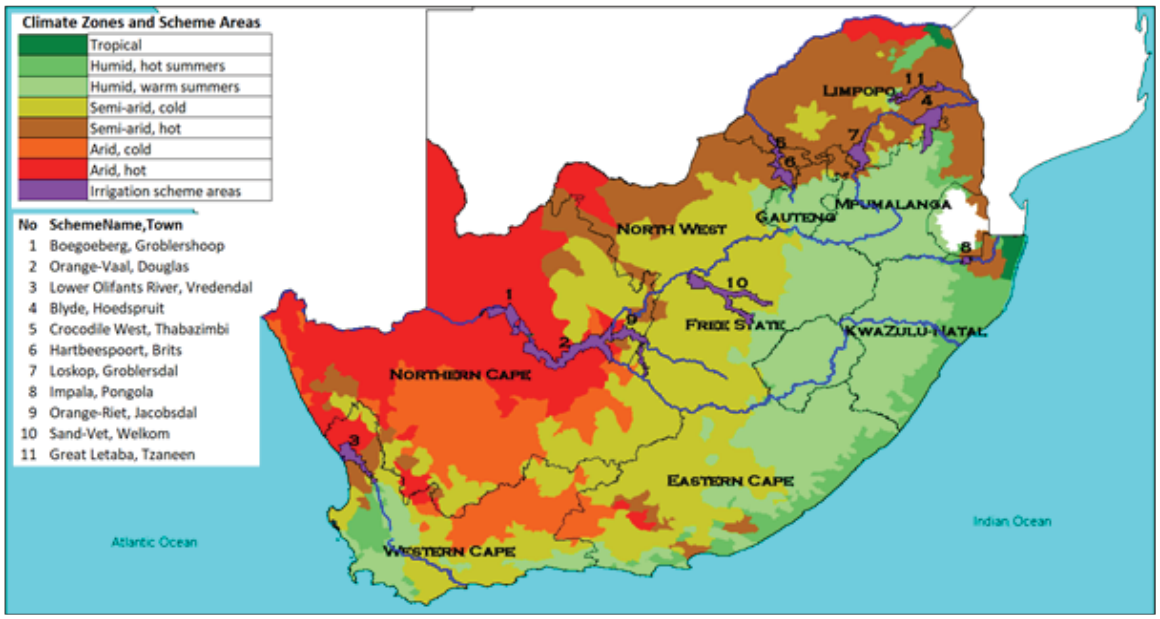
Comparing water needs and allocations

For the purpose of the project, case study areas were selected from across South Africa, in different climatic regions where irrigation takes place.

The research team, Pieter and Gela van Heerden relied on surveys to determine different cropping patterns and soil-, irrigation system and strategies and crop combinations. They also documented which one of the following four irrigation management approaches was used:

Werner Conradie

Irrigation for agriculture remains the largest water user in South Africa.



- Conventional irrigation management, which allows soil water extraction to a level of 50% of readily available soil water, to prevent the development of stress.
- Conservation management, which is applicable when growing large sized seed grain crops, where seeding takes place in the stubble of the previous crop to reduce soil surface evaporation.
- Stress irrigation, which allows for soil water extraction to 100% of readily available water. Water saving through the application of slight stress is a possibility, but estimates indicate noticeable yield losses in more sensitive crops.
- Farmer management: If irrigation management strategies differ from any of the previous three irrigation approaches.

The results show a wide range of deviations between SAPWAT4 estimated crop irrigation water requirements and actual irrigation water quotas of areas.

Specifically, in arid, hot climates, the deviations between the quota and crop requirements are high. In the Boegoeberg, lower-Orange irrigation area water requirements are 165% of the allocated water. The findings showed that the water quotas of five of the eleven WUAs are less than the SAPWAT4 calculated irrigation requirement. At these WUAs the estimated irrigation water requirement ranges from 165% to 113% of the present allocation.

Irrigation area	MAP (mm)	ET_0 (mm d^{-1})	Quota (m3 h^{-1} a^{-1})	Recommended quota (m3 h^{-1} a^{-1})	Change %
Arid, hot climate					
Orange Vaal	288	4.6	10 000	14 426	144
Boegoeberg Middle Orange	215	4.6	10 000	17 009	113
Boegoeberg Lower Orange	215	4.6	15 000	16 534	165
Semiarid, hot climate (winter rainfall)					
LORWUA, Bulshoek Dam downstream of Clanwilliam Dam, Lower Olifants River	260	3.9	12 200	10 025	82
Semiarid, hot climate (summer rainfall)					
Hartbeespoort, Crocodile River downstream of Hartbeespoort Dam	529	4.5	6 200	8 386	135
Crocodile West, Lower Crocodile River	660	4.5	8 000	10 025	109
Impala, Pongola River upstream of Jozini Dam	692	3.9	10 000	7 621	76
Loskop, Olifants River, Loskop Dam	582	4.3	7 700	6 016	78
Blyde, Blyde River, Blyde River Poort Dam	638	4.1	9 900	13 457	136
Semiarid, cold climate					
Orange-Riet, Vanderkloof Dam	486	4.3	11 000	10 750	98
Sand-Vet, Erfenis and Allemanskraal Dams	517	4.1	7 200	5 850	81
Great Letaba, **Humid warm summers**	1 127	3.4	6 620	7 553	114
Great Letaba, **Humid hot summers**	971	3.8	8 920	11 892	133
Great Letaba, **Semiarid hot**	536	4.3	10 900	13 378	123

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Present and recommended irrigation water quotas, including climate regions, average annual rainfall and ET_0

Furthermore, two WUAs fall within a 10% deviation of allocation at 109% to 98% of the present allocation. The irrigation water allocation for the remaining four WUAs is more than the SAPWAT4 estimated irrigation water requirement with values that range from 82% to 76% of the present allocation.

Though the study is a good starting point, Knoetze says more robust research is necessary to verify the findings before the results can be used by policy makers.

For accurate output, accurate input is necessary

Their dependence on WUA managers to provide information such as crop areas planted via questionnaires impacted on the accuracy of the data for some areas, van Heerden says. "Along the Olifants River they take a satellite image every year, so that area's results are tremendously accurate." At the Orange-Vaal irrigation area, the crop patterns are regularly documented, which also results in accurate results, he says. In other areas where such detailed data is not available, the accuracy of the findings are thus affected.

The interpretation of satellite images could be an improvement of the situation, provided that satellite images of spring, summer, autumn and winter cropping patterns are utilised. To obtain long-term cropping patterns, such surveys should be repeated regularly to keep up with changes in climate, cropping patterns and markets.

As for the performance of SAPWAT4, further tweaking could include updating the model's crop coefficient values, as newer varieties have different growing patterns than those currently included. Van Heerden points out that some crops that are coming into production because of market pressure, such as macadamia and blueberries, are not sufficiently researched in terms of crop coefficients yet. "This is also very relevant in the case of subtropical crops, where spring, summer, or autumn growth flushes effects the mid-season crop coefficients."

Last, the quaternary drainage region climate data should be updated and imported into SAPWAT4. Currently ranging from 1950 to 1999, updating these would also enable the SAPWAT4 user to compare short period climate differences as experienced lately.

Insights into on-farm farming operations

The research team found that farmers made very efficient use of rainwater, using it to partially supply their crops' water requirement and reduce the need for irrigation. However, in low rainfall areas, the occurrence of rain is often very erratic and its contribution is usually very low. The general impression is that the farmers know about good irrigation scheduling strategies and that they do apply these as far as possible.

In areas where study results indicated that less irrigation water is received than what the crops require, farmers have adapted short-term crop production strategies. These include planting smaller areas; irrigating higher value crops at the expense of lower value crops; pulling up less profitable orchards and vineyards; pruning tree and vine crops to smaller sizes or to just main and frame stems to reduce irrigation water requirement. Although good strategies, the researchers point out, these are only short-term solutions and are not economically viable.

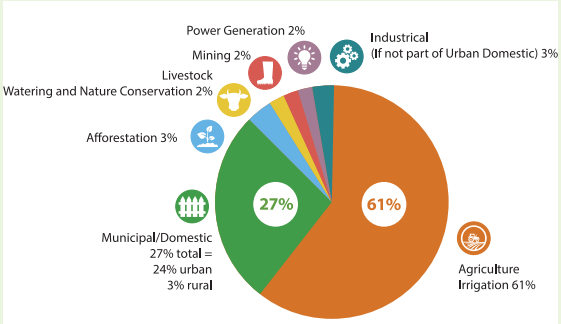
Moving forward

"The project findings are interesting," Knoetze says, "but cannot be accepted as gospel without a follow-up study to produce more reliable figures, especially from on-farm operations." Knoetze was part of the project's reference group, a model applied by the WRC to allow for broad and cross-sectoral consultation of research project methodologies and study results.

Still, van Heerden says that ideally, irrigation water allocations should be adapted from time to time based on the climate and the crop pattern. "The water quota has to be based on the crop's water need," he says. This has to be reviewed every three or four years as cropping patterns and markets change, irrigation systems are upgraded, the climate changes and shorter growing cropping varieties emerge.

In a water scarce country like South Africa, we cannot afford to play irresponsibly with our available water, van Heerden says. Part and parcel of that, is to ensure that an agricultural area receives the correct water quota based on the specific farming practices applied there.

South Africa's water allocation



How we use our water resources in South Africa

According to South Africa's Water and Sanitation Master Plan (2018) agriculture is the country's largest water use at 61% of total water use, followed by municipal use at 27% (including industrial and commercial users provided from municipal systems), with power generation, mining and bulk industrial use, livestock and conservation and afforestation jointly making up the remaining 12%.

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SAFE SANITATION

New sanitation technology brings dignity to Gauteng school

The provision of safe sanitation in all South African schools remains a critical government priority. Tsholetsega Primary School, in Krugersdorp, has become the first recipient of an innovative, next generation sanitation technology implemented through the South African Sanitation Technology Enterprise Programme (SASTEP). Article compiled by Lani van Vuuren.

The containerised treatment unit treats wastewater on site for reuse. The treated water is recirculated for flushing.

SASTEP, a programme developed by the Water Research Commission (WRC) in partnership with the Bill and Melinda Gates Foundation and Department of Science and Innovation, seeks to enable the development of suitable sanitation technologies in South Africa towards the creation of a viable sanitation market. The programme does this by fast-tracking the adoption of innovative and emerging sanitation technologies in South Africa through fostering local manufacturing and commercialisation. The core strategy of the programme is to support and empower sanitation innovators (technology partners) and sanitation entrepreneurs (commercial partners).

This is undertaken in support of government initiatives such as SAFE (Sanitation Appropriate for Education), aimed at replacing pit latrines and other unsafe forms of sanitation at schools with more appropriate and sustainable technologies. The SAFE Programme was launched by President Cyril Ramaphosa in 2018, after a nationwide survey indicated that 3 898 South African schools still had inadequate access to sanitation facilities. Most of these schools are located in the Eastern Cape, Kwazulu-Natal and Limpopo provinces.

SASTEP Programme Manager, Akin Akinsete, noted that the successful introduction of new sanitation technologies was aimed at introducing more sustainable toilet solutions to places suchas schools, while reducing the cost per seat. In addition, the

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WRC Executive Manager, Valerie Naidoo, with one of the new toilets.

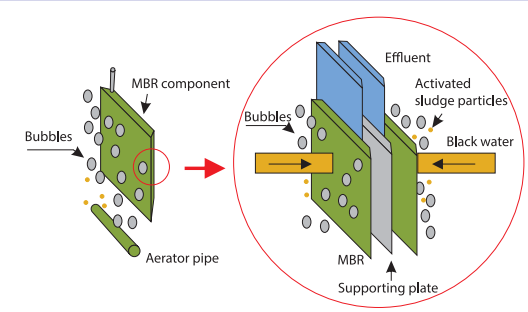
incorporation of a robust operations and maintenance strategy would also prolong the lifespan of these systems.

Since the launch of the SAFE Programme, 577 schools have had their sanitation facilities upgraded, while sanitation is in various phases of planning and/or construction at a further 1 957 schools. According to SAFE Programme Manager, Nompumelelo Nyembe, government aims to provide safe sanitation at all the remaining schools by September 2021.
The technology selected for Tsholetsega Primary School is the Clear recirculating toilet. The toilet system was originally developed by Clear, a Chinese company, but will be manufactured locally by South African firm, Enviroloo.

The system collects waste from flush-type toilets, which is then treated by a closed system on-site. Water is recovered, treated and reused for flushing purposes. The system allows for off-grid set-up, while also allowing for waterborne sanitation in areas with little water supply. Since most of the system is containerised, this negates the need for expensive on-site civil construction.

Two models are currently being tested the school, namely the TT-5 containerised four toilet seat front and backend treatment plant ablution facility, with a total daily maximum capacity of 600 flushes. In turn, the TT-6 backend treatment plant is connected to an existing 25-seat (inclusive of male urinals), with a total max capacity of 4 000 flushes. The installed toilets use between 3L and 5L of water per flush. Wash basins for handwashing using potable water have also been provided. The system is currently plugged into the municipal electricity system, but can operate using solar power. Water samples are regularly tested offsite, and, in the case of an emergency, sewage can be redirected into the municipal sewer line, reducing the risk of spills.

"The system installed at the Tsholetsega Primary School is performing excellently, and preliminary results are very encouraging," noted Enviroloo COO, Mark la Trobe. "We believe that the technology has the potential to transform the landscape of the South African Sanitation industry…The push for the commercialisation and industrialisation of appropriate sanitation technologies in the country is a positive step and has the potential to transform South Africa into a hub of sanitation manufacturing excellence on the African continent."



The waste stream from the toilet is initially stored in a black water collection tank. The tank provides residence time for the wastewater to equalise. The tank inventory is then pumped to the treatment section of the system where it is first treated to remove suspended solids and before undergoing aerobic and anoxic biological treatment. The treated stream is then passed through a membrane biological reactor (MBR). The MBR membranes serve as microbial barriers that can capture most of the biomass for recirculation inside the bioreactor. This produces water that can either be reused for toilet flushing or discharged into downstream sewer directly or be reused as irrigation water.

The outside of the new ablution block. Wastewater is gravity-fed to holding tanks before being treated in the on-site treatment system.

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The Clear TT-5 containerised four toilet seat front and backend treatment plant ablution facility.

Speaking at the official launch of the toilets on World Toilet Day, 19 November, WRC CEO, Dhesigen Naidoo, said that the implementation of the solution at Tsholetsega Primary School offered the opportunity to test a solution in demonstrator format while adding value to the SAFE programme. "The Covid-19 pandemic has reminded us of the importance of access to safe and dignified sanitation. If we want our people to be healthy and safe enough to contribute meaningfully to the development of their society then these are the base investments that we simply have to make," he told delegates during the event.

His sentiments were shared by keynote speaker, Dr Olive Shisana, from the Office of the Presidency. "In a water scarce country, such as South Africa, we need to embrace newer technologies that do not depend on the availability of water in large quantities. The time has come for us to change the sanitation engineering and management model."

The Clear TT-5 containerised four toilet seat front and backend treatment plant ablution facility.

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UNDERUTILISED CROPS

Underutilised crop species offer options for drought mitigation in South Africa

Underutilised crop species can be a valuable option for drought mitigation in South Africa write Tafadzwa Mabhaudhi, Hillary Mugiyo, Vimbayi Chimonyo and Albert T. Modi.

The Centre for Transformative Agricultural and Food Systems (CTAFS) of the University of KwaZulu-Natal (UKZN) was established to contribute to building resilient and sustainable healthy food systems, with a focus on rural resource poor households. This derives from a realisation that rural resource poor households remain vulnerable to food and nutrition insecurity, which is being worsened by challenges of climate change.

In South Africa, there has been an increase in the occurrence and severity of extreme weather events such as floods, heat stress and more importantly, drought. The latter weather phenomenon has been accompanied by poor rainfall distribution, late start of the season, early cessation of the rainy season and extreme temperatures. For agriculture this means poor crop productivity and significant yield losses. Such impacts on productivity are detrimental to farmers, particularly rural resource poor households, who rely on rainfed crop production as the main livelihood strategy, and for their food and nutrition security. Understanding drought can aid in formulating sustainable adaptation strategies and building resilience of farmers.

What is drought?

Drought is a complex phenomenon. There are four types of

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drought: 1) meteorological, 2) hydrological, 3) agricultural, and 4) socio-economic drought. Of importance to food and nutrition security is agricultural drought, which happens when there is a lack of sufficient water in the surface soil layers to support crop growth.

Why is drought an important phenomenon in South Africa?

South Africa is considered the 30th driest country in the world, and the country's water profile is rapidly moving from water-scarce to water stressed. The country's annual average rainfall fluctuates around 500 mm, which is far below the world's average of 860 mm per annum. Rainfall is unevenly distributed, with about 50% of the rain falling on 15% of the land. It is in most of the remaining 85% of the country where rural inhabitants are concentrated.

Severe dry episodes in South Africa are often associated with the effects of El Niño–Southern Oscillation (ENSO). The 2015/16 ENSO induced drought, one of the strongest events of recorded history, had tremendous negative impact on agriculture due to water scarcity. This further led to serious food and nutrition insecurity for the majority of the population in South Africa and the region (Nhlamo et al, 2019).

Evidence suggests that the frequency and intensity of drought due to ongoing climate change is increasing, placing many families at greater risk of food and nutritional insecurity. There is an urgent need for South Africa and the region to develop drought adaptation strategies that will mitigate the risks associated with drought. Part of this requires generating context-specific knowledge on the occurrence of drought and developing tailored solutions for these areas.

Where in South Africa is drought severe?

Figure 1 shows the long-term seasonal time series of the Vegetation Drought Response Index (VegDRI) for South Africa. Vegetation Drought Response Index is a hybrid index that combines traditional climate-based drought indicators, satellite-derived vegetation metrics and biophysical information to show maps of drought. The VegDRI-South Africa map shows a variation of very severe drought 16%, severe drought 34%, moderate drought 38%, slight drought 11% and no drought conditions 1% detected over South Africa. Over the Northern Cape and Eastern Cape provinces, drought is very severe to severe, indicating acute water scarcity. Moderate to no drought conditions are reported from the central to eastern regions of South Africa.

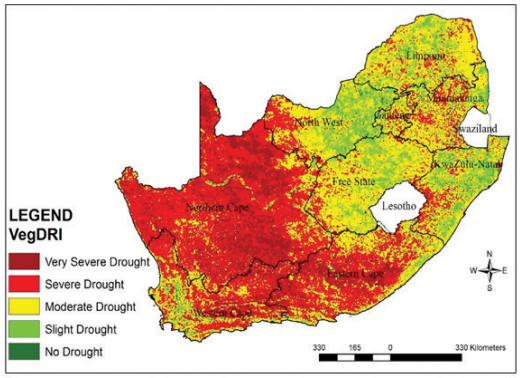

Figure 1. Drought occurrence and severity across South Africa.

Underutilised crop species as a drought mitigation strategy

Currently, delineation of South Africa's rainfed agricultural land use is for a few major cash crops such as maize, sugarcane and soybean. This reflects a lack of agro-biodiversity, which culminates in increased vulnerability of agriculture to climate risks such as drought. An example is the 2015/16 ENSO drought that caused South Africa to import more than 30% of its annual cereal grain requirements due to poor harvests.

Neglected and underutilised crop species (NUS) are reported to be suitable for marginal agro-ecologies. They can help build the resilience of rainfed cropping systems in the wake of climate variability and change. NUS can offer options for increasing productivity, especially in marginal areas, as they are locally adapted and would not strain the environment further. The promotion of indigenous crops such as sorghum, millets, bambara groundnut, cowpea (***Vigna unguiculata),*** taro, and leafy vegetables such as amaranth and wild mustards is integral to ensuring that households consume diverse diets. Identifying areas that are suitable for NUS production could assist farmers to adapt to drought.

Sorghum - also known as "Mabele thoro", "Amazinba" or "Amabele" is the second most important cereal in SA after maize. Sorghum is adapted to warm climates and possess characteristics that make it a drought-tolerant crop. According to Figure 2, there is about 2% of the calculated arable land of South Africa (12 655 859 ha) that is highly suitable (S1), that is, land having no limitations, to produce sorghum. Moderately suitable (S2) land constitutes the most substantial proportion with 61%. In comparison, marginally suitable (S3) and unsuitable (N1) includes 33% and 4%, respectively, of calculated arable land. Large areas of suitable (S1 and S2) land were concentrated in eastern provinces of the country and suitability intensity decrease towards western regions. The suitability map for sorghum suggests that the crop can be grown in areas that experience slight to moderate drought (Figure 1).

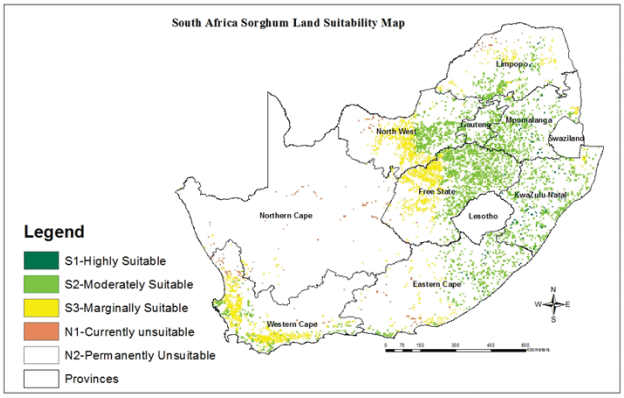

Figure 2. Suitability of sorghum (Sorghum bicolor) across South Africa

Cowpea –also known as "imbumba", "indumba" or "isihlumaya" is a legume crop mainly produced by smallholder farmers in South Africa under rainfed conditions. The crop is well known for its drought-tolerance and can grow in areas with rainfall ranging from 400 to 700 mm per annum. Figure 3 shows the suitability of cowpea, across South Africa. The distribution of land suitable

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for cowpea production was consistent with that of sorghum. The trend was that land designated as moderately suitable (S2) constituted 56% of calculated arable land of South Africa (12 655 859 ha), and this was followed by S3 and S1 with 39 and 3%, respectively.

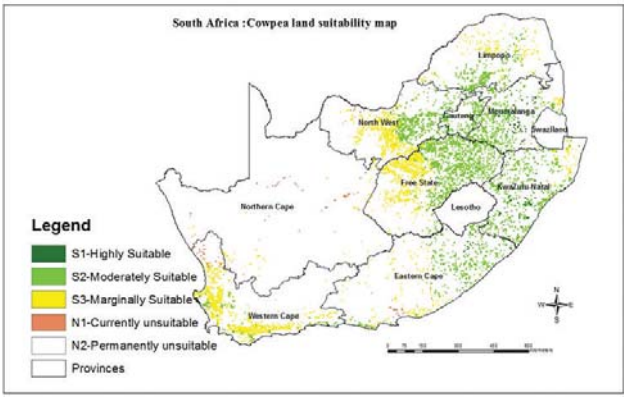

Figure 3. Suitability of cowpea (Vigna unguiculata) across South Africa

Amaranth – often considered a weed in conventional cropping systems, is a popular African Leafy Vegetable that is highly nutritious and shows remarkable drought tolerance. The land suitability analyses indicated that amaranth is highly suitable across South Africa S1=8%, S2=81%, S3=11%, and of calculated arable land of South Africa (12 655 859 ha) and this is because the crop has a short growing period and low water requirement.

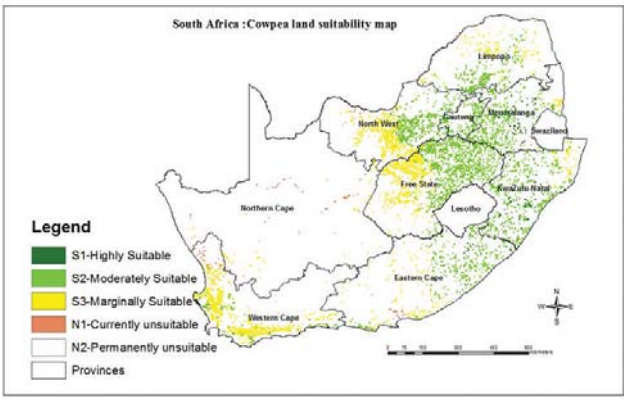

Figure 4. Suitability of amaranth (Amaranth spp) across South Africa

Other strategies to consider

Under limited water availability, agriculture needs to consider strategies that increase water productivity. In response to frequent droughts, an increase in the area under irrigation may seem an obvious solution to mitigating drought. However, considerations need to be given to the availability of water and energy for irrigation expansion and the accessibility of irrigation services to different farming groups in the country. Under marginal farming systems, irrigation is an expensive option and not always readily accessible. Although tapping into South Africa's groundwater resources has been suggested, the extent to which these can contribute to expanding the area under irrigation is unknown given the challenges of quantifying and pumping these resources. Therefore, smallholder farmers currently lack access to water, energy, infrastructure and technical skills to irrigate.

Alternatively, farmers can explore strategies such as rainwater harvesting and soil water conservation techniques, which involve inducing, collecting, storing and conserving runoff water for agriculture. The drawbacks to this are that, apart from scale issues, rainfall has become more erratic and droughts more frequent. Hence, the feasibility of this approach under frequent drought is challenging.

Acknowledgement: the work reported in this article emanates from WRC funded project no. K5/2717//4 on Developing guidelines for estimating green water use of indigenous crops in South Africa and estimating water use using available crop models for selected bio-climatic regions of South Africa.

COMMUNITIES AND WATER

The Muzi swamp reed cutters and their perspectives on a sub-surface peat fire

A current study funded by the Water Research Commission and led by the Agricultural Research Council (ARC), in partnership with Ezemvelo KZN Wildlife, is investigating the impact of peat fires on natural resource harvesting. Article by Jason le Roux, Ayabonga Gangathele, Catharine Hanekom, Althea Grundling.

Reeds harvested and bound into bundles or batches using rope made from sedge leaves. Credit: PL Botha

Natural resource harvesting, such as reed cutting, is widely acknowledged as an ecosystem service provided by wetlands (Bonn et al., 2016) and is practiced amongst some rural communities in South Africa (Kotze et al., 2007). Peatlands are scarce freshwater ecosystems in South Africa, comprising only 1% of the total wetland area in the country (Grundling et al., 2017). They consist of partially decayed vegetation or organic matter which contributes to a range of ecosystem services (Parish et al., 2008).

However, there have been few studies to determine how wetland degradation, associated with sub-surface peat fires, affects peatland functioning and associated natural resource harvesting. Given that there has been a significant increase in peat fires across South Africa, particularly in Maputaland, more research is needed to understand the implications of these sub-surface fires, which can only occur when a peatland is no longer saturated throughout the year due to a drop in the water table (Turetsky et al., 2015). The Agricultural Research Council (ARC), in partnership with Ezemvelo KZN Wildlife, is currently conducting a research study, financed through the Water Research Commission (**WRC Project No. 2019/2020-00098**), which aims to determine the consequences of peat fires and develop rehabilitation protocols for these ecosystems.

One of the project study sites is the Muzi Swamp, a long linear

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Harvested reeds (Phragmites australis) and sedges from the Muzi Swamp. Credit: AT Grundling

peatland system located in the Tembe Elephant Park. This park falls under the uMhlabuyalingana Local Municipality within the uMkhanyakude Municipal District in northern KwaZulu-Natal, commonly known as Maputaland. It spans an area of 300 km^2, is a Big 5 reserve and the ancestral home of the Tembe people who own the reserve. The Muzi Swamp is the only permanent water source found within the park's boundaries, as there are no rivers that run through the park. The wetland pans within the park are seasonal and dependent on rainwater (Grundling et al., 2014). The Muzi Swamp is therefore essential in supplying water for Tembe Elephant Park.

One of the conditions in the proclamation agreement of the Tembe Elephant Park is access to harvesting of natural resources on a sustainable basis from the park by local communities. To ensure sustainable harvesting, Ezemvelo KZN Wildlife established a Resource Utilisation Operational Management Plan (Hanekom et al., 2008). The aim of this document was to reinforce and formalise the management actions relating to resource use within Tembe Elephant Park, which have been in place since the proclamation of the protected area in 1983.

Despite these restrictions, large sections of peat in the Muzi Swamp (to be surveyed under the current project) were exposed to sub-surface fires on three occasions between 2013 and 2017, which entered the park as arson fires from communal lands outside. The most recent sub-surface fire was also the most severe and burnt continuously for 18 months. Apart from the loss of carbon into the atmosphere, large areas on the surface of the peatlands remain bare of vegetation. Many of the common reeds (***Phragmites australis***) that are growing in the wetland are smaller in height and less dense than the reed stands observed in the past. In order to understand the hydrology of Muzi Swamp and how the sub-surface fires have impacted its hydraulics, the project team has installed a series of wells and piezometer nests as well as DFM moisture probes on site.

To assess the consequences of these peat fires on local communities, several reed cutters who mainly harvest reeds (***Phragmites australis***) and sometimes grasses and sedges from the Muzi Swamp were interviewed in September 2020 to understand the role that reed harvesting has in their lives and how the peat fires have affected them directly. The interviews took place on 8 and 9 September 2020 at the KwaMsomi gate, which is the most active of four access control gates for reed cutters.

Tembe Elephant Park regulations control where and when they are allowed to harvest reeds. Reed cutters are restricted to 35 people per day at KwaMsomi and must carry their harvested resources out of the park on the same day, to allow for monitoring of each day's harvest. Harvesting is also limited to six months a year (1 April to 30 September) from Monday to Friday up to around midday. We interviewed 22 reed cutters who were

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divided into five groups (ranging between 3 and 5) as they were not comfortable to be interviewed individually.

The group of reed cutters was composed entirely of women aged between 28 and 61 (averaging about 50 years old) from five wards around KwaMsomi. Some of the respondents have been harvesting reeds in the Tembe Elephant Park for as long as 45 years. A few were born on the land before it was a protected area, and have been harvesting reeds since they were little girls. The women travel an average of two hours on foot, to and from the park, during harvesting days, and walk around an hour to where they harvest the reeds within the wetland.

Reeds and sedges are harvested using bush knives and are bound into bundles or batches using rope made from sedge leaves, also collected from the wetland, that are woven together. Reed bundles are sold for between R15 and R30 each, depending on the length and quality of reeds, and are bought by local community members for construction and thatching purposes. In a good month the reed cutters can make up to R400, whilst in some months not a single bundle is sold. The money generated from the sale of the reeds is for many reed cutters the only source of income for their households, which range from 4 to over 10 people (averaging about 8). Although gumboots are needed to walk in the wetland, only three of the respondents had such boots as the rest could not afford them.

When asked about the peat fires the reed cutters said that whilst they did not feel physically threatened, they feared for their livelihoods as the sub-surface fires were burning the roots (i.e. rhizomes) of the reeds. It concerned them as to why the fires took so long to die out and why they were so difficult to extinguish. For these reasons, the peat fires are seen as a mystery amongst locals. They also reported that as a result of these fires, the reeds do not grow anymore and that grass has taken over. When asked what would happen if the wetland ceased to exist, the reed cutters said that it would lead to extreme poverty, whilst some even said that it would lead to death.

The reed cutters went on to explain that the Muzi Swamp in Tembe Elephant Park is the only wetland in the region where reeds still grow, although the reed beds have been severely degraded. A majority of them believe that the degradation is caused by the wetland drying out due to the plantations adjacent to the park that use large amounts of water. Some were under the impression that the game in the park consumed all the water in the wetland and that the park pumps the remaining water into a waterhole for the animals. They also acknowledged that the drought in the area has dried out all local open water sources and that they buy their potable water from neighbours who have installed boreholes on their properties.

Reed cutters who were interviewed in September 2020. Credit: AT Grundling

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Apart from the Muzi Swamp being the only permanent water source for Tembe Elephant Park, and essential for its existence, the reed cutters confirmed how important the wetland is for them to sustain their livelihoods, and what the potential consequences of additional peat fires could mean for them. Urgent interventions are therefore required and the ARC is grateful to the WRC for making funding available to better understand peat fires in South Africa. Whilst the best solution for sub-surface peat fires would be to mitigate against them occurring in the first place, the fact of the matter is that they have already occurred and, given the dry state of the peat in Muzi Swamp, are likely to occur again in the future. Upon the completion of this research project the ARC hopes to have determined how such fires affect the functioning of peatlands, and what can be done to these ecosystems to restore their function.

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URBAN WATER MANAGEMENT

Managing natural surface runoff water and exercise

Handré Brand, retired psychologist, shares an interesting case of managing water as a plot owner.

Water being distributed to the surrounding shrubs.

According to the Latin phrase ***adastra per aspera***, it is possible that something better could develop from a difficult or delicate situation. Unexpected future positive outcomes can result from current unpleasantness.

At the time (January 1980) when we bought our property, which is located on a downwards slope in a crescent with a street front, natural surface rainwater flowed freely from the four adjoining plots higher up in the area over our garden area, especially in the winter months. It made a natural turn followed the slope and thereafter the stream moved across my neighbour's plot towards the street.

The flow of the water was nowhere artificially directed or channelled. It flowed spontaneously down the slope, with the shortest logical route down the street and the municipal storm water drainage system. Twenty years later, my neighbour next door sold her property and circumstances changed drastically. A solid brick wall was installed on the boundary line by the new owner. The result was that the natural flow channel of the surface groundwater was disturbed and our plot was consequently converted into a potential stormwater catchment area. The diagram below, according to Kane (2012), explains how run-off rainwater flows on a slope very efficiently.

Before buildings are erected on a plot, the interflow is stronger compared to the surface and base flow. As improvements are made in the form of physical structures, the natural surface flow increases proportionally to the intermediate and base flow that flattens out. Before construction takes place, trees, plants and the natural soil surface absorb a large percentage of the surface water, and the runoff is consequently limited. After construction has taken place, the absorption capacity of the surface is significantly reduced. As a result, the surface runoff increases,

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which poses a significant risk of flooding for adjacent plots lower 'downstream'.

Environmental assessments by municipal engineers and the preparation of stormwater management plans can prevent and eliminate this type of problem situation. In our case, however, we were dealing with an existing scenario. All properties were existing structures already completed during the seventies. However, the new boundary wall, which was legal and permissible according to municipal regulations, created an unforeseen natural surface water run-off problem.

I immediately visited the four adjacent neighbours where the natural runoff originated, explained the situation and everyone kindly agreed to contribute financially to install a channel and underground pipe system on our plot to direct the run-off surface water in the direction of the street's storm water drainage system. The surface water problem was thus solved through sober, open communication and good neighbourliness.

The Western Cape, with its dry summers and sporadic rain showers during winter, makes one think twice if a fast-flowing and healthy stream of surface water flows over your garden area from time to time only to disappear into the street's storm water pipeline. This is clearly an untapped potential water source.

The result was that a groundwater catchment dam (length 3 metres, width 2 metres and depth 1.5 metres and approximately 9000 litre capacity) was built in the flow channel of the water, with the overflow or outlet (11 cm in diameter) opening back into the underground channel so that the surplus water can flow out to the street. An Italian DAB pump, which drains almost all water carefully and delicately from the concrete floor of the catchment dam, was connected to different lengths of garden hoses and thus the water is distributed to strategic points in the garden.

The 'storage containers' to which the water is pumped from catchment dam consist of four 240L wheely bins. The containers are placed at four strategic points in the garden from where the water is distributed to the surrounding shrubs by means of two watering-cans, or a sprinkler (Photos 2 and 3).

Before the run-off rainwater ends up in the catchment dam, sand grains and other items with weight such as small stones are first deposited in two sand traps or wells.

The following remarks are important to ensure the success of this system:

- Careful supervision and continuous management of the process, as well as of the water quality is extremely important.
- No municipal regulation may be violated in the process.
- The right amount of chlorine must be applied during the winter months to guarantee the water quality over a long period of time. However, the chlorine content of the water should be zero immediately before application in the garden in summer. The water should not contain any chlorine before application to plants, lawns, shrubs and trees. The regular expert testing and analysis of surface groundwater collected and stored in this way is therefore strongly recommended.
- There are also other excellent disinfectants (e.g. Biodox) available on the market that contain natural antimicrobial ingredients, and can be used well to purify wastewater in such a reservoir.
- The groundwater collection dam is regarded as an additional water source to roof water. The latter is normally is collected by means of gutters from where the flow is directed to upright water tanks. If the average inflows are compared the catchment dam inflow is much faster than the roof inflow. This has the advantage that the catchment dam can regularly (also during the winter) be emptied and the water can be used for all kinds of diverse purposes (e.g. washing cars, flushing toilets), while the roof water in separate tanks can be stored as an additional precious commodity for the hot summer months.
- Mosquitoes are controlled by covering the catchment dam with fine graded shade net. The cement floor is regularly cleaned with a hard yard broom after the catchment dam has been pumped empty.
- During the summer months, the rainwater of the catchment dam, which is pumped to the four wheely bin containers, is used by means of the two watering-cans to water orchids, shrubs and trees in the garden as well as the plants on the pavement. The weight of the water in the watering-cans and the distances over which this weight is carried serve as an excellent additional and collaborate exercise to hiking and mountain biking.

Water should always be seen and managed as a scarce and precious resource and commodity. As explained in this article, the management and storage of both surface and roof water is an activity that can add value to any property. If physical exercise can be combined with this process as an additional outcome, the whole undertaking makes so much more sense and also contributes to personal wellness.

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BEERVLEI – THE DAM THAT IS MEANT TO BE EMPTY

DWS

Cutting an odd picture on the landscape is Beervlei Dam, which is empty most of the time. Few people realise, however, that it is meant to be so.

This flood control dam constructed on the Groot River near Willowmore was completed in 1957.The multiple arch dam stands 31 m high from its lowest foundation and has a crest length of 348 m. The dam has a gross capacity of 100 731 million m^3. Interestingly, due to the high mineral content of the water entering the dam, a super sulphated cement was imported from Belgium and used in the preparation of concrete for the dam.

During the construction of the dam in the mid-1950s it was government policy to make use of convict labour on government infrastructure projects. Thus, around 400 prisoners worked on the dam. They were housed in a large prison labour camp constructed at the site.

Any flood water entering the dam is used as quickly as possible by irrigators downstream, and the reservoir is kept empty for extended periods.

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