GOOD SCIENCE MAKES GOOD POLICY

ETHEKWINI WATER AND SANITATION INNOVATIONS 2012

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THE NEWLANDS-MASHU DEWATS PROJECT

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The eThekwini Municipality in partnership with the Pollution Research Group are investigating a modularised *Decentralised Wastewater Treatment System* (DEWATS) plant for on-site waterborne sanitation. The plant was designed by the non-profit organisation, *Bremen Overseas Research and Development Association* (BORDA) which specialises in the design and implementation of DEWATS plants. Over 1 000 BORDA designed DEWATS plants have been implemented worldwide with the technology awarded with the prestigious *International Water Association Technological Innovation Award* in 2011.

In 2007, the Pollution Research Group, University of KwaZulu-Natal was tasked by BORDA to direct its scientific activities on BORDA DEWATS worldwide. As part of this agreement, a technical evaluation plant was built in 2010 in 71 John Dory Drive, Newlands-Mashu, Durban according to BORDA design guidelines. The eThekwini Municipality provided the land and financed the construction costs for the technical evaluation unit whilst the South African Water Research Commission provided the research costs (Research Project K5/2002). The modularised wastewater treatment plant consists of a biogas/settler pre-treatment step, an anaerobic baffled reactor, two anaerobic filter chambers (Fig.1) and effluent polishing in a constructed wetland (Fig.2).

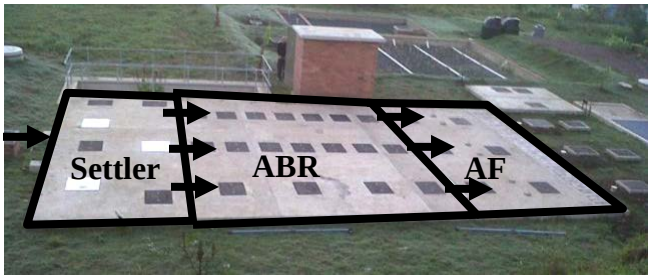

Fig.1: Settler-ABR-AF of DEWATS plant

Fig.2: Vertical flow constructed wetland

The experimental plant was designed to treat domestic wastewater from 86 households linked together by an existing trunk sewer. The plant was built with specific purpose of establishing the technical limitations of a typical BORDA DEWATS plant, to establish a set of practical operating and maintenance procedures for the DEWATS plants, and to serve as a demonstration plant to interested stakeholders and local water authorities. As the plant would be driven to failure (to establish the operational limits of the plant), a safety measure was implemented whereby all treated and untreated streams could be safely bypassed back into the trunk sewer. Other objectives include the microbial risk assessment of irrigating crops with treated effluent, the impact of nutrients on soil conditions and the harvesting of methane. This project is linked to Frasers Community Ablution Block Project in which the same core treatment step, the ABR, is used to treat wastewater.

SUSTAINABLE SANITATION SOLUTIONS
A PUBLIC-PRIVATE PARTNERSHIP
FRASERS COMMUNITY PROJECT

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This partnership is a joint effort to undertake projects that have a development-policy and economic benefit in developing countries. The partnership consists of the public and private entities illustrated above. In this partnership the core driving force was the combination of the strengths by the partners to assist in the promotion of development and create sustainable improvements to the citizen's living conditions.

The objective of the PPP project is to develop a prefabricated sanitation solution for communities and schools. The system should also include a solution for the decentralized treatment of the wastewater. The Frasers informal settlement was chosen as part of the water and sanitation development programme for the informal settlements within the eThekwini Municipality. This programme entails the installation of a containerized ablution block per 75 households. In Frasers, four community ablution blocks (CABs) were installed. Different designs of prefabricated decentralized wastewater treatment plants (DEWATS) were installed to determine the most suitable treatment process for the waste water from the ablution blocks.

DEWATS for the Community Ablution Blocks

School toilet block

eThekwini Water and Sanitation are the agents on behalf of the KZN Department of Education for the implementation of improved sanitation solutions at the schools within the KZN region. At the Sarasvati Primary School (Frasers), the partnership has invested on an improved water and sanitation infrastructure to bring hygiene up to an acceptable standard.

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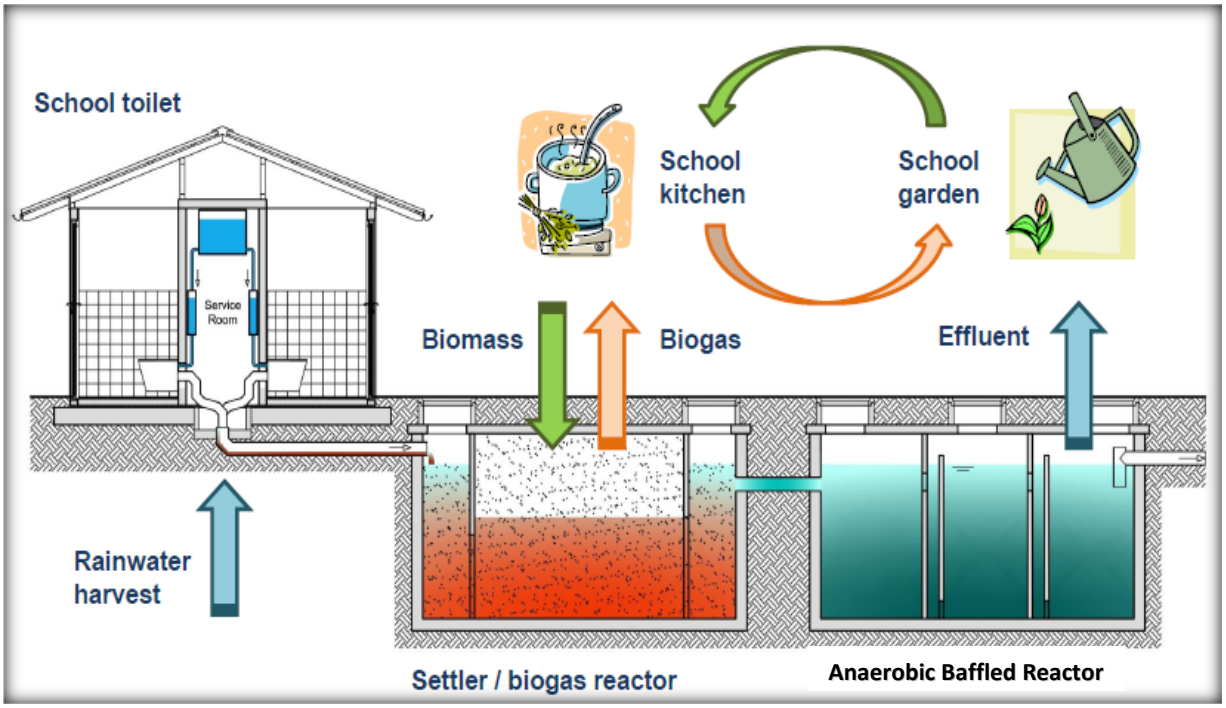
The solution included waterborne toilet blocks, wastewater treatment system with a biogas collection chamber, new rainwater harvesting tanks and a garden for the school. The sanitation solution does not require electricity, hence does not require skilled personnel during operation and maintenance. The primary tasks relating to operations and maintenance are basic cleaning of the toilet blocks. The installations of rainwater harvesting devices allow the user to collect and use the rainwater if it is available, otherwise potable water will be used. This constitutes a huge water saving.

The sanitary fittings are water-saving hence only a basic amount of water is required for each use. The biogas collected in the gas tight biodigester, is used in the kitchen for cooking purposes. This saves on the cost of liquid petroleum gas (LPG). Since the effluent from the waste water treatment plant is nutrient rich, the school is using this resource to restore the community garden within the school premises.

As part of the project, there is an ongoing research programme undertaken by the Pollution Research Group in order to study the water consumption, performance of the wastewater treatment and the biogas collection.

This legacy will change the focus from lack of sanitation, to improving hygiene awareness and practices in the school and surrounding community.



DEWATS for Combined sanitation solution at the school

COMMUNAL ABLUTION BLOCKS IN ETHEKWINI MUNICIPALITY

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The objective of this study was to explore existing and potential opportunities and challenges to the provision of communal water and sanitation (WASTSAN) facilities to low-income consumers living in informal settlements of eThekwini Municipality. This study was carried out in 31 informal settlements. In all, a total of 50 CAB sites were surveyed. CABs consist of two prefabricated shipping containers modified to meet appropriate communal sanitation standards. The containers (serving male and female users respectively) service 50 - 75 dwellings at a maximum distance of 200 m from the facilities. Male blocks have two washbasins, two urinals two toilets and two showers. Female blocks have two washbasins, two or more toilets and two showers. Provision is made for a store room and for (two) external laundry basins. The municipality has installed a total of 350 CABs in 125 informal settlements and is working towards increasing this number to 2 200 by 2015. CABs are an interim solution to the WATSAN backlog, while the municipality upgrades informal settlements into fully serviced homes.

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Results of the survey shows that a high proportion of household members use CABs to meet their WATSAN needs (CABs used for sanitation 80.8%; CABs used for fetching drinking water 75.3%; CABs used for showering 83.2%; children using CABs for sanitation 67.8%). Most of the respondents (97.9%) reported that they washed their hands the last time they went to the toilet. Less than half (43.1%) of those who washed their hands reported using soap. Respondents showed a strong desire for improvement to their sanitation systems. More than half (63.3%) of surveyed households were willing to pay for improved sanitation. On average, households were willing to pay R 112.13 per month for improved sanitation. This willingness provides opportunities for exploring innovative ways of entering the WATSAN market.

The distance of CAB sites from households was reported by 59% of respondents as a compelling factor for using competing sanitation alternatives such as pit latrines and open defecation at nights. Security concerns and opening hours of CABs were also reported by respondents as some of the factors that encouraged the use of competing sanitation alternatives. Other challenges encountered in the earlier phase of implementation include the vandalising of steel pipes, blockage of pipes due to the use of newspapers and other material for anal wiping as well as poor and unhygienic conditions of CABs. Intervention strategies adopted include the replacement of steel pipes with plastic pipes, the provision of free toilet papers by the municipality and hiring of caretakers responsible for maintaining CABs. Through its education programme, the municipality has reduced the maintenance cost of CABs. A dedicated customer call centre facilitates communication between the municipality and CAB users. This has contributed to effective and efficient running of CABs in the municipality.

The project was funded by Unilever and supported by eThekwini Water and Sanitation

REINVENT THE TOILET CHALLENGE

The Pollution Research Group

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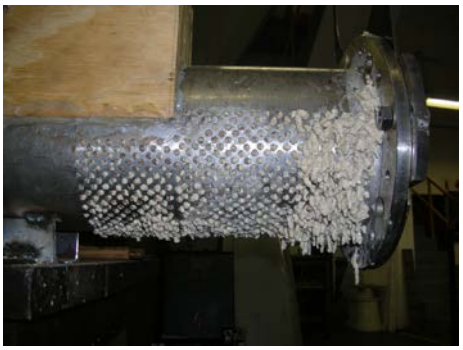
The Pollution Research Group (PRG) in the School of Engineering at the University of KwaZulu-Natal has received a grant from the Bill and Melinda Gates Foundation (BMGF) to participate in the *Reinvent the Toilet Challenge* (RTTC).The Challenge end objective is to produce a new-generation self-sustaining toilet that is able to convert human waste into sterilized fertilizer, potable water, mineral salts and electrical energy. The new-generation toilets will, in contrast to the current standard water-flush toilet, avoid the use of large amounts of clean water and energy to dispose of excreta and instead will treat human waste as a valuable resource. The toilet will be *off-the-grid*, doing away with the need for a connection to large electricity, water or sewerage networks. Affordability is a key goal of the RTTC, with a target combined capital and operating cost for the toilet of less than 10 US cents per person per day.

The toilet will integrate several operations to process the different components of the waste stream (faeces, urine, rubbish and washwater) and recover the useful constituents. The Pollution Research Group's work covers aspects including the design of a pedestal capable of splitting the four waste components at source, characterisation of the waste input streams, and processes for treating the faeces and urine.

The faeces-processing portion of the UKZN toilet design will comprise of an extruder, a dryer and an incinerator. In order for the extruder unit to be designed, rheological data (e.g. viscosity and fluid behaviour type) for fresh human faecal matter as a function of moisture content needs to be acquired for a range of stool intestinal transit times. Similarly, for the design of the drying and the combustor units of the toilet, data on the drying characteristics of fresh human faeces for differing geometric shapes and data on calorific values needs to be obtained. As no database of these properties exists, they will be obtained experimentally. An iterative energy balance will be performed over the three units, optimising the operating conditions of the units in order to minimise the energy consumption of the system and maximise the overall output energy.

Rheometer for analysing the flow properties of faeces



Work on the urine-processing operation is investigating the possible use of different membranes to separate different components of urine, aiming to recover potable water for use in the toilet and nutrients in a form suitable for agricultural applications.

Prototype system for separating faeces and rubbish and extruding faeces for drying

MECHANICAL PROPERTIES OF FAECAL SLUDGE FROM ON-SITE SANITATION FACILITIES

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The Bill and Melinda Gates Foundation (BMGF) has contracted the Pollution Research Group (PRG) at the University of KwaZulu-Natal to carry out a study into the properties of faecal sludge from different types of on-site sanitation facilities. The data generated will inform the design and sizing of mechanical pit-emptying devices, transportation and processing systems for the excavated sludge, and the design of future on-site sanitation facilities.

Characteristics of faecal sludge vary greatly between different locations and types of facilities. To assess the range of properties that may be encountered, faecal sludge samples from a range of on-site sanitation facilities will be analysed, including household ventilated improved pit (VIP) latrines, household urine diversion toilets, community ablution block facilities and school toilet blocks. Chemical, mechanical, rheological and thermal properties will be measured. The data will be analysed to establish correlations (if any) between the quality and quantity of sludge and level of facility use. The data sets produced will be made available to sanitation practitioners globally.

This project will interface closely with other projects from the BMGF which address different aspects of on-site sanitation. eThekwini Water and Sanitation are active partners in the project. The Water Research Commission of South Africa is funding parallel initiatives with the Pollution Research Group (PRG). It will extend the knowledge generated by staff and research students with the PRG. A sludge classification system will be derived which will enable municipalities to describe the sludges in their area and to provide data for designers and operators to provide enhanced sanitation services. Analysis will be made of the implications of the data for the practical applications listed above, integrating with other projects being carried out by the Pollution Research Group.

Faecal sludge from different levels of a pit latrine

Non-homogeneity of pit latrine contents

VENTILATED IMPROVED PIT LATRINES: SLUDGE MANAGEMENT

The Pollution Research Group
Partners in Development

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Two Water Research Commission (WRC) funded projects on management of pit latrines sludge were undertaken by the Pollution Research Group and Partners in Development to understand and quantify sludge accumulation in pit latrines and disposal options for sludge dug up out of pit latrines. These were Project K5/1745 *Understanding the sludge accumulation in VIPs, UDs and other on-site sanitation systems, and strategies to manage desludging in the future when pits are full* and Project K5/1829, *Investigating the potential of deep row entrenchment of pit latrine and waste water sludges for forestry and land rehabilitation purposes.*

It was found that the rate at which a pit latrine fills is dominated by the amount of material added and the fraction of the material added that is biodegradable. The single biggest factor that can be manipulated to reduce pit filling rates is the provision of an effective solid waste management in the community to reduce the incidence of non-degradable material entering pit latrines.

A range of methods for dealing with pit latrine sludge were investigated. In eThekwini municipality, a pit emptying service is provided by the municipality to empty pit latrines on a 5-yearly cycle. The options for disposal and treatment considered were (i) treating the pit sludge *in situ* with additives; (ii) discharge to municipal wastewater treatment plant; (iii) anaerobic digestion; (iv) burial on-site; and (v) burial at a central entrenchment facility in conjunction with agro-forestry. It was found that none of the commercial pit latrine additive products tested had any effect whatsoever on sludge accumulation rates in a pit latrine. The pit latrine sludge was found to be mostly stabilised, with significant solids and nitrogen load. Thus treatment by anaerobic digestion or in a municipal wastewater treatment facility resulted in overload of the facility by solids and nitrogen, with virtually no reduction of organics. Burial of the sludge associated with agro-forestry was found to result in significant benefit to the trees as a result of slow nutrient release, and helminth eggs present in the sludge were shown to deactivate over a period of 3 to 5 years in the entrenchment. Groundwater monitoring on-site did not indicate contamination of groundwater by nitrate, ammonia, phosphate or pathogens. Thus, where possible, deep row entrenchment of pit sludge associated with agroforestry was found to be the most promising and beneficial disposal of pit latrine sludge.

REINVENT THE TOILET CHALLENGE

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The University of Technology Delft (TU Delft) obtained a grant from the Bill and Melinda Gates Foundation to work on the *Reinvent the toilet challenge*. This challenge entails the development of a new toilet system and interface design, based on a new toilet technology, also including an implementation plan. To cope with this challenge two faculties of the TU Delft are working together. The faculty of Mechanical Engineering is developing the technical functionality. This technology is a combination between the usage of micro waves, plasma gasification and a solid oxide fuel cell. The technology aims to work without a connection to the sewer and will provide electricity, water and heat. To bridge the gap between this high-end technology and the target group the expertise of Industrial Design Engineers was requested.

A team of Industrial Design Engineers students came to Durban in March 2012 and worked together with the Pollution Research Group (PRG), Decentralized Environmental Solutions (DES) and the eThekwini Municipality. The overall task of this team started with mapping the user context and will go as far as building a prototype of the user interface, to conduct the first tests with respect to user interaction and product system effectiveness.
The eThekwini Municipality was chosen as the main research location, because this Municipality is seen as the centre of knowledge about water and sanitation. Also, the targeted context is relatively easy accessible thanks to a comfortable cooperation with the Municipality.
The main objectives for the research were to understand the daily life of the residents; gather insights on sanitation rituals with respect to toilet use; and distinguish crucial factors for the success of a new sanitation concept.

The Design Engineers students and Municipality together specified relevant research locations further and relevant contacts were made. In June this year, students of the team of Design Engineer students will arrive in Durban again; this time to test prototypes within the user context and obtain feedback from experts in the Sanitation field.



Finally with all the knowledge obtained through the cooperation with the eThekwini Municipality, DES and PRG, the team of Design Engineers wants to provide a user-centered facility design and feasible project implementation plan. Through this, the team wants to contribute to providing citizens all over the world of proper sanitation.

PROMOTING SANITATION AND NUTRIENT RECOVERY THROUGH URINE SEPARATION:
ROLE OF HEALTH AND HYGIENE EDUCATION

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Background:
Health and hygiene education is one tool that has been used in many countries in the course of Urine Diversion implementation to encourage acceptance, use and maintenance of the facility. Hygiene education is an indispensable part of water supply and sanitation projects, it ensures improved health and sustainability of a system after the assistance of technical experts has been withdrawn.

Aim:
This project aims to explore the influence of health and hygiene education on the social acceptance, utilisation and maintenance of Urine Diversion toilets.

Objectives:
- To explore the factors that influences the use or non-use of Urine Diversion toilets (e.g. education, politics, social, process followed).
- To explore factors that encourages or discourage social acceptance of the Urine Diversion toilet
- To explore the factors contributing to the maintenance and sustainability of the Urine Diversion toilets.
- To explore the methods used within the household and in the community to disseminate information and to understand which achieves the desired goal.
- To draw comprehensive recommendations that will be used to give constructive feedback, to take remedial actions and to shape the future community education programmes.

Method:
Qualitative research methods will be used so as to explore the richness, depth, and complexity of the context in which Urine Diversion toilets are built. The various methods of data collection will be used namely desktop analysis, focus groups, and in-depth interviews. Triangulation is a method used by qualitative researchers to check and establish validity in their studies or projects. The desktop analysis will look at the findings from a parallel questionnaire and other documents that report on similar issues. The focus groups will be formed based on households that are using or not using, appropriately maintaining and those who are not the Urine Diversion toilets. The in-depth interviews will target the key informants' i.e. local leadership and they are influential in terms of how people perceive and accept new initiatives in the community.

Outcomes:
The findings of this project will help shape and inform future community education programmes on health and hygiene to ensure that they are relevant and conscious of the context in which they are rendered. The latter will give result to desired goals which are to see household members using and maintaining the Urine Diversion toilets and other form of sanitation technologies in an appropriate and sustainable manner.

BIODIESEL FROM MICROALGAE

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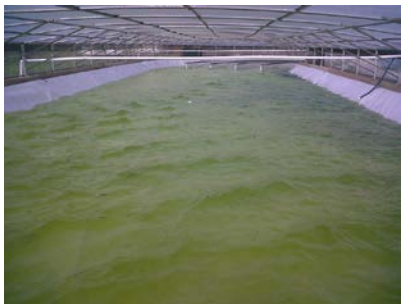
Biodiesel is a mono-alkyl ester produced from various types of oils and is currently produced from soybean oil canola oil, animal fat, palm oil, corn oil, waste cooking oil, and jatropha oil. Utilisation of crop based biofuels currently uses 1% of the arable land available globally to meet 1% of the global requirement. It therefore does not seem feasible to continue to produce biofeuls from crops due to food security issues and the debate as to whether the energy balance is actually favourable.

Algae are perfect candidates for biodiesel production as microalgal productivities can be 15 to 300 times that of oilseed crops, they have faster growth rates, can grow in saline waters, have greater photosynthetic efficiencies than higher plants, require minimal nutrients for growth and have moderate to high lipid content. Domestic wastewater has shown great potential as a nutrient source whilst having the added benefit of tertiary treatment of the wastewater.

Research is currently being carried out in collaboration with eThekwini Municipality on optimizing technology for biodiesel production using final effluent from a wastewater treatment facility. A 300 000 L demonstration plant is situated in the south of Durban.

This project is a first of its kind for a number of reasons:

- The utilisation of wastewater as a growth substrate for lipid production as this has not been demonstrated at large scale;
- Globally, very little work has been undertaken on open pond population dynamics and assessment of population dynamic has not been carried out at pilot scale;
- Optimization of biomass and lipid yields has not been done in SA on a demonstration scale.


Algae being cultivated in the 300 000 L raceway pond at Kingsburgh wastewater treatment works

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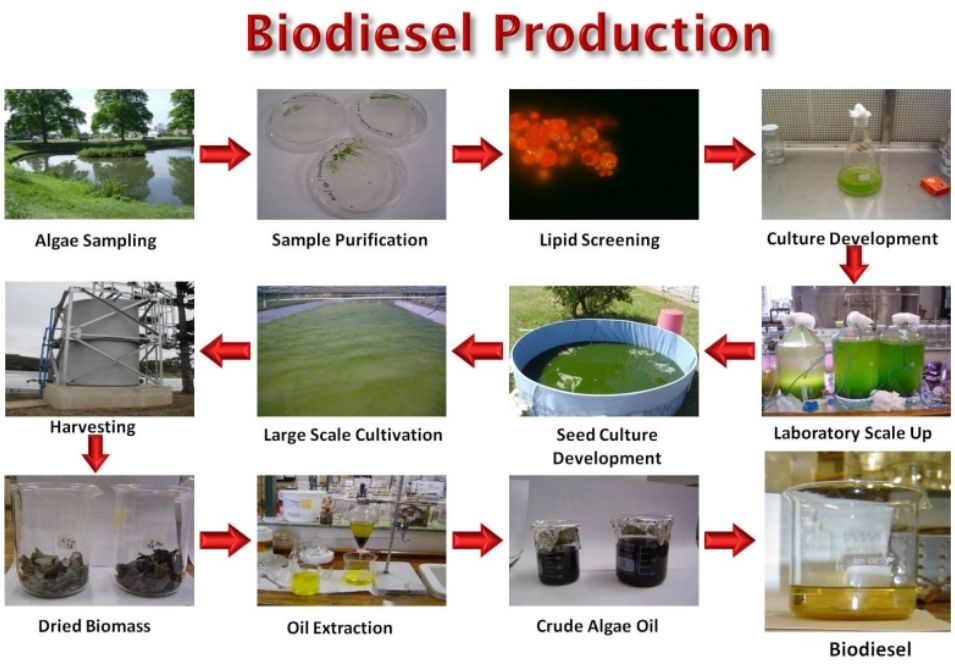
The stages involved in this project include:

- Biomass seed culture development
- Optimization of biomass yields using wastewater as a substrate
- Lipid optimization
- Harvesting of biomass
- Oil extraction
- Transesterification of extracted oils
- Processing of waste biomass for value added purposes
- Biodiesel quality analysis



Biodiesel production flow chart from sampling to the production of the final biodiesel

The challenge in the application of this technology is the scaling up from laboratory to demonstration scale.

The process will further provide tertiary treatment of wastewater streams by removal of residual nitrogen and phosphorous thereby acting as an effluent polishing step. The project will also focus on the utilisation of biomass after oil extraction to produce value added products.

METHANE TO ELECTRICITY

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Background

As part of the sewerage infrastructure, the Unit operates 28 wastewater treatment works (WWTW) which treat over 460 ML/day of sewage, producing the equivalent of 100 tons of sludge per day. A common way of treating this sludge is anaerobic digestion, a by product of which is the generation of methane gas (biogas).

Of the 28 WWTWs, 10 operate anaerobic digesters and it is the aim of the EWS to convert the methane produced at the larger of these WWTWs into electricity. Approximately 50% of the power used by the works can be supplied by the methane, and it is a renewable source of energy that is available as long as the WWTW is operational.

The Water and Sanitation Unit intends to undertake an initial methane to electricity project at the Northern WWTW which will give an output of approximately 350 kW.

Project objectives

The objectives of the project are:

- maximising generation of methane in digesters
- collecting, cleaning and conditioning the digester gas
- generating electricity from the methane
- feeding the electricity into the treatment works electrical system
- providing heat to the existing digesters, while keeping existing heating system as a standby
- operating the plant for 7 years under a contract that provides incentives for generation of electricity and supply of heat to digesters

Fuel cells are also being considered at an alternative to conventional gas engines. Since fuel cell technology is very new, the municipality would require significant support from a technical partner.

MINI HYDRO POWER

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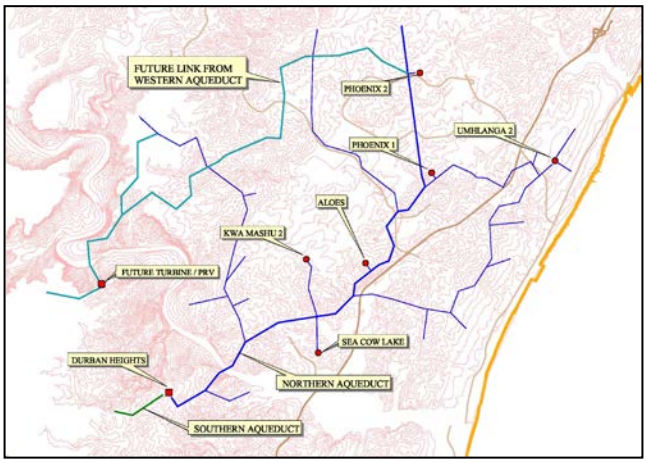
The municipality intends to install between two and four mini turbines fed by the city's Northern Aqueduct water distribution system. The aqueduct supplies water from the large Durban Heights treatment works to the city's northern suburbs.



Due to the differences in elevation between Durban Heights and the reservoirs, there is excess pressure at the inlets to the reservoirs which is currently dissipated by pressure reducing valves. The proposed turbines will use this pressure to generate electricity, which will be fed into the municipal low tension grid. The expected output of the turbines ranges from 120 kW to 180 kW.

The project will consist of a feasibility study phase, a construction phase and a three month operation and training phase.

The feasibility study will entail the following tasks:

- Measuring flows and pressures at each of the four turbine sites over a 3 month period
- Collecting historical data and development plans for the area, and analyse seasonal and long term trends in water demand
- Selecting options for the sizes of the turbine/generator sets
- Carrying out a preliminary design of the civil, mechanical and electrical works
- Carrying out a financial analysis to select the optimum turbine configurations and to confirm the financial feasibility of the project.

On completion of the feasibility, a full design for the project will be carried out, followed by construction of the civil works, and installation and testing the electrical and mechanical equipment. The turbines will then be operated for 3 months while local operators are trained.

The project is expected to run for a period of 2 ½ years.

Funding for the project is currently being sourced.

WATER REUSE

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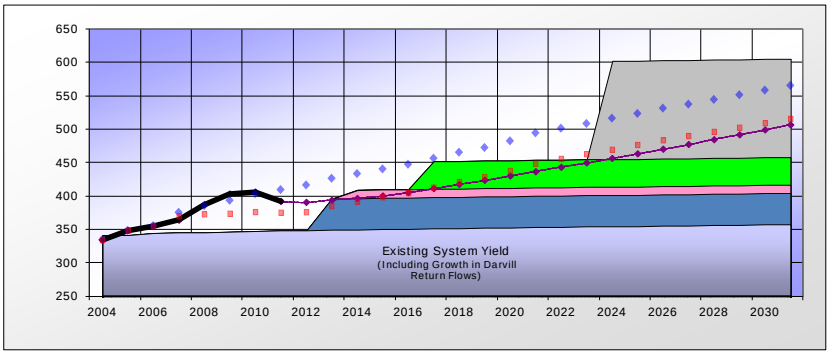
In 2008, the Department of Water Affairs and Forestry (DWAF) concluded their *KZN Coastal Metropolitan Areas – Water Reconciliation Study, 2008* (Reconciliation Study). The report contains the background, analysis and proposed further development for bulk water resources for the KZN Coastal Metropolitan area and concluded that the water supply needs in the eThekwini Municipality and surrounding areas currently exceed the reliable yield of the local water resources.

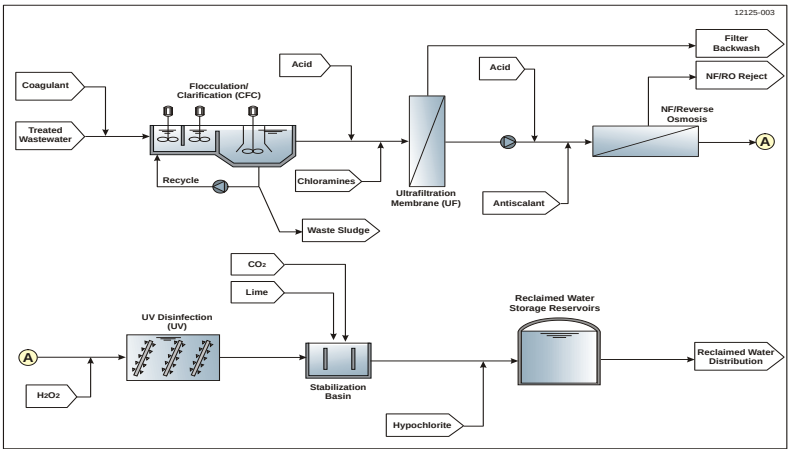


Water supply and demand for the Umgeni catchment as at September 2011. The vertical axis is water supply / demand in million m^3 / year. Statistically there should have been water restrictions for the past 3 years.

While a number of supply schemes are currently under investigation and/or development, these will not be sufficient to meet the water demand going forward. Treated effluent reclamation and re-use is considered to be a viable water resource to overcome the medium-term water constraints. It has been successfully implemented in other parts of the world, as well as locally in Namibia and Beaufort West. The treatment technology is well established and the quality of water produced exceeds current drinking water standards.

On this basis, the Ethekwini Municipality initiated a study in early 2009 to assess the techno-economic feasibility of treated effluent reclamation and re-use as the basis for water supply augmentation. Golder Associates Africa (Pty) Ltd, in association with WRP and Kwezi V3 were appointed by eThekwini Municipality to complete the study.

Outcomes of the initial assessment indicated that the most feasible route is that treated sewage effluent from the KwaMashu and Northern WWTW's, be reclaimed and treated to potable standard. The potable water from KwaMashu potable water reclamation plant will then be discharged into the existing trunk main of the northern aquaduct in the vicinity of Duffs Road while the potable water from the Northern WWTW potable water reclamation plant will be discharged to the northern aqueduct at the nearest practical point from the works.



Direct water reuse treatment route.

An Environmental Impact Assessment (EIA) is currently underway. A public participation process is being followed together with media releases.

FLUIDISED BED REACTOR

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In 1999 the Municipality installed an incinerator (Fluidised Bed Reactor - FBR) and a spouting bed drier (SBD) at KwaMashu Wastewater Treatment Works to incinerate the sludge generated at KwaMashu Wastewater Treatment Works and Northern Wastewater Treatment Works.

The FBR was designed to run together with the SBD which heats sludge fed directly to the drier using the exhaust gases from the FBR to make pellets. These pellets are in turn mixed with the wet sludge feed to the FBR to provide an additional energy source to run the FBR.

Because of odour and pollution problems with the exhaust gases from the spouting bed drier, it is operated in series with a regenerative thermal oxidiser (RTO) which oxidises the harmful and noxious gases before discharging the final exhaust gases into the atmosphere.

In July 2009 the Council appointed a contractor to:

- Evaluate the FBR and make critical repairs
- Recommission the plant, revalidate required permits/licences and report to the Municipality on the financial viability of long term operation
- Operate the plant for the remainder of the 3 year contract and, dependent on the Municipality's decision on the future of the plant, negotiate with the Head: Water & Sanitation for a long term contract to run the plant.

The contractor succeeded in operating the FBR with an average uptime of over 70% and demonstrated that, with further mechanical improvements and an effective operating team, the FBR is able to run reliably.

However, the contractor has reported that the combination of the FBR and the SBD is difficult to control, and that the two units are not well balanced. It is suggested that by replacing the drier and thermal oxidiser with a steam boiler, the plant will be easier to operate, and will moreover be able to run a turbine and generate electricity.

The Water and Sanitation Unit's past experience with the FBR indicates that the Unit is not suited to operate such a complex and finely balanced plant. Moreover, the experience of the current contract indicates that the operator of the FBR should have as much autonomy in the operations, purchasing and managing spares, emergency repairs, enhancements etc. as possible.

For this reason the Unit intends to partner with an external organisation which will manage the operation of the FBR and associated plant for a 15 to 20 year period.

A study will first be undertaken to assess the feasibility of:

- Increasing the capacity of the FBR to enable it to treat all the sludge generated at KwaMashu WWTW
- Constructing and operating a turbine powered by a steam boiler heated by waste heat from the FBR

CO-DIGESTION OF SEWAGE SLUDGE AND INDUSTRIAL CONCENTRATES

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The project co-digestion of high strength industrial concentrates with sewage sludge is currently being undertaken at the Amanzimtoti Wastewater Treatment Works, south of Durban and at the laboratories of the Pollution Research Group. The type of digestion in specific is anaerobic digestion which is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen. Co-digestion is the co-disposal of different waste streams in the same digester. The advantage of combining these streams is that if they have complimentary characteristics it may result in a combined feed stream that is more easily digestible and generates larger amounts of biogas.

The general principle of this research is to capture understanding of the digestion processes and especially the effect of different types of industrial waste streams on the digestion in a model which is run on the WEST platform. The model is then used to simulate the real digester and to predict how the digester will perform under different feeding scenarios, in order to schedule the treatment of the effluent streams.

In order to be able to effectively model the processes, it is necessary to have a set of integrated screening experiments that may be used to generate model parameters. These model parameters may then be used to simulate digester performance and compare it to actual digester performance. The project methodology was thus devised to develop and calibrate a full-scale co-digester model and to develop and model screening experiments to provide data and parameters for this model. Once the model is developed it can be used throughout waste water treatment plants to predict the behaviour of anaerobic co-digesters and hence forms the bridge between science and practice.

Future work for the co-digestion project includes the upgrade of Southern Wastewater Treatment Works, to determine the impact of industrial wastewater on anaerobic digestion at Southern WWTW and inform design of full-scale digestion process. As well as the feasibility of treating textile dye-bath effluent at the Mpumalanga Works sludge digesters to reduce colour and salt loading at the Hammarsdale Waste Water Treatment Works.

Anaerobic Batch stirred Reactors (ASBR's) located at the Pollution Research Group laboratories

Full scale co-digester located at the Amanzimtoti Waste Water Treatment Works

UKZN acknowledges DHI for allowing free use of DHI software, including WEST, for research purposes as per the MOU signed between UKZN and DHI

ASSESSING THE IMPACT OF INDUSTRIAL EFFLUENTS ON WASTEWATER TREATMENT PLANTS

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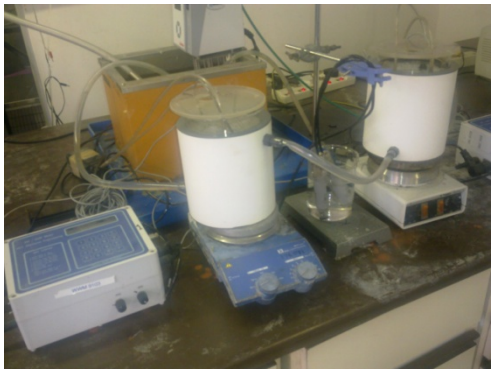
A research project sponsored by the eThekwini Municipality and the Water Research Commission is developing a methodology that will allow the municipality to evaluate the ability of a receiving wastewater treatment plant (WWTP) to accept a factory's effluent and adequately treat it, together with the wastewater received from all other users of the sewer system in the WWTPs catchment, to a standard suitable for release to the environment. The protocol is intended to be used to set limits on what may be discharge to sewer in the process of issuing an effluent discharge permit. The general principle of this research is to capture understanding of the biological treatment processes in a wastewater treatment plant and especially the effect of different types of industrial waste streams on the treatment predicted in a process model. The model (coded in the WEST platform) is then used to simulate the plant operation and to predict how the plant will perform under different feeding scenarios, in order to schedule the treatment of the effluent streams.

In order to be able to effectively model the processes, it is necessary to have a set of integrated screening experiments that may be used to generate model parameters. These model parameters may then be used to simulate the plant performance and compare it to actual plant performance. The project methodology was thus devised to develop and calibrate a full-scale mixed dual-feed model and to develop and model screening experiments to provide data and parameters for this model. Once the model has been developed it can be used throughout wastewater treatment plants to predict the behaviour of the plants and hence forms the bridge between science and practice.

The basic measurement technique is Oxygen Uptake Rate (OUR) respirometry. Measuring the rate at which oxygen is used in the biological reactions monitors the processes taking place, and allows detailed inferences to be drawn about the biological reactions taking place. The protocol is being tested at the JMV Textile factory that discharges to the Verulam Wastewater Treatment Works in the northern part of the eThekwini metropolitan area.



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WATER DISTRIBUTION NETWORK OPERATIONAL OPTIMISATION

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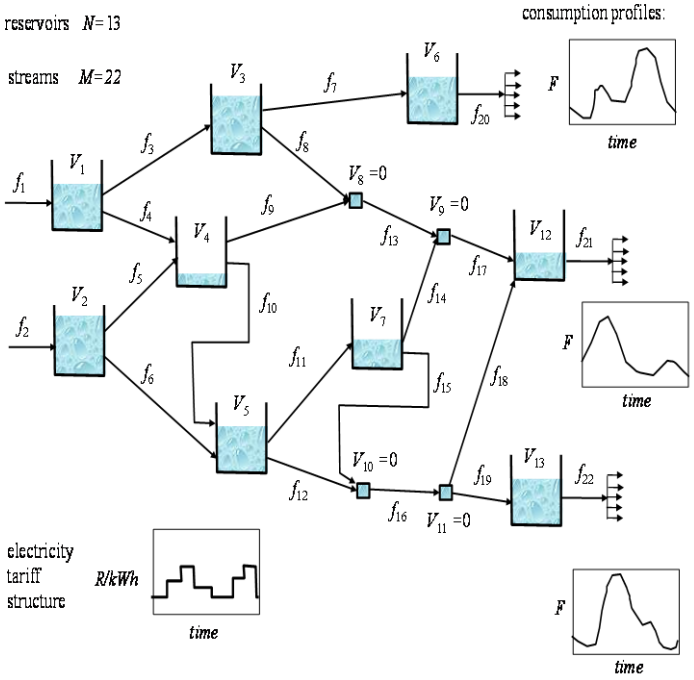
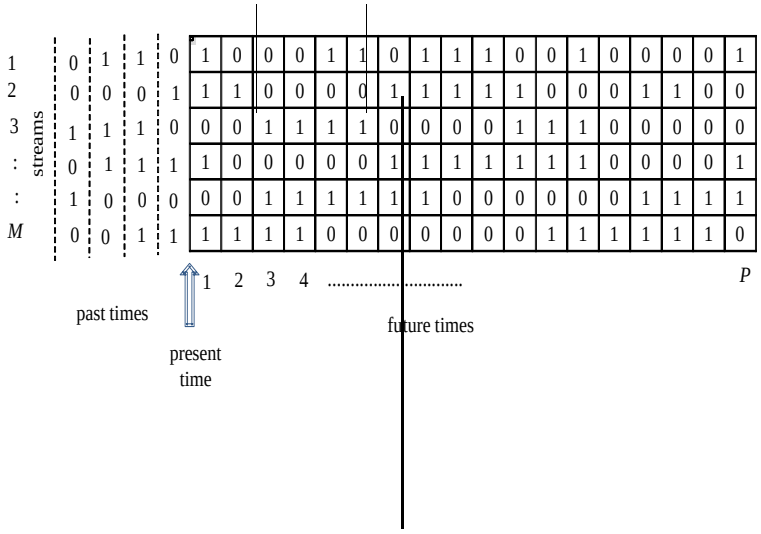
In the Durban municipality, potable water is distributed through a trunk main system to 265 reservoirs. Objectives include compliance with the permitted minimum and maximum reservoir levels, minimisation of pumping costs according to the daily electricity tariff structure, and preservation of chlorine, generally requiring minimisation of residence time. However, the computational load resulted in the algorithm falling behind real-time for more than 10 interconnected reservoirs. Hence the thrust of the present work has been to develop alternative algorithms, aiming to handle larger systems.



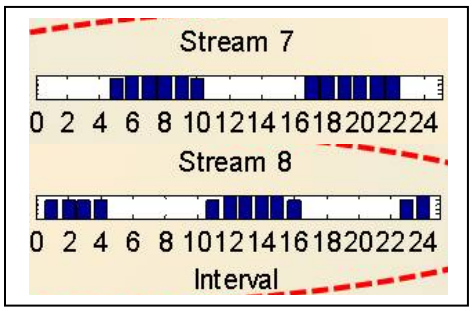


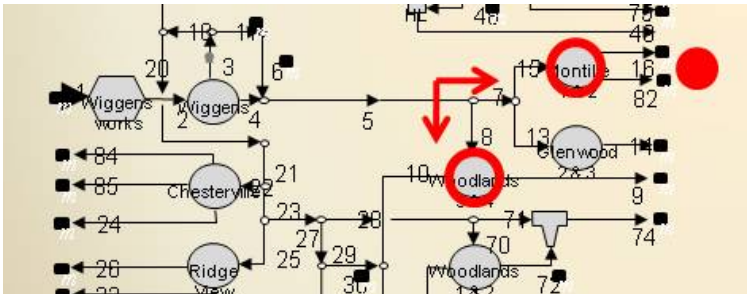
Complicating the matter is the need to comply with the minimum cycle times of some larger pumps –eg. at least 6 hours between switchings. Some success has been achieved using a random technique in which switching gaps are sampled from a distribution of gaps in the desired range. Both *simulated annealing* and *genetic programming* techniques were effective in gradually perturbing the pattern of switching gaps, to probe around the current "best" for improvements.

Continued over page

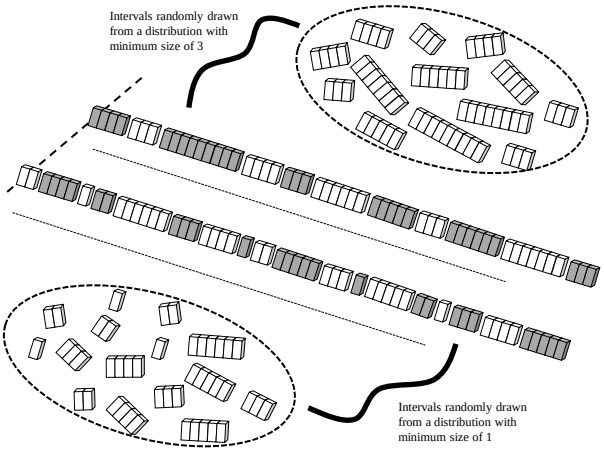
Progress

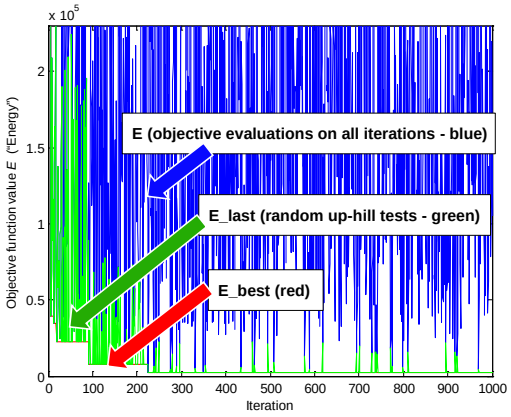
Optimisation methods tested were non-linear programming (NLP) and linear programming (LP) applied to the intervals, and LP applied to the binary problem (using branch-and-bound). Various "tricks" have been attempted to overcome inherent non-linearity in the problem – eg. rewarding discrete solutions in the objective function. Experience with these approaches revealed difficulties in computational demand, "relaxation" of results, and distortion of the result due to the additional items carried in the objective function. Solution of Durban's Southern Aqueduct demonstrated the importance of not operating two major streams (7&8) simultaneously.



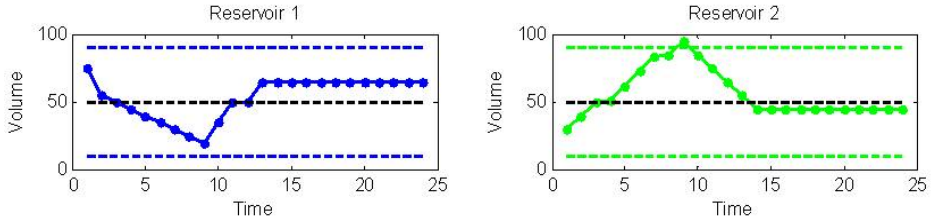


Accepting that the above solutions are not *globally-optimal* anyway, not much was to be lost by attempting more "random" search techniques. Thus *simulated annealing* and *genetic programming* have now been considered with some success.





In *simulated annealing* the algorithm randomly changes some of the sampled intervals in the above sequences, provided the objective function decreases. Increases are followed up, within a shrinking margin, in case they lead out of a local minimum. In *genetic programming* there is a *combination* step, in which the best candidates in the population are "spliced". This is followed by a random *mutation* of some intervals. A steady population is maintained by continuously discarding the poorest candidates.



LEAK IDENTIFICATION IN A WATER DISTRIBUTION NETWORK

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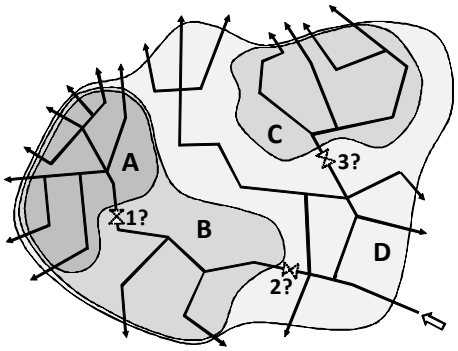
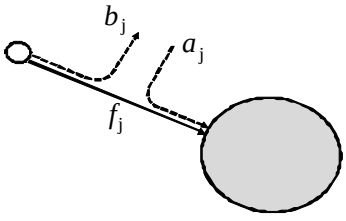
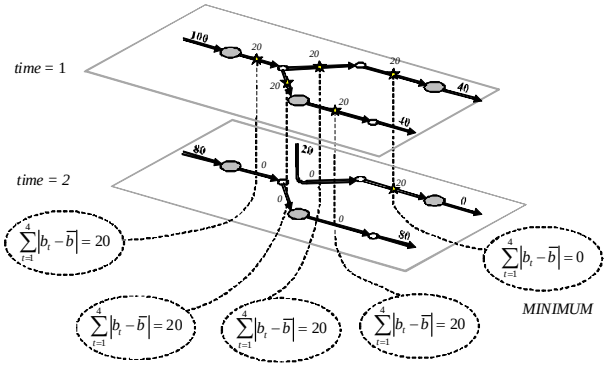
A trunk-main system delivers potable water to 265 reservoirs in the Durban metropolitan region, incurring about 4% water loss en route. Downstream of the reservoirs, the consumer distribution networks suffer even higher losses, due to aging piping and water theft. Losses have been reduced by "pressure management", but a means of identifying leak locations would allow elimination through maintenance. The general problem of leak identification using sparse flow and pressure measurements has been addressed by several workers, using methods ranging from purely statistical approaches to full EPANET modelling, with various "clustering" algorithms to narrow down the leak location. In the present work, a method has been developed employing Linear Programming, for the case where only sparse flow and consumption measurements are available. A feature of the method is that it overlays "snapshots" of the network at a series of points in time, in order to progressively narrow down the part of the network which can commonly account for all observations.



In the figure on the left, consider that a water loss is determined between the network inflow and the sum of its outflows. Take a case where the loss disappears when valve 2 is shut, but persists when valve 2 is open, and valve 1 is shut. The algorithm will determine that the leak is in a part of domain B excluding domain A.





The method employs a concept of "leak-ins" $\boldsymbol{a}_j$ and "leak outs" $\boldsymbol{b}_j$ between nodes, where the balance is based on interconnection matrices $\boldsymbol{A}$ and $\boldsymbol{B}$ as

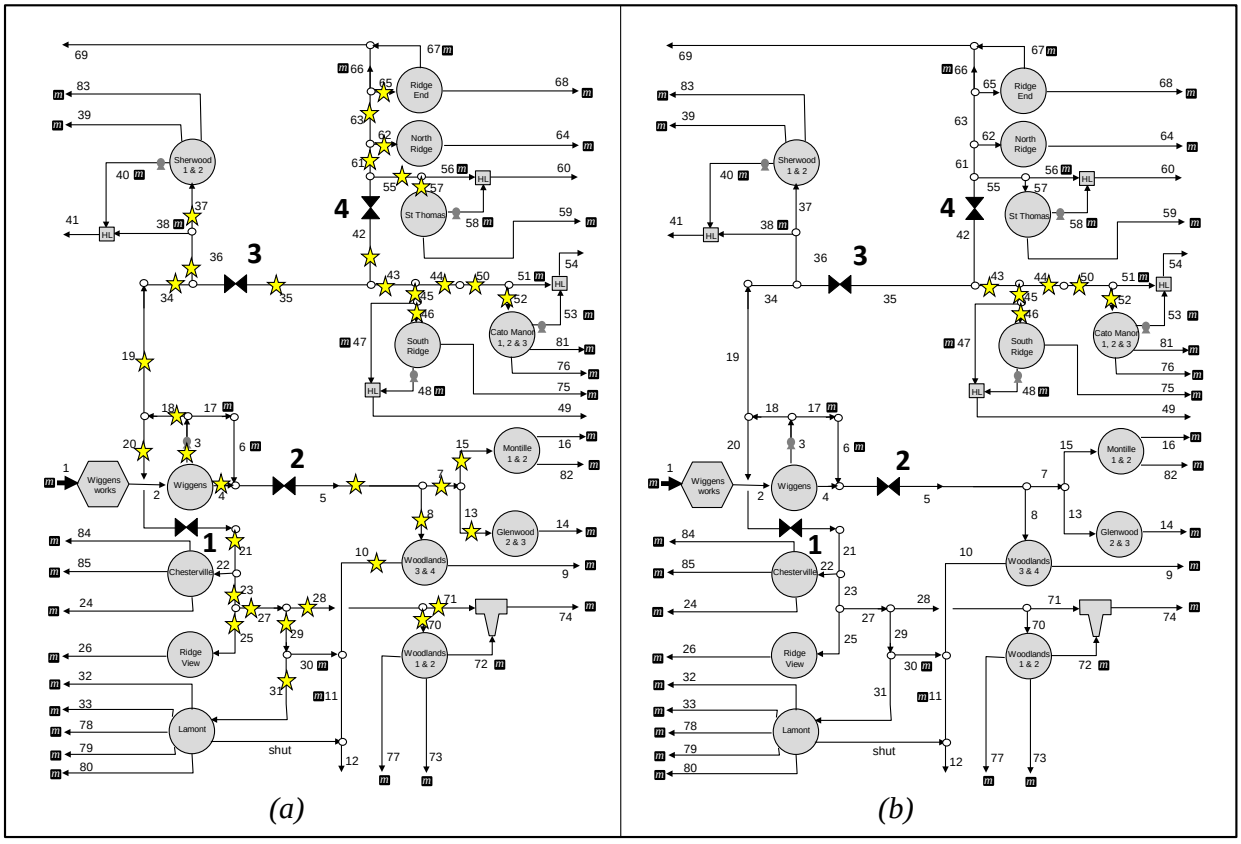
$$\boldsymbol{A}[\boldsymbol{f}+\boldsymbol{a}]-\boldsymbol{B}[\boldsymbol{f}+\boldsymbol{b}]=\frac{d\boldsymbol{V}}{dt}$$

Continued over page

Progress

The task of determining the minimum leak rate, and minimum number of leak locations, that can explain discrepancies in an overall mass-balance in a network, turns out to be an optimisation problem. Additionally, the balance at each node (junction or reservoir) in the system constitutes a set of linear constraints. So the problem was tackled from a *linear programming* (LP) point of view. Staying within the LP context had big solution speed benefits – important for larger systems. An innovative approach was developed to "cluster" possible leak locations. This was done by minimising the "deviation from mean" for all possible leak locations. As a result of this, non-zero leaks would only persist if they could explain the majority of measurements.

The figure below shows part of Durban Municipality's "Southern Aqueduct" trunk-main water distribution system. A set of measurements (shown as '*m*' on a black background), mostly for the exit flows, was taken at five 1-hour intervals. An "error" was inserted, by dropping the pipe 51 "measurement" by 30 m^3h^{-1} at each interval. In *(a)*, the lack of intermediate flow measurements to break up the network means that almost all contiguous unmeasured flow sections become suspect in the first hour. Subsequently, positions 1 to 4 are known to be isolated (pump off or valve shut), each for one hour, resulting in the pattern of possible leak locations *(b)* by the 5th hour.



The method can be implemented using monthly meter readings or continuous flow measurements, or combinations thereof, but will obviously be more effective given more such data sets, eg. several months. The main effort will be in assembling the data sets.

THE POTENTIAL USE OF ABR EFFLUENT IN AGRICULTURE

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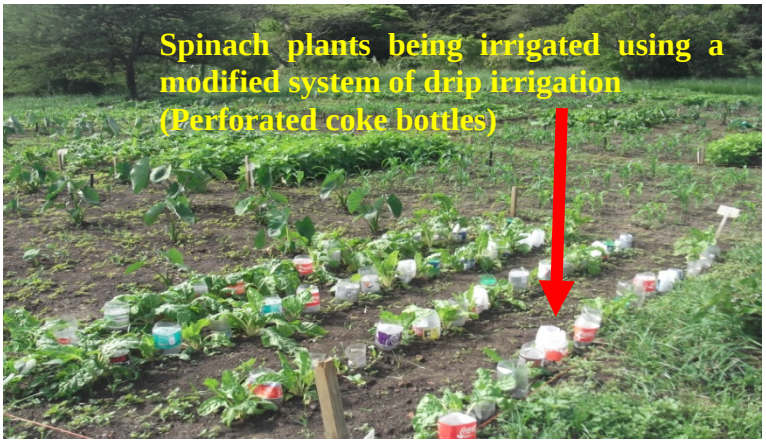
The Decentralized Wastewater Treatment System (DEWATS) located at Newlands Mashu, Durban, was designed by Borda and financed by eThekwini Water and Sanitation. The Water Research Commission is funding a research project to evaluate the system. The plant treats wastewater from 78 households. The DEWATS plant uses 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. With this option, different qualities can be obtained and used for different purposes. The raw or untreated wastewater contains energy and all the pathogens, after the biogas digester, the stream contains some of the residual energy and most of the nutrients and previously particulate components in a soluble form. After the anaerobic baffled reactor section all the particulate components will have been solubilised and some pathogen reduction will have taken place. The anaerobic filter will further reduce the energy content (COD) of the wastewater. Passage through the constructed wetland will further remove pathogens and particulate material.

Continued over page

ABR has been shown to contain important mineral nutrients necessary for plant growth and the potential use of the effluent for agriculture is being investigated. A field experiment has been set up at Newlands Mashu to investigate if ABR effluent can be used sustainably in agriculture without affecting soil properties. The risk of pathogen contamination to workers and potential consumers will also be assessed. The experiment is comparing three water sources (ABR effluent and tap water using drip irrigation and rain water). 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 has been replicated 3 times within the water source treatments. Wetting front detectors (WFDs) were inserted at 30 and 50 mm depths to determine whether nutrients and pathogens can leach beyond the root zone.



Growth variables such as plant height, number of leaves per plant, chlorophyll content, and biomass will be determined. Plant tissue analysis will be done to determine the content of important mineral elements such as nitrogen, phosphorus, potassium and selected micronutrients. 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.

RAIN WATER HARVESTING

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High levels of poverty and unemployment, coupled with the increases in food process has resulted in extreme hardship in the rural areas of eThekwini. To address this problem, the eThekwini Water and Sanitation Unit initiated a programme for the construction of rain water harvesting tanks and the development of community co-operative gardens. This has resulted in a reliable and sustainable supply of water for the irrigation needs of community gardens as well as other domestic needs.

There are basically three components to rainwater harvesting:

- **Catchment:** In most cases the catchment area is the roof of a building (e.g. a house).
- **Conveyance system**: The conveyance system usually consists of gutters or pipes that direct the flow of the rainwater falling on the rooftop to storage tanks (or vessels).
- **Storage:** The water collected is eventually stored in a storage tank (vessel). Storage tanks may be constructed as part of the building or may be built as a separate structure located away from the building.

Selection criteria:

- Roof area must be greater than 50 m^2.
- Type of roof - single pitched (preferable) or double pitched (roof can be thatched) and gutters preferred.
- Required space to build 5 000 lt tank – 4 m x4 m area.
- Targeted low cost housing or rural houses.
- House owner earning less than R1 500-00 per month.
- Gardening activity must be visible around the house.

Process followed:

- Construction of Ferro-cement 5 000 litre storage tanks and the use of an innovative flexible gutter system that could be utilised on informally constructed houses.
- Training of beneficiaries in the implementation of organic homestead gardens as well as the provision of start up tools and materials
- The provision of accredited training for the contractors
- Development of an accredited agricultural training programme for champions in rural areas.

Community gardens:

- Co-operatives receive technically sound training in water harvesting irrigation systems
- Accredited local contractors are given the opportunity to apply their construction skills to the technical elements of the project
- Co-operatives are empowered to sustainable manage their resources
- Livelihood opportunities are increased

Continued over page

Results achieved:

- Implemented in 3 areas (4 wards)
    - INK area - 498 tanks were installed to individual households, 120 tanks to 60 schools and 4 tanks to 4 clinics
    - Clifton - a total of 347 tanks were installed
    - Crowder - 47 tanks were installed
    - Zwelibomvu – 1 500 tanks installed
    - Mzinyathi – 1 050 tanks installed
- Cost to build a tank R 9500 per unit

Recommendations:

- Further education on the self sealing nature of the tanks
- Education on hygiene aspects of using rain water for other household purposes (washing, cooking etc.)
- The food garden training programme needs to encourage the household to get other members involved in the food gardens.
- A closer partnership needs to be built with schools within the vicinity of the households to promote and develop food gardening skills in school going learners using a curriculum approach.
- Further support in composting
- Creating a community garden forum to assist in mentoring and sustainability
- Assist communities in growing the size of their gardens

Challenges:

- Erratic rainfall patterns
- Lack of interest in community gardens by under 30 age group which challenges the sustainability

TECHNICAL ELEMENTS
Construction of Ferro Cement Tanks and installation of Gutters

FOOD GARDEN TRAINING ACTIVITIES
Tools, Training, Seeds & Seedlings

EXTRACTION OF ESSENTIAL OILS FROM VETIVER GRASS *(VETIVERIA ZIZANIOIDES)*

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Vetiver grass is an effective vegetative absorbent and erosion barrier, and the valuable oils extracted from its roots are playing an increasing role in the perfume, food and pharmaceutical industries. The quantity and quality of oil extracted from the vetiver grass depends strongly on location of growth, extraction and separation techniques. The aim of the research project is to evaluate whether locally grown vetiver grass for the extraction of vetiver oil will be a viable project for the Water and Sanitation department of the eThekwini Municipality (EWS) to add value to their treated wastewater and if so which extraction techniques will give the highest yield and quality of vetiver oil.

Possible methods for essential oil extraction and separation are mechanical expression, solvent extraction and distillation. As mentioned above, essential oils (such as vetiver oil) are often used in the food and perfume industry and therefore there is a need to increase the quality of the essential oils extracted. Hence more in depth extraction methods such as microwave assisted extraction; supercritical carbon dioxide extraction (SCE); and subcritical water extraction (SWE) are now being used.

Supercritical Extraction apparatus

Research showed that supercritical carbon dioxide extraction (SCE) gives a higher yield than the other methods tested in this project (hydro distillation and solvent extraction). The optimum extraction method in terms of high yield and valuable components would therefore be supercritical carbon dioxide extraction (SCE).

Locally grown vetiver grass from Newlands Mashu

Vetiver roots harvested from the Newlands Mashu Municipality site in Durban, yielded a dry root mass of 384 kg per hectare of vetiver cultivation for 2 year old roots and a dry root mass of 1 536 kg per hectare of vetiver cultivation for 4 year old roots. These dry root masses are concluded to be very low when compared to the 3 000 kg of dry roots per hectare of vetiver cultivation (1.5 years old) given in literature. This leads to the need for future investigations into the effects of growing conditions of vetiver grass on vetiver oil production. Furthermore it is of interest to the EWS to grow vetiver grass on pontoons as a vegetative absorbent and this will be the next phase of the project.

MENSTRUAL MANAGEMENT & SANITATION SYSTEMS

University of Maryland
Innovations for Poverty Action
University of KwaZulu-Natal
PATH

The University of Maryland, in partnership with PATH, Stockholm Environment Institute, Columbia University, Wits Health Consortium, Mount Holyoke College, and the University of KwaZulu-Natal, is carrying out a research study investigating the links between women's experiences and habits with menstrual management and local sanitation systems. The Menstrual Management and Sanitation Systems project, funded by the Bill & Melinda Gates Foundation, comprises multiple research activities to examine factors that influence demand for various types of menstrual management products, and in turn, how use of these products affect the functioning of sanitation systems in India and South Africa. In recent years, there has been growing concern regarding the difficulties experienced by women and adolescent girls in developing countries in finding adequate means of managing menstruation. In order to inform efforts to expand and improve women's access to menstrual management options, this study is documenting women's habits involving menstrual management, assessing demand for alternative menstrual products, and analyzing the actual impact of menstrual management products on systems that are used.

Menstrual management practices and demand for alternative products

One aspect of the Menstrual Management and Sanitation Systems study is to assess women's acceptance of alternative menstrual products that may have a less negative impact on sanitation systems. The demand study will first document women's current menstrual management practices and then monitor the use of and satisfaction with alternative products, including a reusable silicone product called a menstrual cup (see Figure 1). An understanding of women's preferences concerning menstrual management options and their willingness to pay for alternative products are critical for projecting the evolution of menstrual practices and associated impacts on sanitation systems.

In addition, this study will evaluate the role of women's social networks in influencing their willingness to try and adopt alternative products.

This study aims to understand:

- The experiences of women in managing their menstrual periods, including the products that they use, their perceptions of the sanitation facilities they use, and how their periods may impact their daily routines.
- Women's preferences for alternative menstrual management products that may have less impact on sanitation systems.
- The influence of women's social networks on product adoption and other behaviours.

The study will involve 750 women from four low-income areas in eThekwini, each representing a different sanitation system. We are including an informal settlement with community ablution blocks containing flush toilets, social housing with flush toilets, a peri-urban area with ventilated improved pit latrines, and a rural area with urine diversion dry toilets.

Participants are women between 18 to 45, who experience regular menstruation and do not plan on moving away from their area within the coming year. These women will be interviewed four times over 8 to 10 months, and will be given different opportunities and compensation for their participation.

The researchers will evaluate acceptance of four product types, including biodegradable sanitary pads, reusable sanitary pads, tampons with and without applicators, and menstrual cups. Menstrual cups are medical grade silicone bell-shaped devices that are reusable for up to 5 years (See Figure 1). While upfront costs are high, the cost saving over 5 years is significant.

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Figure 1. Menstrual cup. (Photo: MPower)

Documenting school girls' experiences in menstrual management

The impact of access to menstrual management products on women's mobility, and in particular, school attendance is not well understood, and yet could be an important determinant of public support for distribution of menstrual management products to school-aged girls. The local researchers will engage with three schools in eThekwini municipality. The activities will include self-administered surveys using mobile phone technology, which allows female students to answer questions about their menstrual hygiene needs in a manner that minimizes embarrassment. The researchers will engage girls and teachers in schools, in participatory methods such as drawing and photo voice. In addition, researchers will facilitate reflective writings and memory work with groups of girls to document local stories and understandings of puberty and menstruation. A menstrual hygiene booklet that is contextualized specifically for South Africa will be co-developed by the researchers.

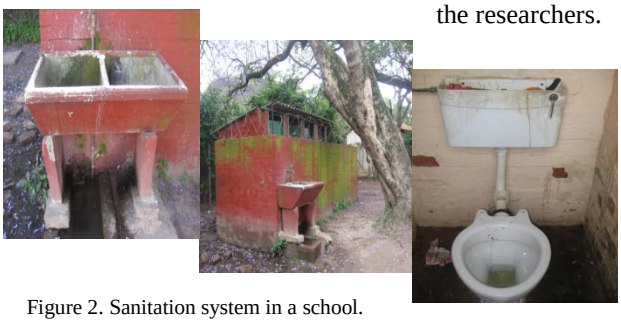

Figure 2. Sanitation system in a school.

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Case studies—sanitation systems & menstrual hygiene

To ensure successful integration of modern menstrual management products with sanitation systems, it will be important to understand what is currently done with menstrual waste in urban and peri-urban settings. This is particularly true in light of global trends towards urbanization and the increasing availability of disposable, non-biodegradable sanitary pads in these settings.

PATH is conducting case studies of sanitation systems for the urban poor to address the lack of existing research on menstrual management. The studies will focus particularly on the interaction of these behaviours and products with sanitation systems. These case studies will shed light on how menstrual management practices and products impact various sanitation systems that are likely to serve low-income populations and be present in urban and peri-urban areas. The systems involved in the study in Durban, South Africa include: (1) flush toilets at the household and community level, (2) ventilated improved pit latrines at the household and community level, and (3) urine diversion dry toilets at the household level.

The systems-focused research aims to address the following four objectives:

- Understanding knowledge, attitudes, and perceptions of individuals within the sanitation sector towards menstruation, menstrual management practices, and materials/products.
- Assessing the present condition of sanitation system(s).
- Projecting potential impacts of the menstrual management practices and materials/products upon sanitation system(s).
- Understanding the needs of the government and the public sector for making informed decisions regarding menstrual management and sanitation system initiatives.

The systems-focused research includes facility assessments, interviews with facility caretakers, and in-depth interviews with local stakeholders. These activities will be complemented by subsequent qualitative research activities such as focus group discussions and a photo story that captures the experiences of women in eThekwini municipality interacting with local sanitation systems.

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PROMOTING SANITATION AND NUTRIENT RECOVERY THROUGH URINE SEPARATION:
A SOCIAL ACCEPTANCE STUDY

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Sanitation through use of the urine diversion (UD) toilet system is on the increase in the eThekwini Municipality. This calls for a reliable social study to assess communities' reactions to this form of sanitation as well as to inform the authorities of any possible problems that might be emerging.

Aim:
This project aims to assess community perceptions, responses and reactions to UD toilets, urine collection and nutrient recycling, and to statistically assess the controls on these views and any changes over time.

Currently, the first round of data is in the process of being analysed. The analysis consists of an in depth statistical examination of a survey that was completed in November 2011. The survey was conducted across 17 000 households. This provides the opportunity to analyse an initial reaction to the proposed sanitation changes. A follow up survey is scheduled to commence in February 2013 to asses changes in the communities that take place as the joint projects progress in time.

Inside view of UDT

Bucket with sand for use after defecation

UDT (Front View)

UDT (Rear view)

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An initial desktop study will be undertaken to acquire a clearer picture of the sanitation situation for households using UD toilets in eThekwini. The existing survey data of 17 000 households will be statistically interrogated and some results will be mapped using ArcGIS. The statistical investigation will incorporate an analysis of sample clustering, and a multivariate regression analysis to determine which variables explain various outcomes related to the perceptions of and reactions to UD toilets, urine products, and the collection and use of urine for economic gain by the producing households or others.

The temporal elements of this dataset will also be interrogated to determine whether views changed with time after UD toilet installation. Since the data were collected across the Municipality at a particular time, but since the roll-out of UD toilets commenced in 2004, a temporal analysis is possible. Temporal changes will be further assessed through the use of another project (VUNA) being undertaken in Lower Maphepheteni data, as the results from this survey can be compared with those of the earlier survey with respect to perceptions of UD toilets and urine usage.

Once the available datasets have been adequately assessed and the results reported, a survey instrument will be designed to answer questions identified from the preliminary analyses and to test hypothesis developed from the initial study results. At this point it is envisaged that a sample will be randomly selected from each community within the UD toilet programme for the survey to be conducted.

The complete report on the social acceptance study will be completed in June 2013. However, on-going contact between the researcher and the authority will assure that any social acceptance problems will be discussed and a solution sought as they are discovered.

The Objectives of this study include:

1. To assess community perceptions and reactions to:
    - i) The use of UD toilets
    - ii) Emptying of the UD toilet vaults
    - iii) The collection and use of urine products
    - iv) The relationship between the provision of water and UD toilets
    - v) To assess any changes over time as far as the above issues are concerned
2. To assess how changes in toilet design, construction and urine collection options have influenced views of these toilets and the use of the products.
3. To assess community understandings of the economic implications of moving away from UD toilets, including the costs of water and maintenance of alternative systems
4. The impact of educational programs on the above issues
5. To map toilet distributions and spatial controls on perceptions and reactions.
6. To provide continuous feedback to the Municipality regarding community perceptions of the UD toilets and any potential community sensitivities or resistance to the technology and the use of its products.

This project forms part of the VUNA collaboration and is funded by the Bill and Melinda Gates Foundation.

END-USE WATER DEMAND MONITORING OF COMMUNITY ABLUTION BLOCKS

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The project of monitoring the end-use water demand of Community Ablution Blocks (CABs) is currently undertaken at Frasers informal settlement outside of Tongaat, north of Durban. The 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-fit 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 is 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 are 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 is 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 CAB and the concrete enclosure used to house the water monitoring equipment, the water meters and data loggers.

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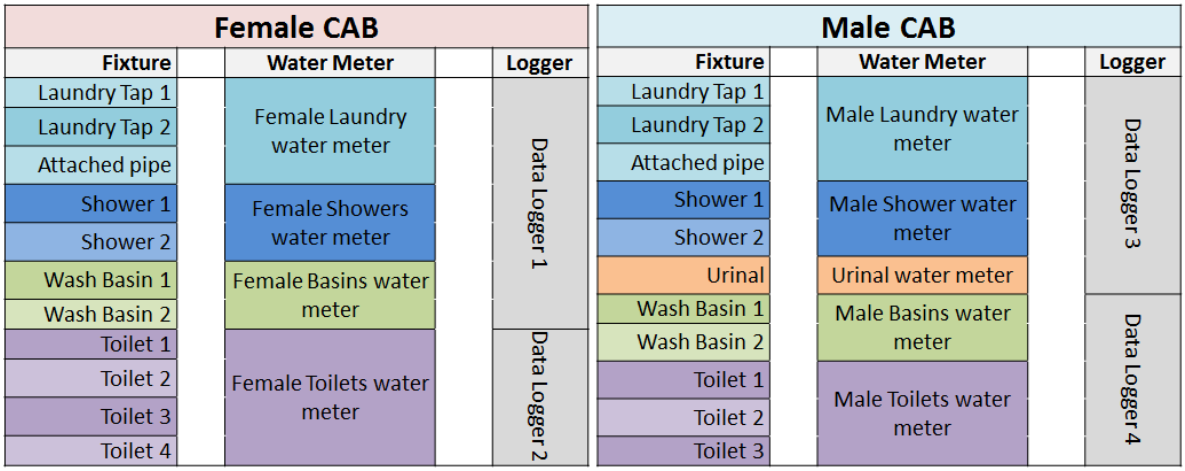
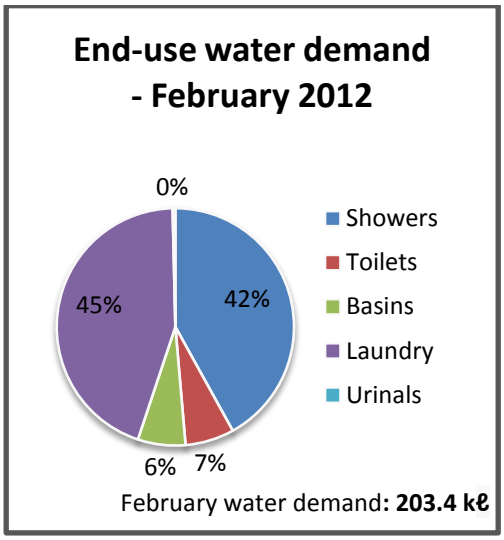
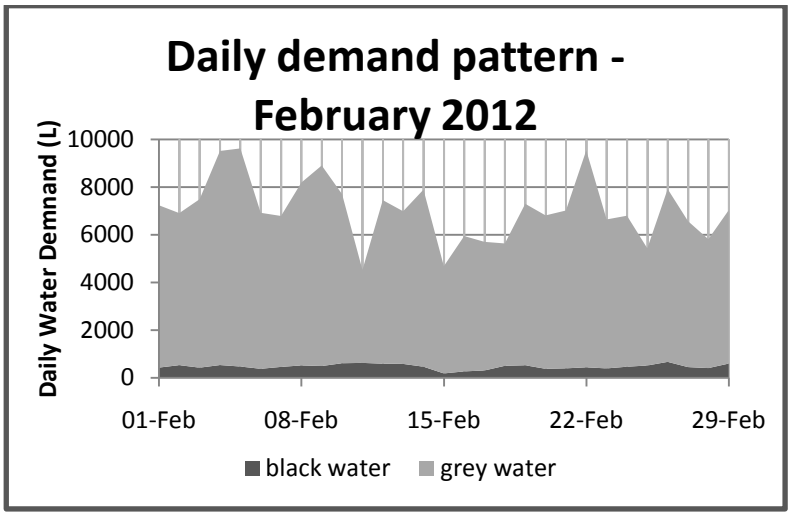


The end-use demand monitoring configuration for the CABs in Frasers informal settlement

The initial results have indicated that the grey-water demand is considerably higher than the black-water demand, constituting more than 90% of the total water demand of the CABs. These findings are significantly different to domestic water demand patterns, with typical domestic water demands of 60% grey-water and 40% black-water. Further, the preliminary results have indicated a daily peak factor of 1.4 and a 15-minute peak factor of 6.1 for the month of February 2012. The other results are shown in the following graphs.





The graphs indicate the end-use water demand of one CAB in the Frasers informal settlement (male and female facilities combined) serving approximately 50 households (120 – 150 people).

Acknowledgements
This research is co-funded by the NRF and UJ research grants.

OPERATION AND OPTIMIZATION OF REACTORS TO TREAT SOURCE-SEPARATED URINE IN ETHEKWINI

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Urine collected in urine-diverting dehydration toilets (UDDTs) is a possible source for fertilizer production, as it contains the majority of nutrients found in wastewater streams.

Within the VUNA project (www.vuna.ch) UKZN cooperates with eThekwini Water and Sanitation (EWS) and the Swiss Institute for Aquatic Science and Technology (Eawag) to optimize reactors for urine treatment. Two reactor setups will be tested, first a struvite reactor and second a combination of nitrification and evaporation. The reactors will be installed in the communities that have been selected as study sites for urine collection and treatment. The reactors will be dimensioned to treat 100 to 200 L urine/day (calculation: 50 to 100 households, 4 people per household on average, 0.5 L urine / pers,d).

In a first step a struvite reactor (see Figure 1) has been built to recover most of the phosphorus contained in urine. Results showed a removal of more than 91% for total phosphorus. For further details please look at the publication “Development and operation of struvite reactors to recover phosphorus from source-separated urine in eThekwini” in the Conference Proceedings of WISA 2012.
In a next step further reactors will be built to recover all nutrients found in urine (e.g. potassium, nitrogen and phosphorus). It consists of a nitrification reactor to biologically stabilize the urine followed by an evaporation reactor to remove most water and producing concentrated solution containing all the nutrients (see Figure 1). The solution can be processed further into powder form having a valuable fertiliser applicable in the field.

Figure 1: Struvite reactor at UKZN (left); Nitrification reactor at Eawag (middle); Evaporation reactor (right, © KMU Umweltschutz GmbH)

INDIVIDUALS' PERCEPTION OF URINE AND ITS POTENTIAL USE AS A FERTILIZER:
A SOCIAL ACCEPTANCE STUDY

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As the price of fertilizer increases taking up a larger portion of households' budget the support of ecological sanitation and the re-use of urine can be encouraged to alleviate poverty and contribute to food security. However, human waste recycling remains quite unfamiliar in South Africa.

Aim:
To understand the perceptions of key stakeholders and the farmers about the use urine as a fertilizer in agriculture. The wider aim is to determine if this practice is socially acceptable as a contribution to food security. The research will be undertaken with individuals who have been or are being trained at the Newlands Mashu Permaculture Learning Centre as well as farmers who are part of the Umbumbulu Agri-Hub both located in the eThekwini Municipality.

The Newlands Mashu Permaculture Learning Centre was started in 2000 as an NGO and is now run by the Infrastructure Management & Socioeconomic (IMS) Development Department of the eThekwini Municipality as one of its agri-hub training centres. Umbumbulu Agri-Hub is a public-private partnership. It was started in September 2010 by the Newlands Mashu Community Development Foundation for the eThekwini municipality and its focus is on supporting small-scale growers through permaculture principles.

Method:
To investigate the attitudes towards urine in agriculture the research will be conducted during two meetings of farmers organizations that consult with the Newlands Mashu Permaculture Learning Centre. The first phase of data collection will be semi-structured interviews with key informants, members of the IMS strategy team. Similar interviews will be conducted with key informants from the Umbumbulu Agri-Hub. The second phase will entail conducting semi-structured interviews with the farmers during two meetings of farmers' organizations that are part of the Newlands Mashu Permaculture Learning Centre programme. At the Umbumbulu Agri-Hub semi-structured interviews will be carried out with farmers together with the mentor during the daily rounds with the farmers.

Continued over page

Once the research has been completed there will be a deeper knowledge how individuals relate to urine and its likely uptake as a fertilizer in agriculture. It is anticipated that the investigation may promote sufficient interest among farmers and key stakeholders that a demonstration project can be undertaken. It would assess the potential in alleviating economic hardship due to purchasing fertilizer, increasing food crops thus decreasing food insecurity and potentially reducing pollution through nutrient recycling.

The Objectives of this study include:

- To understand farmers perception of urine in general (including culturally).
- To understand farmers perception of urine, in relation as its use in fertilizing crops.
- To understand farmers knowledge of urine as a fertilizer and its potential impact on their crops.
- To understand the perceptions and knowledge of urine, in general and as a fertilizer of the key informants who transmit knowledge of permaculture to farmers.
- To assess the possibility of incorporating urine as a fertilizer into the one of the methods of fertilizing in the training programmes and among farmers.

This research will be done in the context of a master's research degree at the School of Built Environment and Development Studies and will be self-funded.

Typical garden layout (in red) – Mzinyathi area

Vegetables at the Newlands Mashu Permaculture Learning Centre

New farmers learning about crop production

Preparing new beds

ECONOMIC FEASIBILITY AND BEHAVIOURAL CHANGE OF HOUSEHOLD URINE COLLECTION, TRANSPORT AND PROCESSING

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Urine is a rich source of nutrients and can be processed into fertilizer. To ensure that fertilizer production can continue without delay, a steady supply of urine is required.

The goal of this research is to determine the conditions under which decentralized households urine collection and transport provides a reliable supply of urine and is economically attractive to both the municipality and the urine-diverting (UD) toilet users. Ultimately, the results will be used to:

- help achieve higher rates of UD toilet use and acceptance in areas where toilets are already installed,
- ensure a steady supply of urine for fertilizer processing,
- analyze whether UD urine collection, transport and processing is an economically feasible sanitation system, and
- demonstrate to other governments how a UDDT program could help them achieve and broader sanitation coverage and reduce open defecation/urination.

The research will be divided into three phases:

PHASE 1: A questionnaire will be given to about 1500 households in 8 districts in order to collect basis household data (socio-economic status, sanitation situation and use, perceptions of UD toilets, agriculture practices) and their willingness to participate in various urine collection and transport schemes. The questionnaire will be given to a control group with UD toilets, a treatment group with UD toilets (which will later on participate in new systems of urine collection and transportation) and a VIP group (households that own a VIP, and not a UD). Trained fieldworkers will administer the questionnaire and the responses will be collected on mobile phones, to allow for rapid, paperless, data-collection and cleaning. Figure 1 shows a group of fieldworkers during a training session where they learned how to use the mobile phones for the questionnaire. In addition to the socio-economic questionnaire, and to determine the current usage of toilets, the volume of urine will be measured for each household.

Figure 1: Fieldworker training with mobile phone-based questionnaire

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As shown in Figure 2, the urine tank is weighed, and the weight is used to calculate the volume of urine in the tank.

Figure 2: Household urine measurement in rural eThekwini

PHASE 2: The effect of various collection and transport schemes on households' participation levels, as well as the effect on the use and maintenance of the household toilets will be analysed. We expect that households who previously used the toilet very little and/or have a very low income will show high participation rates and an increase in toilet use, given that one version of a collection and transport scheme will include some form of remuneration for the urine produced (which has a value in form of fertilizer). Maintenance and repairs will be monitored as a way of measuring "acceptance" or coming to hold the toilet in higher esteem, such that households consider UDs as something valuable, which is worth investing in.

PHASE 3: The UD program costs (with various collection and transport schemes) will be compared to those of the VIP program (which includes subsidized emptying) in order to determine how cost effective a system based on UDs with urine collection, transport and processing is. The determination of cost-effectiveness will include the entire urine-collection, transport, and processing stages of the program, including the costs incurred for any remuneration of households, and the benefits obtained from the sale of the final fertilizer product. From the perspective of EWS, the goal will be to determine if increased use and the value of nutrients recovered can justify urine collection and transportation and how such a sanitation scheme compares with heavily subsidized VIP programs.

Using currently available sanitation data, projections and recommendations will be made for other parts of South Africa and Sub-Saharan Africa.

STRUVITE CROP TRIALS

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Phosphorus supply is a major limitation to global food production. Global estimates suggest that 0.3 to 3.3 million tons/year of Phosphorus can be generated from human faeces and urine. Interest in nutrient recovery has focused more on technology optimization; however limited research exists with regards to the use of these products for agricultural production.

The aim of this study was to compare two different sources of excreta derived fertilizers, Struvite and LaDePa pellets, with a commercial phosphate fertilizer (Single Superphosphate) to determine the effect on maize growth at various stages up to 6 weeks in different soils (acidic loam, clay and a sand).

Figure 1: Struvite Powder

Struvite, shown in Figure 1, is a magnesium ammonium phosphate formed by combining source-separated human urine with a magnesium salt to produce an odourless and safe fertilizer. It is thought to be a promising compound that can provide an alternative and cheap source of phosphorus for the future.

LaDePa (Latrine Dehydration and Pasteurisation) is a process developed by eThekwini Water and Sanitation in conjunction with PSS (Particle Separation Systems) which produces dry pasteurised pellets from the sludge from Ventilated Improved Pit latrines (VIP).

The study was carried out in a glasshouse (Figure 2) at the University of KwaZulu-Natal, Pietermaritzburg.

Figure 2: Experimental layout in the glassshouse

The results at 3 weeks growth suggested that Struvite was comparable to inorganic fertilizer, but performed better than LaDePa pellets with regards to Maize growth and seedling vigour. This trend persisted up to six weeks, although all the plants began to show symptoms of nitrogen deficiency (see Figure 3).

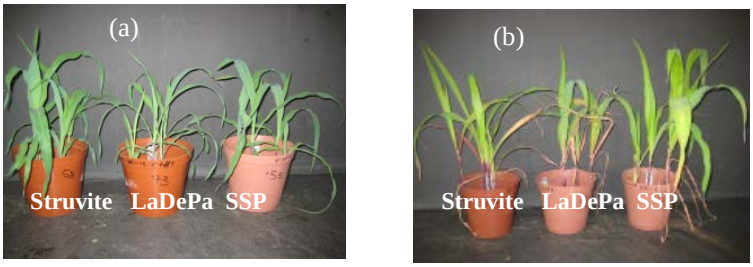

Figure 3: Maize at (a) 3 weeks and (b) 6 weeks of growth after the application of double the optimal rate of Struvite and Ladepa pellets.

Further comparisons were made to determine the response of Maize to different concentrations of Struvite application. Additions were made at half, normal and double the phosphorus requirements for Maize. These results are shown in Figure 4 compared to a Maize plant where no Struvite was added (control).

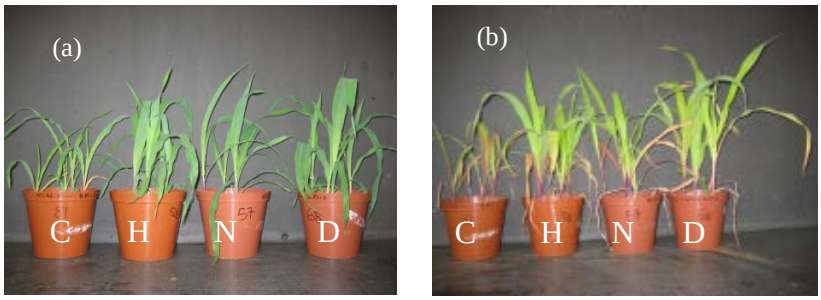

Figure 4: Struvite applied at 3 different rates half (H), normal (N), double (D) and control (C) on maize plants growing on a sand for (a) 3 weeks and (b) 6 weeks.

Figure 4 shows that there was an increase in Maize growth with increasing struvite concentrations at both 3 and 6 weeks growth.

A further study investigated the response of Maize to the addition of Struvite and LaDePa at double the optimum phosphorus concentrations. These results are shown in Figure 5.

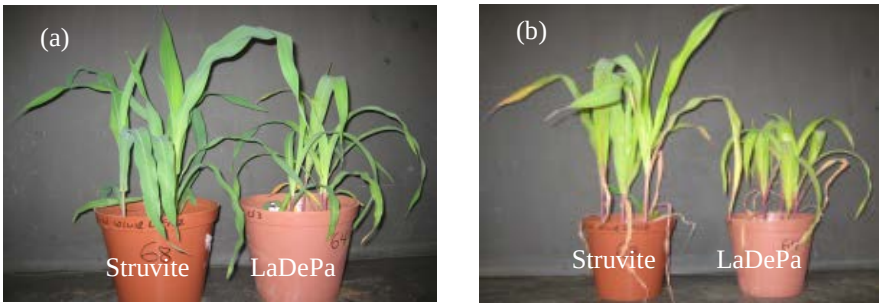

Figure 5: Maize at (a) 3 weeks and (b) 6 weeks of growth after the application of double the optimal rate of Struvite and Ladepa pellets.

These preliminary results suggest that Struvite has potential as a phosphorus source. It is thought that the reason Struvite performed better than LaDePa pellets is due to its higher phosphorus content and that phosphorus plays an important role during early seed development.

Soil and plant tissue analysis are ongoing which will provide further evidence on uptake and utilisation of these fertilizer sources and assess phosphorus release.