GOOD SCIENCE MAKES GOOD POLICY

A PARTNERSHIP BETWEEN ETHEKWINI MUNICIPALITY AND THE UNIVERSITY OF KWAZULU-NATAL

In 2006 Mayor Obed Mlaba presented the first cheque to Deputy Vice Chancellor Professor Fikile Mazibuko at the inauguration of the 5-year Memorandum of Agreement between the Municipality and the University

A strong working partnership has been forged between eThekwini Municipality and the University of KwaZulu-Natal. 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. Additional research funding is provided by the Water Research Commission and the National Research Foundation.

SOCIAL PERSPECTIVES ON WATER AND SANITATION

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Socio-economic and political dynamics are important factors bearing on successful implementation of good technological options. Increasingly, professionals are looking to collaborate across the disciplines to solve today's complex implementation challenges. Communities are key partners in service delivery, and ultimately, must drive their own development.

Zoë joined the Pollution Research Group in 2006 to work on identifying sustainable water and sanitation solutions that fit with community expectations and bolster strengths and entrepreneurial processes. Recent initiatives include: Zoë Wilson, Mandla Malakoana and Teddy Gounden. (2008), **"Trusting Consumers: involving communities in water service decision-making in Durban South Africa."**, *Water SA*, Vol. 34, No. 2; Zoë Wilson and Bill Pfaff. (2008). **"Religious, Philosophical and Environmentalist Perspectives on Potable Wastewater Reuse in Durban."** *Desalination*, 228: 1-9.

A PRO-POOR WATER TARIFF STRUCTURE

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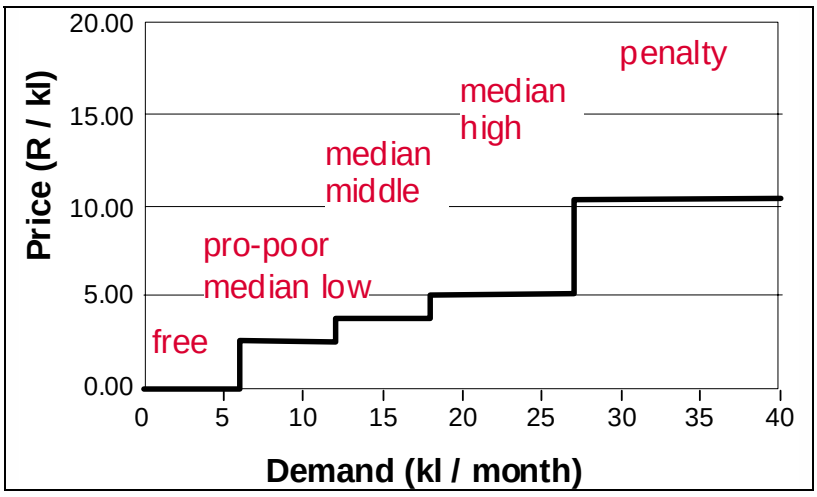
A water supply tariff can be used to promote a number of economic, environmental and socio-political objectives. In South Africa, increasing block tariffs are prescribed by regulations under the Water Services Act of 1997 to address problems of unequal income distribution and provide fair access to water.

A block tariff system is defined by the size and price of each block. Ramsey pricing principles were applied to the design of a tariff structure, using the domestic water consumers in Durban as a case study.

The water demand characteristics of low, middle and high income households were investigated. The water demand functions and price elasticity of demand for the three groups were estimated using econometric models. A tariff structure based on Ramsey pricing principles was proposed. This should have a positive impact on social welfare, provide sufficient revenue for water service providers and support the conservation of water resources.



The optimal tariff structure for water considered the revenue required to cover metering, billing, consumer service, planning, construction and maintenance, the cost of buying bulk water from Umgeni Water and the government's directive to provide 6 kl/per month free to each household. The econometric model was based on the analysis of seven years of historical data on water bills. The tariff is designed to meet the economic, social and political constraints while promoting water conservation, with high users subsidizing other users.

ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF WATER AND SANITATION SYSTEMS IN eTHEKWINI

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This study (funded by the Water Research Commission) aimed to assess the environmental burdens due to abstracting, treating, distributing, collecting and disposing (including recycling) water in an urban context. The environmental burdens were calculated from the abstraction of water from rivers through to the return of the same water (after it was used) to the sea.

The LCA scores calculated for the treatment of raw water, the distribution of potable water and the collection of and treatment of wastewater are dominated by the electricity requirements due to pumping in the operation stage. Chemicals and infrastructure have a relatively low environmental burden. This is in line with many other LCA studies on water treatment, where the use stage tends to be the most influential due to the continuous use of energy and materials. Electricity was shown to be the input leading to the largest impacts. This directed the investigation into the processes which had the highest electrical demand.

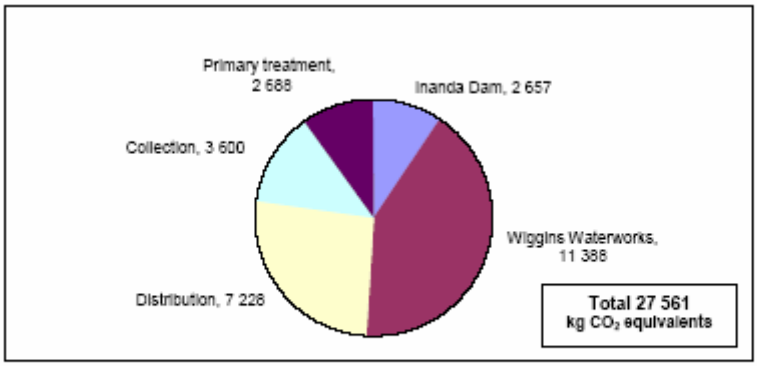

Figure 7.6: Global warming impact (kg CO_2 equivalents) for the base case for the supply of water and sanitation services to an additional 200 000 households per day.

For the provision of potable water to new customers which have not been previously served, two scenarios (200 000 new customers in an urban environment with waterborne sewage and in a peri-urban environment with on-site sanitation) were considered. The benefits of on-site sanitation and the avoidance of the use of electricity were quantified. The recycling of water is followed by maximising the use of existing assets as the most environmentally friendly options. The construction of new infrastructure carries a higher environmental burden and the use of bottled water for drinking (an additional scenario) carries the highest environmental burden.

QUALITY OF DRINKING WATER IN STORAGE CONTAINERS

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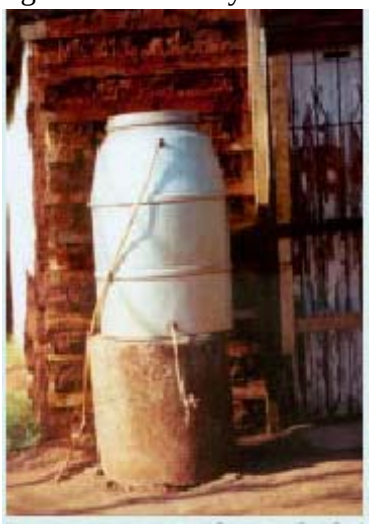
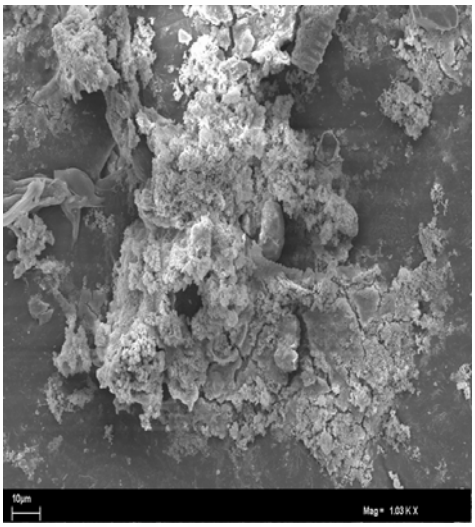
eThekwini Municipality delivers drinking water to consumers at four levels: full pressure; household roof tanks; household ground tanks; and communal standpipes. The last two levels of service require storage of water prior to use. eThekwini Municipality requires information on water quality "at the consumers' lips", and on the factors influencing this, in order to design suitable interventions. Pilot studies indicated that microbial quality of water stored in ground tanks, and in closed or open containers in the home in peri-urban communities in Durban did indeed deteriorate in both summer and winter, and that biofilm formation (bacteria and complex biological compounds adhering to surfaces usually immersed in water) in ground tanks may contribute to this.





More extensive studies are presently in progress, sampling larger groups and testing the effects of factors such as age distribution of households and types of storage containers on water quality. Again ground tanks from the community are also being subjected to intensive study of biofilms on their inner surfaces, and their contribution to deterioration in water quality. Data are being analysed in collaboration with a major epidemiological study which demonstrated that eThekwini policy of providing water, on-site sanitation and health education significantly improves community health outcomes. By correlating these data with microbial water quality data, predictors of poor in-house water quality and health effects are being sought.

REUSE OF GREYWATER FOR IRRIGATION IN PERI-URBAN AND RURAL AREAS

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Greywater is untreated household effluent from baths, showers, kitchen and hand wash basins, and laundry (*i.e.* all non-toilet uses). More than half of indoor household water use is normally used for these purposes and can potentially be intercepted by the householder for additional uses. Greywater reuse holds the potential to contribute significantly to food security in poor communities by providing a source of both irrigation water and nutrients for crop plants (from chemicals present in the greywater). eThekwini Municipality has conducted a trial project in the community to determine whether such a practice is feasible and acceptable to the community. The trial project was successful, but before implementing greywater reuse as part of its policy, eThekwini wishes to establish the microbial safety of the crops produced, and to ensure that greywater does not damage the soil or the environment.

Trials have been conducted at the University in which crop plants are grown in bags, irrigated below the soil surface with one of tap water, water with commercial plant fertiliser added, or greywater. Results available indicate 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.

SCIENTIFIC SUPPORT FOR DESIGN AND OPERATION OF VENTILATED IMPROVED PIT LATRINES (VIPs)

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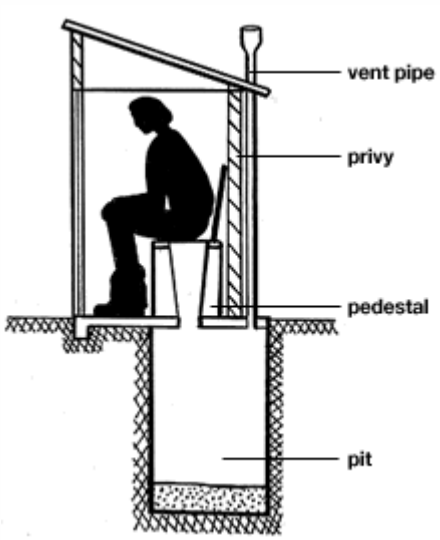
Ventilated Improved Pit Latrines (VIPs) are the minimum acceptable level of sanitation in South Africa. In eThekwini Municipality alone, there are more than 100 000 VIPs, many of which are full and in need of emptying. Despite being approved by authorities, there are many practical difficulties associated with the technology that may be a result of the technology itself, user practices, or uncontrollable environmental conditions. This project aims to understand the processes in a pit latrine and how they may be affected by different environmental and human factors. In particular the role of pit latrine additive products in the maintenance of pit latrines is being studied.



The project has two thrusts: Firstly sampling, analysis and mathematical modelling of processes in real VIPs in eThekwini municipality will assist in identifying how waste degradation occurs in a pit latrine. It is particularly important that the effect of chemical and biological conditions on the rates of processes is understood so that recommendations on how to increase degradation rates may be made. Secondly, the effect of using chemical and proprietary additive products to improve degradation rates, fly and odour control is being investigated. The results of both investigations will be brought together to inform the preparation of guidelines for pit latrine maintenance.

Preliminary results indicate that two factors may inhibit the bioconversion performance of a pit latrine: High organic load and associated organic acid production cause inhibition of biological processes; additionally, certain key micro-organisms may be absent or under-represented in the microbial consortia present in the pit contents.

EMPTYING OF PIT LATRINES

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There are over 100 000 ventilated improved pit (VIP) latrines in the eThekwini municipality. It is estimated that about 10 000 per year will need to be emptied on a continuous basis.

A study is being undertaken with partial funding from the Water Research Commission to develop an understanding of the sludge accumulation in VIPs and strategies to manage desludging in the future when the pits are full. The research will establish how many VIPs in the future will require some form of intervention to sustain their use. It will also look at finding more affordable and easier ways of desludging VIPs when they are full. The study aims to cover the following:

- consolidating knowledge on sludge build up and intervention strategies
- auditing and establishing how many pits are reaching their operational lifespan and determining the conditions thereof
- determining sludge build-up in VIPs over their life span through field investigations
- developing new technologies, strategies and processes to manage desludging and their safe disposal. This must include safe treatment and disposal, as well comparative costing of all options.
- determining how to desludge full pits and safely treat and manage the contents.

It will cover all aspects relating to the methods of desludging pits (technical/manual), management and treatment of sludges and economics thereof, international and local experiences, as well as determining innovative techniques.

SCIENTIFIC SUPPORT FOR RESEARCH INTO URINE DIVERSION TOILETS IN ETHEKWINI

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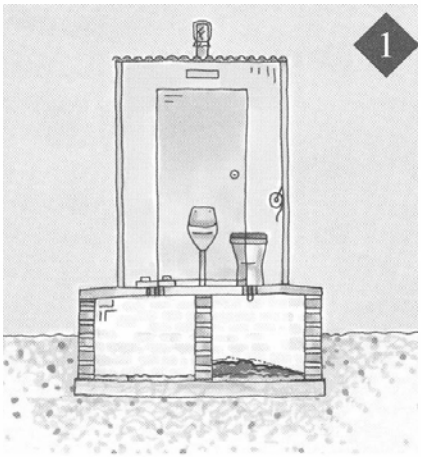
By 2007 eThekwini Municipality had built more than 50 000 urine diversion toilets in communities outside the urban centre. The eThekwini urine diversion toilet is a double vault dry toilet with urine diverted to a soak-away located near the unit. Dry material (faeces, anal cleansing material and bulking agent) accumulates in one of two vaults. Once the first vault is full, the pedestal is moved to the second vault and the first is sealed and allowed to stand. Once the second vault is full, the first vault is opened via a back plate and manually emptied. The pedestal is then returned to its position above the first vault and the second vault is closed and left to stand while the first refills.



The motivation for a urine-diverting design is that the volume of material that requires handling is substantially less than in a pit latrine which receives urine and often greywater as well as faeces and cleansing material. Thus a far smaller vault needs to be constructed. The smaller volume of the vault contents and their relative dryness means that they can be removed relatively easily by the householder with an appropriately sized rake or spade. Despite the obvious benefits of the design, there are a number of unresolved scientific, technological, social and health-related questions about how the design works and what the real health and environmental risks are to the householder, community and any outsiders involved in the pit emptying process. In particular the risk of infection by geohelminths such as *Ascaris* has been identified as being an important factor in calculating the benefit of sanitation provision in terms of community health and quality of life. Collaborative research on UD toilets aims to:

- Provide a scientific basis for the design and operation of UD toilets as used in eThekwini.
- Evaluate the effectiveness of UD toilets in improving the wellbeing of the user community.
- Determine the fate of *Ascaris* eggs from UD toilets, in full and filling vaults.

POLLUTION RESEARCH GROUP TEST SITE

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Many of the research questions regarding on-site sanitation which have emerged during eThekwini's implementation of its sanitation and water supply policy, have indicated the need for a safe, dedicated test site where experiments can be conducted under near-field conditions, but with the ability to control the experimental conditions. In 2002 the Pollution Research Group together with eThekwini Water and Sanitation took the first steps in developing such a site on the premises of the University.

Today, the PRG Test Site boasts an enclosed lockable area for crop growth experiments (presently used to test the use of greywater for irrigating crop plants) or for field experiments using easily disturbed or expensive equipment; enclosed columns used for testing the fate of buried waste from urine diversion toilets, including the growth of plants above buried waste; additional columns to be used to construct model pit latrines to study water movement in and out of pits; three fully functional urine diversion toilets, currently being used to study mechanisms occurring in urine soak-aways, including the possibility of growing plants above soak-aways. The toilet vaults are soon to be filled with urine diversion toilet waste to conduct a range of experiments on the microbial, chemical and physical processes that occur in urine diversion waste vaults during filling and standing. All these experiments will produce data which will assist eThekwini Municipality in constantly improving their service delivery.

THE ANAEROBIC BAFFLED REACTOR FOR ON-SITE OR DECENTRALISED SANITATION

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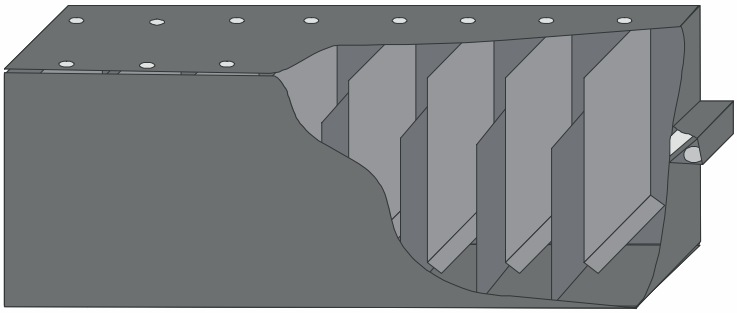
The Anaerobic Baffled Reactor (ABR) is a high rate anaerobic digester that is internally compartmentalised by a series of hanging and standing baffles. Wastewater enters the reactor and flows under a natural head under and over the hanging and standing baffles. No oxygen or mechanical mixing is applied; treatment is achieved by anaerobic digestion by naturally selected anaerobic microbial consortia The ABR is similar in concept to a septic tank in that passive treatment of wastewater is obtained by the (relatively) unassisted development of anaerobic micro-organism consortia in a simple digester design. However, compartmentalisation results in significantly improved performance compared to a septic tank.



A pilot-scale ABR was constructed and operated over a five year period and characteristics of the reactor performance with respect to conditions within the compartments and effluent quality were monitored during this time. A simple conceptual model of steady-state operation of the ABR was developed and calibrated with experimental data where available. A protocol for specifying ABR design parameters for the treatment of a wastewater with specific flow and load characteristics has been developed and the calibrated model used to determine values for the design parameters. This provides a framework within which a process engineer can design an ABR for the treatment of a specific domestic wastewater.

EU EUROMBRA PROJECT
MEMBRANE BIOREACTORS FOR ON-SITE OR DECENTRALISED SANITATION

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The objective of this project of this project is to develop and incorporate membrane technology into an Anaerobic Baffled Reactor system for areas with limited sanitation access. The project forms part of the EUROMBRA project, a collaborative research effort by European Union (EU) countries that also includes research groups from South Africa and Australia, to develop membrane bioreactor for municipal wastewater treatment. The project is co-funded by the EU and the South African Water Research Commission (WRC).

The primary aim of the Durban section of the project is to develop a low-cost, waterborne sanitation treatment system for areas without access to the local waterborne sewage network and which are inappropriate for on-site sanitation systems, such VIP and UD toilets. The secondary objective is to develop a membrane integrated ABR system that could be employed in these areas.
The specific aims are to:

- assess the effect of operating conditions (microbiological, flux and backwash / cleaning) on the productivity of different membrane modules, including pathogen removal
- build and operate a 100 L ABR for the treatment of domestic wastewater according to the design guidelines developed in an earlier study
- investigate methods of cleaning membranes under anaerobic conditions
- undertake a streamlined life cycle assessment study of the ABR/MBR system for low cost waterborne sanitation
- incorporate membrane polishing in a mathematical model of the ABR

FULL-SCALE EVALUATION OF THE DEWATS SYSTEM OF DECENTRALISED WASTEWATER TREATMENT

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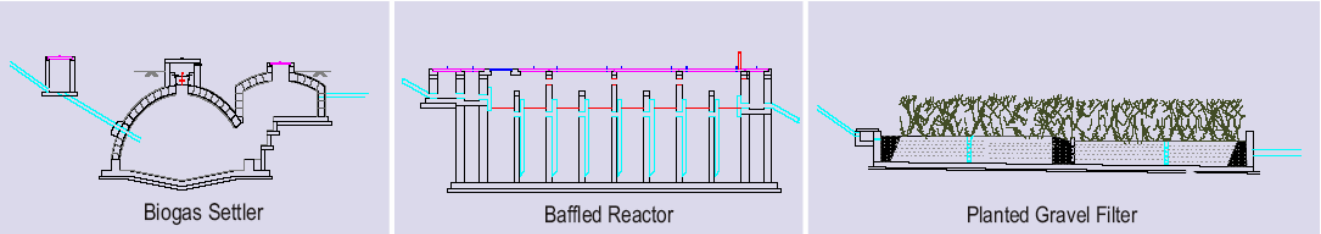
The DEWATS system for decentralised wastewater treatment has been developed by a German NGO (Borda) and an anaerobic baffled reactor is the core treatment process. A DEWATS system is being designed and built by eThekwini Water and Sanitation and Borda in order to evaluate it for new communal housing developments in areas which are remote from the established sewer network and where on-site treatment is not appropriate. The DEWATS system will treat the wastewater from about 80 low-income households. The components of the system include:

- a biogas reactor
- an anaerobic baffled reactor
- an anaerobic filter
- a planted gravel filter

A full-scale evaluation of the membrane process (developed in a parallel project) will disinfect the final effluent to product a nutrient rich pathogen-free water which will be evaluated for use in communal food gardens.



The system will operate without external electrical power. The flow of water through the membranes will be driven by a low pressure head (less than 1 000 mm). As the system does not remove nitrogen and phosphate compounds the product water will be high in plant nutrients.

The evaluation will answer the following technical questions:

- characteristics of the effluent from a low-income community
- the performance of the different components of the DEWATS system
- the performance and cleaning requirements for three types of membrane systems
- the characteristics of the membrane product water and its suitability for crop production
- the growth and yield of different crops grown using the treated water

ANTINOMOS

A knowledge network for solving real-life water problems in developing countries

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The Antinomos project, funded under the European Union Sixth Framework Programme, seeks to support the development of a world-wide knowledge network cross-cutting the fields of knowledge of the individual disciplinary professional water research institutes to share knowledge and best practices in water supply and sanitation and help developing countries find viable and socially compatible technological solutions. There are 13 partners from Europe, Mexico and South Africa.

ANTINOMOS contributes to the EU Water Initiative which was launched by the EU in 2002, as a catalyst and foundation for future action to meet the water and sanitation Millennium Development Goals. In particular, the initiative acknowledges the need to overcome the conventional fragmented approaches to water-related issues and to adopt a partnership approach and foster coordination and cooperation at all levels.

Global knowledge about water supply and sanitation technologies rarely ask for integration with indigenous knowledge systems and often works in isolation: their objectives are often mutually in contrast and their strategies conflicting.

The focus of Antinomos is on technologies and practices for water and sanitation services in poor rural and urban areas. The specific objectives are to:

- refine real life water problems and to define the methodological approach for the evaluation of WSS technologies and practices.
- analyze selected outside knowledge based technological systems.
- analyze selected inside knowledge based technological systems.
- develop multi-stakeholders discussions for learning across disciplines, countries and scale.
- foster knowledge generation and management throughout the project and to provide innovative KM tools
- facilitate the uptake of the project's results by existing global and local networks and main actors responsible for WSS in dev countries

The role of the Pollution Research Group is to provide and analyse case studies from South Africa with particular reference to interventions developed and implemented by the eThekwini Municipality.

EARTHWORMS AND BIOSOLIDS REDUCTION

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Mounting piles of belt-pressed biosolids (sludge) from wastewater treatment plants has become a growing problem world-wide. While land application of this sludge has some potential, there are risks from pathogens and heavy metals. An approach to pathogen reduction is the co-composting of biosolids with shredded garden waste (e.g. from landfills) and rely on thermophilic processes to effect pathogen killing. The drawback of this approach is one of increasing bulk, thereby increasing transport costs.

Earthworms (Figure below, left) take in organic matter through the mouth, after which the gizzard muscles mill the ingested material with sand particles. Digestive enzymes, as well as specialist bacteria resident in the earthworm gut further act upon the organic matter, and ultimately *droppings* or castings are produced (Figure below, right). It is reported that organic matter may undergo a volumetric reduction of 50 to 80%, depending on its type and origin.

Trials, which will be seen at the Experimental Site, consist of different sludge combinations:

1) Unpressed sludge; 2) Coagulant-treated belt-pressed sludge; 3) Traditionally composted sludge, including woodchips; 3) Sifted traditionally prepared compost; 4) Unpressed sludge and traditional compost; 5) Belt-pressed sludge and traditional compost in order to find optimal operating parameters for waste minimization.

IMPROVED METHOD FOR RECOVERING *ASCARIS* OVA FROM SOLID WASTE

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The evaluation of health risks associated with biosolids from UD toilets requires a reliable, accurate and simple method to detect and enumerate *Ascaris* ova in mixed soil-faecal samples. Commonly methods for the isolation and detection of ova in faecal samples include the Kato-Katz protocol, or the formal-ether method. These were deemed unsatisfactory for UD waste samples. Similarly, methods for the detection of *Ascaris* ova in wastewater samples, the modified Bailenger method, or the method currently implemented by the eThekwini municipality gave variable results. It appeared that siliceous particles (sand) of different sizes present in unprocessed UD samples, in some way led to unreliable results.

The removal of the unwanted siliceous material by selective sieving using a series of filters of decreasing mesh size, known as a Visser® filter method, is reputed to be rapid and simple for the recovery of helminth egg from excreta. Disadvantages of this method is that samples are prepared individually, and large amounts of water are used for the sieving process.

PRG has developed a protocol which gives high recovey from UD samples and is easy to implement, requiring minimal laboratory equipment. It is referred to as the AMBIC protocol, reflecting the use of Ammonium BICarbonate to dissociate ova from siliceous particles. It may be summarized thus:

> ***1g sample of U.D. waste mixed with ammonium bicarbonate (AMBIC); vortex for 45 mins, centrifuge and pour off supernatant. Resuspend pellet in distilled water ("washing" step),vortex, centrifuge and pour off supernatant. Vortex and float ova from pellet using $ZnSO_4$ of SG 1.3. Centrifuge and remove entire supernatant (containing ova) into 4 clean tubes of distilled water. Centrifuge and discard supernatant and examine pellet by light microscopy for ova, and viable embryos.***

A publication describing applications of the methods is in preparation, and the method has been adopted as the standard method for use in the South African Sludge Guidelines.