WATER AND TECHNOLOGY

New technology to transform water quality testing in South Africa

A new technology that will take the specialised task of water quality testing from over-burdened laboratories to field testing sites countrywide is being developed at the Water and Health Research Centre (WHRC) of the University of Johannesburg (UJ) with funding from the Water Research Commission. The innovative equipment is expected to deliver near-instant results and expand the spread of water resources being monitored. The equipment includes a mobile water testing facility with supplementary drone technology and state-of-the-art digital bacterial water quality testing probes. Petro Kotzé reports.

The project could fill a serious gap in South Africa's water resources management. Monitoring and assessment of the quality of water resources are critical to determining if they are suitable for various uses, including for drinking and personal use, and the country's national monitoring programmes monitor raw surface water quality in rivers and dams for trends in, for example, chemistry, eutrophication, microbiology and ecosystems. Spot tests also need to be conducted if there are any concern, for example, when sewage treatment works fail or chemical spills occur.

However, there is currently a huge backlog in water quality testing, and results are often only available after anything from three weeks to six months. Among the many implications is the health risk to water users, who might still use contaminated water due to a lack of test results that indicate any danger.

It is a serious concern in South Africa. According to the 2022 Green Drop Report, more than a third of wastewater treatment works (334 or, 39%, out of a total of 955 systems) are classified as critical, with one of the greatest concerns being that treated effluent is not meeting the required discharge standards, particularly regarding bacteriological parameters. This can have serious consequences for the health of users and the ecosystem downstream. According to the World Health Organisation, some of the water-borne diseases that pose a high risk to South Africans include gastroenteritis, cholera, viral hepatitis, typhoid fever, bilharziasis and dysentery. Outbreaks of waterborne

diseases have already led to the deaths and hospitalisation of hundreds of people over the past two decades and more recently due to cholera oubreaks in Hammanskraal, Pretoria. (see sidebar). More challenges, over and above the long turnaround time for test results, are the limited sites covered by the national monitoring programme, and that the data that is generated is not being stored on a central database for access by all water users.

"Our water resources are not being monitored as robustly as they should," says Yazeed van Wyk, Research Manager at the WRC. Van Wyk says the current project is one of many that form part of a framework to improve data collection and availability across South Africa, as part of the larger service that the WRC is delivering to the Department of Water and Sanitation. Another project, for example, is the development of a mobile application (app) that will allow ordinary citizens to add borehole locations and characteristics to a database for groundwater monitoring (refer to ***App for hydrocensus and groundwater monitoring – A citizen science approach***, published in The Water Wheel January/February 2023 edition, Visit: https://bit.ly/3pTTe4r).

The current study is a multi-institutional collaboration between UJ and Stellenbosch University (SUN) local startup company Drobotics and LS Telcom, each of which contributed a unique specialty to the product development.

A technology that amalgamates expertise

The seed for the project was already planted years ago, around 2004, says project leader Dr Kousar Hoorzook, currently the Programme Manager for water quality and management at UJ Process Energy Environment Technology Station (PEETS). As a post-graduate biotechnology student conducting research at UJ WHRC, she made several trips with her research group to rural Venda in Limpopo Province to collect samples to test for ***Escherichia coli*** (***E. coli***) and various other waterborne pathogens. Her Master's and Doctoral projects, supervised by Prof Tobias G. Barnard at the WHRC, focused mainly on ***E. coli,*** which is a bacterium that causes diarrhea and is found in faecal contaminated water sources.

The many sampling site visits entailed the laborious process of packing up the necessary laboratory equipment and travelling with it over long distances to their research base in the rural areas where they had to get water samples from. Often, Hoorzook remembers, this was an empty hut found in disarray, that first had to be thoroughly cleaned before they could start. The team members stayed there for weeks at a time, traveling to waterbodies or homes to gather sources to sample and analyse. They then had to return with their equipment and samples to the university's registered laboratory for further analysis. Hoorzook's experience is not uncommon. There are only a handful of registered laboratories across the country that can analyse water samples, all of them located far away from rural areas where water users are often most at risk.

The situation led to Barnard and Hoorzook coming up with the idea to build a mobile water testing laboratory, so the work that had to be undertaken back at the university's laboratory could be done on site, and the results be available within 24 hours. However, at the time the idea did not gain much traction. From 2004 to 2017, Hoorzook wrote business plans and tried to secure funding, but without luck. Then, with new people that had new ideas in the organizations, the mobile lab's potential was recognised by UJ Technology Transfer Office (TTO) and the Technology Innovation Agency (TIA). Thirteen years after they first speculated about its development, the lab, designed by Hoorzook, Barnard, Director of the WHRC at UJ and industrial designer Robin Robertson, could be built.

All photographs supplied

Project team members from University of Johannesburg Water and Health Research Centre, Drobotics, LS telecom and Stellenbosch University.

The mobile laboratory, UbuntuBlu.

The lab has high road clearance and is towed by a 4x4 vehicle. It can be parked on-site for several days at a time, and allows analysis to start immediately and continuously, without needing to travel back and forth between accommodation and a fixed laboratory in a city. It also includes a side tent for accommodation.

The mobile lab can run all basic analyses necessitated by the South African national standards for drinking water quality, including ***E. coli*** and other bacteria that cause dysentery, typhoid fever and cholera. It runs sample fridges and incubators, analysis equipment and air-conditioning on solar panels, a generator and batteries and carries its own safe water supply. It can also be customised for different types of equipment for different types of analyses.

The lab could thus be a cost-effective option to monitor not only water bodies or rural water supply, but also anything from water treatment plants, schools, clinics and hospitals. It could be used by municipalities that do not have access to accredited laboratories close by; academic institutions without laboratories, where researchers would like to start working in aspects related to water quality; and areas with waterborne disease outbreaks located far away from testing facilities. The labs could also help to create research networks to increase the available water quality data.

Now, the new project is taking the idea much, much further, to expand its reach and efficiency and potentially make an even larger impact on the country's water quality monitoring and testing.

Up, up and beyond

The mobile laboratory is now being upgraded and packaged as a unit with drone technology (from Drobotics) and digital biosensing probes (developed by SUN) through funding that Hoorzook jointly applied with Drobotics and SUN, received from the WRC while doing her Postdoctoral Fellowship at the WHRC in 2022. The specialised drone is fitted with a winch lift system and can submerge digital probes directly into the water that needs to be tested. The probes can test for bacterial and physio-chemical content in water. The data will be sent from the digital sensor probes to the drone winch to the mobile laboratory in real-time via Wi-Fi.

In total, the Integrated Mobile System comprises a UJ designed and developed mobile laboratory, UJ designed and developed water sampler, Drobotics winch/hoist, jig and real-time communications system, LS Multicopter owned and operated Matrice 600 PRO drone, SU designed and developed water bacteria testing biosensor, and off the shelf chemical and heavy metal digital test probes.

The technology can deliver water quality test results in near real-time from geo-referenced recorded test locations to the mobile laboratory to the cloud to a dashboard. The platform can carry out drone launches for water sampling operations and includes optic lenses for photogrammetry, LiDAR, thermal and hyperspectral applications for real-time surveys, security and to inspect the scope of activities. The expanded opticgammetry scope can be expanded more for the detection of physical pollutants in water through computer deep learning generated analytics interpreted hyperspectral imaging.

The technology has many benefits, van Wyk says. For one, drones can cover much larger areas of water bodies very quickly and efficiently, reducing necessary time and resources. More remote waterbodies, difficult to access by people, can also be reached. Not only is the technology more efficient than sending out people to take samples, but it promises improved accuracy and precision. The novel biosensors can provide accurate, very precise measurements of water quality parameters with very, very limited associated uncertainty, van Wyk says. "That reduces the risk of errors." By removing the human element, we are getting more reliable data," he adds. Another benefit is the turnaround time. "The results are available almost immediately." The improved efficiency will result in a massive improvement in our resilience to water quality challenges, he says.

The project is set to end in March 2024 and Hoorzook says their product is already 70% there. A provisional demonstration of the system was carried out at UJ Island at the Vaal Dam in March. The following was successfully demonstrated: the jig attached to the winch, simulating water quality test applications in operational offshore environment; real-time communications through onshore connection of the Stellenbosch communications device to an on-board computer to laptop; and, successful flight operations within an operational offshore environment to simulate the launch of digital probes for water quality testing applications of the attached winch and jig system and sampling operations to and from predetermined GPS points.

Before the development of the mobile laboratory, specialised equipment had to be transported from laboratories in town to available facilities close to testing sites – a laborious process.

Students clean a hut they have to work from during field trips to Venda in the Limpopo Province.

A major demonstration of the full, integrated system is scheduled for July, to also test the following: conventional water quality test applications; digital water quality test applications; drone-supported water sampling operations; aerial photogrammetry applications; and real-time/near-real-time results (from the probe to the winch, the mobile lab and to the cloud).

Future solutions lie in research-backed innovation

The national backlog in water quality test results is a massive, serious issue that will not just disappear overnight, van Wyk says but we need to come up with innovative ways to solve the problem or at least, to start generating baseline information. This project is one example of how that can be done.

Over and above that, the new technology will serve as an early warning detection system. We can detect any changes in the water quality that might indicate a problem before it becomes a major issue, he says. "Early detection can allow us a quick response time to prevent further damage to the water resources and minimise the impact on human health."

The new technology includes a drone that is fitted with a winch and jig system to house chemical bacterial probes to test for certain quality-related parameters.

The importance of water quality testing to prevent death and disease

In 2000 and 2001, an unexpected cholera epidemic that broke out in KwaZulu Natal resulted in 114 000 people infected and 260 deaths. The communities at the epicentre of the epidemic experienced constant interruptions to their piped water supply and reverted to traditional water sources, which were contaminated. The primary route for the epidemic's rapid spread through northern KwaZulu-Natal to the Eastern Cape and beyond appears to have been along catchment areas (according to the South African Health Review 2016).

Since then, there have been more outbreaks of waterborne disease. The first was an outbreak of diarrhoea and typhoid in the town of Delmas in 2005. A lack of well-managed water treatment, particularly chlorination, was identified as a significant causative factor. The second outbreak, in uKhahlamba District in 2008, involved the contamination of drinking water with E. coli following the breakdown of the local wastewater treatment plant. The outbreak was reported to have led to the death of 78 infants.

In 2014, following violent protests against municipal failure to fix broken sewage pipes at Bloemhof, an E. Coli outbreak led to the widely reported infection of over 200 people and the deaths of at least three babies (some reports state the number as high as 18). The same year national media reported on the death of more than eleven infants at Biesiesvlei, close to Sannieshof, due to diarrhoea linked to contaminated water from failing sewage infrastructure. At the time of writing, investigations were continuing to determine the source of a cholera outbreak in Hammanskraal, in May, which killed at least 22 people.

Source: The South African Health Review, 2016, published by the Health Systems Trust