Good Science makes Good Policy

How research supports WASH projects within the eThekwini Municipality

"Without data, it's just an opinion"

ETHEKWINI MUNICIPALITY

WATER AND SANITATION

A Message from eThekwini Water and Sanitation

"eThekwini Water and Sanitation was established as public water service provider in 1996, and in 2000 our boundaries were expanded, resulting in the challenge of bringing services to more than one million people that did not have access to water or sanitation.

Innovation has underpinned all of our work for the past 22 years. Technologies used to bring services to the poor such as electronic bailiff units, community ablution blocks, and the construction of 80 000 urine diversion toilets speak to our past. What we have realised is that into the future we need to find new technologies that meets people's expectations when it comes to sanitation.

Due to the passion and commitment that staff in this organization have for their work eThekwini Municipality has been put on the map as with regard to the provision of water and sanitation services.

Over the years we have been fortunate to be able to learn from many international and local organisations, in turn through the establishment of MILE (Municipal Institute of Learning) we have been able to share our experiences with other local authorities.

We'd like to also thank the political leadership of our city - His Worship Councillor James Nxumalo, members of the Executive Committee and the entire eThekwini Council - for creating an enabling environment for the unit to deliver on the needs of the city".

"Research collaboration between the University of KwaZulu-Natal and EWS dates back to early 2006, when a formal agreement was signed between the two institutions. Funded by the city, it has the goals of developing capacity to provide service delivery, researching improved water and sanitation systems and ensuring that implemented projects are economically and environmentally sustainable. In-house capacity for this type of research does not exist within EWS and we therefore looked to forming a collaborative relationship with a research organisation that had the capacity and the skills to undertake such work. Additionally, EWS also recognised the need to develop water and sanitation skills to a wide range of people with whom it interacts. Particular emphasis was to be placed on previously disadvantaged people. There are a number of benefits to EWS, the main benefit has been that decisions can now be made based on scientific facts rather than on assumptions. Research can be undertaken on a relatively small scale in the field and the results incorporated into strategic decisions. In this way, money is not wasted as the results are directly relevant to the needs. Another important benefit is the development of post graduate students who have skills, knowledge and experience in the water and sanitation field".

Ednick Msweli
Head, EWS

Neil Macleod
Previous Head of EWS

Teddy Gounden
Acting Project Executive, EWS

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Introduction

This document aims to provide a summary of various Water Sanitation and Hygiene (WASH) projects undertaken by research organisations, consultancies and tertiary educational institutions to support the Water and Sanitation Unit within the eThekwini Municipality (EWS) in the implementation of basic water and sanitation services.

The Challenges

EWS has the responsibility of managing water and sanitation services within the eThekwini Municipality. In 1996 the boundaries of the municipality were extended to create a Metro, and then again in 2001 to become a Unicity, which resulted in an increase in the number of households with no access to water or sanitation being incorporated into the EWS service mandate.

EWS must operate a ring-fenced, full-cost recovery service from a limited water resource to a growing number of poor customers. Those that need to be supplied include deep rural households, peri-urban housing estates and informal settlements. Furthermore, many households are unable to pay for basic services and the profile of the major water users has shifted from industry to poor households. In addition to the water and sanitation aspects, EWS must also ensure that the beach and aquatic environment is free from pollution in order to maintain and grow tourism activities.

In order to meet their responsibilities, the EWS identified various levels of service that would allow provision of water and sanitation to all residents of the Unicity in the urban, peri-urban and rural areas. Challenges that were faced included blockages of pipes, misuse and wastage of water, vandalism, high levels of non-payment, difficulty in accessing remote areas, and the presence of water borne diseases such as Cholera.

The WASH Guiding Principles of EWS include the following:

- Working within the boundaries of a water-scarce environment by linking sanitation systems to water supply
- Following the “Law of EcoSan” by investigating ways in which nutrients can be recovered for use in agriculture
- Ensuring that implementation is backed by sound scientific research through creating partnerships with local and international organisations
- Regularly interacting with the people they serve to ensure two-way communication and awareness through an extensive educational and outreach programme
- Sharing of expertise with other municipalities through the MILE initiative.

The Law of EcoSan

Ecological sanitation (or EcoSan), is an approach which aims to safely "close the loop" between sanitation and agriculture. Ecosan systems safely recycle excreta resources (plant nutrients and organic matter) to crop production in such a way that the use of non-renewable resources is minimised. When properly designed and operated, EcoSan systems can strive to provide a hygienically safe, economical, and closed-loop system to convert human excreta into nutrients to be returned to the soil, and water to be returned to the land.

Partnerships and Collaborations

As far back as 2003 EWS recognised the need to work with local tertiary organisations to strengthen collaboration on research and development, capacity building and knowledge management, in order to achieve growth and development, in keeping with the Municipality's Integrated Development Plan (IDP). The desired outcomes included a stronger economy, an improvement in the quality of life for all citizens and the development of a higher skills and technology base.

Over the years, partnerships have therefore been formed with a number of organisations to conduct research projects to support these Guiding Principles.

Organisations included in this document are:

- University of KwaZulu-Natal, Durban (UKZN), and in particular the Pollution Research Group (PRG)
- Durban University of Technology (DUT)
- Khyanisa Projects
- Partners in Development

Many of these projects are undertaken with joint funding from local and international funding organisations. These include:

- South African Water Research Commission (WRC)
- Bill & Melinda Gates Foundation (BMGF)
- Bremen Overseas Research and Development Association (BORDA)
- National Research Foundation (NRF)
- Department of Science and Technology (DST)

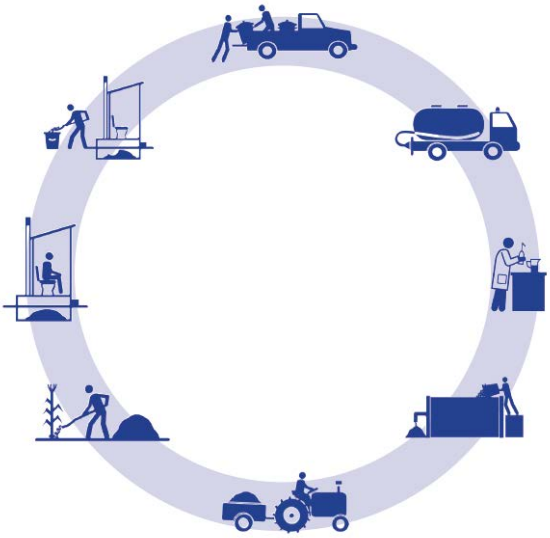
Good Science makes Good Policy

This document is divided into six categories:

- Section 1: Overarching research initiatives
- Section 2: Research projects at the Newlands Mashu Research Facility
- Section 3: Research and Ventilated Improved Pit Latrines
- Section 4: Research and Urine Diversion Toilets
- Section 5: Research and Pour Flush Toilets
- Section 6: Research related to Water and Sanitation Management

Each section contains a fact sheet on a particular research initiative together with contact details for further information.

Section 1
Overarching Research Initiatives



Through open discussion of the challenges and problems faced by EWS with academics at a range of institutions many different research projects have been initiated. By providing data and access to facilities, the researchers have been able to lever funding from organisations such as the Water Research Commission, National Research Foundation and the Bill & Melinda Gates Foundation.

Specific research facilities have been provided by EWS to enable researchers to work at scale on real production streams. Facilities include:

- ***Newlands Mashu (Decentralised wastewater treatment, urine processing, agricultural trials)***
- ***Prior Road (Urine nitrification reactors)***
- ***Kingsburgh Wastewater Treatment Works (Algae raceway)***
- ***Amanzimtoti Wastewater Treatment Works (Anaerobic Digestion)***
- ***Southern Wastewater Treatment Works (Anaerobic Digestion)***
- ***Isipingo Wastewater Treatment Works (Black Soldier Fly processing)***

Reinvent the Toilet Challenge Phase 2

Authors:	**Susan Mercer**
Organisations:	Pollution Research Group
Funding:	Bill & Melinda Gates Foundation
Status:	Completed
Contact details:	**mercer@ukzn.ac.za**

The project awarded to the Pollution Research Group (PRG) builds on the knowledge, strengths and experience gained by the team during the Phase 1 implementation. The objective was to characterise physical and chemical properties of excreta streams from dry on-site sanitation systems or from decentralized low-water consuming sanitation systems. The data were then passed to other grantees for use in their research.

Assistance was provided to other Bill & Melinda Gates Foundation (BMGF) grantees in establishing and evaluating their prototypes in Durban, and providing a support of their work by:

- obtaining experimental data of a range of excreta streams,
- undertaking generic process investigations on selected excreta streams,
- developing process models of material flows and transformations,
- facilitating field trials for BMGF grantees in Durban, and
- obtaining data from other African countries (either field or from prototypes) in the last few months of the project.

In order to achieve these aims, the following activities were undertaken:

- a survey of the needs of the other BMGF grantees in terms of data requirements, laboratory assistance, field work and spending time in Durban;
- the provision of existing data regarding sludge, faecal and urine characteristics;
- the recruitment of Masters students to undertake investigations into various aspects of the project in order to obtain further data;
- using the data from student projects to undertake process modelling;
- providing access to the PRG laboratory for visiting grantees and assistance with analyses;
- facilitating access to various sites within the eThekwini Municipality for field testing of prototypes in conjunction with eThekwini Water and Sanitation (EWS);
- making contact with other organisations within Africa in order to determine capabilities for testing of faecal sludge and provision of samples.

In total, assistance has been provided to more than 25 organisations, including Grantees and other sanitation practitioners. This support was in the form of data provision, field testing, prototype testing, and training.

Under this project, six Masters students were appointed to undertake in-depth studies into specific aspects of excreta streams.

The focus was divided in two main streams: urine which can be collected from Urine Diversion Toilets (UDTs) and, to a lesser extent, from urinals; and faecal sludge collected from Ventilated Improved Pit (VIP) latrines.

Each of the Masters research projects was conducted by a master student, supervised by a post-doctoral fellow.

The projects investigated were:

- Thermal Properties and Drying Characteristics of Faecal Sludge
- Rheology, Extrusion and Pelletisation of Faecal Sludges
- Forward Osmosis as a Final Step in the Recovery of Water from Urine
- Micro-filtration of Liquid Excreta Streams
- Separation Products of Urine
- Nano-filtration of Liquid Excreta Streams

The aim of the research projects was to provide data to the other grantees relevant to their prototype toilets and processing technologies, and to explore alternative treatment processing options.

Further information can be found on the PRG website: http://prg.ukzn.ac.za/

Support to Sanitation Practitioners

Authors:	**Susan Mercer**
Organisations:	Pollution Research Group
Funding:	Bill & Melinda Gates Foundation
Status:	On-going
Contact details:	**mercer@ukzn.ac.za**

The Pollution Research Group has been awarded a Capacity Grant by the Bill & Melinda Gates Foundation to provide laboratory and field support to sanitation practitioners.

The main aim of this grant is to provide the capacity for the PRG to support the testing of sanitation prototypes developed under the Reinvent the Toilet Challenge, and to support other practitioners in the sanitation field through the provision of data and laboratory assistance. This grant is enabling the PRG to upgrade the current laboratory facilities through increasing space allocation and the purchasing of new equipment. It will also ensure that all relevant health and safety requirements are in place.

The benefits of the Grant to the sanitation field include:

- Access to a laboratory that has experience in the handling and analysis of faecal waste streams
- Well tested standard operating procedures developed for faecal waste streams
- Subsidised laboratory analysis as the labour and facility costs are covered (only consumable costs need to be paid)
- Access to training in laboratory analyses
- Monitoring of sanitation systems to characterise input streams and output products
- Advice on the design and operation of sanitation systems based on scientific results
- Access to field sites in which prototypes can be tested due to the close collaboration of the PRG with eThekwini Water and Sanitation

Further information can be found on the PRG website: http://prg.ukzn.ac.za/

UKZN Life Sciences Participation in Studies on Sustainable Sanitation

Authors:	**Dr Nicola Rodda**
Organisation:	School of Life Sciences: PRG-BioSciences (UKZN)
Funding:	eThekwini Water and Sanitation; Water Research Commission
Status:	On-going
Contact details:	**roddan@ukzn.ac.za**

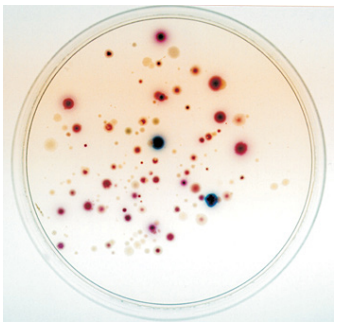
The PRG-BioSciences grouping in the School of Life Sciences of the University of KwaZulu-Natal has been engaged in supporting and collaborative research with the Pollution Research Group (PRG) since 2006. This has included projects funded by eThekwini Water and Sanitation, the Water Research Commission and the Bill & Melinda Gates Foundation. The projects typically fall into two groupings:

- Health-related microbiology.
- Wastewater and sludge reuse for food security.

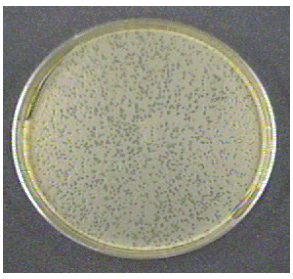
Health-related microbiology

A variety of water and waste samples have been analysed for indicator micro-organisms and certain microbial pathogens. In collaboration with UKZN parasitologist, Colleen Archer, samples have also been analysed for eggs of geohelminths, especially *Ascaris*.

Projects have included:

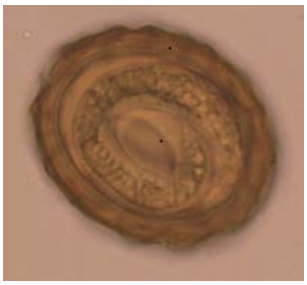


- Microbiological quality of point-of-use drinking water in households in peri-urban areas.
- Microbiological quality of soil and plants above buried faecal sludge from urine diversion toilets (UDTs).
- Microbiological quality of soil and plants irrigated with mixed domestic greywater, and health risks associated with these.
- Movement of microbial indicator organisms out of pits of VIP latrines.
- Effect of temperature and humidity on survival of helminth eggs in UDT faecal sludge.
- Presence of health-related organisms in source-separated urine from UDTs, and the effect of drying on their survival.
- Efficacy of household disinfectants in inactivating helminth eggs in sludge spilled in and around



households during manual emptying of VIPs.

- Levels of helminth eggs in faecal sludge in from various on-site sanitation systems.
- The presence of health-related organisms on black soldier flies grown on UDT faecal sludge, in residual sludge and in leachate from the sludge.



Wastewater and sludge reuse for food security

Small-scale greenhouse and semi-field plant growth experiments are conducted to investigate the effect of various waste fractions on plants from germination to harvest, and on the properties of soil irrigated or amended with these waste fractions. In addition to basic measurements of plant growth and soil characteristics, collaboration with the Plant Ecophysiology Research Group of the School of Life Sciences has enabled the investigation of aspects of plant physiological responses to growth in the presence of waste fractions. This provides insight into the mechanisms by which wastes interact with plants and thereby offers guidance regarding how waste reuse can be improved to maximise quantity and quality of crop plants. Typically, these experiments involve food crops which can potentially be grown to improve household food security in poor households. Most recently, African leafy vegetables have been included among the plant species investigated.

Projects have included:

- Growth and quality of soil and of crops planted above buried UDT waste.
- Effect of deep row entrenchment of VIP sludge on growth of trees.
- Effect of irrigation with a number of greywater fractions on plant growth and soil. The latest work includes chemical profiling of different greywater fractions with the aim of linking chemical properties to contrasting results when using different greywater fractions for irrigation.
- Optimising the ratio of UDT faecal sludge and various sources of organic waste for the production of black soldier fly larvae on UDT faecal sludge (potential for animal feed additive).

Expertise in the Field of WASH at DUT

Authors:	**T.A. Stenstrom, I.D Amoah and J.T. Arra.**
Organisation:	Institute for Water and Wastewater Technology (Durban University of Technology)
Funding:	Water Research Commission, NRF, EWS
Status:	Various
Contact details:	**aisaacdennis@yahoo.com**

1. Development of Sanitation Safety Plans
    - Systematically identify and manage health risk, pollution sources, and exposure along the sanitation chain
    - Guide investments based on actual risks
    - Provide assurance to authorities and the public on safety of sanitation related products and services.

2. Pathogen reduction efficiency of wastewater treatment plants, executed in collaboration with the Pollution Research Group of University of KwaZulu-Natal
    - In collaboration with the Pollution Research Group of University of KwaZulu-Natal and Bremen Overseas Research and Development Association (BORDA) measure the efficiency of the DEWATS plants at Newlands-Mashu (Durban), Lesotho, India and Cambodia in reducing pathogens.

3. Risk of infection with pathogens from the use of polluted water bodies for agriculture
    - Using Quantitative Microbial Risk Assessment (QMRA) framework to determine the risk of infections for different exposed populations.

4. Establishment of a consortium using a common method for the detection of Soil Transmitted Helminths (STHs) in environmental samples.
    - A consortium of laboratories working on environmental sample in the area of STHs would be established under a project sponsored by the Melinda & Bill Gates Foundation.
    - This will provide uniformity in the methods used for measurement of STHs ova/egg in the environment.

5. Disaster Risk Reduction (DRR): WASH and RESCUE (**WA**ter, **S**anitation and **H**ygiene in **RES**ilient **C**ities and **U**rban areas adapting to **E**xtreme waters)
    - Investigate effective social learning (SL) between stakeholders for learning about accepted adaptations (e.g. for infrastructure, building standards, regulation, management of ecosystem services and land use in the river basin etc.).
    - Coordinated by the Stockholm Environment Institute (SEI) in Sweden the study focuses on the preventive actions needed for WASH systems in Resilient Cities

- Stakeholder aspects, perception and PPP related to flooding and the effects on water, sanitation and health
- Case studies with different stakeholder groups are held in different parts of the world (The Philippines, India, Colombia and in Europe)

6. Microbial population database - A tool for evaluating the Biological Nutrient Removal (BNR) process in full scale wastewater treatment plants:
    - Identify and quantify functional microbial populations and their composition in BNR plants with molecular techniques and correlate to plant operating conditions and wastewater characteristics
    - Create a microbial database for BNR plants in KwaZulu-Natal

7. Evaluation of seasonal impacts on nitrifiers and nitrification performance of a full-scale activated sludge system:
    - To determine the effect of seasonal variations and operating conditions on nitrifying population (AOB), (NOB), and (AOA) and nitrification performance in full scale wastewater treatment plants

8. Developing and adapting low-cost alternative wastewater treatment technology for rural and peri-urban application:
    - Assess different low-cost technologies for blackwater and greywater treatment in peri-urban settings with focus on wetland, filter beds, high-rate algal ponds and anaerobic processes.
    - It will include reduction of pathogens (incl. virus surrogates), nutrients and organic content.

DUT Research Support to WASH

Authors:	**Faizal Bux**
Organisation:	Institute for Water and Wastewater Technology (Durban University of Technology)
Funding:	Water Research Commission, NRF, EWS
Status:	Various
Contact details:	**faizalb@dut.ac.za**

The Institute for Water and Wastewater, within the Durban University of Technology was established in 1995 and has developed into centre of excellence serving the water research needs of local and national government, water utilities and industry.

Algal technology

Institute for Water and Wastewater Technology (IWWT) in partnership with eThekwini municipality is undertaking a project for the production of biodiesel from microalgae. This partnership began in 2008 with eThekwini's Economic Development Unit for laboratory scale and pre-pilot scale cultivation trials of indigenous microalgae for lipids and subsequently biodiesel production. The partnership continued with eThekwini's Water and Sanitation division. A demonstration scale 300 000L raceway pond and laboratory facility was constructed at the Kingsburg Wastewater Treatment facility for the production of biodiesel to be used in the city fleet. The utilisation of conventional media for algae cultivation is not economically feasible and can account for up to 30% of the total production cost. Wastewater has proven to be a potentially viable replacement to conventional media with the added benefits of nutrient recovery and superior quality effluent due to the removal of residual nutrients from the wastewater effluent. We have investigated several wastewater streams for their applicability to algal cultivation and determined that utilisation of wastewater effluent is a viable water source but is lacking in nutrients to obtain optimal biomass and thus optimal lipid productivity. We have subsequently determined that domestic influent is a superior to final effluent however has additional challenges of bacterial contamination and is still below optimal levels of nutrients for biomass production. Supplementation trials using other waste streams such as waste sludge, anaerobic digester effluent and sludge holding tank supernatant are underway. Cost effective harvesting and conversion of algal lipids to biodiesel are still bottlenecks to the technology. We are testing several techniques for low cost harvesting of biomass. IWWT, Hitachi and Nagoya University (Japan) have submitted a joint JICA-SATREPs application for technology evaluation, scale up and transfer on harvesting and conversion technology. In order to further improve the economics of the technology we have adopted a biorefinery approach whereby value will be added to the process by utilisation of the residual biomass after extraction. We are currently undertaking a project to assess the effect of algal biomass as a supplement to aquaculture feed in order to improve the nutritional value of farmed Tilapia. The experimentation is being conducted at eThekwini's Northdene aquaculture facility.

The Activated Sludge BIOS

This functional piece of software is the culmination of a 2 year long WRC project (completed in 2013) and is an intuitive and interactive tool aligned specifically to the needs of those within the wastewater services sector. The basic framework of the tool, allows it to act as a collated repository of previous literature, coupled with our own observations on full scale wastewater treatment plants, to provide a comprehensive overview on WWTW process control. This application includes sections on common AS physiochemical characteristics; works design; and wastewater microbiology, as well as a troubleshooting guide for diagnosing and alleviating the common problems occurring within a BNR-WWTW. This new approach serves to integrate the previously

disparate topics of wastewater microbiology, chemistry and engineering into a single, easily accessible software package that both is designed to educate and upskill WWTW operators and water researchers.

The Wastewater Knowledge Hub

The Wastewater Knowledge Hub is an online repository of all the essential information pertaining to the wastewater infrastructure and professional wastewater treatment community in South Africa. This website is an extension of the Activated Sludge BIOS app interface, and is designed to grow through the direct input of and collaboration with the user base. Being the only website of its kind to service the South African wastewater and water community, we seek to educate the scientists and engineers involved in the wastewater treatment community, and get them communicating with each other in an unbiased open forum that allows for the exchange of ideas in order to further the state of the science as a whole.

Developing Anammox Technology for Nitrogen Removal

Anaerobic ammonia oxidising (anammox) bacteria are a group of planctomycetes that have been found to be able to oxidise ammonia to free nitrogen in the absence of oxygen. Application of the anammox process to wastewater treatment allows for a lower oxygen demand, minimal sludge production and no requirement for an external carbon source as compared to conventional nitrification and denitrification processes. Integration of the anammox process into conventional systems may save up to 90% of operating costs, as well as an increase in efficiency in ammonia removal. Within the context of limited space, limited budget, and minimal energy expenditure, the implications of a self- contained nitrification-denitrification process through anammox, becomes a clear advantage over the conventional means.

Elucidating the role of Filamentous bacteria in Bulking and Foaming in full Scale Wastewater Treatment Plants

Filamentous bacteria are often beneficial to the wastewater treatment process by aiding in floc formation, sequestration of suspended particles and even contributing to the nutrient removal process. Under adverse operational conditions, the filamentous bacteria grow in excess, resulting in adverse bulking and foaming conditions within the system. By approaching this problem in a uniquely holistic way, we seek to develop a mathematical model. This model interprets real time plant data to generate a probability distribution on (1) the chances of the occurrence of filamentous bulking; (2) the type of filamentous bacteria; and (3) the control parameters to mitigate this condition.

Improving our understanding of microbial contribution in full scale wastewater treatment processes

We are presently engaged on a WRC project that seeks to characterize, model and improve the functionality of biological wastewater treatment processes over three provinces across South Africa. By understanding the parameters that govern the remediation of domestic wastewater across a variety of climates, influent types and processes, we seek to optimize the treatment of wastewater.

The microorganisms involved in wastewater treatment are highly specialised to their environmental niche. They develop and thrive in the harsh conditions of the wastewater treatment system. With consideration to the strong selection pressure exerted by the wastewater system, this implies that adequate control of the wastewater process directly affects the microbiota within. By correlating full scale operational processes to its microbial fingerprint, we seek to optimise plant performance for all types of process configurations, microbial populations and metabolic activity. This will allow us to troubleshoot plant performance problems in a sustainable manner at an ecological level by manipulating operational control over the long term.

Infrastructure and resources

The Institute comprises of well-equipped laboratories with state of art high end equipment including Genetic Analyser/Sequencer, Quantitative PCR, TOC analyser, Atomic absorption spectrometer, Ion Chromatograph, Gas Chromatograph Mass Spectrometer, Gas Chromatographs with FID, TCD, NPD, Carl Zeiss Z1 imager with Apotome, Gallery Discrete Water analyser. The Institute has successfully secured funding (> R 45 million) from the DHET and DUT for the construction of a new building which should be completed in 2016.

Climate Change and Urban Water Governance: Pathways to Social Transformation (CLIMWAYS)

Authors:	Catherine Sutherland (UKZN) and Trond Vedeld (NIBR)
Organisations:	NIBR in Oslo, Norway, School of Built Environment and Development Studies, UKZN, School of Geographical and Environmental Science, UCT and uMphilo waManzi
Funding:	A partnership between the Norwegian Research Council, Norway and NRF, South Africa
Status:	On-going
Contact details:	**sutherlandc@ukzn.ac.za**

The CLIMWAYS project is a partnership between NIBR in Oslo, Norway, School of Built Environment and Development Studies, UKZN, School of Geographical and Environmental Science, UCT and uMphilo waManzi, in South Africa. The people involved in the project are provided in the table below.

Institution	Research Team	Funding
Norwegian Institute of Urban and Regional Research	Trond Vedeld, Einar Braathen, Berit Aasen and David Jordhus-Lier	Norwegian Research Council
School of Built Environment and Development Studies, UKZN	Catherine Sutherland, Vicky Sim, Sibongile Buthelezi, MaDudu Khumalo, Linda Hlengwa and Nolwazi Ntini	National Research Foundation
Environmental and Geographical Science Department, UCT	Gina Ziervogel, Dianne Scott, Anna Taylor, Londeka Mahlanza	National Research Foundation

The challenges posed by climate change require multi-level and multi-actor governance approaches. Climate risks related to water resources management cut across administrative, social, and ecological boundaries and engage an array of state, municipal and non-state actors at multiple levels and scales. Moreover, important drivers of rapid urbanization and the proliferation of urban informal settlements and thus urban vulnerability to climate hazards, relate to factors outside the boundaries of the metropolitan areas and control of urban authorities. Hence, for *city governments* in South Africa, as elsewhere in Africa, increased climate variability raises added challenges to urban governance and development planning, while for *urban citizens* climate risks are superimposed on other factors that create risks and threats and undermine local welfare. Increasing awareness of climate change impacts and the efforts of local champions have opened up the political opportunity to link climate change adaptation to critical development challenges in cities, such as job creation through the green economy, the provision of more sustainable public services and the need for greater participation of all citizens in decision making.

This research explored the relationships between politics, institutions and collective action in both the water and climate governance arena which shape outcomes (including policies, practices, interventions, encounters and entanglements), in part to meet an expressed demand among city authorities in Durban and Cape Town for policy relevant knowledge. Linking multiple scales and sites of governance at the international national, local and community level appears to be a necessity in water and climate governance. Hence this research analysed climate and water governance at different levels and scales.

The research combines the theoretical frames of multi-level governance and social mobilization to explore the institutional arrangements, partnerships and networks that have developed in the two cities, and to reflect on the outcomes of such arrangements and engagements as they land in real spaces on the ground, through state practices and encounters with local people in the implementation of projects. This can inform policy relevant

knowledge of more integrated approaches, practices and interventions required for climate change adaptation between water and climate actors.

This project is an action research project with strong partnerships between the researchers and the municipalities (eThekwini Municipality and the City of Cape Town). A successful launch meeting was held in September 2014 in Durban. The Durban, Cape Town and Norwegian teams participated in this workshop, along with three experts including an official from the eThekwini Municipality who is working on trans-disciplinarity. Post this workshop, members of the three teams conducted a number important interviews with the main actors in water and climate governance both at the municipal and community level in Durban. Good relationships have been built with community leadership in both the Palmiet Catchment and Mzinyathi which has enabled the Durban team to hold four focus groups and collect baseline data through surveys (100 surveys in Quarry Road informal settlement on the Palmiet and 30 surveys in Mzinyathi). The most significant outcome of the project thus far in Durban is that a joint university-municipal technical workshop on the Palmiet Rehabilitation Project will be held on 9 April 2015 to report on the research outcomes on the Palmiet, most of which have been generated by the CLIMWAYS project, so as to drive this project forward through the integrated efforts of the municipality, UKZN researchers and communities, as it forms a core part of the broader Umgeni Ecological Infrastructure Partnership.

The main contribution of the project to transformation is due to its 'action research' focus. In Durban, the project has enabled researchers from UKZN to build relationships with the informal settlement community at Quarry Road West and with peri-urban residents in Mzinyathi. The Area Committee in Quarry Road is largely made up of women and we have been working with this group of leaders over the past six months, linking them to the municipality through the research process. One outcome of these connections is that the municipality is now supporting the development of a waste-trepeneur project in Quarry Road. The baseline data that we are currently producing will inform the municipality in the development of the Palmiet Rehabilitation project. The research conducted in Mzinyathi has been shared with eThekwini Water and Sanitation in meetings that have focused on the challenges of providing sanitation in the water scarce, fast growing, rapidly densifying areas of the rural periphery which faces the risk of increased surface water flow due to climate change.

The project has enabled the Durban team to work with communities along the Palmiet River and in Mzinyathi to jointly asses their understanding of climate and water governance. The participatory approaches that have been adopted will enable partnerships to be built between municipal officials, researchers and community members and private actors. These partnerships, their processes and the knowledge they produce will provide insight in to the types of governance models that are appropriate for addressing climate and water risks.

In Cape Town first there has been engagement on storm water issues, including discussions with officials in the City of Cape Town around storm water management and the integration of climate change in planning new storm water systems. This has been followed up by a local case study where there will be investigation into the perception of how permeable paving has been viewed and implemented to reduce urban storm water runoff.

Secondly, there has been engagement with a local NGO, Environmental Monitoring Group (EMG). CLIMWAYS researchers will reflect on how EMG has engaged with civil society around water and climate change issues. In February, one of our researchers attended a first meeting with Water Caucus representatives and EMG staff to meet with Dunoon residents about the prospective work.

Thirdly, researchers have engaged with the City of Cape Town and local residents in Green Park informal settlement around the issue of flooding in informal settlements. Interviews were held in February when one of the Norwegian researchers was in Cape Town and a field visit was made to Green Park to explore the potential for understanding the responses to flood risk management.

WASH Educational Programme

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The EWS identified various levels of service that would allow provision of water and sanitation to all residents of the Unicity in the urban, peri-urban and rural areas. These included the installation of full pressure, semi pressure (roof tanks) and ground tanks for the provision of water, and the use of water borne sewerage systems, ventilated pit latrines, ablution blocks and urine diversion toilets for sanitation. It was important to ensure that the type of sanitation system used matched the type of water supply system. A free basic water supply of 9kl per month per household was also introduced.

Challenges that EWS faced included blockages of pipes, misuse and wastage of water, vandalism, high levels of non-revenue water, difficulty in accessing remote areas and the presence of water borne diseases such as cholera. Many of these challenges were as a result of a lack of awareness and education, especially in those areas that had not previously had access to water or sanitation services, while others consumers had never had a voice with regard to any services and a significant constituency and therefore considered non-payment, passive protest and vandalism of infrastructure to be legitimate action. As a result, the EWS embarked on an extensive awareness and education programme incorporating a participatory approach to ensure a two-way communication system. This programme was initiated in 1997 and works alongside the service provision programme to ensure continuous interaction with the target communities, awareness and education in the proper use and management of the services, and to monitor the acceptance, problems and successes of the services delivered.

A number of different approaches were used in the education and awareness programme in order to achieve these objectives. These included the use of posters and leaflets, house visits, the creation of forums, training, schools programmes, street theatre and media publications.

The success of the participatory approach to education and awareness has been a successful one demonstrated by some of the headline results:

- An increase in satisfaction levels with sanitation systems.
- No further cholera outbreaks recorded due to sub-standard water and sanitation.
- A reduction in diarrhoea incidents by 31% as compared to areas with no on-site sanitation and improved conditions for children.
- A reduction in non-revenue water (from 40% to 29%).
- A number of customers are now on debt relief and thus accounts now regularized.
- A reduction in consumption levels resulting in substantial cost savings.

- A reduction in illegal connections.
- Blockage rate reduced from 3800 per month to approximately 400 / month in one year resulting in substantial operational and maintenance savings.
- The use of a customer *report card* which makes use of market researchers to consistently track customer satisfaction and the creation of focus groups has allowed for EWS to identify problem areas and has highlighted focus areas for further awareness and training programmes.
- Evaluation and assessment of the education programme is undertaken to match understanding levels and provide feedback on the education content.
- Within one year more than 600 street theatre performances were held reaching approximately 38 000 adults and 45 000 school children.
- Over 230 educators completed professional development programme on water and sanitation.
- Citizen's Voice programme rolled to entire municipality.

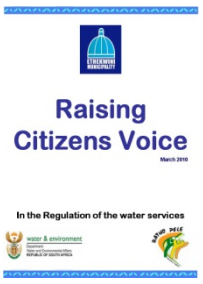
The lessons learnt during this process include:

- Leaflets and resource materials are inadequate and of no educational value unless they are included as part of a structured approach. If materials are just dropped off at schools and adult community centres there is limited impact – educators and community leaders need to be trained themselves.
- There is a need for continuous follow up and education to ensure that all community members are informed of the initiatives and how to make use of the water and sanitation systems.

- There is also a need to establish a point of contact in the community and within the institution (EWS) to allow for rapid responses to queries and problems that may arise. For example, a call centre has been established to receive complaints and dispatch technical staff to attend to the problem. This is also used as a tool to measure customer satisfaction. A customer service charter and service level standards have also been developed to ensure that EWS provide a quality service.
- Project delivery is enhanced when local people from the community act as facilitators, care takers and trainers.

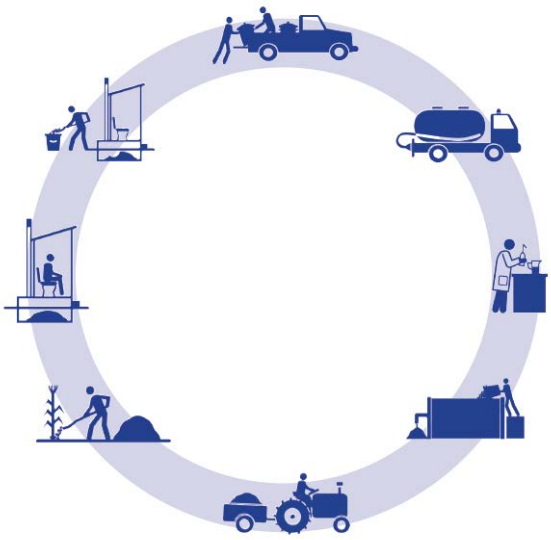
- It is important to use the correct language (English is often the second language) and to ensure that the level of understanding is met.
- In engaging communities in the Raising the Citizen's Voice programme the EWS has adapted and changed policies leading to empowerment of communities in the decision making process.

It is important that the programme is sustainable and these aspects have been taken into account in the development and implementation of the education and awareness practices. Social, economic, environmental and cultural sustainability have been addressed. All communities have been targeted with the programmes with a focus on poor communities, women, children (schools) and educators. Continuous feedback is sought and programmes are re-evaluated on a regular basis. Investment in education material is recovered through the savings made in the reduction in water use, illegal connections and an increase in revenue from previously non-paying consumers. Through increased awareness and improved practices, pollution of rivers and land has decreased. The traditional beliefs and indigenous knowledge was incorporated into all educational material developed to ensure acceptance by the targeted communities.



Section 2

Research Initiatives at Newlands Mashu Research Facility



The Newlands Mashu Research Facility enables investigations on real wastes to be undertaken at scale in an environmentally safe way. The researchers are able to push processes and practises to failure in a safe and responsible manner.

The Newlands Mashu Research Facility

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Funding:	eThekwini Water and Sanitation; Water Research Commission; BORDA
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The Newlands Mashu Research Facility has been developed in order to undertake integrated research on sanitation, decentralised waste water treatment, nutrient recovery and recycling, and agriculture. The site provides a controlled environment where sanitation systems, resource recovery, and agricultural recycling of recovered resources can be evaluated and developed. Trials at Newlands are part of the eThekwini Municipality's long-term strategy relative to sanitation systems for both existing and new housing projects. The research focus encompasses several important life cycle considerations that support planning for services that extend beyond a single goal of providing sanitation.

Currently, there are three main focus areas of research at the Newlands Research Site:

1. sanitation systems of various types
2. technologies to recover valuable resources from sanitation systems
3. agricultural use recycling and reuse of resources to the soil

Sanitation Systems

Sanitation systems currently being evaluated at the Newlands Research Site include a decentralised wastewater treatment system (DEWATS) and on-site urine diversion dry sanitation toilet systems. DEWATS is designed to treat waterborne sanitation systems with no- to low-energy use, with possibility of energy recovery from methane gas, and water with dilute nutrients of nitrogen and phosphorus.

Urine diversion dry sanitation toilet systems are being tested on site. This technology is appropriate for areas outside the waterborne edge where installation of sanitary sewers is impractical. Urine contains most of the nutrients that are in a domestic sanitation system and valuable for recycling to the soil. These same nutrients are pollutants at certain concentrations causing algal blooms and hypoxic conditions in rivers and waterways, and exert a burden on sanitation systems to remove them for safe release into the environment.

Resource Recovery

Valuable resources can be recovered from sanitation systems, and when properly treated and hygienised, can be reused and recycled into agricultural projects. These resources include nutrients that are formed into fertilisers, purified water, soil amendments, and energy.

The nutrients targeted are phosphorus and nitrogen among others. Phosphorus (P) supplies are finite, in decline, and have no replacement. Phosphorus is essential for growing food, thus relates to the food security concerns. Nitrogen (N) fertilisers are produced by fixing nitrogen gas that is readily available in the atmosphere with electricity, and thus require a certain expense for this production.

Treated effluent from the DEWATS plant contains the resources of water and diluted nutrients. DEWATS effluent is currently being evaluated in agricultural trials at the site.

In a separate trial, urine which has been collected from UDTs is being used to recover nutrients for subsequent reuse. This diverted urine has the resources of high concentrations of the nutrients P and N. Two reactors are being evaluated for the recovery of these nutrients and incorporation into usable fertilisers. One is a struvite reactor that recovers most of phosphorus present in the urine by adding dissolved magnesium salts. There is a simple reactor that could be used at agricultural sites, as well as an automated, computer-controlled reactor that could be used in more densely populated settings. The struvite reactor yields a phosphorus-rich solid fertilizer. The other reactor is a biological treatment unit with evaporation that aims to recover the majority of nutrients initially present in the urine by using bacteria to convert ammonia nitrogen to nitrate nitrogen. The nitrification/evaporation reactor yields a concentrated liquid fertiliser and water. This work is being carried out under the VUNA project funded by the Bill & Melinda Gates Foundation.

Agricultural Reuse

Agricultural trials currently underway at the research site involve growing trials with the DEWATS effluent, struvite fertilizer, and LaDePa pellets (pasteurised, dried pit latrine contents). Response from a variety of food crops are being evaluated, as well as the nutrient availability in the soil and plant uptake.

DEWATS plant and growing tunnel

Agricultural field trials

Laboratory

Urine processing reactors

DEWATS – Decentralized Wastewater Treatment Systems

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The Pollution Research Group was made the nexus of BORDAs international research activities. This not only includes managing local BORDA research activities, but also conducting in-Depth research on DEWATS systems with a focus on the Anaerobic Baffled Reactor as a main component of DEWATS. Furthermore, in cooperation between Ethekwini Water & Sanitation and BORDA an evaluation and demonstration DEWATS plant was constructed to examine its suitability for in the municipal context of providing sanitation in peri-urban areas of South Africa.

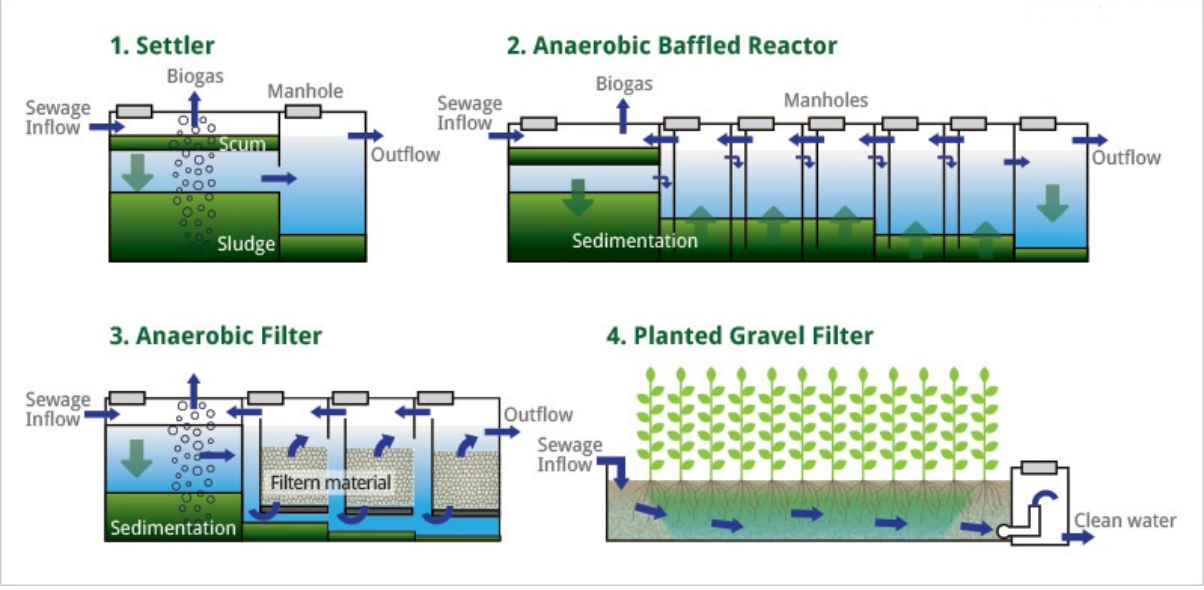
DEWATS principles:

- Low maintenance
- No electricity necessary
- Modular design of all components
- Robust design
- Potential for agricultural reuse of effluent

DEWATS
BY BORDA
Decentralized Wastewater Treatment Solutions

DEWATS consists of 3 main treatment steps as shown below:

- Primary treatment: Sedimentation and flotation (1)
- Secondary treatment: Organic reduction of waste and stabilization (2,3)
- Tertiary treatment: Removal of nutrients and polishing (4)



Typical DEWATS modules

Treatment of domestic wastewater can be seen in the following picture, beginning with raw wastewater on the left and after final treatment to the right.

Results from studies on DEWATS performance have shown:

Manual scum removal

- Start-up of the plants do not benefit from seeding during the start-up phase under subtropical conditions.
- Tolerance to organic and hydraulic shock loads: DEWATS plants showed to be able to easily cope with higher organic loads. Robustness against hydraulic shock loads could be seen as well, however, extreme storm-water intrusion can temporarily disturb treatment efficiency.
- In combination with Planted Gravel Filters DEWATS plants can reach South African discharge standards regarding organic pollutants, solids and nutrients.
- DEWATS effluent is suitable for use in agriculture helping in creating higher value and reducing the need for potable water for irrigation in water scarce areas.
- High amounts of Fat-, Oil- and Grease based scum must be tackled by operation and maintenance measures to ensure stable treatment performance.

Assessing the use of Excreta Streams in Agricultural Trials

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A pilot Decentralized Wastewater Treatment System (DEWATS) is located at Newlands Mashu, Durban, and was designed by BORDA and financed by eThekwini Water and Sanitation. In addition a reactor processing urine into Nitrified urine concentrate and struvite has been installed.

The DEWATS plant treats wastewater from 84 households using anaerobic digestion processes to remove the excess energy (COD) from the wastewaters. If this stream were to be used for irrigation the excess energy would result in the root zone becoming depleted in oxygen due to microbial processes in the soil. This causes stress on the plants. The anaerobic processes transform the energy into gaseous methane and liberate ammonia from complex bio-molecules. This results in a stream which could be used beneficially in agriculture as a source of water and nutrients. The DEWATS plant consists of a number of unit processes each of which produces a treated water stream with different characteristics. After the anaerobic baffled reactor (ABR) section all the particulate components will have been solubilised and some pathogen reduction will have taken place. The anaerobic reactor will further reduce the energy content (COD) of the wastewater. Passage through the constructed wetland (vertical and horizontal) will further remove pathogens and particulate material as well as some nutrients. However, the nutrient reduction does not permit the effluent to be disposed in waterways unless the wetland crops are actively managed. Further challenges include the disposal of waste from about 100 000 UD and VIP toilets which the municipality has rolled out. Sludge from VIPs is being transformed into LaDePa pellets and the urine taken to the Newlands Mashu reactor to be processed to Struvite and nitrified urine concentrate. The Water Research Commission is funding a research project on the possible use of DEWATS effluent and waste product derivatives for agricultural use.

BORDA DEWATS has potential in South Africa for densely populated communities where there is an urgent need for sanitation services. These systems could be installed as a temporary service technology treating domestic wastewater from communal ablution blocks (CABs) (showers, laundry area, flushing toilets) until such time the settlement is upgraded or relocated to a housing project. Alternatively, it could be implemented in areas where septic tanks are not appropriate such as densely clustered low-cost housing areas.

If the final effluent from these DEWATS can be shown to have beneficial use on agriculture with no adverse effects on the soil, groundwater or agricultural products, there is the potential to link the installation of these systems to community gardens thereby providing a further benefit to the area. The processing of waste into fertilizer products could also provide innovative plant nutrient sources for crop production.

Trials were conducted both on a laboratory scale using plants in pots, to field trials both at Newlands Mashu and the University of KwaZulu-Natal using DEWATS effluent, LaDePa pellets, Struvite and nitrified urine concentrate.

Aspects that were investigated included growth variables such as plant height, number of leaves per plant, chlorophyll content, and biomass. Plant tissue analysis was also done to determine the content of important mineral elements such as nitrogen, phosphorus, potassium and selected micronutrients. The risk of pathogen contamination to workers and potential consumers was also assessed.

The field trials compared three water sources (ABR effluent, tap water and rain water using drip irrigation. For each water source, 4 different crop species selected on the basis of microbial risk and importance to local diets have been planted. These are Swiss chard, dry bean, maize and taro (madumbie). Each crop species was replicated 3 times within the water source treatments. Wetting front detectors (WFDs) were inserted at 300 and 500 mm depths to determine whether nutrients and pathogens can leach beyond the root zone. At the end of this trial another field trial was established with banana/taro (madumbe) intercrop. Data on crop variables is being collected as well as leachates within and below the root zone.

Pots trials have been expanded to include the use of LaDePa, struvite and nitrified urine concentrate on soybean, indigenous vegetables, maize and perennial ryegrass.

The knowledge gained from this study will be important in estimating the amount of ABR effluent that may be needed to irrigate a specified area of land for different crop species.

The outcomes from this investigation will assist the municipality in the roll out of further DEWATS systems and linking these to community gardens.

Further studies are underway in this area at Newlands Mashu. A weather station and an irrigation system have been installed. Continual monitoring of the crops is taking place. Data generated will be used to develop a decision support tool for the management of waste and waste water that links sanitation and agriculture.

Use of Urine Derived Products as Fertiliser Sources in Agriculture

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The eThekwini Municipality collects and stores urine from urine diversion toilet technology. Urine has been shown to contain plant nutrients which pose a problem when disposed of in the environment (Drangert, 1997). Struvite ($NH_4MgPO_4 \cdot 6H2O$) is a phosphorus fertiliser precipitated from the addition of magnesium salts (MgO, $MgSO_4$ or $MgCl_2$) into urine (Barak and Stafford, 2006). The struvite production process cannot remove all the N (Etter et al., 2011), hence the effluent can be used for crop production as well. Urine can further be nitrified directly to produce a nutrient source with more of nitrate- N than ammonium- N giving a product called Nitrified Urine Concentrate (NUC), which could be important for plant production.

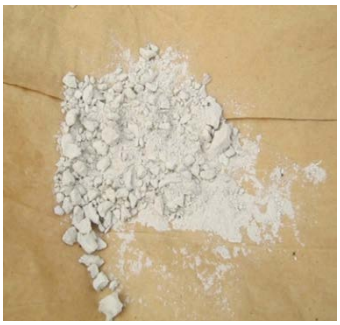

Figure 1: Struvite processed from source-separated urine

Project aims and objectives: To investigate the potential use urine based products (Struvite – Figure 1; and Nitrified Urine Concentrate (NUC); Figure 2) for crop production.

Laboratory and tunnel experiments were carried out in order to determine N and P release patterns from struvite and NUC different soil types.

Figure 2: Nitrified Urine Concentrate (NUC) processed from source-separated urine

Main highlights of the results from the laboratory and tunnel experiments

Struvite as a plant nutrient source

- An incubation study was conducted to determine nitrogen release from struvite in two soils (acidic and non-acidic).
- There was a better release in the non-acidic Ukulinga soil than acidic of struvite
- The results from the incubation study suggests that struvite could continue releasing nitrates steadily even beyond the 70th day of the incubation period.
- There was a high release observed for struvite when used in combination with immediately available fertilizers than when used alone.

Urine –based fertilizers effects on ryegrass

- These include urine, Struvite-effluent (SE) and nitrified Urine Concentrate (NUC); and were used as fertilizer to grow perennial ryegrass in a tunnel experiment (Figure 3).
- Urine-based fertilizers have potential to be soil amendment, particularly in soils that are able to mineralize urine-based ammonium sources.
- Soil characteristics need to be carefully considered when deciding to amend soil with urine-based fertilizers.
- Sandy soils with low clay and organic matter may mineralize the ammonium to plant-available nitrate but equally may lose large amounts of ammonium by volatilization and any nitrate produced may be lost by leaching unless immediately taken up by roots.

Figure 3: Perennial ryegrass grown on pots using urine-based fertilizers.

Nitrogen source and application rate on the yield and nutritional quality of African nightshade

- NUC, chicken manure and the inorganic fertilizer urea were used as nitrogen sources to grow African nightshade.
- The nitrogen sources were applied at increased rates under water limiting conditions.
- The highest biomass was achieved at the recommended fertilizer rate of 2.6 g N per plant.
- Both urea and NUC had a burning effect on the leaves.
- The effect of NUC could have also been due to its high sodium concentration.

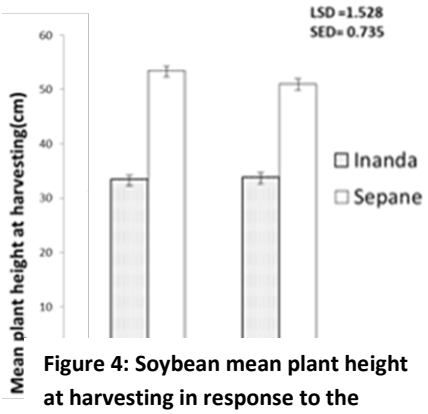

Figure 4: Soybean mean plant height at harvesting in response to the application various human-excreta-derived materials.

Urine derived nutrient sources: effect on soybean nodulation and yield

- Nitrified urine concentrate (NUC) effluent was compared with urea in a pot study using soybeans to determine their effect on nodulation and yield.
- Significant differences in relation to plant height over time as a function of soil type were observed. The clay soil resulted in taller plants in all treatments. However, no significant differences between the treatments imply that the effectiveness of these Nitrified urine concentrate depends on the soil's chemical and physical properties (Figure 4).

Conclusions

- All urine-derived materials used have potential to be soil fertilizers that provide N and P across a wide variety of soil types.
- Struvite can be as effective as commercial fertilizers and can be more effective due to its slow reaction rates.

Future research: More studies need to be done to measure forms in which nitrogen losses occur from soils or fields fertilized with urine plant nutrient products.

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The use of DEWATS Effluent in Agriculture: Laboratory and Growing Tunnel Trials

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Funding:	Water Research Commission
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The eThekwini Municipality is currently considering new plans for social housing projects to cater for communities residing at the periphery of municipal boundaries and who cannot get connected to water-borne sanitation systems. The Municipality is considering alternative approaches in which water is provided through roof-tank reticulated sewage, a BORDA Decentralized Wastewater Treatment System/Anaerobic Baffled Reactor (DEWATS/ABR), a horizontal-flow constructed wetland and an adjacent agricultural area. The DEWATS/ABR system is successfully used in other developing countries such as Indonesia (Malisie, 2008; Reynaud et al., 2009) and India (Eales, 2012) and the wastewater from the system has been found suitable for irrigation onto agricultural land.

Figure 1: Decentralized Wastewater Treatment (DEWATS) plant effluent

Project aims and objectives: To investigate the potential use of DEWATS effluent and to assess the health and environmental risks associated with the practice of using effluent for crop production. The focus is on nutrient recovery and use and modelling to simulate nutrient uptake and soil processes so as to know what goes into waterways.

Key to this project is firstly, the determination of land requirements for crop production if agriculture is integrated in the development of housing schemes; and secondly effluent disposal systems during the wet/summer season when crop water requirements are met by rainfall. This information will allow for the development of a decision support tool to enable policy makers to come up with a holistic approach towards integrated urban sanitation and agriculture.

Laboratory and tunnel experiments were carried out to determine N and P movement, uptake and field experiments were done to determine effluent loading, impacts on soils, crops and water bodies.

Figure 2: N and P retention investigated in a column experiment

The study determined the following:

- the capacity of three different top soils (Sand, clay and acidic soils) to retain nitrogen and phosphorus from DEWATS effluent and their uptake by perennial rye grass;
    - the movement of nitrogen and phosphorus contained in DEWATS effluent through Sand, clay and acidic soils types;
    - Pathogen loading and survival in response to application of DEWATS effluent to the three soils.
- The acidic (Inanda) soil was least able to prevent N leaching from the soil especially in the planted columns.
- Creation of channels by the roots might have also allowed a faster flow of DEWATS effluent through the Inanda (Figure 3).

- The clay soil was the most efficient in reducing the leaching of N and despite having shorter rooting depth than either the acidic or the sand soil. The clay soil however produced higher biomass.

Results from the pathogen analyses suggest that either contamination occurred or the samples underwent changes between being sampled and being analysed and are not conclusive.

The results show that:

- The DEWATS effluent has the potential to provide N and P for plant growth.
- Soil type plays a major role in determining retention of N and P allowing uptake by plants.
- Perennial rye grass was able to efficiently absorb large quantities of N and P from the effluent as was indicated by an increase in dry matter over time (Figure 4).
- Leaching of nutrients was more pronounced through the soils that had vegetation probably due to channel flow around roots as they grow.
- The result also confirm that the DEWATS effluent has a liming effect (Figure 5) and was able to increase nodulation and yield in soybean in a strongly acid soil (Figure 6).

Figure 3: Perennial root growth in the Sepane (Se), Inanda (Ia) and Cartreff soils (Cf) in columns irrigated using DEWATS effluent

Figure 4: Perennial ryegrass growth in an acidic, clay and sand soil

Conclusions

The DEWATS effluent was confirmed to have a clear liming effect on a very acid soil.

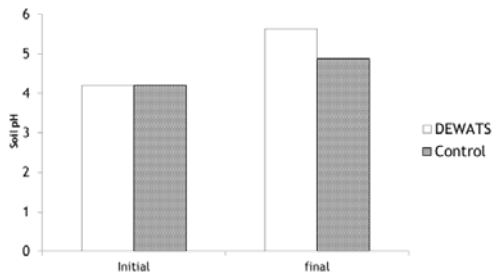

Figure 5: Changes in soil pH in response to DEWATS effluent application to an acidic soil

Figure 6: The effect of the DEWATS effluent on soybean root growth in an acidic soil

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The Use of DEWATS Effluent in Agriculture: Field Trials

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Key to using the DEWATS effluent for agriculture is to determine the land requirements for crop production if agriculture is integrated in the development of housing schemes; and secondly effluent disposal systems during the wet/summer season when crop water requirements are met by rainfall. This information will allow for the development of a decision support tool to enable policy makers to come up with a holistic approach towards integrated urban sanitation and agriculture.

Figure 1: Banana/taro intercrop planted at Newlands Mashu and irrigated using the

Field experiments are therefore being carried out in Newlands Mashu in order to assess changes in soil characteristics, nutrient uptake from effluent, leachate characteristics within the root zone and movement of water away from the experimental plot that may impact on surrounding rivers and groundwater.

Banana water requirements

- Rainfall and evapotranspiration data recorded from the weather station for the period November 2013 when the crops were planted to November 2014 showed that the total rainfall received over this period was 587 mm and the total evapotranspiration (ET) was 1117 mm.
- The annual DEWATS effluent use for the same period is estimated at 136 896 L p.a. per 70m^2.
- At this rate of use a hectare would require about 19 576 128 L p.a.
- The DEWATS plant at Newlands-Mashu has an annual production of effluent of 3 650 000 L p.a. (10 m^3 per day).
- To use all the effluent produced at the rate for the field experiment would require 0.2 ha of land.
- The total ET = 10 420 000 L ha-1 yr^{-1}; total rainfall = 5 770 000 L ha^{-1} yr^{-1}.
- Deficit = 4 650 000 L ha-1 yr^{-1}.
- The effluent applied was equivalent to 19 576 128 L ha^{-1} yr-1 which resulted in a 'surplus' of 14 926 128 L ha-1 yr^{-1}.
- This equates to 1 500 mm with regard to the crop requirement.

From a water supply point of view much more of the effluent could have been irrigated onto the experimental plots.

Nutrient loading

- Estimated annual total of DEWATS effluent irrigated per 70 m^2 at Newlands-Mashu is 136 896 litres.
- N content = 61 mg L^{-1}.
- P content = 5.1 mg L^{-1}.
- Annual loading of 1193 kg N ha^{-1}.
- Annual loading of 100 kg P ha^{-1}.
- Banana: 200 - 400 kg N ha^{-1}; 45 - 60 kg P ha^{-1}.
- Taro: up to 400 kg N ha^{-1} and 100 kg P ha^{-1}.
- Amounts added are higher than that required, especially for N.

BUT much of the effluent N is ammonium and (a) some may be held exchangeably in the soil; (b) not all will be converted to nitrate; and (c) some will be lost by denitrification and volatilization due to the wet soil conditions.

Conclusions

- DEWATS output at Newlands needs about 0.2 ha for complete utilisation at the rate used. However, considerably more of the DEWATS effluent could be used to irrigate ("fertigate") the banana/taro trial as the amount added to date is at the lower end of these crop's water requirements.
- Banana and taro would take up any extra P applied and P leaching is unlikely.
- There is an apparent calculated over-supply of N. But a combination of crop use, ammonium held by the soil and loss of N by denitrification and volatilization would account for the apparent over-supply and allow for more N to be applied if effluent irrigation was increased.
- No water had been measured in the water samplers (piezometers) installed at the trial site.
- Leaching down-profile has not occurred.

Future research

The results of this work are site-specific and cannot be extrapolated to other sites. It is impractical to conduct field experiments in many sites to have an understanding of the effects of using the DEWATS effluent for irrigation. Future research will focus on modelling the fate of the DEWATS effluent when used for irrigation.

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The use of LaDePa Pellets as an organic fertiliser: Effects on soils.

Authors:	**Alfred Odindo, Irene Baume, William Musazura and Chris Buckley**
Organisations:	Pollution Research Group, UKZN
Funding:	Water Research Commission
Status:	On-going
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The eThekwini Water and Sanitation (EWS), the municipal entity responsible for providing sanitation services to Durban and its surrounds, has co-invented low cost technology called LaDePa (see page 44). The technology can convert pit latrine and other sludge into dry product that can be used for agricultural (Nikiema et al., 2013). However, LaDePa pellets have a significant potential for agricultural use, through improved soil structure and increase nutrient uptake. Furthermore, it can act as a source of mineral nutrients.

Figure 1: Latrine Dehydration Pasteurization (LaDePa) agricultural pellets processed from sludge.

Project aims and objectives: To investigate the potential use of LaDePa pellets for crop production. Laboratory and tunnel experiments were carried out to determine N and P release patterns from LaDePa pellets in different soil types.

Main highlights of the results from the laboratory and tunnel experiments

LaDePa pellets as a plant nutrient sources

- An incubation study was conducted to determine nitrogen release from LaDePa pellets in two soils (acidic and non-acidic).
- There was a better release of N and P in the non-acidic (clay soil) than the acidic soil.
- The results from the incubation study suggest that LaDePa pellets could continue releasing nitrates steadily even beyond the 70th day of the incubation period.
- There was a high release observed for LaDePa pellets used in combination with immediately available fertilizers than when used alone.

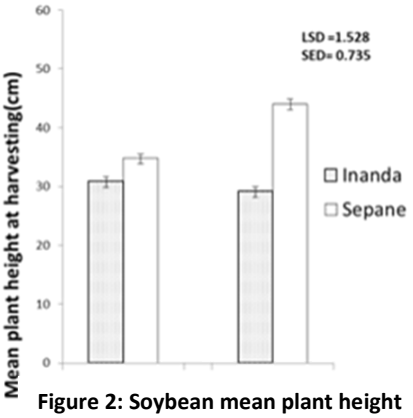

Figure 2: Soybean mean plant height at harvesting in response to the application of LaDePa.

Effect of LaDePa pellets on soybean nodulation and yield

- LaDePa pellets were compared with urea in a pot study using soybeans to determine their effect on nodulation and yield.
- Significant differences in relation to plant height over time as a function of soil type were observed. The clay soil resulted in taller plants in all treatments (Figure 2). However, no significant differences between the treatments imply that the effectiveness of LaDePa pellets depends on the soil's chemical and physical properties.

Conclusions: LaDePa pellets have potential to be soil fertilizers that provide N and P across a wide variety of soil types.

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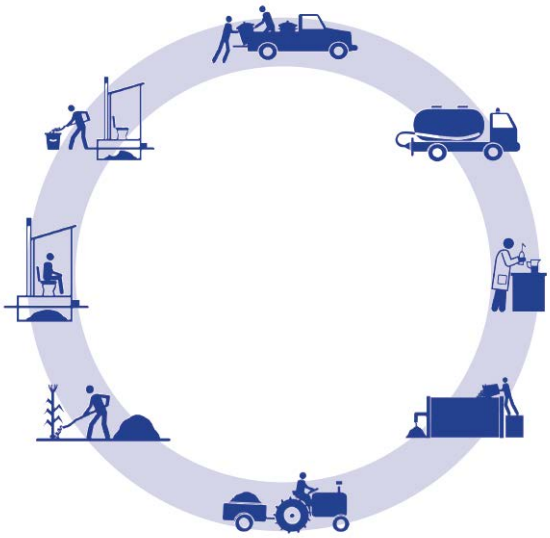
Section 3
Research and Ventilated Improved Pit Latrines



Ventilated Improved Pit (VIP) Latrines are widely used throughout Africa; however there is very little data about the composition of their contents, filling rates, emptying techniques and faecal sludge management. This research serves to add to the body of scientific knowledge on this type of sanitation system.

Disposing of Pit Sludge using Deep Row Entrenchment

Authors:	**Dave Still**
Organisations:	Partners in Development
Funding:	Water Research Commission
Status:	Completed
Contact details:	**Dave@pid.co.za**

Where to dispose of pit sludge?

Much of South Africa's basic sanitation infrastructure is reaching capacity: pits are full. The options for disposal of pit sludge are few. Because of the concentrated nature of pit sludge, only a limited quantity can be processed at a wastewater treatment works before COD and solids overload of the system causes process failure. The number of landfills prepared to accept sludge is diminishing and disposal costs at landfills are exorbitant. Transport of faecal sludge is logistically complicated, potentially environmentally hazardous and generally expensive.

Sludge is both a resource and a hazard

South Africa's *Guidelines for the Utilisation and Disposal of Wastewater Sludge* encourage sludge management options that include recovering energy, recycling the nutrients or synthesising commercial products from sludge. Disposal without beneficiation is to be considered the last resort: when the sludge quality is of a high enough standard to be used beneficially, the sludge producer must prove to the authorities which beneficial use options were investigated and why they were not feasible, before disposal will be allowed.

The potential benefits of the nutrients (nitrogen, phosphorus and potassium as well as micro nutrients) and the high organic carbon content of sludge have been well demonstrated. Using sludge to improve soil would yield a number of benefits in the South African context, including reducing reliance on expensive fertilisers derived from scarce phosphorus reserves and increasing food security when applied at the subsistence level.

The utilisation of sludge must, however, be managed using stringent safety measures in order to prevent the uptake of harmful chemicals by humans or animals, contamination of the environment or the potential of exposure of humans to the pathogens found in sludge. Options such as surface application of sludge or use of composted sludge require treatment prior to use to stabilise the sludge and destroy pathogens.

The deep row entrenchment method

A method of entrenching sludge which requires no prior treatment has been used since the 1980s near Washington, D.C. in the USA. Sludge is buried in deep rows, covered with soil and planted with trees. This method provides adequate management of odour and the risk of disease transmission and can be used to benefit forestry, wildlife habitats or assist in the reclamation of land.

Over a 6 year period from 2008 - 2014, Partners in Development conducted a study on behalf of the Water Research Commission to investigate the application of the deep row entrenchment method under South African conditions.

The study looked at the following questions:

- Do the nutrients and pathogens in sludge pose a hazard after it is buried in the ground?
- Could the nutrients in buried sludge be used to enhance the growth of trees?

Pit latrine sludge was buried at different loading rates on a sandy site near Durban while wastewater sludge was entrenched at a Sappi research site near Howick. The impact of sludge on tree growth under controlled conditions and the use of deep row entrenchment of sludge at the household level (combined with the planting of fruit trees) were also investigated in two smaller studies.

The findings of the study after 4 years of deep row entrenchment are as follows:

- Tree growth is enhanced. When sludge is buried in close proximity to eucalyptus trees (a primary crop in South African forestry plantations) total timber volume is increased by as much as 50% (It remains to be seen whether this difference will be sustained over a nine or ten year growth cycle.) This additional timber volume offsets the cost of the entrenchment process by as much as a third or even a half.
- Soil quality is enhanced. The increased potassium and phosphorus levels in the soil will be lasting and will benefit future tree growth cycles.
- Nutrients do not contaminate ground water. Despite very high nutrient loading rates, no significant impact on the groundwater was observed over four years of monitoring. It was found that the phosphorus in the sludge binds to soil particles near the point of burial while most of the nitrogen returns to the atmosphere through the process of denitrification and does not leach away.
- Pathogens die off. While a significant number of helminth ova were found in pit latrine sludge before entrenchment, after 3 years of entrenchment no viable *A. lumbricoides* (the marker helminth) eggs could be found in sludge samples.

Applying deep row entrenchment

For municipalities in South Africa, the deep row entrenchment method opens up a range of possibilities for the disposal of both wastewater and pit latrine sludge, overcoming the problems associated with the stabilisation of sludges, while providing benefits to non-edible crops and to soil. Potential risks to the environment or public health can be managed effectively with periodic monitoring of groundwater and soil. Partnerships between municipalities and forestry could provide mutual benefit to both, with sludge handled, applied and monitored by forestry companies on their own land or with sludge entrenched and monitored by municipalities on municipal land with a forestry company contracted to manage a timber crop on the entrenchment site. On site entrenchment of pit latrine sludge at the household level accompanied by planting of trees where space is available overcomes the difficulties and costs associated with the transport, treatment and disposal of sludge. Entrenchment on small decentralised plots is another option which may prove useful to municipalities.

A guideline has been developed and is available which is based on South African legislation and regulations, the recommendations of studies conducted in the US over the past 40 years and the knowledge gained from this research.

Latrine Dehydration and Pelletisation (LaDePa)

Authors:	**Dave Wilson and John Harrison**
Organisation:	eThekwini Water and Sanitation
Funding:	eThekwini Water and Sanitation; Particle Separation Systems (PSS)
Status:	Pilot moving to full scale
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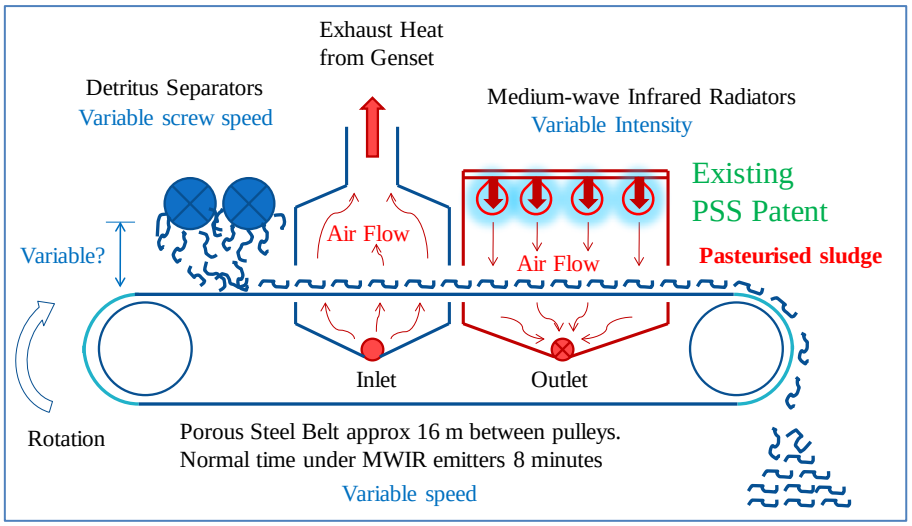
There are six major technical challenges associated with pit latrine sludge management:

1. Space and Access – prevents relocation of pit latrines in dense settlements and access for large scale mechanical equipment. In addition space is required for the final disposal of the sludge.
2. Human pathogen transmission.
3. Detritus disposed with the human faecal matter.
4. Material handling difficulties associated with the "stickiness" of sludge.
5. Added transport costs associated with mass of excess water.
6. Disposal of sludge.

From an environmental perspective, phosphates are a scarce non-renewable resource found in urine and therefore deposited in pit latrine sludge. The previous sludge disposal methods, not only wastes the phosphate and other nutrients, but also takes up air space on the landfill sites. In addition the pathogenic nature of the material means it has to be declassified using lime treatment.

Disposal of sludge at sewerage treatment works is not a viable option as it creates problems with the nitrification process and organically overloads the digesters.

The eThekwini Water and Sanitation division have developed, in conjunction with their technology partner Particle Separation Systems (PSS), a machine for the dehydration and pasteurisation of VIP sludge and the production of pellets. The machine is branded LaDePa (latrine dehydration and pasteurisation) and has won the IWA development award in 2011.



LaDePa is a machine that provides a containerised method of producing a nutrient rich soil conditioner that is workable and improves sustainability on a number of fronts, by removing the detritus, and pasteurising and drying the sludge to beyond the sticky phase. Due to its use of low technology, LaDePa relates well to the social environment where pit latrines are usually encountered in the developing world urban areas as it provides both business and work opportunities for the poorly skilled.

The operation of the pilot LaDePa in Durban and the Municipality's pit emptying project, together with tests done on the product from the machine, indicate that LaDePa should significantly shift the Pit Latrine sludge management paradigm towards sustainability.

Specification:

Capacity 2 500 kg/day at 70% solids (8 h/d)
Services population of 62 000 (8 h/d, 365 d/y)
Diesel consumption 100 l/d
i.e. 1 l diesel /25 kg dried sludge (70% solids)
0,6 l diesel/person/annum

Research Support to LaDePa

Authors:	**Simon Mirara and Chris Buckley**
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Funding:	Water Research Commission
Status:	Completed
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In order to optimise the operational process of the LaDePa, a research project funded by the Water Research Commission was undertaken by the Pollution Research Group making use of a laboratory scale LaDePa machine supplied by PSS.

There are two main objectives of this research:

- To characterize the drying and pasteurization behaviour of VIP faecal sludge in LaDePa machine.
- To determine the chemical and thermal characteristics of the processed pellets, in order to evaluate the use of the dried product for agricultural purposes or as a biofuel.

Laboratory-scale LaDePa machine

In order to characterize the drying and pasteurisation of pellets in the LaDePa machine, various parameters were investigated.

Table comparing specifications of the full-scale and laboratory-scale LaDePa machines

Feature	Full-scale LaDePa (located at Tongaat)	Lab-scale LaDePa (located at the PRG laboratory)
Belt width	950 mm	250 mm
Belt aperture opening	300 µm	200 µm
Heated width	1350 mm	220 mm
Heated length	11,000 mm	880 mm
MIR power	3 emitters each 48kW	2 emitters each 3.7kW
Blower power	5.5kW	0.75kW

From the moisture content measured at different residence times and medium infrared (MIR) emitter settings, drying curves were plotted in order to study drying kinetics, whilst volatile solids and ash content were determined in order to understand how the properties of the dried solid could change during the process. From the measurements of temperature at the core and surface of the pellets, the thermal history of the pellets was obtained, which enables to a better understanding of the drying phenomenology in our context. Through the calculation of the moisture removal as a function of the supplied power and the measurement of viable Ascaris eggs concentration, the drying and pasteurization efficiencies of the process were evaluated. The chemical and thermal properties of the dried sludge, and their variability as a function of the operating conditions were determined in order to evaluate their potential use in agriculture or as a biofuel.

Outcomes from this study showed:

- At high MIR emitter intensity (temperatures higher than 200°C), drying occurs the fastest and it is the most efficient, but there is considerable risk of undesirable thermal degradation and burning of the pellets. At medium MIR emitter intensity (temperatures between 100°C and 200°C), the risk of thermal degradation is avoided but drying takes longer. Under these conditions, a residence time of approximately 20 minutes is necessary to reduce the moisture content to 20%. At low MIR intensity (temperatures lower than 100°C), drying is too slow. In some cases, complete pasteurization is ensured in less than 8 minutes.
- The recommended MIR emitter intensity should be the highest one possible without thermal degradation of the pellets. For future work, it is important to determine the temperature and corresponding intensity at which thermal degradation first occurs.
- Minimizing the distance between the emitters and the conveyer belt would lead to energy saving due to lower MIR intensity required to achieve the targeted moisture content and complete pasteurization.
- Decreasing the pellet size leads to faster drying and a more efficient process.
- Drying will be faster by increasing the air flowrate in the heating zone as it will lead to a better evacuation of the evaporated moisture from the surface of the pellets to the environment. However, the air should be heated in order to avoid a cooling effect on particle surface, which has a negative effect on drying rate.
- From a phenomenological point of view, pellet drying is isothermal in the early stage, thereafter the temperature at the surface increases and becomes considerably higher than at the core. This suggests that the pellet surface gets dried before the core. If the heating flux from MIR emitters is too high, the dried surface can be thermally degraded while the core continues to dry.
- Drying provokes some chemical and physical modifications in the pellets: a decrease of the concentration of the soluble nitrogenous compounds, suggesting chemical changes of the nitrogen form in the sample; a decrease in the thermal conductivity and heat capacity, leading to globally a slight increase of the thermal diffusivity.
- The dried pellets present an interesting nutrient composition in terms of macronutrients, P and K, and micronutrients, Mg and Ca. If used for agricultural purposes, most of the phosphorous will be slowly released in the soil. A considerable part of the potassium, magnesium and calcium could be expected to be fast released in the soil, as these compounds are very soluble in water. The dried pellets would rapidly release some nitrogen, mainly as ammonium and nitrites. These forms are not the most optimal for assimilation by the plants, compared to nitrates, but they can be converted into the latter one by soil microbial activity.
- The use of dried pellets as a biofuel is a potentially interesting alternative, because of the relatively high calorific value and good thermal diffusivity of the material.

Mechanical Properties of Faecal Sludge

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Organisation:	Pollution Research Group, UKZN
Funding:	Bill & Melinda Gates Foundation
Status:	Completed. Final Report Submitted.
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The Pollution Research Group (PRG) was contracted by the Bill & Melinda Gates Foundation (BMGF) to carry out a study into the properties of faecal sludge from different types of on-site sanitation facilities. The aim of this study was to generate data to provide a better understanding of the potential use of faecal sludge as a biofuel or fertiliser, but mainly to support the design and sizing of mechanical pit-emptying devices, transportation and processing systems for the excavated sludge, as well as the design of future on-site sanitation facilities.

Characteristics of faecal sludge vary greatly between different locations and types of facilities and in order to assess the range of properties that may be encountered, faecal sludge samples were collected and analysed for typical on-site sanitation facilities in the Durban metro area, such as: wet and dry household VIP latrines, household UD toilets, household unimproved pit latrines, community ablution block VIP latrines, and school VIP toilet blocks.

During the course of this project, 45 different on-site sanitation facilities in Durban peri-urban and rural areas were emptied and 211 subsamples were selected and analysed in total for physico-chemical, thermal, mechanical and biological properties. The variation between properties from different sludge depth levels within one and the same pit or toilet were investigated and compared to other facilities from the same or different type.

A number of trends were observed as a result of this study:

- Properties of sludge tend to change with sludge depth.
- The moisture content was higher in the upper layers of sludge and reduced with depth, i.e. with age of the sludge.
- The volatile solids content was higher in the upper layers of sludge and reduced with depth, i.e. age of the sludge. The ash content increased with the sludge age.
- The nutrients content (NPK) varied broadly in the sludge layers and a correlation with the sludge age was not established.
- The total COD varied through the sludge age, similarly to other properties. There was a trend of reducing COD with depth at the

back sections of household VIPs and increasing COD with depth of the front sections.

- The pH within the pits was generally neutral (between 6.65 to 7.60) except for the school VIPs where it was higher than 8. No trend of pH variation with sludge age and depth was observed.
- The measured thermal properties of the faecal sludge did not show a clear trend of variation with sludge age. However, expected linear correlations were observed between the thermal conductivity and moisture content, as well as between the calorific value and COD.

- In terms of rheological properties, the sludge displayed a yield stress and was sheer thinning.
- The sludge from all sanitation facilities, especially from the lower levels of the pit, showed higher viable helminth egg content than the limit of <1 helminth egg/g TS set by WHO (2006). Hence, the sludge is not safe and suitable protective equipment must be used by workers who empty pits manually. This indicated that the household users might be also at risk if have contact with the sludge. The school toilets VIP sludge showed much higher helminth egg counts, which indicates that school children potentially carry higher loads of helminths. The significant difference between helminth egg counts in the inactive vaults and the active vaults of UD toilets supports the assumption that standing time alone can sanitise vault contents (WHO, 2006), assuming that no additional treatments were applied to the inactive vaults sampled.

Data generated from this project has been shared with other sanitation practitioners world-wide to assist them in the design of their pit emptying prototypes, or in the design of innovative sanitation solutions.

Economic Modelling of Pit Emptying and Treatment

Authors:	**Ruth Cottingham, Dave Still and Susan Mercer**
Organisation:	Pollution Research Group; Partners in Development
Funding:	Bill & Melinda Gates Foundation
Status:	Completed
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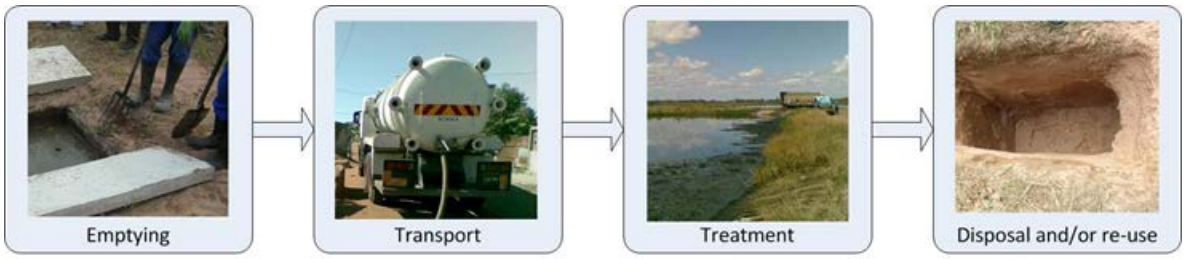
The objective of this study was to carry out an economic evaluation of (i) the LaDePa process and (ii) a total combustion processes for sludge disposal and/or re-use. These were compared against the option of disposing of sludge to landfill. A versatile economic model was developed that enables a total cost comparison of the processes to be carried out, from the latrine pit to the point of end disposal or sale of the treated sludge product.



The model was developed and populated by making use of data from eThekwini Water and Sanitation (Durban, South Africa) on the pit emptying process and the operation of the LaDePa pelletising machine. Additional data on the pit sludge, LaDePa pellet and combustion ash characteristics were obtained through laboratory analysis and from existing data within the Pollution Research Group (University of KwaZulu-Natal). A data set was also obtained for faecal sludge collection, transport and treatment in Dakar, Senegal (compiled by Eawag) and used for validation.

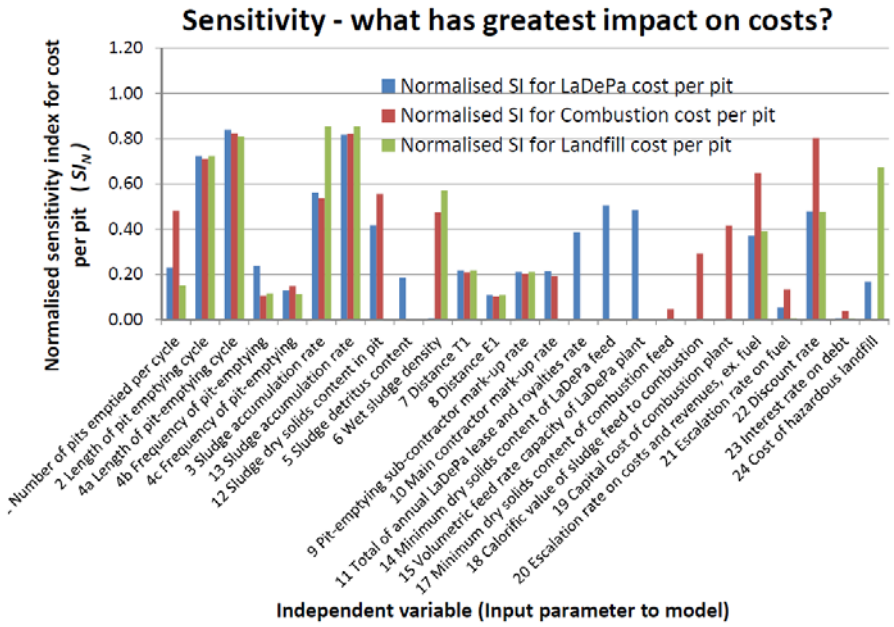
The model can be used to inform both investment and operational decisions, for example:

- Designing the optimal depth and volume of a VIP pit.
- Deciding how best to invest limited capital in an FSM system: e.g. in road improvements to reduce transport times, or in improved sludge processing facilities.
- Optimising the structure of a pit-emptying programme: what frequency of pit emptying optimises costs in a particular geographical context?
- Assessing where and to what level the costs of FSM can be offset: reducing the costs of collection and treatment versus generating income from the sale of processed sludge product.
- Estimating the break-even service charges for FSM services, e.g. pit-emptying, in a particular district, to enable effective cross-subsidising between districts and services.

The model also calculates the potential agricultural value of sludge end products, through (i) simple valuation of the products' NPK value and (ii) partial budget analysis of the economic benefit of replacing commercial fertilisers with treated sludge for a specific crop.

At the base case eThekwini conditions, the costs for all three disposal options were found to be similar (376 USD/pit for disposal via the LaDePa process, 359 USD/pit for combustion and 326 USD/pit for disposal in a hazardous landfill). All costs included emptying and conveyance costs, with the LaDePa option being slightly more expensive than the other two. The cost of producing LaDePa pellets was calculated to be 1 226 USD/tonne pellets. In comparison, the maximum competitive selling price for the pellets, if they were to be used to fertilise a dry beans crop in place of an existing organic fertiliser, was 18 USD/tonne. This is not a representative value as it is based on the NPK nutrient content of a very small number of pellet samples, and did not take into account micro-nutrients.

The model also identified the key set of operating parameters that, if optimised, would make the LaDePa option significantly more cost-effective than the other options. For eThekwini municipality these included: the optimal level of decentralisation of processing plants, the structure of the pit-emptying programme, control of sludge accumulation rates in pits (e.g. through improved solid waste collection services and pit design) and the cost of drying sludge prior to processing.

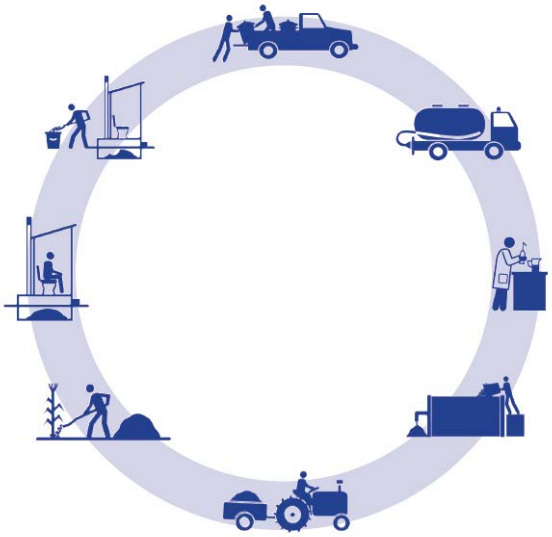


The application of the model to the eThekwini municipality context exemplified how the model can be used by decision-makers in other geographical locations responsible for the design and implementation of FSM systems, including policy makers, municipalities, funding organisations and FSM service providers. Future work will focus on the refinement of the model (e.g. incorporating further co-dependencies between operating conditions such as sludge dry solids content and sludge accumulation rates) and on making it accessible and applicable to as wide a range of users as possible.

The model and full report can be downloaded via the following links:

- Link to report (which includes the guide on how to use the model, assumptions, limitations, sensitivity analysis etc): https://db.tt/0Tk2eAx0
- Link to spreadsheet model: https://db.tt/0in45kBZ

Section 4
Research and Urine Diversion Toilets



Sanitation is a very personal practise, so undertaking research on excreta streams can be very difficult to initiate. EWS provides the opportunities for researchers to access excreta streams from urine diversion toilets for characterisation and treatment trials. House to house surveys undertaken in conjunction with EWS officials provide a deep insight into user preferences and practices.

Social Acceptance of Urine Diversion Toilets: Survey Results

Authors:	**Dr Lisa Frost Ramsay**
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Funding:	Eawag (VUNA project)
Status:	Completed
Contact details:	**ramsayl@ukzn.ac.za**

Dry sanitation in eThekwini commenced in 2001 with the expansion of municipal boundaries to include an additional 75,000 households, 80% of which were without appropriate services. The eThekwini Municipality identified urine-diverting dehydration toilets (UDTs) as an option for sanitation delivery at the scale and urgency required and embarked on a project to provide UDTs to households in unserviced areas. By 2011, more than 75,000 UDTs had been installed. At present this number stands at approximately 82,000 UDTs.

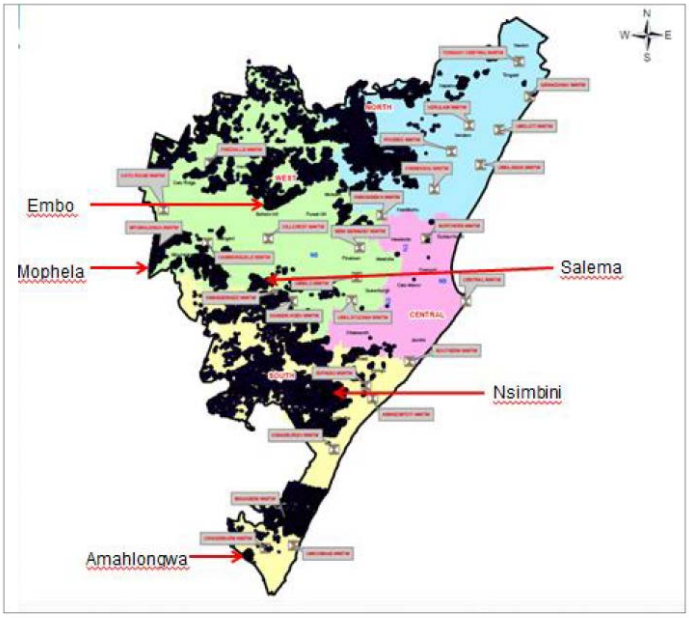

Figure 1: Location of 2014 sample areas in eThekwini Municipality

An intensive household survey was commissioned by eThekwini in 2011 to explore usage levels, social acceptance, and any problems associated with construction of UDTs in the region. A structured questionnaire was developed and administered (using mobile phone technology) to 17,449 householders in 65 areas of eThekwini between January and May 2011. Considering the magnitude of the sample size, mobile phones offered a more efficient approach than pen and paper (with immediate digital data capture) and allowed for better quality control of the data (fieldworkers were monitored in real time). The research instrument consisted of 14 questions and an observation checklist, which was completed by trained fieldworkers.

A repeat assessment, with a smaller sample size, was conducted in 2014. This campaign sought to answer the following key questions:

- How satisfied are users with UDTs?
- What proportion of users were educated on DUD usage and maintenance at installation or subsequently?
- What are the post-implementation issues?
- What is the scope for chamber emptying and nutrient re-use?

In 2011, the three key complaints were odour, the toilet door not closing and poor construction. In 2014 these were odour, the toilet door not closing and emptying the chamber.

Other key comparisons include:

- In 2011, 14% of households surveyed maintained a pit toilet in addition to their UDTs. In 2014, this value was 17%.

- In the 2011 sample, 80% respondents indicated that they used UDTs all the time and 7% none of the time. In the 2014 sample, this was 81% daily usage and 8% never.
- In 2011, 51% of male respondents indicated that they used the urinal. In 2014, 40% of the male respondents indicated that the urinal was being used, 52% that it was not being used, 4% were unsure, 2% that there were no male household members, and 2% did not respond to the question.
- In 2011, the vast majority of the households (84%) reported that their chambers were emptied by a family member, and only a small proportion (9%) hired an entrepreneur to perform this task. In 2014, 8% indicated that someone was hired to empty the UDT chambers.
- In 2011, the vast majority of sampled households (90%) reported having received education on the use and maintenance of UDTs. In 2014, this value was 66% with a 3% of respondents indicating that they do not know whether education was received and a further 1% not answering this question.

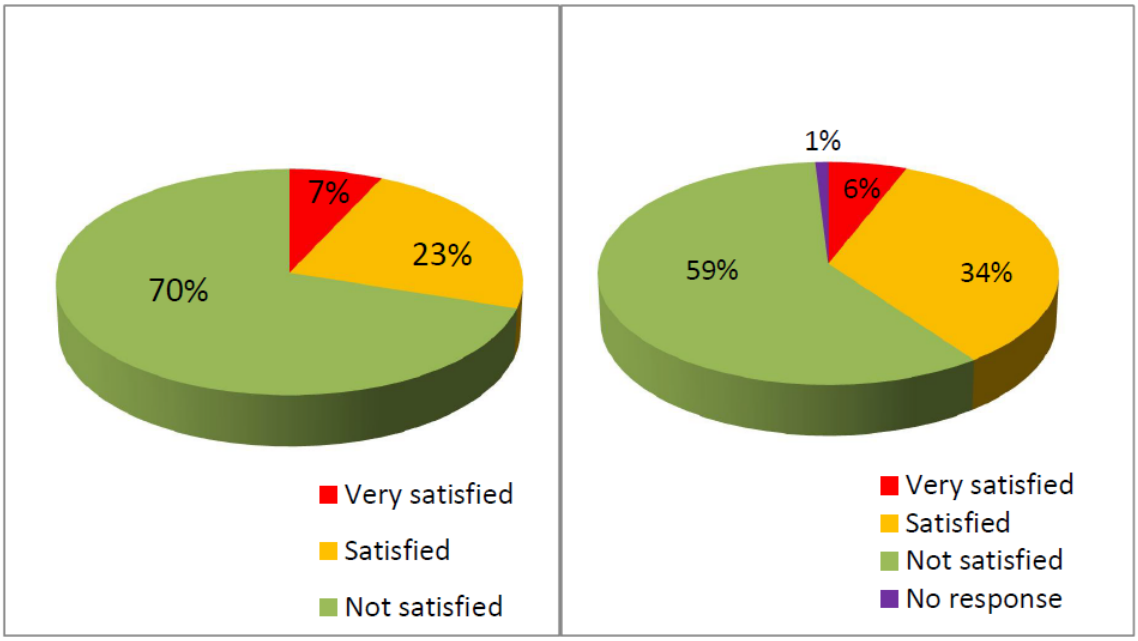

Figure 2: Respondents' satisfaction with UDDTs in 2011 (left, n = 17,449) and 2014 (right, n = 1567)

The 2011 survey revealed a significant association between perceived UDT odour and poor reconnection of the urine pipe, modifications were made to the connection for future UDT installations. The results of the second survey suggest that perceived odour remains a concern in 2014, but the level of concern appears to have decreased. The acceptability of a chamber clearing service and the preference that chamber contents are removed offsite is considered positive in light of eThekwini's plans for nutrient collection and reuse (albeit from urine, not faeces). There was a clear difference in support for chamber content removal between the more remote and more central areas, with the more remote communities showing lower levels of support. Superstitions on the use of bodily waste in witchcraft need further investigation.

Addressing user satisfaction is vital for the next stage of 'drop and reuse' sanitation. Educational activities play a fundamental role in overcoming negative perceptions and barriers towards collection and reuse. Results from the 2014 survey suggested a decrease in the proportion of respondents who had been educated on UDT usage and maintenance. Research into effective educational approaches forms part of the VUNA study and future campaigns aim to address this gap and highlight the importance and safety of nutrient reuse.

The Role of Health and Hygiene Education in the Acceptance, Utilisation, and Maintenance of Urine Diversion Toilets (UDT)

Authors:	**Nosipho Mkhize, Myra Taylor, Kai M. Udert, Teddy G. Gounden, Chris A. Buckley**
Organisations:	eThekwini Water and Sanitation, Discipline of Public Health Medicine, School of Nursing and Public Health (UKZN), Earth and Environmental Sciences (UKZN), Eawag, Swiss Federal Institute of Aquatic Science and Technology, Pollution Research Group (UKZN)
Funding:	Eawag
Status:	Final draft
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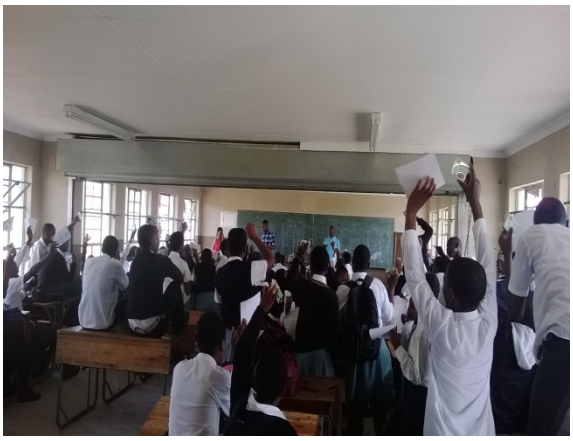
The Masters study was part of the VUNA project contracted by Bill & Melinda Gates Foundation (BMGF) to design and implement a health and hygiene education campaign informed by the users of the Urine Diversion Toilet (UDT). The aim of the study was to have health and hygiene education programme that will enhance acceptance, use and maintenance of the UDT.

The qualitative approaches were used to explore the role of health and hygiene education in promoting acceptance, usage and maintenance of the UDT. The study was undertaken in three peri-urban areas of eThekwini Municipality, namely Zwelibomvu (West), Lower Maphephetheni (North) and Hlanzeni (South). In each study area 40 households were randomly selected from an aerial map. At each household a short questionnaire was administered on the first visit to ascertain if the household was (1) maintaining the toilet properly, (2) not maintaining the toilet properly or (3) not using the toilet. The latter groupings helped in forming the homogenous focus groups. Purposive sampling was later used in selecting the key informants as they were selected according to their involvement in the UDT project, the position they hold in their community and their knowledge about the UDT. The qualitative data were analysed manually through the process of content analysis, data were verified, then statements were used to code and make meaning from words, thereafter categories were developed and were later linked to get a more complete meaning. The findings were then used to develop the health and hygiene education programme.

121 people participated in focus group discussions and 25 key informants were interviewed in the qualitative component of the study. More than 60% of participants were females and the ages varied from 22 to 63 years. The household participants were grouped into categories based on the condition of their UDT. Below are some of what the users shared as contributing factors towards acceptance, use and maintenance.

- Overall, 80% of households were not maintaining the UDT properly i.e. broken items were not repaired, toilet items were repaired with unsuitable material and the toilet was not kept in a usable and hygienic state.
- A proportional number of participants reported that they do not regard the UDT as a permanent asset of their household.
- More than 95% of participants aspire to have a flush toilet. *"No one who thinks highly of you will give you this toilet [UDT]…I feel undermined, (focus group discussion).*
- Community role models change UDT to flush or septic tank.
- The younger participants between the ages of 20 and 29 years were more accepting of the UDT as a permanent asset.
- A large proportion of participants reported that they did not receive education when provided with the UDT.
- All participants reported that children below 4 years were not allowed to use the UDT but to do open defecation due to risk of falling.
- The participants reported that they are not aware of how their neighbours feel or how they are maintaining the UDT.
- Emptying the UDT was one main challenges reported.
- The shallowness of the vault was another negative aspect
- Washing hands after toilet use was not a priority.



The health and hygiene education programme was then designed to address all of the above issues comprised of various education materials for different age groups. The programme was rendered to schools and influential community structures. The education programme was conducted in two rural areas and 953 people were reached. The health and hygiene education programme will be evaluated after one year.

Harvesting Nutrients from Urine: VUNA

Authors:	**Kai Udert and Chris Buckley**
Organisations:	Eawag; Pollution Research Group
Funding:	Eawag; Swiss National Science Foundation; US National Science Foundation
Status:	Pilot stage
Contact details:	**buckley@ukzn.ac.za**

In 2010, eThekwini Water and Sanitation (EWS), teamed up with Eawag to develop a new and improved sanitation system that allows for nutrient recovery from urine in order to promote sanitation.

The project had three basic objectives:

- Promote the use of toilets by giving urine a value;
- Produce a valuable fertiliser;
- Protect the environment by reducing pollution.

The project was named VUNA, which means “harvest” in isiZulu but which also stands for “Valorisation of Urine Nutrients in Africa”. By bringing together science and practice, the partners aimed to develop the technologies and managements tools necessary for the large-scale implementation of nutrient recovery from urine in Durban and other cities facing similar sanitation challenges.

The project was divided into three main areas: (i) technology; (ii) social and (iii) logistics. Within the technology research areas, the focus was on the development of treatment processes for recovering nutrients from urine and determining the quality of the final products.

The first of the three basic processes investigated was struvite precipitation, a simple procedure for phosphorus recovery The second process investigated was complete nutrient recovery by combining nitrification and distillation, while the third process was electrolysis which can be used for very small on-site treatment units when nutrient removal, rather than nutrient recovery, is the primary goal of treatment. Efficient treatment processes are crucial for quality fertiliser products. In particular, the treatment must remove any harmful substances, such as pharmaceuticals or pathogens, and ensure good availability of the nutrients.

Logistical and social aspect focused on the way in which urine is sourced and transported. This required that urine-diverting toilets must be accepted and used by the population, that urine collection is organised in an efficient and reliable way, and that the overall system is economically viable.

Two basic urine collection schemes in the field; namely:

- An institutionalised scheme where municipal workers collected urine in jerry cans from households; and
- An incentivised scheme whereby toilet users were compensated with monetary incentives when they dropped off their urine jerry cans at local collection points.

Based on the outcomes of this research, computer models could be used to identify ways in which costs could be minimised and revenue from the product maximised. This information was used to develop business models for the upscaling of the system.

User surveys assessed the acceptance of the urine diversion concept and, especially, the toilets. An inadequate understanding of the rationale behind urine diversion was often the reason for low acceptance rates for the toilets. In an effort to improve the awareness and acceptance, interactive health and hygiene education methods were developed.

Overall, the project has received a lot of attention from researchers and practitioners in South Africa, Europe and around the world. The Swiss Federal Office for Agriculture recently granted a license for the fertiliser produced using the VUNA Project's complete nutrient recovery process. This is another valuable endorsement for VUNA's nutrient recovery process – harvesting urine from a sanitation system, reducing environmental pollution and turning waste into a valuable, marketable product.

The final report on this project is available at: www.vuna.ch

Urine Diversion Toilet Waste Removal and Processing using Black Soldier Fly (BSF) Technology

Authors:	**Nick Alcock**
Organisations:	Khanyisa Projects
Funding:	Bill & Melinda Gates Foundation
Status:	Pilot stage
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Since 2002, eThekwini Municipality has installed over 80 000 Urine Diversion (UD) double vault toilets at the household level in rural areas. This technology was selected to replace Ventilated Improved Pit Latrines (VIPs) as the Municipality's basic onsite sanitation option as it was expected that the UD systems would produce a degraded sludge which could be safely removed and buried on site by the resident. This approach eliminated the challenges and costs encountered when servicing VIP systems, which included access to pits, removal of sludge containing solid waste, and transport and disposal of sludge.

However, a number of concerns have since arisen over the removal of faecal material from UD toilets. These include health risks to residents who handle the potentially pathogenic sludge and dissatisfaction amongst household owners over the expectation that they will remove the faecal matter from their systems themselves while other recipients of basic sanitation receive a free service from the Municipality. The Municipality therefore needed to identify other safe and economically feasible faecal matter removal options which can be provided to the 80 000 (and increasing) homes.

Though funding from the Bill & Melinda Gates Foundation (BMGF), the eThekwini Municipality's Water and Sanitation Unit (EWS), together with a professional consulting team (Khanyisa Projects, Partners and Development and the University of KwaZulu-Natal's Pollution Research Group) began exploring the use of business partnerships using incentivized contracts for the safe and efficient removal and disposal or processing of the UD contents.

The project will involve the disposal or recycling of waste by means of two options:

1. Where there is space on site and poor access, burial of waste on-site (with planting of a tree)
2. Where there is limited space, socio political pressures and good access, removal of waste to a decentralized processing plant and production of valuable end products

In order to implement these two disposal / recycling options the project has been divided into two components. The first component is the rollout of a management contract which will include the appointment of local labour to undertake the removal of faecal waste from the UD toilet vaults and either bury onsite or transport the contents to a central BSF processing plant. It will be stipulated that the managing contractor must adhere to all health, safety and environmental requirements. A mentoring program will be initiated for local labour showing business potential through the establishment of a Business Incubation Unit. The final

step will be the selection of contractors for the second rollout (cycle 2) without the need for a managing contractor. In summary, the key steps that are taking place are:

- Development and approval of tender document
- Management of tender process
- Contracting of managing contractor with requirements for employment of local labour or local businesses
- Establishment of business incubator
- Management of removal and transport contract
- Selection of potential businesses for cycle 2 rollout
- Evaluation

It is envisaged that the second UD waste removal cycle will be initiated during the last six months of this program.

The second component is the establishment and operation of a faecal waste processing plant utilizing the Black Soldier Fly (BSF) Technology. During Phase 1, the Project team engaged with the private organization Biocycle which has been piloting the BSF technology to process faecal waste for several years. The larvae of the Black Soldier Fly consume organic waste in order to grow to adult size. The adult larvae are then processed into products such as chicken feed, pet food and oils. The residue can be used as a soil conditioner or converted into biochar. Business modelling was undertaken and a draft service level agreement was drawn up with a view to establishing a form of public private partnership between the Municipality and Biocycle. The Isipingo Waste Water Treatment Works was identified as a suitable site for the establishment of the processing plant. The following steps are taking place:

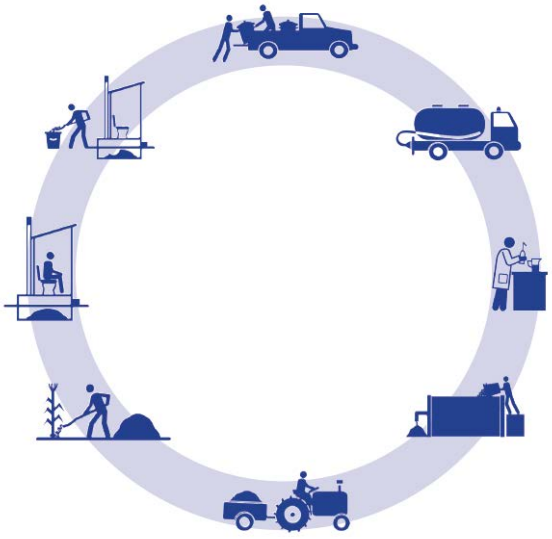
- Finalization of Service Level Agreement including financial aspects
- Signing of Service Level Agreement
- Reports to National Treasury and Council Procurement Committees
- Approval of Procurement process by Council and National Treasury
- Approval of land use by Council
- Establishment of BSF processing plant
- Monitoring of Operation
- Evaluation

Should the business partnership be successful, then the disposal costs that the Municipality would normally pay for disposal at a hazardous waste site would be substantially reduced. There are still some risks associated with the model as the operator cannot say with certainty how the market will accept the products if faecal sludge forms part of the feedstock. The business partnership that has been agreed between the Municipality and the selected operator involves the sharing of the risks and potential profit on a 50/50 basis. The project has also been significantly de-risked through the provision of funds by the BMGF for the capital expenditure of the BSF plant.

The Municipality's vision is that the profit that it derives from the first BSF plant will be used to establish additional BSF plants to ultimately address all UD and other faecal waste at minimal cost to the City.

The second element of the vision is that local businesses are empowered to form sustainable sanitation businesses that can provide ongoing waste removal services for the City.

Section 5
Research and Pour Flush Toilets



Innovative sanitation systems need to be evaluated in small-scale pilot trials, modified and then larger trials undertaken so that ultimately they can be rolled out at scale. The pour (or low) flush pedestal is being taken through the development phases prior to full-scale evaluation.

Pour Flush and Low Flush On-site Sanitation

Authors:	**Dave Still**
Organisations:	Partners in Development
Funding:	Water Research Commission
Status:	Completed
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This new toilet technology is based on the "pour flush" system which is widely used in Asia. The interest in investigating this technology was in response to the following challenges facing sanitation in South Africa:

People want flush toilets but waterborne sanitation isn't always possible

Many consumers of basic sanitation aspire to use full flush toilets, seeing them as a symbol of equality with residents of more affluent areas.

Waterborne sanitation, however, is not always feasible as a basic sanitation option because of the logistical problems with sewering crowded informal settlements or the cost constraints of sewering sparely populated rural areas. In addition, waterborne sanitation has major drawbacks in terms of sustainable use of water resources and the environmental impact of breaks and blockages.

VIPs are better than homemade toilets but leave some thorny problems unsolved

While the VIP does provide safer and healthier sanitation than homebuilt latrines, this technology remains limited in several ways:

- Research has found that VIPs do not always work as a sanitation solution for the whole family. Because of the fear of small children falling through the pedestal into the pit (reported by 51% of householders in a recent survey of 111 householders in Limpopo) some families instruct young children to defecate outside rather than use the toilet. This defeats the purpose of sanitation because of the risk of diseases spreading from the faeces that are deposited in the open.
- While a properly built VIP should be a safe and stable structure, VIPs built with inferior materials or construction methods may be at risk of collapse into the pit.
- In the absence of a municipal waste collection service, many families view the VIP as the safest or most convenient place to dispose of household rubbish. The addition of non-degradable waste to the pit often reduces its lifespan to less than half of what it should have been.
- VIPs are difficult to empty because the pit is directly under the pedestal and often contains a large amount of rubbish. In some communities pits have collapsed when they were emptied.
- The sight and smell of faeces under the pedestal is offensive to many users.

There is a shortage of proven technologies to bridge the gap between the VIP and the full flush toilets

Septic tank systems are expensive and require more space than is available at some households. They also do not address the need for water efficiency.

Some low flush technologies have been developed which use moving parts which can break (e.g. a flap in the bowl) or have complicated parts that can clog. If fittings are not easy to source from local hardware stores, or local plumbers don't know how to service the technologies, a simple maintenance issue could result in a failed technology.

RESEARCH AND DEVELOPMENT

Prompted by the WRC, research was initiated into the applicability of pour flush technology for South Africa began in 2010 and a prototype was produced which was adapted to the South African user (who typically prefers to sit, rather than squat, and to use toilet paper rather than water for anal cleansing). Key design requirements were as follows:

- It must have no complicated, easily breakable parts and no more moving parts than a standard flush toilet
- It must have a water seal
- It must not be blocked if newspaper is used for anal cleansing
- It must be aesthetically acceptable to users
- It must require no more than 2 litres of water to flush

Pour flush units have been tested in over 200 homes since 2010. Low flush units were installed in 2 schools in KZN in 2013 and pour flush units in 6 schools in Limpopo in 2014 and several more in the Eastern Cape. No recurring issues with blockages or other problems have been reported by users during follow up. In schools where low flush units were installed alongside standard full flush toilets, users showed no awareness of the difference or preference for one or the other over time.

Based on our research, the plastic sanitary ware company Envirosan have invested a large amount of their own funds in developing injection moulds to enable the low flush / pour flush pedestal to be made at scale and at an affordable price.

The pour flush / low flush design provides the following advantages to users and service providers:

- The pit is offset from the pedestal, so there is no risk of a child falling through the pedestal into the pit or of the pedestal collapsing into the pit.
- The toilet can be built inside the house or adjacent to the house, eliminating the fear or discomfort of walking a considerable distance to the toilet in the dark or in cold or wet weather.
- The pour flush toilet only needs 1 litre to flush after urinating and 2 litres after defecating; the low flush requires only 2.5 litres to flush.
- A water seal prevents odours and insects from coming up from the pit into the pedestal
- The user does not see the contents of the pit when using the toilet
- The design can be retrofitted onto an existing VIP.
- The pour flush option can be used where there is not a reliable water supply, but can be converted later to a low flush if desired.
- The pit is easier to empty than that of a VIP because the pit is not under the pedestal and because the sludge is virtually rubbish free.
- Newspaper can be used for anal cleansing if users can't afford toilet paper.
- Toilets cannot leak continually, wasting water.
- The toilet can be serviced using standard plumbing knowledge and equipment.
- The toilet looks much like a standard flush toilet.

Scientific Support to Pour Flush Toilets

Authors:	**Aoife Byrnes and Chris Buckley**
Organisations:	Pollution Research Group
Funding:	Water Research Commission
Status:	Completed
Contact details:	**buckley@ukzn.ac.za**

Partners in Development (PID) installed approximately 25 pour-flush toilets in the greater Edendale area, which are located in the uMsunduzi Municipality. The toilets were installed between September 2010 and August 2012 as part of a pilot scheme to test the development of a pour-flush pedestal adapted from the standard Asian design to the South African user. To date, the pilot has been successful, with high user acceptance, limited odour issues and minimal operation and maintenance problems.

There is limited knowledge about the chemical, physical, and biological properties of the sludge produced from the pour-flush system, either from the Asian design or the newly implemented South African design. Hence, the aim of this part of the project was to begin building data about the chemical components of the sludge, how it behaves physically and mechanical and the process of degradation occurring inside the leach pit.

The main objectives of this project were to:

- Determine the filling rate of the pour-flush leach pit
- Characterise the pour-flush sludge chemically, physically and biologically
- Compare the contents of active and standing pit
- Compare the pour-flush system to the VIP latrine system
- Determine if the ammonia concentration is high enough to disinfectant the sludge
- Determine appropriate equipment for sludge sampling

Of the 25 pour-flush toilets constructed by PID, four sites were selected for the purpose of this project with a total of 6 pits being sampled continuously over 11 months.

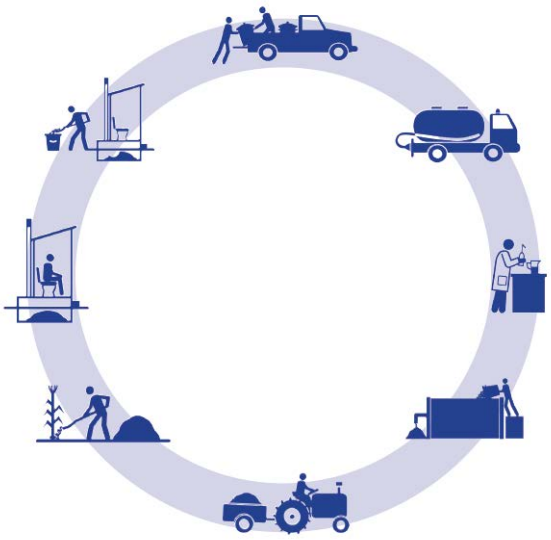
The study showed that the VIP and pour-flush sludge have similar chemical characteristics, however the pour-flush sludge has a slower filling rate as a result of less non-faecal material present in the leach pit and the ability of the liquid component to seep into the surrounding soil, taking with it soluble material, reducing the mass of solids in the pit.

The masses of chemical components were plotted against a time period of 11 months, to determine processes occurring in the pit over time. It was observed that a general increase in the mass of total solids and ash in both the active and standing pits. The mass of moisture, volatile solids, suspended solids and COD all increase in active pits while they decrease in standing pits. It is difficult to determine a pattern over time in the mass of the nitrogen species, phosphates and potassium. An increase in sodium was observed in both active and standing pits.

More extensive testing of the physical properties is needed to determine the most appropriate method of characterising physical attributes of faecal sludge. Physical tests should be developed together with pit emptying methods, so as to provide value to the results obtained from physical tests. Relating the results of physical tests of sludge to the ease with which it was removed from the pit by specific pit emptying equipment would provide valuable information to improve efficiency in the pit emptying process.

More information can be found on the PRG website: http://prg.ukzn.ac.za and the Water Research Commission Website: www.wrc.org.za

Section 6
Research Related to Water and Sanitation Management



All the different water supply and sanitation service delivery options need to be analysed from a system perspective and to ensure that their operation can be managed in an efficient way.

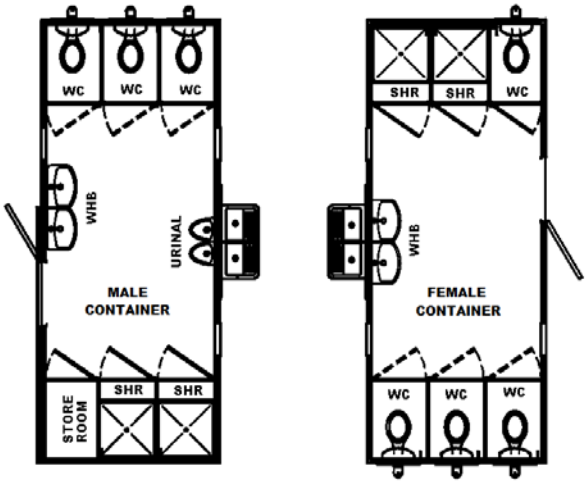
Monitoring of Water use in Community Ablution Blocks

Authors:	**Peter Crous and Chris Buckley**
Organisations:	The Water Research Group (University of Johannesburg); Pollution Research Group (UKZN)
Funding:	NRF and University of Johannesburg research grants
Status:	Completed
Contact details:	**buckley@ukzn.ac.za**

A project to monitor the end-use water demand of Community Ablution Blocks (CABs) was undertaken at Frasers informal settlement outside of Tongaat, north of Durban during 2012. This settlement is home to less than 500 households and is being provided with five CAB facilities, which are each monitored in order to investigate the usage patterns within these communal facilities in order to optimise the future design of the water supply and wastewater treatment to similar facilities – namely the peak factors and total water demand requirements of these facilities.

CABs have been rolled out to informal settlements throughout the eThekwini municipal area and consist of male and female facilities constructed out of retro-fitted used shipping containers. Each container is internally provided with a number of toilets, hand wash basins, and showers in both male and female facilities and urinals in the male facilities. Externally, the CABs provide laundry washing basins.

Monitoring of the end-use water demand was achieved by measuring the water consumption of each type of fitting (toilets, showers, laundry, hand wash basins, urinals) in the male and the female containers using domestic water meters (9 water meters in total for the CAB facility). These water meters were then connected to telemetric data loggers which record the data at 15-minute intervals and transmit the data on a daily basis to an internet based server where it can remotely be accessed and analysed. The data loggers can monitor up to three water meter inputs (requiring a total of 4 data loggers per facility). The monitoring equipment was stored in a concrete enclosure with a lockable manhole cover to secure it from vandalism and theft.



Although most of the informal settlements are located within the waterborne edge – where waterborne sanitation is economically viable, there are settlements located outside the waterborne edge where there is a need for decentralised, on-site treatment through the provision of septic tanks or anaerobic baffled reactors. These decentralised treatment systems are being piloted in the Frasers informal settlement. The quantitative understanding of the end-use demand patterns will provide guidelines which will enable optimisation of the design of these decentralised treatment facilities for communal water and sanitation facilities.

The results from four CABs in Frasers informal settlement indicate that the average household daily water demand is 82 litres per household per day from the CABs. Accounting for the standpipe water consumption, the estimated household water demand for the CABs was adjusted to 97 litres per household per day which is approximately three times less than the free basic water allowance of 300 litres per household per day in eThekwini. Adjusting the end-use water demand to account for the presence of 5 standpipes in Frasers, it was found that the water supplied to the CABs was predominantly used for laundry washing (60%), showering (20%) and toilet water consumption (16%).

Average daily water demand per fitting in each of the CABs ($\ell \cdot CAB^{-1}d^{-1}$)

	CAB 1 ($\ell \cdot d^{-1}$)	CAB 2 ($\ell \cdot d^{-1}$)	CAB 3 ($\ell \cdot d^{-1}$)	CAB 5 ($\ell \cdot d^{-1}$)
Toilet	2 170	1 790	755	440
Urinal	504	194	187	14.7
Shower	1 670	1 830	1 660	745
Hand wash basin	898	300	385	145
Laundry	6 760	5 200	4 050	3 020
Blackwater	2 670	1 990	942	455
Greywater	9 330	7 330	6 100	3 910
CAB Water	12 000	9 320	7 040	4 370

P Crouse, J Haarhof and CA Buckley: Water SA Vol 339 No 3, Wisa 2012 Special Edition (2013)

It is recommended that future water demand studies account for water consumption from other sources, such as standpipes, in order to identify the total water demand of the settlement. Further research into the end-use water demand of CABs will enable more accurate water provision and wastewater treatment (centralised and decentralised) planning.

Grey Water Management

Authors:	**Nicola Rodda**
Organisations:	School of Life Sciences; Pollution Research Group
Funding:	eThekwini Water and Sanitation
Status:	Completed and Implemented
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eThekwini Water and Sanitation have realised that grey water management is important in protection health and environment. Some of the problems identified with respect to grey water are:

- Health hazards through the pooling of water
- Erosion of soil on steep banks
- Wastage of water (a valuable resource)

A desktop study was undertaken to analyse:

- Best suited plants and trees
- Plants which can prevent erosion
- Plants which are suited to wet conditions

A pilot project was launched in two project areas (Ekuthuleni and Mandela Park) where vegetable gardens were established and plants and trees were used to prevent erosion.

The grey water was stored in 100 litre plastic tanks near the washing area and drawn from tank by means of a tap. The water was then carried to garden by means of watering can or other container. Where gardens were further away and below the level of the home, the grey water was stored in 100 litre plastic tank near the washing area with pipes linking the tank to the garden or bank to be watered. The water was drawn from pipe by means of a tap. Irrigation took place by means of 2 litre water bottles with holes in them which were placed throughout the garden.

In this pilot project, over 20 residents from both areas participated fully and nearly 70% of the gardens were in a satisfactory or good condition with 77% of equipment being used correctly. Evidence of pooling was reduced drastically and residents were able to sustain the process by growing own seedlings in community nurseries.

However, come concerns were raised regarding the quality of vegetables / fruit grown and if there were any health risks of vegetables grown above or below ground. In order to investigate this, trials were set up at the UKZN Campus.

Plants that were investigated included both above ground (cabbage and peppers) and below ground (carrots; potatoes and madumbes) vegetables.

Grey water was collected from communities and three watering treatments were used:

- Negative control – tap water
- Positive control – hydroponics solution (added fertilizer)
- Experimental – greywater

Growth was recorded weekly and both visual inspection and statistical and microbiological analysis undertaken.

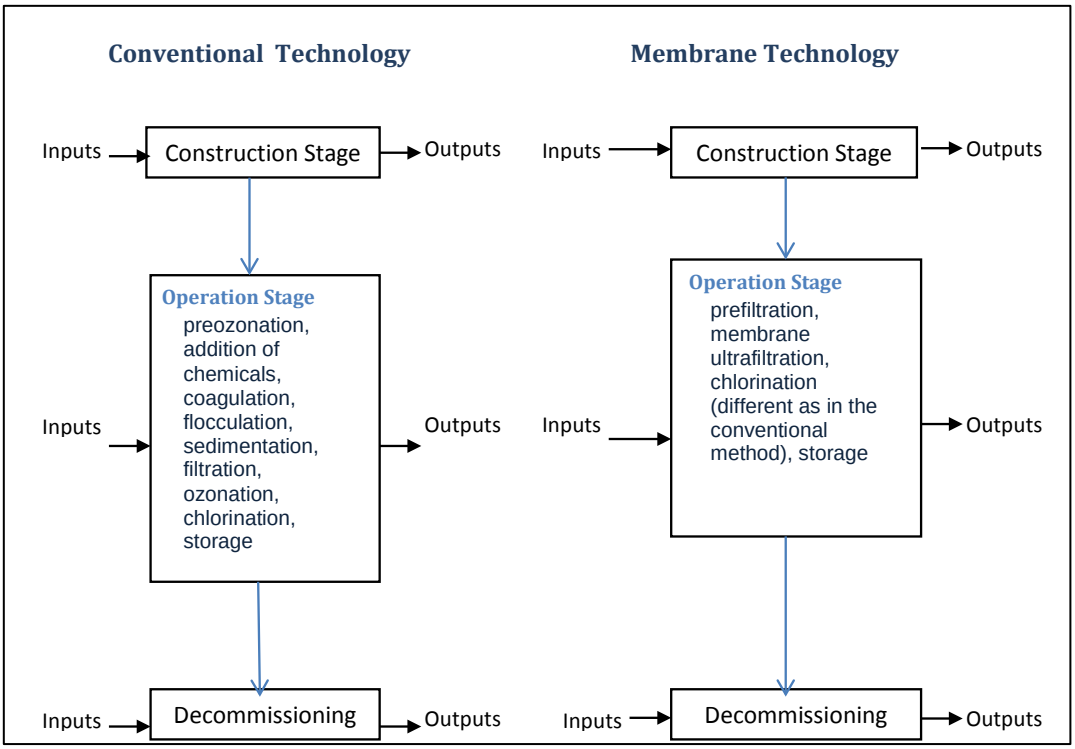
Results indicated that greywater boosts plant growth in a manner similar to that shown by water with added fertiliser for up to 5 crop cycles before effects on plant growth and productivity occur. The microbial quality of crops harvested was comparable across all treatments, and comparable to similar crops bought from shops.

Environmental Life Cycle Assessment to improve water treatment processes

Authors:	**E Friedrich and CA Buckley**
Organisation:	Pollution Research Group (PRG)
Funding:	Water Research Commission (WRC)
Status:	Completed.
Contact details:	**Friedriche@ukzn.ac.za**

The PRG was contracted by the WRC to undertake a comparative study for the production of potable water by means of a life cycle assessment (LCA). A LCA is a modelling tool which allows for comparison and targeted improvement of different processes. It is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a service system throughout its life cycle. As such it identifies opportunities for improvement. It has emerged as a valuable decision-support tool for both policy makers and industry in assessing the cradle-to-grave impacts of products and processes. LCA has been used in the water industry extensively, and a few studies have been conducted in South Africa. For example, in Durban the production of potable water by two methods was compared as shown in the figure below. The overall scores for the conventional technology were more environmental friendly compared to the ones from the membrane technology.

Improvements in membrane technology will reduce the impact of this process. The greatest environmental impact was due to electricity use. The electricity consumption per unit potable water produced can be used as a surrogate for environmental impact.



Furthermore, the entire water system of the eThekwini Municipality was investigated with particular emphasis on energy and materials. Energy consumption was identified as the main contributor to the environmental burdens of this system and the process involved and the energy consumed are presented in Table 1.

Table 1
Processes investigated in the eThekwini case study and their energy requirements

Process	Amount (kℓ)	Loss (%)	Energy (kWh/kℓ)
Abstraction of water - Inanda Dam	1	0	0 (gravity is used)
Purification of water – Wiggins and Durban Heights Waterworks	0.97	1.5 and 3 %	0.10 and 0.07
Distribution of water- municipality network	0.68	30 %	0.10
Use of water – domestic consumers	0.41	40 %	0 – assumed only for this study
Collection of wastewater	0.41	0 %	0.14
Treatment of wastewater (total)	0.41	0 %	0.44 of which
Primary			0.11
Secondary (clarifiers and activated sludge)			0.28
Tertiary (recycling)			0.05

Table 1 shows clearly that secondary treatment of wastewater is the most energy intensive process and also that the losses in the distribution system are having a considerable impact on the system.

These results have been published in 2 WRC reports as well as in 3 scientific articles and have been communicated at one local and one international conference

An Analysis of the Debt Relief Programme in Siyanda Township

Authors:	**Keke Mehlomakhulu**
Organisation:	Pollution Research Group
Funding:	eThekwini Water and Sanitation
Status:	On-going
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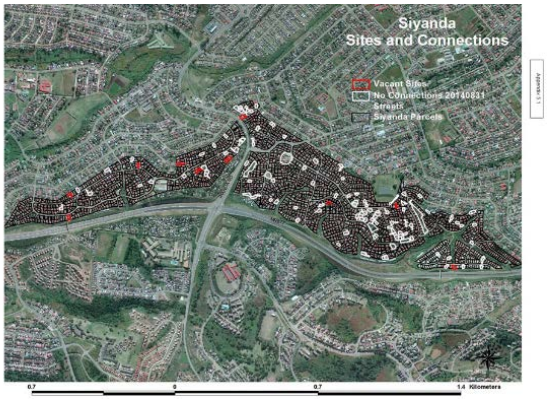
For a country (South Africa) that is said to be on a trajectory towards water shortage, the issue of water being lost without generating revenue is a huge concern. A low costing housing project was completed in Siyanda Township near Durban a few years ago. High levels of non-payment in this area is a concern to EWS. This population is characterised by their low income (indigent), which could lead to a difficulty on their part to pay for water services. This therefore leads to high debt rates for water services and ultimately, disconnections.



The debt relief programme was designed by EWS to address high levels of non-payment by providing debt relief to indigent customers such as Siyanda Township residents, and develop a culture of payment for water services among residents. The programme is innovative in that it takes difficult financial circumstances into account and rewards positive behaviour, bringing customers into positive payment cycles and credit ratings. However, if customers default on their monthly instalments after signing their debt relief contract, their debt will be reinstated.

The strategies involved the following:

- Council agreed to provide a window period within which poor customers in arrears could become debt free by making regular monthly payments
- Policy was formulated which included:
    - Qualifications such as property value must be less than R 250 000 and arrears of 90 days or more.
    - Debt would be written off over 20 months as long as the monthly payments for current consumption are settled in full and on time.
    - If no payments were made for 4 months then the debt relief contract would be cancelled and the remaining debt reinstated.
    - Customers in houses with a value greater than R250 000 but whose residents were indigent, child headed or pensioners would also be targeted.

The following steps were taken:

- Policy formulation
- Establishment of Project Team for roll out
- Community consultation and advertising
- Development of education programme
- Debt relief budget was set aside by Council
- Accounting systems were established within customer database

A Masters project has been initiated in order to investigate the interventions that substantially and sustainably improve payment for water services in Siyanda Township. By analysing water consumption and payment histories of the customers in the township, and how these respond to various interventions, an effective strategy for reducing non-revenue water losses can be developed. The desired outcomes of the project are minimized water losses, substantially increased revenue to the municipality, and encouraging responsible water usage.

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