PAPER 18

# BRIDGING THE GAP BETWEEN ONSITE AND CONVENTIONAL SANITATION: DECENTRALISED WASTEWATER TREATMENT SOLUTIONS (DEWATS)

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## ABSTRACT

Waterborne sanitation is highly desirable and aspirational for unserved and underserved South Africans; however, the costs and maintenance requirements of a conventional system with extensive trunk sewer networks and numerous pump stations can be prohibitive in peri-urban and rural areas. Waterless onsite sanitation options, such as ventilated improved pit latrines and urine diverting toilets, are less desirable to users than waterborne sanitation (Duncker et al. 2007).

Decentralised Wastewater Treatment Solutions (DEWATS) can fill the gap between waterless onsite sanitation and conventional sewers with centralised wastewater treatment. DEWATS is an innovative, modular approach to wastewater treatment that usually includes an anaerobic baffled reactor and constructed wetlands. By decentralising treatment, DEWATS greatly reduces trunk sewers and eliminates pump stations, reducing cost and maintenance requirements. DEWATS can treat domestic or industrial organic wastewater streams of1 to 1 500 m$^3$ per day without chemicals or energy input (BORDA 2017). Maintenance requirements are low compared to conventional treatment, and operation and maintenance tasks can be carried out by service providers or by supervised and trained maintenance personnel on-site. Due to its modular nature, DEWATS may be appropriate for many applications, including residential, institutional, schools, SMMEs, hospitals, faecal sludge, and emergencies. Various treatment modules are combined and customized according to local conditions. Key benefits of DEWATS include:

- No energy input required
- Relatively simple to operate and maintain
- Tolerant to inflow fluctuations
- Can be placed in or near community
- Minimal equipment with scrap value
- Potential to produce biogas and reuse treated effluent for irrigation

eThekwini Water and Sanitation (EWS), in partnership with the University of KwaZulu-Natal (UKZN) and the Bremen Overseas Research and Development Association (BORDA), constructed the Newlands Mashu Demonstration and Research DEWATS in 2009. The Newlands Mashu DEWATS receives wastewater from 84 existing households, treating up to 40m$^3$ of domestic wastewater per day. A second phase of DEWATS pilot plants is underway in eThekwini to demonstrate how DEWATS can perform under full operational conditions.

The proposed designs were informed by the experience at Newlands Mashu and from information gathered by monitoring DEWATS plants worldwide. EWS considers DEWATS to be an accepted technology and is drafting policy to guide its implementation within the municipality. DEWATS is an innovative approach to wastewater treatment that may enable more South Africans to gain access to desirable waterborne sanitation.

## INTRODUCTION

With approximately one quarter of South Africans lacking access to safely managed sanitation (WHO & UNICEF 2017), South African municipalities are striving to provide effective, appropriate sanitation solutions to their residents. While waterborne sanitation is highly desirable, conventional sewer networks with many kilometers of sewer pipes, pump stations, and centralised treatment works are expensive and challenging to construct, operate, and maintain. Particularly in peri-urban areas, a decentralised approach to wastewater treatment may prove more cost-effective and easier to maintain than a conventional sewer network.

## eTHEKWINI SANITATION CONTEXT

eThekwini Municipality safely manages 74%of its wastewater and faecal sludge, utilizing a mix of sanitation technologies, both waterborne and waterless-onsite (Cross & Buckley 2016). EWS provides different levels of water and sanitation service to households depending on the housing density of the area. In high-density areas (<20 du/ha), EWS provides piped water to each site and waterborne sanitation. In low- and medium-density areas (4-20 du/ha), EWS provides individual to communal water points and onsite sanitation (eThekwini Municipality 2017). eThekwini has a conventional sewer network with over 8 000 km of sewer pipe (Figure 1), 245 pump stations, and 28 wastewater treatment works in varying states of functionality. Because waterborne sanitation is highly desirable and aspirational to its low-income residents, EWS aims to provide waterborne sanitation whenever feasible.

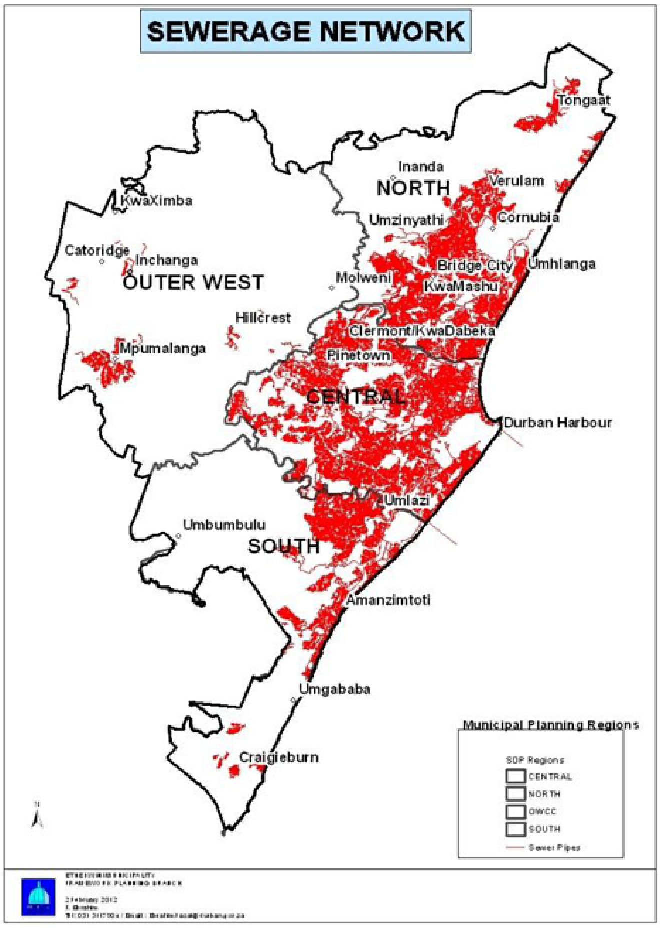


**Figure 1: eThekwini conventional sewer network is concentrated in the urban core. Image: eThekwini Municipality Spatial Development Framework, 2017**

**Figure 2: Community Ablution Block (CAB) and caretaker in an informal settlement in eThekwini. Image: Carley Truyens.**

However, Municipal Infrastructure Grants (MIGs) from the national government, which are intended to cover the costs of water and sanitation infrastructure for fully subsidized housing, do not cover the cost of waterborne sanitation, and EWS must cover the balance (Gounden et al. 2006).

EWS identified a sewer boundary surrounding the urban core, outside of which it is too costly to extend the existing conventional sewer network. Indigent households receive a package of free services which include basic free water (300 l/du/d) and free sanitation. The water and sanitation services need to be seen as a coherent package. Dense settlements cannot absorb large quantities of wastewater while conventional sewers require a minimal water flow.

In addition to the conventional sewer infrastructure, eThekwini has two main types of waterless onsite sanitation:

- 30 000 ventilated improved pit latrines (VIPs) that are emptied free to the user once every five years by entrepreneurs who are trained to empty pits safely. During the last major pit emptying campaign, eThekwini pelletized and pasteurized the VIP sludge using the LaDePa machine (Harrison & Wilson 2012).
- More than 80 000 urine diversion dry toilets (UDDTs) that are emptied free to the user every 2 years. In the southern portion of eThekwini, UDDT sludge is brought to a Black Soldier Fly plant for processing (WIN-SA 2017), while in other areas, service providers empty the UDDT chambers and bury the faecal sludge on the property of the household.

To provide water, sanitation, and hygiene services to residents in informal settlements, eThekwini has implemented more than 1 500 Community Ablution Blocks (CABs) (eThekwini Municipality 2012, Wilson 2018), which are containerised, gender-separated ablution facilities with toilets, urinals, showers, sinks, and wash basins (Figure 2). Within the sewered edge of the municipality, the CABs are connected to the sewer network. For CABs located outside the sewered edge, the toilets are VIPs. Each CAB has a caretaker hired from the community through the Expanded Public Works Programme (EPWP).

eThekwini, like all municipalities in South Africa, has a mandate to provide fully subsidized housing to indigent residents. eThekwini's housing backlog currently sits at approximately 412 000 units (eThekwini Municipality 2017). Although houses are being constructed, the demand for subsidized housing grows due in part to rural to urban migration. Much of the land available for new housing settlements is located in areas where there is no access to the conventional sewer network, yet desired housing densities for the settlements dictate that waterborne sanitation must be provided.

Due in part to an organizational culture that supports experimentation and lacks fear of potential failure, EWS is an innovative provider of and sanitation services that learns from its experiences and engages users in the process (Sutherland et al. 2014). This culture has led to a close research relationship with UKZN and the development of innovative water supply and sanitation services. EWS (under the leadership of its former director, Neil Macleod, won the Stockholm Industry Water Award in 2014 being described as *one of the most progressive water utilities in the world*(Petterson 2014).

## DEWATS Overview

DEWATS is not a specific treatment technology, but rather a technical approach to wastewater treatment (Gutterer et al. 2009). DEWATS is based on the principles of (1) decentralisation, (2) simplicity, and (3) reuse of the treatment products. By decentralising treatment, DEWATS allows for greatly reduced lengths of trunk sewers and fewer pump stations, reducing cost and maintenance requirements. DEWATS is simple, in that wastewater is treated on site without the use of chemicals or electro-chemical equipment/energy input, and maintenance requirements are relatively low compared to conventional treatment.

Operation and maintenance of DEWATS can be carried out by service providers or by supervised and trained maintenance personnel on-site. The reuse of treatment products may include using treated effluent for agricultural irrigation or collecting and using biogas for cooking. Common DEWATS modules are shown in Figure 3 below.

## DEWATS modules

A settling chamber is often the first module of a DEWATS plant, providing primary treatment through sedimentation and flotation. If use of biogas is desired, a biogas digester is used in place of the settler. Next, the anaerobic baffled reactor (ABR) is a key component of most DEWATS plants, providing much of the degradation of organics. The ABR consists of a series of chambers separated by baffles that force the wastewater to travel up and down through the chambers. This process anaerobically degrades suspended and soluble solids. The biomass that settles at the bottom of each chamber forms a sludge blanket which provides intimate contact with the influent wastewater.

Progressive anaerobic degradation occurs in the successive chambers. To further degrade organics, an anaerobic filter (AF) may follow the ABR. The AF chambers are filled with coarse filter material such as stones, cinder or plastic rings, which provides surface area for bio-films to attach. The anaerobic microorganisms in the biofilm further transform organic matter. There

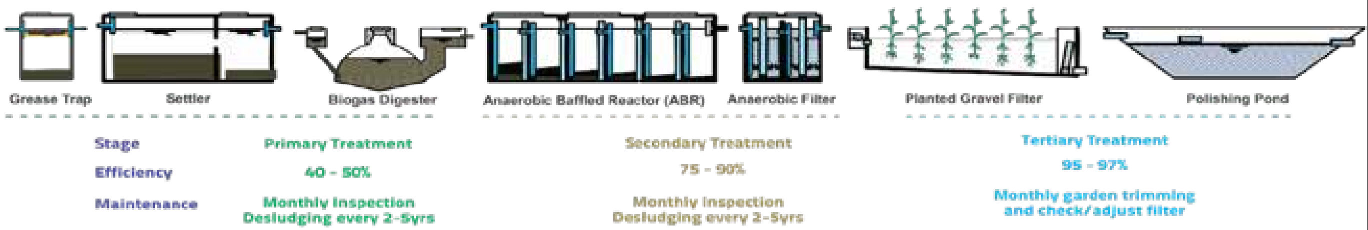


**Figure 3: Common DEWATS modules. Image: CDD Society**

is no removal of nitrogen and phosphorus species. Compared to a septic tank, the ABR is significantly more efficient in degrading organic material, and an ABR with AF can achieve a biodegradable COD reduction rate of up to 90%.

The combined ABR and AF can achieve a 1-2 log reduction of pathogens. The settling chamber, ABR, and AF may be combined into a single structure (BORDA 2017).

Following the ABR and AF, additional treatment steps are required for tertiary treatment, further removing pathogens and nutrients. Tertiary treatment modules may include horizontal-flow planted gravel filters, vertical-flow planted sand filters, polishing ponds, or other treatment technologies, depending on the discharge standards and reuse requirements for the effluent.

## Operation and maintenance

Although a DEWATS does not require a highly skilled operator and complex operation and maintenance tasks, proper operation and maintenance is critical for proper plant performance. Cleaning screens, descumming, checking for blockages, and desludging are among tasks that must be completed on a regular basis (Table 1).

**Table 1: Regular maintenance requirements and frequencies for DEWATS**

| Maintenance requirement | Frequency |
|---|---|
| Clean screens | As needed, daily |
| Remove scum from settler | Weekly |
| Sewer Control | Monthly |
| Monitor effluent | Monthly |
| Desludge | Yearly |
| Flush anaerobic filter | Every four years |

## DEWATS in eThekwini

The Pollution Research Group (PRG) at the University of KwaZulu-Natal (then University of Natal) began investigating ABRs in 1998 as a possible approach to treating wastewater from low-income peri-urban communities. DEWATS was identified as having potential to bridge the gap between less-desirable onsite, waterless sanitation and conventional waterborne sanitation (Figure 4). Following the bench-scale and small-scale ABR research, a full-scale pilot DEWATS was proposed to more fully research DEWATS in the South African context (Pillay et al. 2012).

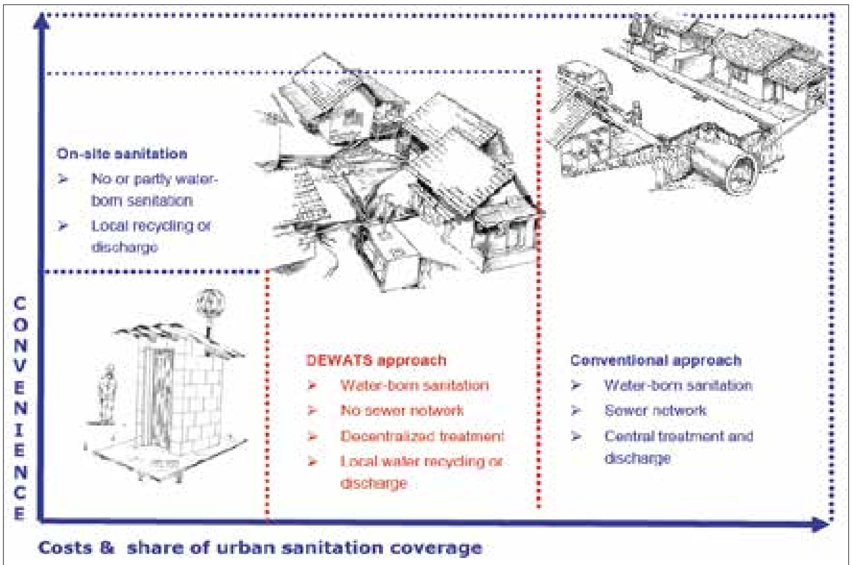


**Figure 4: DEWATS bridges the gap between onsite, waterless sanitation and conventional waterborne sanitation. Image: BORDA**

## Newlands Mashu Demonstration and Research DEWATS

The Newlands Mashu Demonstration and Research DEWATS (Figure 5),constructed in Newlands East in eThekwini Municipality in 2009, receives wastewater from 84 existing households, treating up to 40 m3/d of domestic wastewater. The site was chosen due to its potential to connect a DEWATS to an existing sewer line serving a moderate number of households, and then discharge the treated effluent back into the existing sewer pipe. This allowed for a safe space to conduct research on DEWATS without potential harm to the environment in the event of a failure.

The design for the DEWATS took into consideration best practice from global DEWATS implementations, construction and maintenance requirements from EWS, and research requirements from PRG. The Newlands Mashu DEWATS modules include a settling chamber, anaerobic baffled reactor, anaerobic filter, vertical flow planted gravel filter, and horizontal flow planted gravel filter.

**Figure 5: Newlands Mashu Demonstration and Research DEWATS. Image: Viloshin Govender**

More than 20 BSc, MScEng, and PhD dissertations have been based on research conducted at Newlands Mashu. This research has shown that DEWATS is an effective approach to treating wastewater in the South African context (Foxon et al. 2004, Pillay et al. 2014). Agricultural research indicates that partially-treated DEWATS effluent is a valuable source of irrigation water and fertilizer (Musazura et al. 2018). Due to the extensive research that has been conducted at Newlands Mashu, the demonstration DEWATS plant has been frequently altered or pushed beyond its limits for the purposes of research. Although sampling from the DEWATS has been conducted (Figure 6), effluent monitoring results from the plant running in optimal operational conditions are not available.

An intensive three-month monitoring period planned for 2018 will demonstrate the effluent quality that can be produced by the Newlands Mashu DEWATS plant when it is operating under ideal conditions, as opposed to research conditions. Based on the experience at Newlands Mashu, EWS considers DEWATS to be an accepted technology and is drafting a policy document to handle future ABR-based decentralised wastewater treatment facilities.

**Figure 6:** Samples collected from different modules of the Newlands Mashu DEWATS. Image: Bjoern Pietruschka.

## Banana City and KwaDabeka Projects

A second phase of DEWATS pilots is currently being undertaken in eThekwini. EWS has identified Banana City and KwaDabeka A Infill, existing informal settlements that will undergo in-situ upgrading, as sites for second-phase pilot DEWATS plants. Both Banana City (Figure 7) and KwaDabeka A Infill are in the catchment of the Northern Wastewater Treatment Works, which has reached its hydraulic capacity (Wilson 2018). For this reason, wastewater from the upgraded settlements may not discharge into the existing sewer, despite the existing trunk sewers running through the sites.


**Figure 7:** Aerial view of Banana City informal settlement, eThekwini, South Africa in March 2018. Image: Google Earth

The 423 households proposed for the Banana City upgrade (Figure 8) will be served by two DEWATS, while 3 DEWATS will serve 665 households in KwaDabeka A Infill (Table 2). The plants have been designed to meet General Authorisation discharge standards (DWA 2013) and will discharge treated effluent into an existing watercourse on site.

However, the sewer reticulation will also connect to the existing trunk sewer as a backup, in the event that emergency maintenance or planned alterations are required.

| | Banana 1 | Banana 2 | KwaDabeka 1 | KwaDabeka 2 | KwaDabeka 3 |
|---|---|---|---|---|---|
| Houses (#) | 232 | 191 | 489 | 56 | 120 |
| Design flow (m³/d) | 116 | 95 | 245 | 28 | 60 |
| Area of settler, ABR, AF (m²) | 348 | 286 | 734 | 84 | 180 |
| Area of sand filter 1 (m²) | 580 | 476 | 1223 | 140 | 300 |
| Area of sand filter 2 (m²) | 812 | 667 | 1712 | 196 | 420 |
| Total treatment area (m²) | 1 740 | 1 429 | 3 669 | 420 | 900 |
| Total area with 60% growth | 2 784 | 2 286 | 5 870 | 672 | 1 440 |

**Table 2:** Treatment capacity and sizes of proposed DEWATS for Banana City and KwaDabeka A Infill informal settlement upgrades

The designs for the proposed pilot DEWATS at Banana City and KwaDabeka A Infill were informed by the operational experience and research conducted at Newlands Mashu, as well as from information gathered by the BORDA Global Monitoring and Evaluation Program. The proposed DEWATS within this second pilot phase will have similar designs to each other: a screen to remove detritus, a settling chamber for primary treatment, an anaerobic baffled reactor (ABR) and anaerobic filter (AF) for secondary treatment, followed by two consecutive planted vertical-flow sand filters for tertiary treatment. Compared to a horizontal-flow planted gravel filter, a VSF is more efficient in terms of area required for treatment.

Due to space constraints within Banana City and KwaDabeka A Infill, VSFs were chosen for tertiary treatment (Langergraber 2017). In a VSF, the wastewater must be equally distributed across the surface of the filter, where it then flows vertically down through the media before it flows by gravity along the base of the filter to a discharge point. For a VSF to provide proper anaerobic treatment, it must be loaded in batches, with alternating wet/dry periods to achieve aerobic treatment (Tilley et al. 2014). A siphon, as shown schematically in Figure 9, is used to batch-load the VSF with partially treated wastewater from the AF without the use of electricity.

Because of their pilot nature, the DEWATS plants are being designed in co-ordination with researchers from UKZN to ensure that performance data can be collected and analysed. The first three pilot plants, proposed for the Banana City and KwaDabeka Unit A Infill housing projects in eThekwini, are slated to begin construction at the end of 2018. A due diligence assessment of the plants will be conducted by WADER, the Water Technologies Demonstrator Program of the Water Research Commission, once operational. This will show whether the DEWATS are meeting General Authorisation discharge standards or whether alterations to the design are required.

EWS will be responsible for the operation and maintenance of the DEWATS at Banana City and KwaDabeka.

## CONCLUSIONS

DEWATS has the potential to fill a gap in the South African sanitation sector. Constructed within a community,


**Figure 8:** Town planning layout for the Banana City upgrade, including two DEWATS shown in grey. Image: Mabune Consulting

DEWATS can provide a low-maintenance wastewater treatment solution without energy input. A decentralised approach to wastewater treatment may facilitate the implementation waterborne sanitation in areas that were previously not able to be served by conventional sewer networks due to high capital costs, operating costs, and operation and maintenance requirements. At the other end of the scale, onsite, waterless sanitation is less convenient and less acceptable to users than waterborne sanitation. When compared to the use of individual household septic tanks, DEWATS has several potential benefits, including a higher level of treatment. The use of septic tanks dictates that the plots be large enough to accommodate evapotranspiration areas, greatly reducing the maximum housing density.

Further, eThekwini has experienced that the large plot size required for evapotranspiration has facilitated the construction of "backyard shacks" on the plots, increasing wastewater flows and disturbing evapotranspiration areas. This has resulted in the discharge of untreated wastewater, risking both human health and the environment.

The second phase of DEWATS pilots at Banana City and KwaDabeka A Infill will facilitate provision of waterborne sanitation in peri-urban eThekwini. While the Newlands Mashu pilot DEWATS has been instrumental in understanding how DEWATS works in South Africa, the full-scale plants with designs based on the lessons learnt at Newlands will be vital for bringing DEWATS to scale in South Africa.

DEWATS may provide opportunities for wastewater reuse, as the treated effluent can be used for irrigation or other non-potable uses close to the source, provided certain safety precautions are taken (Amoah et al. 2018). For these pilot projects, EWS wants to ensure that the treatment process is complete, regardless of whether reuse is planned; therefore, the two VSFs will be constructed for each pilot DEWATS to remove nutrients.

If agricultural reuse is desired, the VSFs can be bypassed. Reuse of DEWATS effluent has potential to close the nutrient cycle and address the water-food-energy nexus, through both agricultural irrigation and production of biogas.

## RECOMMENDATIONS

In combination with conventional sewer networks and other unsewered sanitation technologies, DEWATS provides municipalities with an additional tool to deliver sanitation services in locations that cannot easily be served by conventional sewers. When no conventional sewer network is accessible, DEWATS should be considered as an option for treating wastewater from housing developments, CABs in informal settlements, schools and institutions, and other producers of organic wastewater.

As climate change progresses, eThekwini, and South Africa as a whole, will experience an increase in large storm events leading to flooding, as well as increased incidence of drought in the water stressed country (eThekwini Municipality 2017). We must consider ways of using our water more wisely, including reuse of treated wastewater. South Africa must look at innovative approaches to managing its water resources, and DEWATS may be one aspect of a holistic water sensitive design approach to urban and peri-urban planning.

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