BIOMIMICRY

Turning to nature to solve modern day problems

A Water Research Commission project has been piloting a nature-inspired sustainable and ecological wastewater treatment system in Langrug township in the Western Cape. Article by Petro Kotzé.

Photo supplied

As populations grow and settlements expand, the landscape is rapidly changed and increasingly modified to accommodate people. Green areas are replaced with grey infrastructure, and necessary natural resources, such as water and soil, are polluted, impacting the wider environment. Grey infrastructure developments require expert knowledge to construct and maintain, are vulnerable to natural disasters and fluctuating climatic conditions and can create bigger problems should they fail.

In many parts of the world, engineers are now looking back to nature to build resilience into designs for more sustainable solutions. Incorporating plants and other natural elements into infrastructure have been proven to have many benefits in comparison to traditional building methods. Construction material is often cheaper, can create added benefits to communities, such as fodder and thatching, increases in strength over time, and is easier to maintain – a plus for local residents in difficult-to-reach places. Knock-on benefits are improved local biodiversity and a more beautiful landscape.

There are various terms for this movement, but bio-inspired is one, sometimes used as an umbrella term for design approaches that use biology as a resource for solutions. There is a broad range of applications, from those copying biological processes, to others simply incorporating nature into the design, and a combination of almost everything in between. This is according to Biomimicry South Africa founding director, Claire Janisch. The

Before wastewater created uncomfortable and unsanitary conditions. After installation of the disposal points, the impact of the project on the surroundings were soon clear.

Conditions in the Langrug settlement visibly improved after installation and construction of the project.

Western Cape Government

organisation defines biomimicry as "the practice of learning from and emulating nature's genius to create products, processes and systems that are sustainable and resilient – even regenerative". As a formal profession, biomimicry only emerged in the last 15 to 20 years, but the practice of individuals or communities looking to nature for inspiration has been around for centuries, she says.

The concept is growing in recognition in South Africa too, one example of which is an ongoing project in the Western Cape piloting the application of biomimicry to treat heavily polluted wastewater. A WRC-funded project monitored and evaluated the treatment system, and found the technology to have substantial potential to improve service delivery and quality of life in areas in South Africa where it is needed most.

An novel approach to service delivery

Langrug is an informal settlement located on a mountain slope in scenic Franschoek, outside of Stellenbosch. The settlement was established in the 1990s, when migrants from the Eastern Cape flocked to the area for job opportunities in the surrounding wine industry. Though originally established illegally, the municipality has since provided basic sanitation services, such as toilets and taps. Some of these have broken or fallen victim to vandalism, resulting in even fewer assets where those available were already stretched to the limit. Reports indicated that by 2011 about 10% of the 91 toilets were out of order. The Community Organisation Resource Centre reported in 2012 that there was one toilet for every 50 people in Langrug.

Sewage is not the only challenge here. Langrug residents have to collect water from communal taps. Residents use water extremely efficiently, and water is usually used multiple times before it is discarded. The resulting highly-concentrated greywater flows down a matrix of unsanitary channels, delivering the untreated wastewater to the bottom of the hill, and into the Berg River.

The impact of these challenges at Langrug reverberate much further afield. Water from the Berg River is used to irrigate orchards and vineyards, the products of which are also meant for exports. The potential economic impacts, the declining state of the river, and the social circumstances at Langrug made the settlement the ideal area to pilot a sustainable and ecological wastewater treatment system.

Cleaning wastewater with nature's helping hand

The project is a partnership between Biomimicry South Africa, John Todd Ecological Design (JTED), Greenhouse Systems Development, Maluti GSM and Isidima Design and Development. The system constructed at Langrug, which treats greywater from the source to eventual disposal into the river, is part of a project funded by the Western Cape Government, called the Western Cape 110% Green Initiative. The Biomimicry Genius of Space system in Langrug is a flagship of this project. Due to unexpected delays, a section of this system (which provides final treatment) was not completed in time for the WRC funded study, resulting in monitoring and evaluation of a similar system, treating water of a similar quality, built on the Plankenbrug River in Stellenbosch.

The Langrug system serves 115 households in two blocks of the settlement. Greywater is collected at disposal points serving about five households each, explains Jonny Harris, founder and director of Isidima Design and Development. A filter removes

solids like tissue paper and food scraps, before the water is led through a narrow, flexible pipe, allowing it to curve around the bends and turns of the surrounding infrastructure. Along the way, small gardens have been constructed, which are actually micro-wetlands that provide biological filtration and maintain an aerobic condition. The water is then led to a series of tree gardens. As each tree bed becomes saturated, water overflows into the next. The deep pit tree wells purify the greywater through absorption, decomposition and microorganisms and fungal communities. Nutrients and organic material are removed from the greywater and converted to humus, allowing purified effluent to infiltrate back into the ground.

In the process, the tree garden and sewer system feed off the water and nutrients, creating a sustainable green corridor through the settlement. Over time, the system will leave behind a network of deep planted tree wells with rich, high-carbon soils.

Results indicate that biomimicry systems could treat polluted effluents similar to that of Langrug to a quality that complies with the general authorisation limits for the discharge of treated effluent back into the river.

Tree pits just after installation at Langrug informal settlement. In a couple of decades these will be a outstanding feature of the settlement landscape, while still serving as a wastewater management system.

From here, the water is treated in a system based on biomimetic and ecological design principles. The design is based on the EcoMachine concept developed by Dr John Todd, and relies on biodiversity and natural processes to create mechanically simple but biologically complex systems to treat contaminants and human waste streams. In a nutshell, nature is employed to clean wastewater.

The EcoMachine consists of multiple cells divided into three trains. Within each of the cells, all five kingdoms of life are represented, from microbes, bacteria and fungi to higher life forms such as snails and fish. Combined, these organisms work together to metabolise, degrade and sequester organics, pathogens and heavy metals from the wastewater.

To the naked eye, the cells are "beautiful, robust water gardens". Anaerobic digestion, aerobic digestion, nitrification and denitrification are all microbial processes that take place within the solar aquatic cells – a series of cells through which effluent is treated by mimicking natural water purification within wetland ecosystems. Microbial films grow on a mass of suspended solids and plant roots (flocculants). Nitrification occurs in the biofilms which attach to the media. Phosphorus is removed through luxury uptake by bacteria. Pathogens are reduced due to predation by zooplankton and animals, and heavy metals are accumulated in the attached algal biomass that forms on the sides of the tanks.

Initial performance indicates great potential

The pilot greywater filter system was completed in September 2016 and initial observation and water quality tests confirmed that highly-polluted greywater is effectively being separated from stormwater. This water can successfully be used to create green space within the informal settlement.

Secondly, the tree gardens were successfully reducing the greywater flows from the prototype system. As was expected at the time when the study report was written, the water was only treated minimally throughout the system, but it did prevent solids from entering the pipes and causing obstructions. At the time of writing, the EcoMachine had just been commissioned downstream of Langrug to treat water flowing into the Stiebeul River, which is heavily polluted by urban run-off from Langrug and the neighbouring Groendal community. The successful testing of this system will demonstrate the completion of the greywater treatment train to collect polluted greywater, use this to promote greening within the community and then further purify this water so that it can used to sustain urban agriculture and other forms of beneficiation, says Harris.

This has been proven by the results from water quality tests conducted at the treatment system installed at the Plankenbrug River. Results indicate that biomimicry systems could treat polluted effluents similar to that of Langrug to a quality that complies with the general authorisation limits for the discharge of treated effluent back into the river.

According to the final project report, the water quality samples taken at Plankenbrug have confirmed a 99% reduction in the ***E. coli*** through the system from greater than 10 million ***E. coli*** per 100ml to 4 700, with effluent concentrations reaching as low as

One of the greywater disposal points in Langrug settlement.

16 ***E.coli*** per 100ml for lower flow rates. A comparable reduction in Ammonia and chemical oxygen demand (COD) was also observed.

The project team found that indigenous ecologies performed the treatment functions well. "For obvious reasons, we did not want to use invasive plants like water hyacinth," says Harris. Based on their initial findings, the use of indigenous ecology has certainly proven to be promising and enable the required treatment performance.

Elements that contribute to the successful pilot run

This process was, and continues to be a learning experience, says Harris, but a number of promising aspects have already been identified that could be repeated at different sites in future. The project was designed, for example, in close collaboration between the project team, the community and government, and developed with the use of rapid prototyping.

"We could visit the site with concept drawings that would change and develop over time," Harris notes. "This is very unusual for a project, but we could follow this approach because we had Stellenbosch Municipality and the Western Cape government on board. This co-design process contributed greatly to the success of the project."

Community involvement is highlighted as another element of success, and is reported as the base of the necessary building blocks. Janisch says that this was a question that they wanted to answer when they started the pilot project – whether you could have community involvement throughout the project, and for maintenance of the system. To help facilitate this, the community was engaged throughout the process, explains Harris. Community members provided valuable input to the initial design of the project, and were provided employment to construct and maintain the system. "They could do this with relatively little external support," he says.

Social buy-in required a conscious commitment from the team that implemented the system, and time to allow for the benefits to transpire, adds Harris. The Langrug community realised that the project team was serious as time progressed and they remained committed to the project. According to Harris, the immediate benefit of local employment also helped to gain community support, and the project was purposefully designed to be labour intensive to facilitate this. The social component turned out to be a huge part of the overall process, says Janisch, which added another layer of complexity to the project.

A return to green from grey

Harris says that the system has proven to have many promising benefits to informal settlements. In terms of service supply – if you are working in an area where there are currently no treatment systems, any system is better. However, a 'green' option such as the pilot system also requires minimal energy input, and can work in the absence of mechanical parts. Maintenance is thus prompt, straightforward, and much easier than for conventional treatment systems.

At Langrug, maintenance can be conducted at community level, by the community members. This is partly because, says Janisch, maintenance for a living system, such as this for project, becomes a gardening more than an engineering activity, for which technical expertise is necessary. She adds that they were told that the involved community members had shared the project with another community, which is part of the proof of how much they see the benefit in it. And further into the future, 20 to 50 or so years from now, the face of Langrug would be improved much by the presence of the big trees.

Just as importantly, Janisch says that the project team were allowed to, and were able to push new boundaries, with innovative thinking.

Challenges to moving forward with the broad scope of bioengineering applications are, however, still ample, she says. Traditional building standards, laws and norms are some. Successful application of such systems also necessitate technical expertise often across multiple disciplines. And, the implementation and maintenance of the system is hugely dependent on social support, often just as necessary or even more than technical know-how.

Janisch reports that as they are training more young professionals, and getting more biomimicry systems incorporated into projects, familiarity and support are already increasing. Really, she says, we cannot simply look at conventional solutions any more. For a more sustainable future, one in which nature is part of the solution "we have to change the way we think."