SANITATION SYSTEMS
WHERE THE SEWER DOES NOT GO

Decentralised wastewater treatment systems (DEWATS) are the sweet spot between waterless on-site sanitation and conventional sewers with centralised wastewater treatment. Bremen Overseas Research and Development Association (BORDA) has been partnering with eThekwini Municipality to pilot and implement DEWATS wherever a wastewater processing solution is needed. **By Kirsten Kelly**

"DEWATS is an approach rather than a technical hardware package. With DEWATS, the system must be adapted to suit a specific context," explains Lloyd Govender, project engineer, BORDA SA.

The standard system is independent of electricity and chemicals (but can be modified to use both) and is easy to install. DEWATS is also tolerant towards inflow fluctuations. It can treat between 1 m^3/day and 1 500 m^3/day of wastewater.

"The aim is to keep the construction of DEWATS simple. When disseminating information, there should be basic diagrams and all construction materials should be as generic as possible – easily found at any hardware store. This helps in ensuring all DEWATS parts are readily available for construction and maintenance," adds Govender. BORDA has worked out that DEWATS needs 1.5 m^2 in space per person. They have successfully reduced the size of the system every year through continuously assessing their current system.

The global NGO has worked with eThekwini Municipality for many years to exchange knowledge and build capacity in the water and sanitation sector. They advise on innovative technologies and the local implementation of DEWATS, while funding student research and projects.

While South Africa has strict wastewater discharge limits, DEWATS can be modelled to achieve different discharge criteria. Additional mechanisms can be added like ultraviolet disinfection or chemical treatment with chlorine.

Settler

The first stage is the settler, or septic tank. This consists of a minimum of two, sometimes three, compartments. The settling chamber allows for the wastewater to settle first, where scum is formed at the top and heavy particles sink to the bottom. A grease trap can also be used in the settler.

Lloyd Govender, project engineer, BORDA SA

DECENTRALISED PLANTS

Wastewater will flow through the first chamber and solids will settle, with the rest of the wastewater flowing up and down from one chamber to the next. This extends the retention of solids, achieving better treatments.

The second chamber is usually half the width of the first compartment. It contains only a little sludge, which allows for the water to flow without disturbance from rising gas bubbles. Two treatment principles – namely the mechanical treatment by sedimentation and the biological treatment (sludge digestion) by contact between fresh wastewater and active sludge – are taking place. Optimal sedimentation occurs when the flow is smooth and undisturbed. Biological treatment is optimised by quick and intensive contact between new inflow and old sludge.

As the settled sludge passes through the system, it sinks lower. The wastewater particles that are not heavy enough to sink move to the anaerobic baffled reactor. The inlet and outlet have a t-pipe, preventing blockages. The outlet should be about 20 cm lower than the inlet.

DEWATS usually achieves a 20% to 30% biological oxygen demand (BOD) removal efficiency. Desludging is necessary every one to three years and can be achieved with a vacuum truck or something similar. Dissolved and suspended matter passes untreated to the next stage.

Anaerobic baffled reactor

This is a usually a precast concrete block chamber because it is difficult to steal and cannot be sold for scrap. The baffled reactor consists of a series of chambers designed to increase the path taken by particles from the time they enter the inlet and leave at the outlet.

"Initially, we designed an ABR with seven chambers, but it was found that three or four chambers are all that is needed," adds Govender.

Suspended and dissolved solids in the pre-settled wastewater undergo anaerobic degradation. The activated sludge settles down at the bottom of each chamber and the influent wastewater is forced to flow through this sludge blanket where anaerobic bacteria make use of the pollutants for their metabolism. Progressive decomposition occurs in the successive chambers.

A part of the last chambers can optionally be filled up with coarse filter material like stones, cinder or plastic rings. The filter material acts as carrier material for an attached biofilm, consuming the organic water pollutants. That kind of reactor is called combined ABR. In ABR plants, the pathogen reduction ranges from 40% to 75%. The baffled reactor is resistant to shock load and variable inflow. It operates by gravity and maintenance is reduced to desludging of the chambers at intervals of one to two years. Subsoil construction of the module saves space.

"Key design parameters in the ABR are the retention time, number of chambers, temperature and the outflow velocity. The ABR can achieve up to 95% of BOD removal," states Govender.

Biogas digester (BGD)

DEWATS allows for the utilisation of biogas, especially in combination with concentrated wastewater streams. To become economically viable, biogas should be used regularly and purposefully directly at site.

By using BGDs, approximately 200 litres of biogas can be recovered from 1 kg of COD (chemical oxygen demand) removed. On household level, this requires 2 m^3 to 3 m^3 of biogas per day for cooking, meaning 20 m^3 wastewater with BOD of not less than 1 000 mg/ℓ is required to serve one kitchen. In order to get strong substrate from domestic wastewater, flow stream separation from toilets and less concentrated greywater are recommended.

Biogas plants are designed as half-ball shape, made by bricks and integrated into the ground. Incoming wastewater is separated into liquid and solid phases, and organic solids are biologically digested.

Processes take place without oxygen input under anaerobic conditions, generating biogas useful for cooking, light and heating.

However, Govender notes that there are instances where BGD components are stolen and sold for their scrap value.

"Also, one has to consider the infrastructure required (and its maintenance) for biogas storage and usage. For example, if the biogas generated by 10 families can only be used by one family, how would one decide which family can use it? In these circumstances, biogas must be used for communal lighting and heating."

Anaerobic filter

The anaerobic filter, also known as a fixed-bed or fixed-film reactor, includes the treatment of non-settleable and dissolved solids by bringing them into close contact with a surplus of active microbial mass. 'Hungry' microorganisms digest the dispersed or dissolved organic matter within a short retention time. It is designed based on the amount of wastewater received per day.

Most of the microorganisms are immobile; they attach themselves to solid particles or the reactor walls, for example. Filter material – such as gravel, rocks, cinder or specially formed plastic shapes – provides additional surface area for them to settle. The material needs to be non-porous and between 3 cm and 6 cm in diameter. By forcing the fresh wastewater to flow through this material, intensive contact with active microorganisms is established – the larger the surface for microbial growth, the quicker the digestion.

Comprising two chambers, the anaerobic filter forces the wastewater to flow upwards.

Mechanical siphon

In order to achieve a system that is independent of electricity, a mechanical siphon is used for the distribution of wastewater from the collection chambers on to the constructed wetlands. This is achieved by using the principles of buoyancy. While this type of pump is available in Europe and the US, it was decided that it should be designed in Africa, to ensure readily available parts.

BORDA, together with Partners in Development, began the design and testing of a mechanical siphon in South Africa for use on the Banana City DEWATS in KwaZulu-Natal. Designed with easily accessible materials (steel and plastic) that are found in any hardware store, the mechanical siphon can achieve a flow rate of over 60 ℓ/s. The design of the pump is available to the public and does not have any intellectual property rights attached to it.

Constructed wetlands

"DEWATS can have two types of wetlands – vertical flow, where wastewater will flow vertically from the top, and horizontal flow, where the wastewater flows across the wetland," explains Govender.

The wastewater is pumped into two constructed wetlands, with each wetland designed to treat to the necessary COD limit. Both aerobic and anaerobic conditions are used to treat the nitrogen compounds, pathogens and organic pollutants. The wastewater is then discharged to an outfall structure that prevents soil erosion.

Planted gravel filters are suitable for wastewater with a low percentage of suspended solids that have already been removed by pre-treatment. The main removal or treatment mechanisms are biological conversion, physical filtration and chemical adsorption. In the case of planted gravel filters, the bottom slope is 1% and the flow direction is mainly horizontal in agricultural systems and vertical in environmental discharge systems.

The gravel filter is permanently soaked with partially treated wastewater and operates as partly aerobic, partly anoxic and partly anaerobic. It combines physical filtration processes and the influence of plantation (on the biological treatment process and oxygen intake). The BOD reduction rate is 75% to 90% and

BORDA – BREMEN OVERSEAS RESEARCH AND DEVELOPMENT ASSOCIATION

- An expert NGO specialising in full-cycle decentralised sanitation
- Together with governments, local enterprises and partner organisations, BORDA works on-site to improve communal planning processes, sanitation supply structures and basic needs services. They tackle unsolved sanitation challenges and bring tried and tested solutions to challenging places
- Headquarters in Bremen, Germany, and regional offices in Tanzania, India, Jordan, Thailand and Mexico
- With a network of local partner organisations, BORDA is active in more than 20 countries
- BORDA has been working in South Africa since 2006 to extend the wastewater infrastructure for inhabitants of peri-urban areas
- Focused on projects in new and existing low-income housing developments, informal settlements and schools
- Has partnered with eThekwini Municipality to exchange knowledge and build capacity in the water and sanitation sector, and to advise on innovative technologies and local implementation of DEWATS

pathogen removal rates are high, but dependent on the composition of the incoming wastewater. The operation and maintenance requirements are considered simple.

"Constructing a fence around the wetland adds to the cost of DEWATS, but there is always a possibility that children will play within the wetland or people will use the wetland as a toilet. One can also prevent this from happening through the design of the wetland. Tall or spiky plants can be added to the perimeter. Plants can be used to attract birds and insects and create a habitat," adds Govender.

Constructed wetlands take up a lot of space but you can design them innovatively, which makes a world of difference to the acceptability of decentralised systems.

Community education

"DEWATS is doomed to fail if there is no education on why the system is in place and what it does. A good portion of one's annual operations and maintenance budget should be allocated towards continuous community education. This prevents vandalism and theft, while improving community acceptance," says Govender.

"Sometimes, communities perceive DEWATS as inferior to conventional wastewater treatments. They do not want to see the treatment, but we use education and transform these initial negatives into strengths and positives. Before we lay the first brick on-site, we must have acceptance by the community. Education campaigns teach the community the value of a good sanitation system. We distribute pamphlets, conduct training courses, and transfer knowledge to the community on the importance of not just having a system but practising good personal hygiene. You would be surprised how happy the communities are to receive this form of knowledge," he adds.

These systems are also designed so that local community members can be employed to build and operate them, thus creating a feeling of ownership.

Construction

Different combinations of treatment modules can be used, depending on factors like the required treatment efficiency, costs and land availability.

Making the best use of gravity, DEWATS is placed at the lowest point of the site being serviced. The entire system (except for the constructed wetlands) is underground, and this reduces any smell due the anaerobic treatment. The plants can also block off the smell and the vent pipes are strategically positioned above nose level at the DEWATS site.

"To be sustainable, DEWATS must be low-cost, require little to no water and electricity to run, use locally available materials and bio-based processes and, most importantly, be simple to operate and maintain. Sustainability also requires buy-in and ownership from the local community, as well as policy support from local government. BORDA and its partners design, implement and evaluate decentralised sanitation systems around the world. Our partnerships are leading the way in piloting innovative solutions in the face of increasing water scarcity," concludes Govender.

TABLE 1 Centralised vs Decentralised Systems

	Centralised systems	Decentralised systems
Flexibility	• Difficult to adjust size • Prone to complete system failure • Dimensions have to cater for high fluctuations	• Size adjusted when and where needed • Does need maintenance, but significantly less • Can adapt to flow changes
Cost	• High investment costs • Pumping costs for both treated and untreated wastewater	• Built where needed • Reuse options where needed