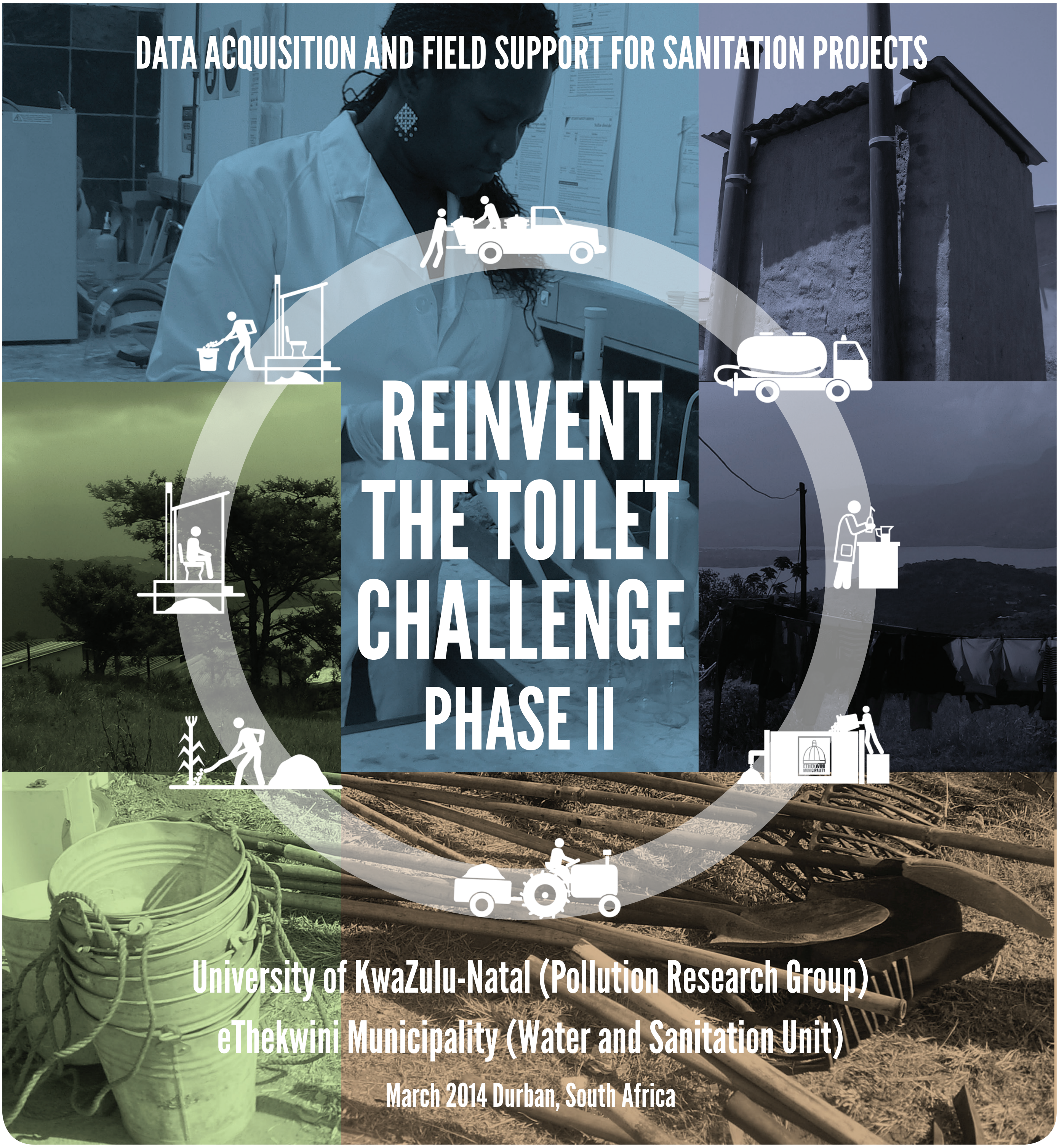
WATER AND SANITATION

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

PRG
pollution research group



DATA ACQUISITION AND FIELD SUPPORT FOR SANITATION PROJECTS

# REINVENT THE TOILET CHALLENGE

## PHASE II

University of KwaZulu-Natal (Pollution Research Group)
eThekwini Municipality (Water and Sanitation Unit)

March 2014 Durban, South Africa

# REINVENT THE TOILET CHALLENGE

## PHASE II

Funded by the Bill & Melinda Gates Foundation

# Aim

The aim of this booklet is to introduce the research being undertaken by the Pollution Research Group (University of KwaZulu-Natal) and the eThekwini Water and Sanitation Unit (eThekwini Municipality) under the Reinvent the Toilet Challenge Phase II funded by the Bill & Melinda Gates Foundation. Further information is provided on the DVD and the detailed data sets will be provided on request.

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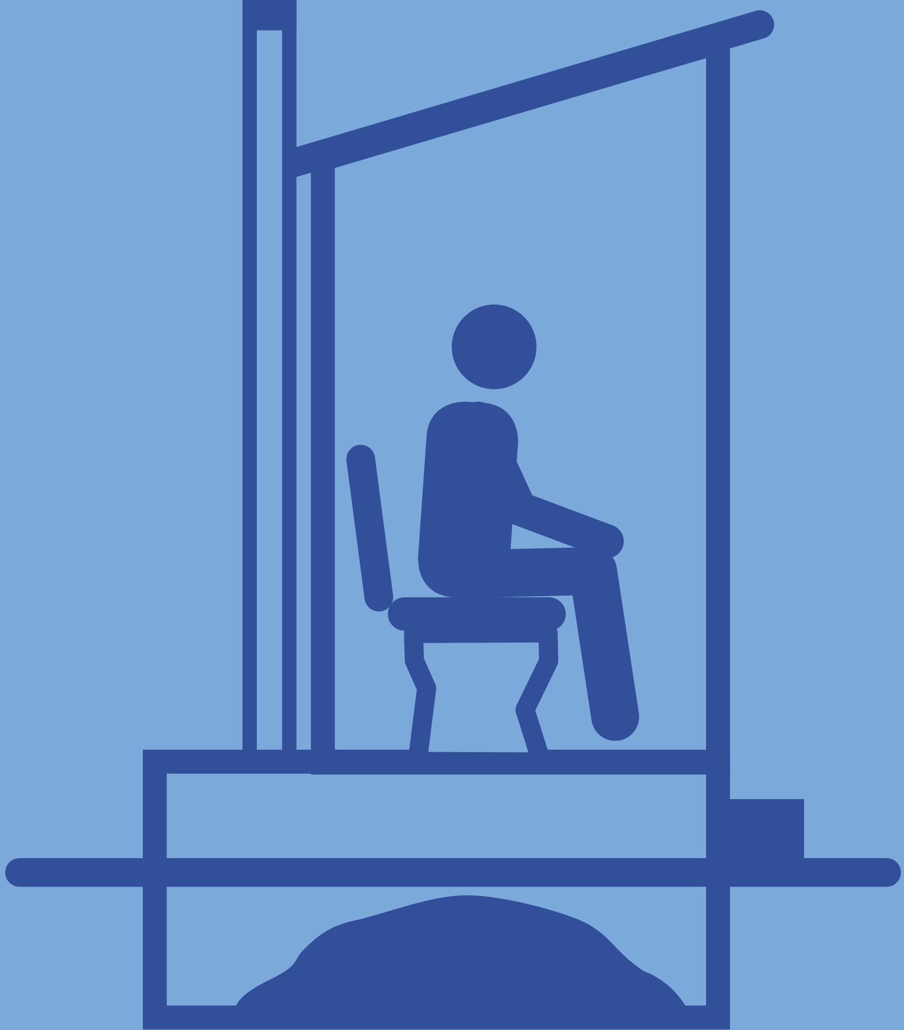
# Introduction



# Durban – a City of Contrasts

**eThekwini Municipal Area (EMA)** is located on the eastern seaboard of South Africa within the Province of KwaZulu-Natal and covers an area of 2 297 square kilometres. While the total area of the EMA is only 1.4% of the total area of the province, it contains just over a third of the population of KwaZulu-Natal (approximately 3.7 million people) and 60% of its economic activity.

The EMA was formed in December 2001. The boundary of the EMA increased the boundary of the previous Durban Metropolitan Area by 68% whilst increasing the population by only 9%. Some 35% of the EMA is predominantly urban in character, with over 80% of the population living in these areas. The remainder is rural in nature. The extensive peri-urban districts of the municipality are semi-rural in character, with low population density (in other words, the municipality extends beyond the urban area).

The EMA is characterised by diverse topography, from steep escarpments to the west to a relatively flat coastal plain in the east. Climate is humid subtropical. Flooding sometimes affects some settlements, but is not a severe problem. Industrial activity is extensive and diverse. There is significant agricultural activity within the metropolitan area, which includes low-density semi-rural districts. A significant proportion of the population lives in low-income townships, including informal settlements. This makes it difficult to identify the exact number of households within the Municipality and numbers are estimated based on the aerial photography. A survey carried out in 2011 identified the presence of just over 912 400 households within the EMA consisting of formal houses (54%); informal settlements including backyard shacks (34%); and rural households (12%).

According to the 2011 Water Services Development Plan, in the region of 54% of households have flush toilets connected to sewerage, about 4% have flush toilets connected a septic tank, 10% have urine-diverting dry toilets (85 000 installed), about 4% have improved (ventilated) pit latrines (32 000 installed), and 4% have access to community ablution blocks (520 installed), giving a sanitation backlog (i.e. still to be installed) of 24%. Of this backlog, some of these households will have some form of sanitation which is inadequate based on the WHO/UNICEF Joint Monitoring Programme definition (mostly unimproved pit latrines, though there may be some bucket latrines or no facilities). Durban is the only city in sub-Saharan Africa with a large number of urine-diverting dry toilets, mostly constructed with government subsidy in low-density semi-rural districts of the municipality.



# Reinvent the Toilet Challenge

# A History of Collaboration

**As far back as 2003** eThekwini Municipality and other businesses recognised the need to work with local tertiary organisations and a Memorandum of Understanding (MOU) was signed with three tertiary educational institutions (the University of KwaZulu-Natal, the Durban Institute of Technology and Mangosuthu Technikon). The aim of this MOU was to strengthen collaboration on research and development, capacity building and knowledge management, in order to achieve growth and development, in keeping with the Municipality's Integrated Development Plan (IDP). The desired outcomes included a stronger economy, an improvement in the quality of life for all citizens and the development of a higher skills and technology base.

Following on from this MOU, a number of Memoranda of Agreement (MOA) have been signed between the Municipality and the University of KwaZulu-Natal outlining specific collaboration undertakings within various departments in the University. The MOA specific to the Water and Sanitation Unit (EWS) and the Pollution Research Group (PRG) was signed in February 2006 and formalised the desire of both parties to promote the knowledge base in water and sanitation delivery and to expand research capacity and expertise in this field.

This MOA was initially signed for a period of 5 years (2006 to 2010) and was then extended for a further 2 years to end in 2012. A second MOA was signed in 2013 for a further 2 years (to 2015). Under this MOA, the eThekwini Municipality, through EWS, has committed an annual budget to fund applied research projects that would be undertaken by the PRG

The MOA specifies that co-ordination will be guided by Neil Macleod and Chris Buckley (the heads of the respective organisations) and outlines the role of EWS and the PRG. On the side of EWS, this involved identifying the issues that required researching and prioritising them for the PRG. They also needed to provide access to data, internal expertise and their facilities for research, as well as field support for interaction with communities. In return, the PRG would provide students to undertake the research and laboratory facilities to produce scientifically credible results that would guide the decision making process within EWS.

There have been a number of research projects undertaken, the results of which have assisted EWS in their service delivery. These projects include not only technical issues, but also social and economic aspects. In some cases, these projects are funded solely by the EWS, while in others, joint funding from the South African Water Research Commission (WRC) and other international sources such as the Bill & Melinda Gates Foundation (Gates foundation), BORDA (Bremen Overseas Research and Development Association) and Eawag (Swiss Federal Institute of Aquatic Sciences and Technology) is used.

*(Extracted from WIN-SA Field Note, December 2011)*

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# Bill & Melinda Gates Foundation - Reinvent the Toilet Challenge  Phase II Data Acquisition and Field Support for Sanitation Projects

## Outcomes of Phase I

Phase I of the Reinvent the Toilet Challenge resulted in the development of a prototype pedestal for the segregation of excreta streams and processing of the individual wastes. Theoretical models were developed for the handling and treatment of urine, faecal matter and washwater. In order to develop the prototype and the models, an extensive sampling and analyses programme was undertaken to generate data on faecal matter. However at the end of this Phase, the final design could not be manufactured.

The main outcomes from Phase I highlighted the strengths of the UKZN team (through the PRG) and the importance of collaboration with EWS. This includes:

- Access to various on-site sanitation systems to obtain different excreta streams
- Sampling of these on-site sanitation systems
- Laboratory analysis to determine mechanical, chemical and biological properties of the various excreta streams
- Undertaking detailed investigations into the processing of segregated streams

Phase II of the project, therefore aims to build on the lessons learnt, knowledge, strengths and experience gained by the team during Phase I implementation.

## Outline of Phase II

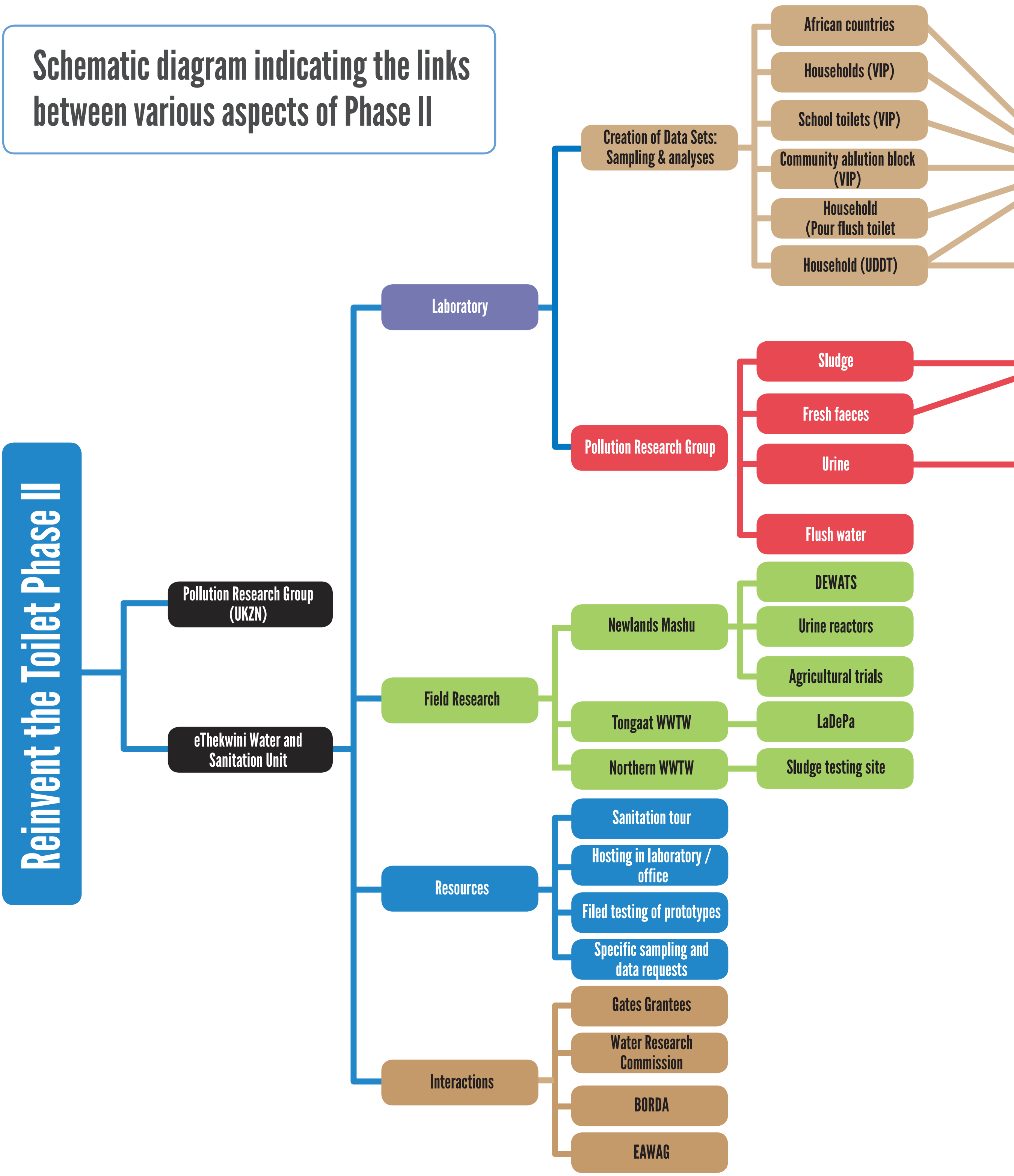
Phase II of the project is based on the realisation that other Gates grantees, in order to design and build their prototypes, required data on various excreta streams, access to different sanitation systems and field testing of their prototypes. The PRG, together with EWS, are in a unique position to offer these services.

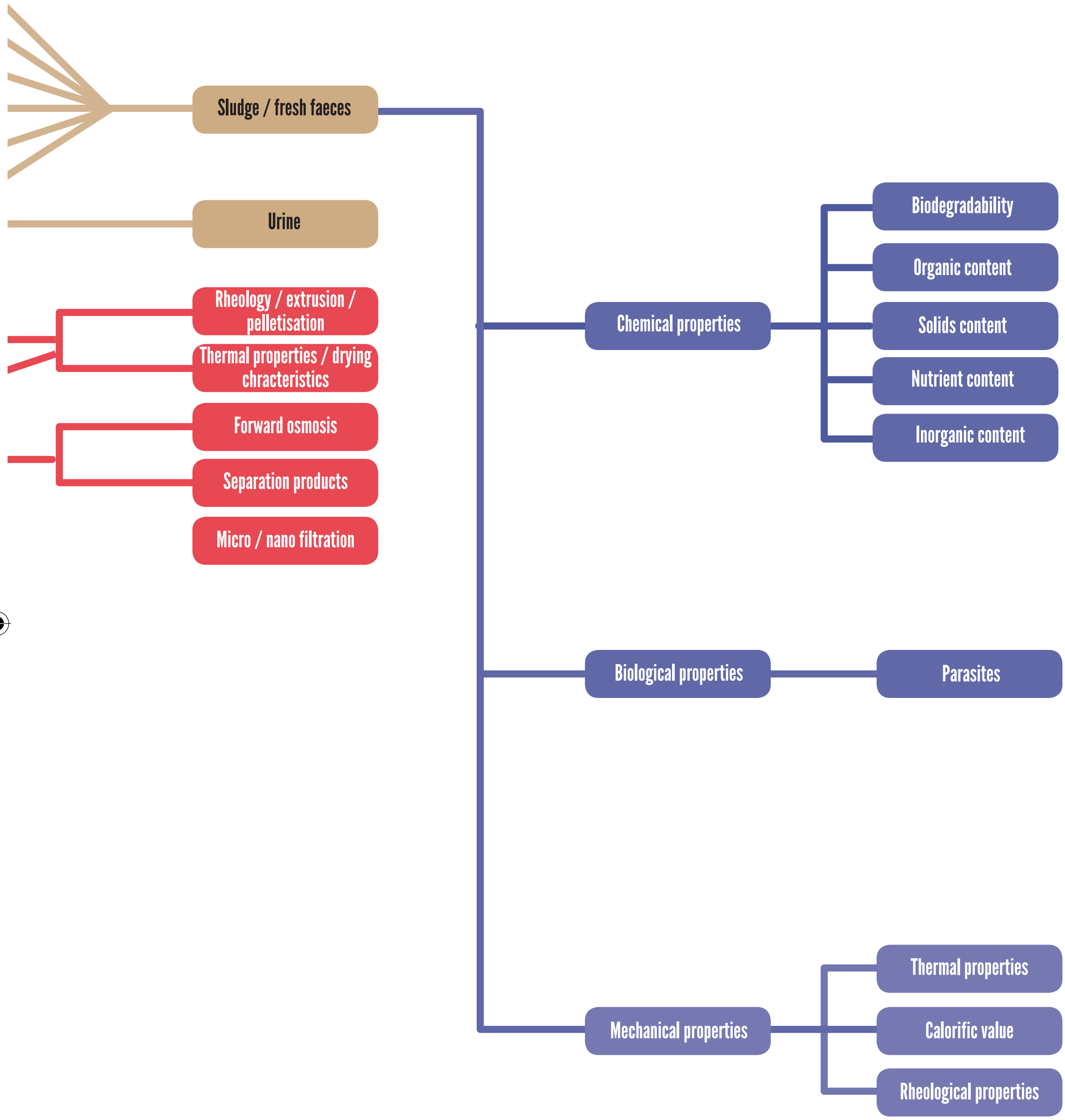
The aim of Phase II is therefore to characterise mechanical, chemical and biological properties of excreta streams from dry on-site sanitation systems or from decentralized low-water consuming sanitation systems, and to distribute this data to other Gates grantees to support their research.

Assistance will be also be provided to other grantees in establishing and evaluating their prototypes in Durban, and supporting their work by:

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

# Schematic diagram indicating the links between various aspects of Phase II





Sludge / fresh faeces
Urine
Rheology / extrusion / pelletisation
Thermal properties / drying chracteristics
Forward osmosis
Separation products
Micro / nano filtration
Chemical properties
Biodegradability
Organic content
Solids content
Nutrient content
Inorganic content
Biological properties
Parasites
Mechanical properties
Thermal properties
Calorific value
Rheological properties

# Phase II Approach

The aim of Phase II is to provide a detailed data set and reports on the mechanical, chemical and biological characteristics of various excreta streams which are generated from laboratory and field research, other related research projects and testing of prototypes.

## Laboratory Research

Routine laboratory analysis of samples collected from on-site sanitation facilities is undertaken following standard operational procedures. Detailed investigations into the processing of segregated excreta streams is also being undertaken by chemical engineering masters students.

## Field Research

Field trials and analysis of various demonstration and full-scale installation is undertaken, including a decentralised wastewater treatment plant, urine reactors, agricultural trials and a machine for the processing of pit latrine sludge (LaDePa).

## Other Resources

In addition to the data sets generated from the laboratory and field work, and various resources are available to other Gates grantees such as specific data analysis requests, field testing of prototypes, sanitation tours, and hosting of grantees in the PRG laboratories and offices.

## Collaborative Projects

There are a number of related projects undertaken by the PRG together with EWS that provide input into the data sets and this information is also available to grantees.

## Output: Mechanical, Chemical and Biological Properties

All research carried out in the laboratory and the field are being collated to provide a data set of mechanical, chemical and biological properties of the various excreta streams.

More detail on each of these is provided in this booklet.

# Laboratory Research

# Laboratory Research

**Data on various excreta streams are obtained in the following ways:**

- Through sampling and laboratory analysis of excreta streams from different sanitation systems; and
- Through in-depth research projects on segregated streams

## Sampling and Creation of Data Sets

Sampling from various sanitation systems is undertaken by researchers and technicians at the PRG together with EWS staff and, where necessary, a pit emptying contractor. The samples are then transported and stored in the PRG laboratory laboratory prior to analysis.

**Samples are collected from the following sources:**

- Sludge from ventilated improved pit latrines from households, community ablution blocks and schools
- Sludge from urine diversion dehydration toilets on a household level
- Sludge from pour flush toilets on a household level
- Fresh faeces from individual donors
- Urine from urine diversion dehydration toilets on a household level
- Sludge from other African countries (type and level still to be determined)

Typical analyses carried out on the selected samples include laboratory testing of chemical, mechanical and biological properties, following standard operational procedures. This includes solids (total, volatile, fixed and suspended) and moisture contents, pH, organic (COD) and nutrient contents (P, K, N), thermal conductivity, calorific value, specific heat, volume settlement index, particle size distribution, density, rheological and extrusion properties of sludges, and parasite content.

## Research on Segregated Streams

There are six Chemical Engineering masters students undertaking research projects on segregated excreta streams. These are:

- Project 1: Thermal Properties and Drying Characteristics of Faecal Sludge
- Project 2: Rheology, Extrusion and Pelletisation of Faecal Sludges
- Project 3: Forward Osmosis as a Final Step in the Recovery of Water from Urine
- Project 4: Micro-filtration of Liquid Excreta Streams
- Project 5: Separation Products of Urine
- Project 6: Nano-filtration of Liquid Excreta Streams

Additional research projects are underway which are related to the Phase II projects and these are explained in more details under the Interactions section.

## Project 1: Thermal Properties and Drying Characteristics of Faecal Sludge

**Name of student: Blessing S. N. Makununika**

**Nationality: Zimbabwe**

**Degree held: BScEng (Chemical) (University of KwaZulu Natal, 2013)**

### Project description

The project falls under the Reinvent the Toilet Challenge (RTTC), supported by the Gates foundation, aimed at providing low cost sanitation and using faecal sludge to obtain high value end products that could be used as energy source. With more research being conducted in testing the viability of using faecal sludge as solid fuel, an end use that could be environmentally and financially beneficial, there is currently little or no literature available on the analytical design data.

One of the fundamental aspects of utilising faecal sludge is the removal of water from the sludge to desired moisture content. This project seeks to analyse the drying characteristics and thermal properties of faecal sludge by using a custom designed drying rig that will allow control of the essential drying parameters which are drying air temperature, air flow rate and air humidity. Using classical drying theory, models of the drying process will be developed for ultimate inclusion in a simulation-based design. The dried faeces will then be combusted using a calorimeter to determine the amount of energy that can be extracted from the combustion of faecal sludge dried under different conditions.

### Methodology

Dry air is humidified by counter current contact with water in a packed column. The humidified air is then heated to the desired temperature before it enters a drying chamber where the faecal samples would be dried. A mass balance is attached to the drying chamber so that the mass of the sample may be monitored during the experiment. The mass balance is connected to a computer which will track the loss in mass of the sample with time.

### Progress to date

Construction of the drying rig is almost complete apart from the pressure and temperature probes. Once these are installed, the drying rig will be commissioned and experiments begun.

## Project 2: Rheology, Extrusion and Pelletisation of Faecal Sludges

**Name of Masters Student: Lehlohonolo Teba**

**Nationality: Lesotho**

**Degree held: BScEng (Chemical) from University of Cape Town, South Africa.**

### Aim of the project:

- To investigate simple techniques which can be used by field staff and pit emptiers to assess the shear strength (viscosity) of faecal sludge in a VIP latrine pit.
- To analyse rheological properties (viscosity and elasticity) of non-Newtonian faecal sludges from various VIP latrines.
- To calculate mechanical energy requirements for pit emptying equipment, hauling and extrusion systems from the rheological properties.
- To develop characteristic/performance curves for the LaDePa extruder.

### Objective:

- To suggest simple techniques which can be used by field staff and pit emptiers to assess the viscosity of faecal sludge in a VIP latrine pit so as to be able to make decisions about emptying and disposal strategies.
- To provide rheological and mechanical energy requirements data to improve existing (and design new) pit emptying, haulage and disposal technologies for faecal sludge from VIP latrines towards minimisation of handling hazardous pathogens present in faecal sludges when pit emptying and disposal of untreated faecal sludges onto the land and water.
- To perform evaluation / modelling for the LaDePa extruder.

### Methodology:

- Experimental measurement of shear strength (viscosity) of faecal sludges from VIP latrines will be done with a simple cone penetrometer.
- Experimental measurement of rheological properties (viscosity and elasticity) of faecal sludges from VIP latrines will be done with a rotational rheometer.
- Mechanical energy requirements for pit emptying equipment, hauling and extrusion systems will be quantified based on the rheological properties experimentally measured from a simple capillary extruder rheometer.
- Calibrate the speed and perform extrusion trials on the LaDePa extruder.

### Progress to date:

Experimental measurements on the artificial sludge are ongoing. Next steps include undertaking experimental measurements on the faecal sludge from VIP latrines.

## Project 3: Forward Osmosis as a Final Step in the Recovery of Water from Urine

**Name: Albert Muzhingi**

**Nationality: Zimbabwean**

**Degree held: BSc Chemical Engineering (University of KwaZulu-Natal, 2010-2013)**

### Background

The project falls under the Gates foundation's Reinvent the Toilet Challenge (RTTC) that underscores the provision of low cost sanitation. The project is the first of its kind that will desalinate Urine using forward osmosis. In a futuristic toilet envisioned under this project, portable water will be obtained together with fertilizer from the urine. A membrane will be utilised to effect the separation. The feed solution will contain the raw urine to be separated and an Ammonium Bicarbonate solution with a higher osmotic potential will be utilised as the draw solution.

The proposed research will investigate the solute separation, draw solution back diffusion, permeate flux and fouling propensity as a function of solvent recovery. The recovery of the draw solution will not be investigated. The results will be used to produce a simple in-put out-put model suitable for evaluating different flow sheets and mass balances for possible incorporation in a reinvented toilet.

### Methodology

A forward osmosis rig will be designed, built and commissioned. The capacity of the rig will be of the order of 1 litre of urine per day. Urine will be sourced from student volunteers and from urinals and source separation toilets which have been installed by eThekwini Municipality throughout the city. Chemical and physical analysis of the feed solution will be undertaken in the Pollution Research Group laboratories. Mass balance and chemical speciation calculations will be undertaken to ensure accuracy of the results. Physical measurements such as conductivity and osmotic pressure will also be used as a consistency check.

### Progress to date

All the equipment has been purchased and delivered except for the two rotameters that should arrive in mid-March 2014. The rig will be built and commissioned using synthetic urine. Once commissioned, experiments will proceed.

## Project 4: Micro-filtration of Flush Water

**Name of student: Joyce Ouma**

**Nationality: Kenyan**

**Degree: BSc water and environmental engineering from Egerton University, Kenya**

### Background

Flush water can offer alternative source of water that leads to reduced competition to domestic water. Such alternative source can be re-used if subjected to proper treatment. For flush water to be reused, pollutants should be reduced to acceptable levels. This can be achieved through membrane filtration such as microfiltration. Apart from the potential for reuse, proper flush water management can contribute significantly to wastewater management. Additionally, the available nutrients can be used for crop production consequently fighting poverty. This can be achieved through research as is proposed in this study. This topic will identify the filtration stages necessary, the properties of the product streams and the energy requirements to apply the filtration.

### Project Description

This project is one of a number of projects being undertaken by PRG which aims to obtain data on the properties of generic excreta streams and excreta streams that have undergone separation. This data will inform the design of a "Reinvented Toilet". This project will be investigating the use of pressure driven membrane processes (i.e. microfiltration) on liquid excreta streams (for example: - urine, faecally contaminated urine and contaminated wash water). Aspects to be investigated include specific flux (volume / area / unit pressure / time), membrane resistance and membrane fouling. The experimental set up consists of; a pressure gauge, an Amicon® dead-end filtration cell for holding the membranes, a magnetic stirrer for stirring the cell, a beaker for collecting the permeate, a mass balance for weighing the permeate, a thermometer for measuring the temperature of the permeate and a computer connected to the mass balance to take readings directly from the balance.

### Progress to date

To date a literature search has been undertaken, the experimental equipment set up and several tests have been carried out on the samples before they undergo membrane filtration. The next step will be to start the filtration experiment and data collection. The data collected from the experiment will be used to achieve the objectives of the study.

### Expected outcomes

It is expected that the faecally contaminated urine and contaminated wash water will clog the membranes more than the pure urine. Thus the permeate flux will be low due to fouling. Also, it is expected that the increase in pressure will increase the permeate flux and vice versa.

# Project 5: Separation Products of Urine

**Name of Masters Student: Khonzaphi Dube**

**Nationality: Zimbabwean**

**Degree held: BEng(Hon) (Chemical) at the National University of Science and Technology (NUST) in Zimbabwe.**

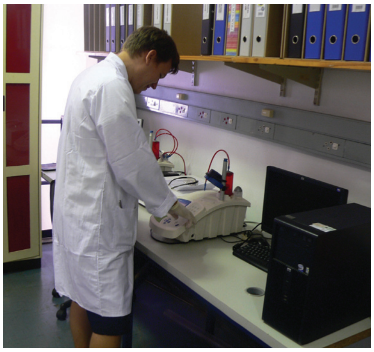
## Project description

The aim of the project is to present experimental data on the thermophysical properties of urine. This data are essential for the design and determination of optimum operating conditions for urine separation processes such as distillation. This project will be carried out in collaboration with the Thermodynamics Research Group at UKZN to determine the thermophysical properties of urine which include; vapour pressure, heat capacity, osmotic pressure, density, thermal conductivity, and viscosity.

## Progress to date

Currently, a study to define the composition of typical human urine and the synthetic urine recipes proposed by various authors is being undertaken.

## Project 6: Nano-filtration of Flush Water



**Name: Donovan Horstman**

**Nationality: South African**

**Degree held: BSc Chemical Engineering (University of KwaZulu-Natal, 2011)**

### Project description

Most of the nutrients present in human waste are concentrated in the urine, while most of the pollutants, apart from micro-pollutants, are concentrated in the faeces. Treating urine and recovering these nutrients is of vital importance to ensure the economic viability of the new toilet system envisioned by the Reinvent the Toilet Challenge (RTTC).

### Methodology

This study will focus solely on the processing of the urine and flush water entering the proposed sewage treatment system. Membranes have been identified as being potentially useful to process urine, in the RTTC context, as membrane systems are generally lower in energy consumption and mechanical complexity than corresponding thermally or biologically based systems used in waste water treatment and desalination. The purpose of this study will be to place membranes in the context of other possible treatment options and to identify the key knowledge gaps and fill in the knowledge through experimentation.

### Progress to date

Thus far research has been done to place membrane technology in the context of other treatment options. Experimentation is planned, of which most of the equipment has been purchased and is currently being set up, to investigate the viability of nanofiltration to treat urine which has already passed through a microfiltration setup.

# Field Research

# Field Research

Data from pilot and full scale trials is also being collated for use by other Gates grantees. An overview of the available field facilities is provided below.

## Newlands Research Facility

A research facility has been established by EWS at Newlands Mashu situated in Newlands East just north of Durban. Facilities at this site include:

- A pilot decentralised wastewater treatment system (DEWATS)
- Reactors for the processing of urine to extract nutrients
- Agricultural trials (field and growing tunnel)
- Testing of prototype UDD toilets

## DEWATS

The technical evaluation Decentralised Wastewater Treatment System (DEWATS) plant built at Newlands Mashu is connected to a main trunk sewer conveying wastewater from 84 low to medium income households. The modularised plant consists of three treatment steps

- A settling chamber/biogas collector,
- Three parallel ABR trains and two anaerobic filter (AF) modules. Two of the ABR trains (trains 1 and 2) had seven identical chambers whilst the last ABR train (Train 3) had four chambers with front three double the chamber size of the other ABR trains
- Polishing in either a vertical flow constructed wetland (VFCW) or horizontal flow constructed wetland (HFCW)

This DEWATS plant has been evaluated by a number of post-graduate students (see **Interactions** section).

## Urine Processing

Urine that has been diverted and collected contains high concentrations of the nutrients Phosphorus and Nitrogen. Two reactors are being evaluated for the recovery of these nutrients and their incorporation into usable fertilisers.

The first reactor is a struvite reactor that recovers most of phosphorus present in the urine by adding dissolved magnesium salts. A simple reactor has been developed that could be used in-situ at agricultural sites, as well as an automated, computer-controlled reactor that could be used in more densely populated settings. The struvite reactor yields a phosphorus-rich solid fertilizer.

The second reactor is a biological treatment unit combined with evaporation that aims to recover the majority of nutrients initially present in the urine by using bacteria to convert ammonia nitrogen to nitrate nitrogen. The nitrification/evaporation reactor yields a concentrated liquid fertiliser and water.

Research on this project is undertaken in conjunction with Eawag and is funded through the Gates foundation. It has been termed VUNA – the Valorisation of Urine Nutrients in Africa.

## Agricultural Trials

There is currently a multidisciplinary research project being undertaken by UKZN on the integration of agriculture in the development of innovative and low cost sanitation technologies when planning new social housing schemes in urban areas. The agricultural team is made up of Dr Alfred Odindo (Crop Scientist), Prof Jeffery Hughes (Soil Scientist), Dr Irene Bame (Soil Scientist) and a number of postgraduate students. The overall aim is to develop decision support tools that can aid policy makers, planners and engineers in the integration of agriculture in the development of social housing schemes that could lead to the sustainable management of waste in ways that could also benefit communities.

Trials are being conducted at Newlands Research Facility, the primary focus of which is the development of nutrient and water balance simulations for the use of ABR effluent for irrigating crops. Weather data collected from the automatic weather station installed at the experiment site and data on soil characteristics of wide range of soils and crop growth variables of selected crops including banana, taro, Swiss chard, potato and maize will be used to calibrate and validate the models.

### Testing of Prototype UDD Toilets

Demonstration urine diversion dehydration toilets have been installed at Newlands by local companies in order to showcase state-of-the-art double-vault UDDTs to national and international visitors, and to test the various units with the aim of improving the design and equipment for future installations. These toilets are the only sanitation system at the research site thereby enabling visitors, researchers and staff to obtain a first-hand experience with urine diversion toilets.

## Tongaat Wastewater Treatment Works

The Tongaat Wastewater Treatment Works is the site where the LaDePa (latrine dehydration and pasteurisation) pelletiser is situated. This machine was developed by EWS in conjunction with their technology partner, Particle Separation Systems (PSS) for the dehydration and pasteurisation of VIP sludge and the production of pellets. The machine works on the use of heat and medium-wave infrared technology to deactivate the pathogens and create a pellet-type product that can be used as a fertilizer. The pellets which are produced are analysed to determine the mechanical, chemical and biological properties. Trials to determine the effect as a fertiliser have also been undertaken.

A laboratory scale version of this machine is housed at the PRG laboratories and is being used by Masters students to investigate the effect of various operational changes on the efficiency of the process.

## Northern Wastewater Treatment Works

There is currently (March 2014) no field trials underway at Northern Wastewater Treatment Works, but this site provides a secure venue for the testing of larger prototypes. Plans are underway to use this site to test prototypes from other Gates grantees.

## Marianhill Wastewater Treatment Works

This treatment works is the proposed site for investigating the use of black soldier fly larvae to degrade vault-contented sludge from, for example, urine diversion dehydration toilets.

# Resources

# Resources

**Other resources available to Gates grantees under Phase II include:**

- Sanitation tour
- Hosting in the PRG laboratory and offices
- Field testing of prototypes
- Specific sampling and data requests
- Data from other African countries

## Sanitation Tour

The "Sanitation Tour" aims to introduce visiting researchers to different types of sanitation and treatment technologies currently in place within eThekwini and the research being undertaken by EWS and the PRG at the University of KwaZulu-Natal.

## Hosting of Visitors

The PRG welcomes other grantees to visit and work in the laboratory in order to further develop their research aims. Office and laboratory space are allocated, and all training in health and safety and laboratory equipment is provided by the laboratory manager. Visitors can be assisted in obtaining samples and analysing results.

## Field Testing

Field testing of prototypes can be undertaken by the PRG and EWS for grantees. Alternatively, visiting grantees can be assisted in carrying out field trials.

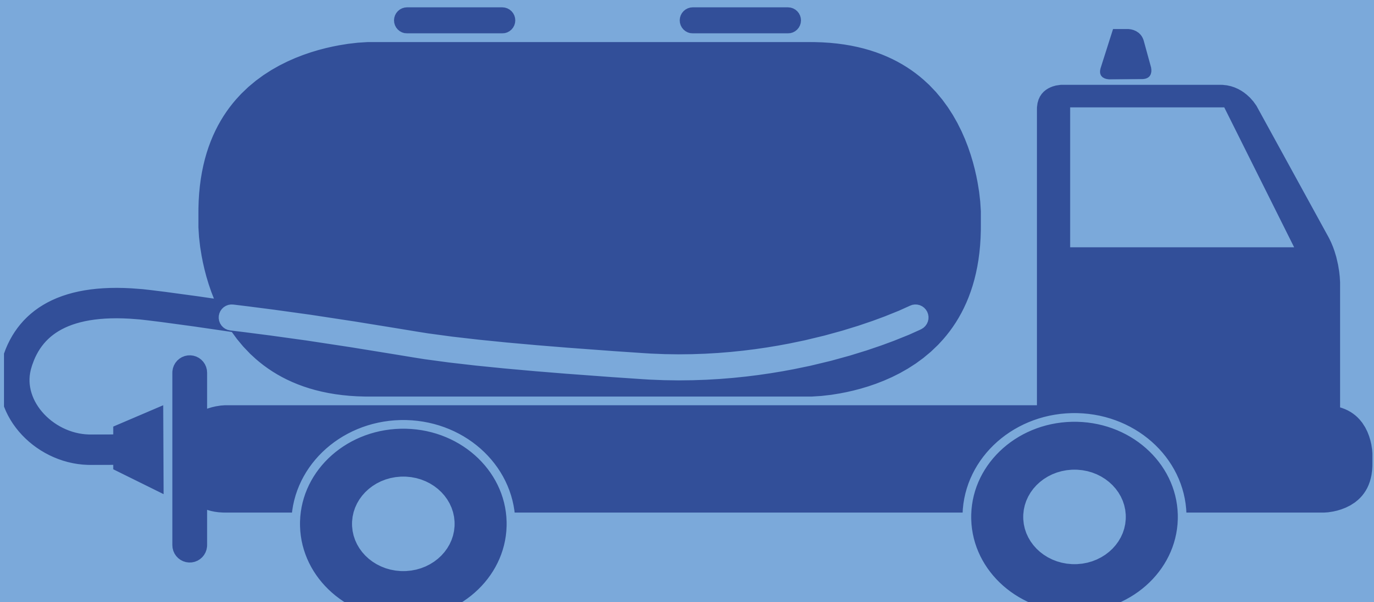
## Specific Requests

A key aspect of Phase II is to provide data sets to support the development of prototypes. Grantees can submit requests for specific tests to be carried out on excreta streams (provided the necessary equipment is available in the laboratory). A number of grantees have been assisted in this way.

## Data from other African countries

Data from the analysis of excreta streams from on-sanitation systems in other African countries will be collated by the PRG researchers for inclusion into the existing database in order to support further prototype development.

# Interactions



# Interactions with other Organisations

A number of other projects carried out by the PRG, in conjunction with EWS, provide input into Phase II. These projects are funded by the Gates foundation, the South African Water Research Commission (WRC), Bremen Overseas Research and Development Association (BORDA) and other institutions including Gates grantee organisations. Some of the key projects are described below.

## Research Projects

### Mechanical Properties of Faecal Sludge

**Funded by:** Bill & Melinda Gates Foundation

Project lead: Pollution Research Group (UKZN)

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 the following types of facilities were analysed: wet and dry household VIP latrines, household UDD toilets, household unimproved pit latrines, community ablution block VIP latrines, and school VIP toilet blocks. Samples were collected from the various on-site sanitation facilities and analysed to determine their chemical, mechanical, rheological and thermal properties. The results of the study will support the design of appropriate toilet facilities, mechanical pit-emptying devices and sludge processing technologies. The data-set produced is publicly available to other grantees.

The project was initiated in May 2012 and ends in March 2014.

## Economic Evaluation of Faecal Sludge Disposal Routes

**Funded by:** Bill & Melinda Gates Foundation

Project lead: Pollution Research Group (UKZN)

Project partners: Partners in Development; SANDEC (Eawag)

The Latrine Dehydration and Pasteurisation (LaDePa) process is a treatment system for faecal sludge, reducing the volume of solids to be disposed of and producing a pathogen-free product that may be used in agricultural applications. The objective of this study was to carry out an economic evaluation of (i) the LaDePa process and (ii) a total combustion processes for sludge disposal and/or re-use. These were compared against the option of disposing of sludge to landfill. A versatile economic spreadsheet model was developed that enables a total cost comparison of the processes to be carried out, from the latrine pit to the point of end disposal or sale of the treated sludge product.

The model was developed and populated by making use of data from EWS on the pit emptying process and the operation of the LaDePa pelletising machine. Additional data on the pit sludge, LaDePa pellet and combustion ash characteristics were obtained through laboratory analysis and from existing data within the PRG. A data set was also obtained for faecal sludge collection, transport and treatment in Dakar, Senegal and used for validation.

This consultancy project was completed in November 2013 and the spreadsheet model is available to other grantees on request.

## Promoting Sanitation & Nutrient Recovery through Urine Separation (VUNA - Valorisation of Urine Nutrients in Africa)

**Funded by:** The VUNA Project is mainly funded by the Bill & Melinda Gates Foundation. Additional funds are provided by the Swiss National Science Foundation and the US National Science Foundation

**Project lead:** Eawag

By recovering nutrients from urine in small decentralised reactors, the project aims to develop a dry sanitation system, which is affordable for the poor, produces a valuable fertilizer, promotes entrepreneurship and reduces pollution of water resources.

This project consists of a number of smaller research projects each of which are undertaken by Masers and Doctorate students in both the PRG (Durban) and EAWAG (Switzerland). These can be broadly divided into the following aspects:

- Technology (reactors)
- Social
- Logistics

Those aspects that are being carried out in South Africa are described below.

### Technology Aspects

### Operation and Optimization of Reactors to Treat Source-separated Urine in eThekwini

**Name of Student: Sara Rhoton (PhD student)**

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.

Two reactor setups are being tested: (i) a struvite reactor and (ii) a combination of nitrification and evaporation. The reactors were first installed and trialled in the PRG laboratories and have now been installed at the Newlands Mashu evaluation facility.

The struvite reactor recovers most of the phosphorus contained in urine. Results show a removal of more than 91% for total phosphorus. The nitrification and evaporation reactors aim 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 which could be applied as fertiliser in the field.

# Social Aspects

## The Role of Health and Hygiene Education in the Acceptance, Utilisation, and Maintenance of Urine Diversion Dry (UDD) toilets in Rural Communities of KwaZulu Natal

**Name of Student: Nosipho N. Mkhize**

**Qualification held: BSocWork (Hons) from UKZN**

This Masters project is being undertaken in the school of Public Health Medicine (UKZN). The aim of the project is to explore the influence that health and hygiene education have on social acceptance, utilisation and maintenance of the UDD toilets. Health and Hygiene education plays a vital role because resources can be invested in building and designing the toilet in the way experts believe is suitable but if people are not accepting of the toilet or using it properly, it will be resources wasted and the health problems will persist. Therefore, the latter makes health and hygiene education a vital element in the provision of sanitation because the information shared assist in encouraging people to appreciate the sanitation product, to maintain and use it properly.

Qualitative methods were used to explore and investigate the role of health and hygiene education, focus groups and in-depth interviews were used in engaging with the users of the UDD toilets.

The project is at the stage where health and education material is being developed, which will be implemented in two rural communities of eThekwini that are using the UDD toilets. The study will be conducted in 40 households per area, two schools per area, community care givers, youth groups and women's groups. Thereafter the evaluation will explore if the education had an impact. The findings from the evaluation will assist in identifying areas for improvement in our future health and hygiene education programmes, how communities should be consulted and how information should be presented to them.

## Promoting sanitation and nutrient recovery through urine separation: A social acceptance study

**Name of Student: Marietjie Coertzen**

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

An initial in depth statistical examination of a survey that was completed in November 2011 was initially undertaken from a survey conducted across 17 000 households. This provided the opportunity to analyse an initial reaction to the proposed sanitation changes. A follow up survey was conducted in 2013 to assess any changes in the communities as the joint VUNA projects progressed.

# Logistic Aspects

## Develop and Describe a Suitable Logistic Collection System for Urine Harvesting in eThekwini

**Name of Student: Hope Rebekah Joseph**

**Qualification held: BScEng (Civil) (UKZN)**

The main goal of this study is to develop and describe a suitable collection system for urine harvesting. Two approaches can be used, namely an incentivised approach or an institutionalized approach. The study will focus on the institutionalised approach which requires the cooperation of EWS staff for urine collection. This Master's thesis is linked to the VUNA Project.

Provision of adequate sanitation services is a basic necessity for all residents in South Africa. EThekwini Municipality has adopted the Urine Diversion Dry Toilets (UDDT) as a means of sanitation in the rural areas. Durban has 85 000 UDDTs, the highest number in the world. Urine is separated at the source. Recent studies have shown that urine contain essential and recoverable nutrients. The methodology that will be used for this study will be partially experimental and theoretical. Software such as Geographical Information System (GIS) has been used to understand the area in terms of distances, terrain and model routes for urine collection. A pilot project is the next step to determine the costs associated with the collection of urine. This pilot will take cognisance of the lessons learned in the previous pilot conducted in affiliation with a PhD study. Expected outcome of this study is a financially viable transportation system for urine collection.

## City Partnership for Urban Sanitation

**Funded by: Bill & Melinda Gates Foundation**

**Project lead: Khanyisa Projects (Principal Agent) in association with Partners in Development (PID)**

The eThekwini Municipality has over the last 10 years provided over 85 000 urine diversion double pit toilets to residents of the city who previously had no sanitation services. These residents typically live on the urban fringe. The original plan was that residents remove the safe decomposed contents and bury onsite. However, research has shown that the contents are not decomposing sufficiently and consequently residents are at risk when removing or burying the waste.

The project will design a rollout programme that will provide a safe, cost effective service through partnerships and performance based contracts with private organizations and contractors. Furthermore, the value of the waste will be harnessed through the planting of trees above buried contents. Where this localized solution is not feasible, the waste contents will be transported to a central processing plant or smaller decentralized plants which will convert the waste into valuable products which can be used in agriculture.

The program will thus develop partnerships for safe, compliant solutions that will be sustainable in terms of costs and acceptable to residents.

## Characterisation of on-site Sanitation Material and Products: VIP latrines and pour-flush toilets

**Funded by: South African Water Research Commission**

**Project lead: Pollution Research Group (UKZN)**

**Project Partners: Partners in Development (PID)**

### Part 1: Assessment of Pour flush toilets

**Name of student: Aoife Byrne, Dublin, Ireland**
**Degree held: Bachelor of Engineering (Civil, Structural and Environmental) in 2012 from Trinity College Dublin.**

The pour-flush latrine is a relatively new sanitation system in South Africa and is an improvement to the Ventilated Improved Pit (VIP) latrine. It originates from India where it was first designed and is still used extensively. Partners in Development (Pty) Ltd have adapted the design to suit the South African user, allowing for the users to sit on a pedestal rather than squat over a pan and to use toilet paper instead of water for anal cleansing. The excreta and toilet paper are transported from the toilet, via a pipe system with a small amount of flushwater (approximately 1 litre) to the leach pit, which stores the faecal sludge. The system can be constructed with either one or two leach pits on site. Where two leach pits are constructed on site, one is active and the other is standing i.e. out of use. Once the active leach pit is full, the flow of waste from the toilet is redirected to the standing leach pit and so becomes the active leach pit. This is the first time pour-flush toilets have been adapted in such a way and used in South Africa,and there is therefore little knowledge and experience about the chemical, physical and biological nature of pour-flush faecal sludge, the rate at which it accumulates in the leach pit and the way in which the sludge is degrading over time.

This project involves the collection and analysis of sludge samples from both the active and standing pour-flush leach pits. The characteristics of interest are the concentration of total solids, volatile solids, ash, water content, COD,  biodegradability tests are yet to be performed. The information collected from this study will aid the development of the design of the pour-flush system in South Africa, as well as providing information about the filling rate of the leach pits and how best to approach emptying the contents once the leach pit is full and best practices for retrieving samples from the leach pits for future work. Potential for the reuse of the sludge when the leach pit has been emptied may also be estimated.

## Part 2: Processing of Sludge from VIP Latrines

**Name of student: Simon W. Mirara, Kenya**

**Degree held: Bachelor's degree in Agricultural Engineering at Egerton University, Kenya (2012).**

The project aims to assess the processing of sludge from ventilated improved pit (VIP) latrines. The drying of sludge will be investigated using the laboratory scale Latrine Dehydration and Pasteurisation (LaDePa) machine installed at the PRG's laboratory. This 'baby' LaDePa is a smaller version of the full-scale machine operating at the eThekwini Water and Sanitation's Tongaat Wastewater Treatment Works, which processes sludge from pits emptied by the municipality. It converts sludge into a pasteurised material which could be used for soil conditioning or incinerated for heat energy.

This research project focusses on establishing conditions for efficient drying and pasteurisation. This would make it possible to dry sludge from different sources and enable up-scaling of current sludge processing.

To reduce contamination during the initial stages of the experiments, a synthetic sludge will be used to commission the LaDePa machine. As soon as it is operational actual pit sludge will be used. Currently, the work in progress is to get the LaDePa running and to prepare the operating procedures. After this is done various tests on the extruder and the drier will be carried out.

**The larger LaDePa compares in size to the 'baby' LaDePa as follows.**

- Belt width from 950 mm to 250mm
- Belt aperture from300µm to 200µm
- Medium wave infrared power from 144kW to 7.4kW
- Heated width from 1350mm to 220mm
- Heated length from 11000 to 880 mm
- The power supply to the blower from 5.5kW to 0.75kW

## Evaluation of the DEWATS Process for Decentralised Wastewater Treatment

**Funded by: South African Water Research Commission, Bremen Overseas Research and Development Association (BORDA) and EWS**

**Project lead: Pollution Research Group (UKZN)**

**Project Partners: Hering South Africa**

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

A pilot DEWATS plant was established at Newlands Mashu in order to investigate the applicability of the DEWATS system to treat the wastewater from a small housing development, and to identify any operational problems and how these could be overcome. In addition, the use of the treated wastewater from the Anaerobic Baffled Reactor (ABR) for agricultural purposes was assessed in terms of impact on plant growth, soil quality and health implications.

This initial project was completed in 2013, but further research into the DEWATS process is being undertaken by Bjorn Pietruschka (PhD Student).

Björn Pietruschka is a masters graduate from the Internationale Hochschulinstitut Zittau (IHI) – now Technical University of Dresden. His doctoral project is funded by BORDA (Bremen Overseas Research and Development Association) a German international NGO. The project focuses on quantifying and characterising the changes in the solids over time within the different compartments of the anaerobic baffled reactor section of the DEWATS plant at Newlands-Mashu. The ABR compartments act as a solids retaining system. The solids consist of three fractions, biologically inert, active micro-organisms and unbiodegraded material. The unbiodegraded material slowly degrades over time to yield additional biomass and additional biologically inert material. The rates of the different processes will be determined and used in a model of the process. The output from the research will be knowledge to better manage the operation of the system so as to obtain as high organic material removal as possible. Further, it will improve the design procedure for new plants.

## The Sanitation Research Fund for Africa Project

**Funded by: Bill & Melinda Gates Foundation and the South African Water Research Commission**

**Project lead: South African Water Research Commission (WRC)**

The Sanitation Research Fund for Africa (SRFA) project aims to build FSM capacity in Africa through a better understanding of pit processes under varying conditions and developing sustainable technological options.

Twelve projects have been selected under the SRFA project with two focus areas:

- **Pit Characterisation**
  - Jimma University, Ethiopia
  - Egerton University, Kenya
  - Makerere University, Uganda
  - University of Malawi, Malawi
  - University of Zambia, Zambia
  - University of Botswana, Botswana
- **Developing Innovative Tools for Desludging and Beneficiation**
  - Water for People, Uganda
  - Mzuzu University, Malawi
  - Chinhoyi University, Zimbabwe
  - North-West Uni., RSA
  - ATL-Hydro, RSA
  - Rhodes University, RSA

# Other Interactions

The PRG and EWS interact with a number of other organisations through provision of data, hosting of visitors, assistance on research projects, discussions and so on.

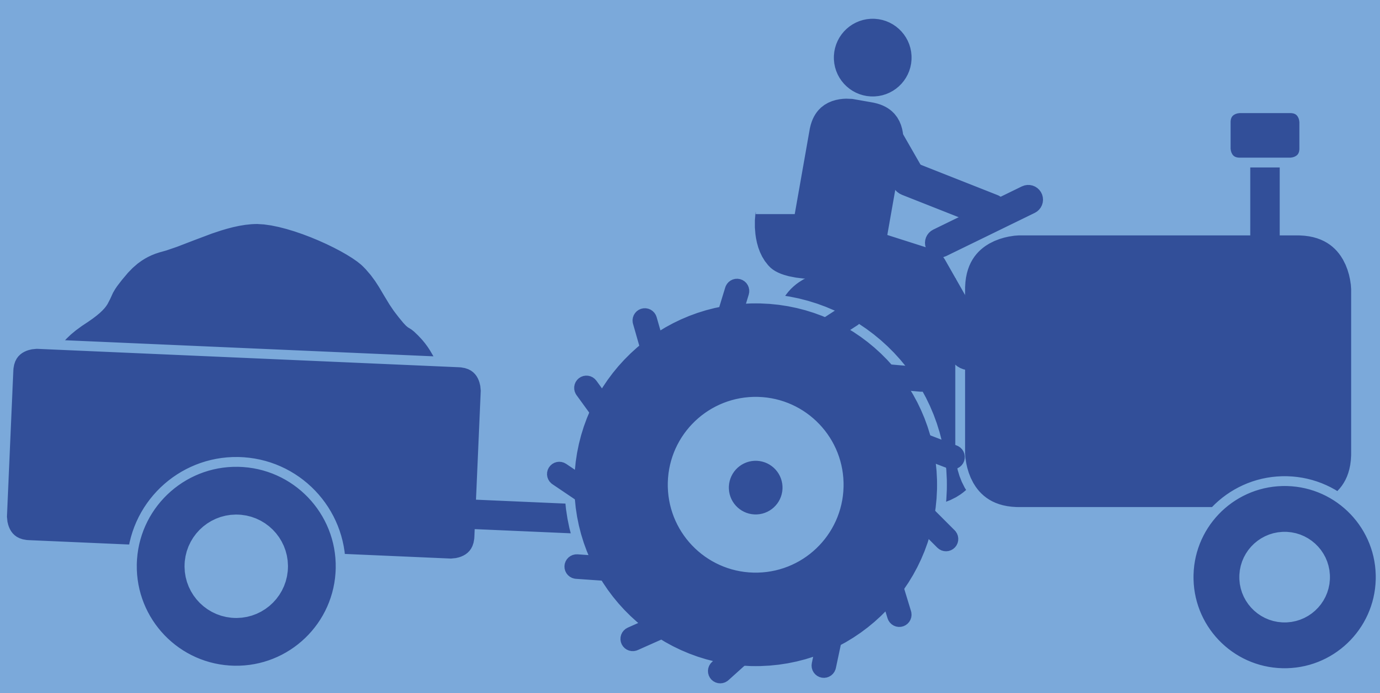
## International Organisations

- Asian Institute of Technology
- Climate Foundation
- Sanergy
- Delft University of Technology
- Duke University
- Research Triangle Institute
- University of the West of England, Bristol
- Wageningen University
- Synapse
- Swedish Environmental Institute
- London School of Hygiene and Tropical Medicine
- University of Maryland
- University of Colorado Bolder
- Santec
- Beaumont Design
- E3Energy Partners
- UNESCO-IHE
- Kansas State University
- Swiss Federal Institute of Aquatic Science and Technology (EAWAG)
- University of Toronto
- Oklahoma State University
- Plymouth Marine Laboratory
- University College, London
- North Carolina State University
- Swedish University of Agricultural Sciences
- Janicki Industries
- Loughborough University
- Reckitt Benckiser
- Agriprotein
- Boston Consulting
- Path
- Firmenich
- Mott MacDonald
- Swiss Federal Institute of Technology in Zurich (ETHZ)
- University of Laval, Montreal
- Unilever
- Bear Valley Ventures
- Cranfield University

## African Municipalities

- Kitwe Municipality
- Kabwe Municipality
- Botswana Government

# Outputs



# Output - Mechanical, Chemical and Biological Properties

Data generated from the various laboratory analyses and research projects can be broadly divided into mechanical, chemical and biological properties. This data can then be used to assist in the design of prototypes, pit emptying devices, and health and safety aspects. The database of information is continuously expanding as samples are analysed and includes data on sludge from VIPs, urine diversion toilets, pour flush toilets, fresh faeces, urine and pellets from the LaDePa process. A brief overview of the methods used is provided below, followed by a table summarising the data collated as of March 2014. More detailed data is available on request.

Standard operating procedures have developed for all analyses and these are also available on request.

## Mechanical Properties

This group includes analyses on rheological properties, plastic and liquid limits, stickiness coefficient, thermal conductivity, specific heat, calorific value, sludge volume index (SVI) and particle size distribution. They provide data required for improved design of pit emptying devices, toilet pedestals, coating and facilities. They also support the assessment of sludge treatment processes such as drying, combusting and heating and the design of sludge treatment facilities.

## Chemical Properties

This group includes analyses such as: total, volatile, fixed, suspended solids and moisture contents, chemical oxygen demand (COD), phosphorus, nitrogen, potassium and sodium contents, pH and ion conductivity. Total solids (TS), volatile solids (VS) and suspended solids (SS) provide respectively the total amount of solids and their distribution between organic, inorganic, suspended and dissolved fractions. Moisture transports the soluble components and is an important factor for the biological processes in the pit. The solids content helps to understand the degree of stabilisation in the pit and the mechanical behaviour of sludge in terms of mixing, drying, flowing, floating, settling, clogging and combusting. Determining the chemical oxygen demand provides an indication of the degree of biodegradability and age of sludge in pits. pH affects the degradation processes and can be an inhibiting factors for the anaerobic digestion of faecal sludge. Nitrogen in various forms is found in the protein fraction of faecal matter and urea in urine. TKN is the sum of organic N compounds, free ammonia (NH3) and ammonium (NH¬4+), important for the pH balance in anaerobic digestion. Nitrogen, phosphorus and potassium contents of faeces and urine indicate their nutritional content, hence their potential for further use in agriculture.

## Biological Properties

Biological analyses are currently focussed on quantifying the helminth content of the various excreta streams. This work is carried out by the Helminth-Group which is based at the Westville Campus of the University of KwaZulu-Natal, Durban, South Africa.

Various types of sanitation samples can be processed by a simple “Ambic” method and then examined microscopically for the presence/absence of helminths. The helminths most commonly found in eThekwini, KwaZulu-Natal, are *Ascaris lumbricoides, Trichuris trichiura and Taenia* spp. (identical eggs of T. *saginata* and T. *solium* prevent species identification).

# Data Set

Table 1 summarises the data set available to date (1st March 2014). The figures provide the average values between all on-site sanitation facilities, including: 10 dry VIPs, 10 wet VIPs, 10 UD toilets, 2 community ablution blocks, 6 pour flush toilets and 1 school toilet. Samples from urine and LaDePa pellets were also collected and analysed. Detailed data can be provided on request.

**Table 1: Data Set (as of 1st March 2014).**

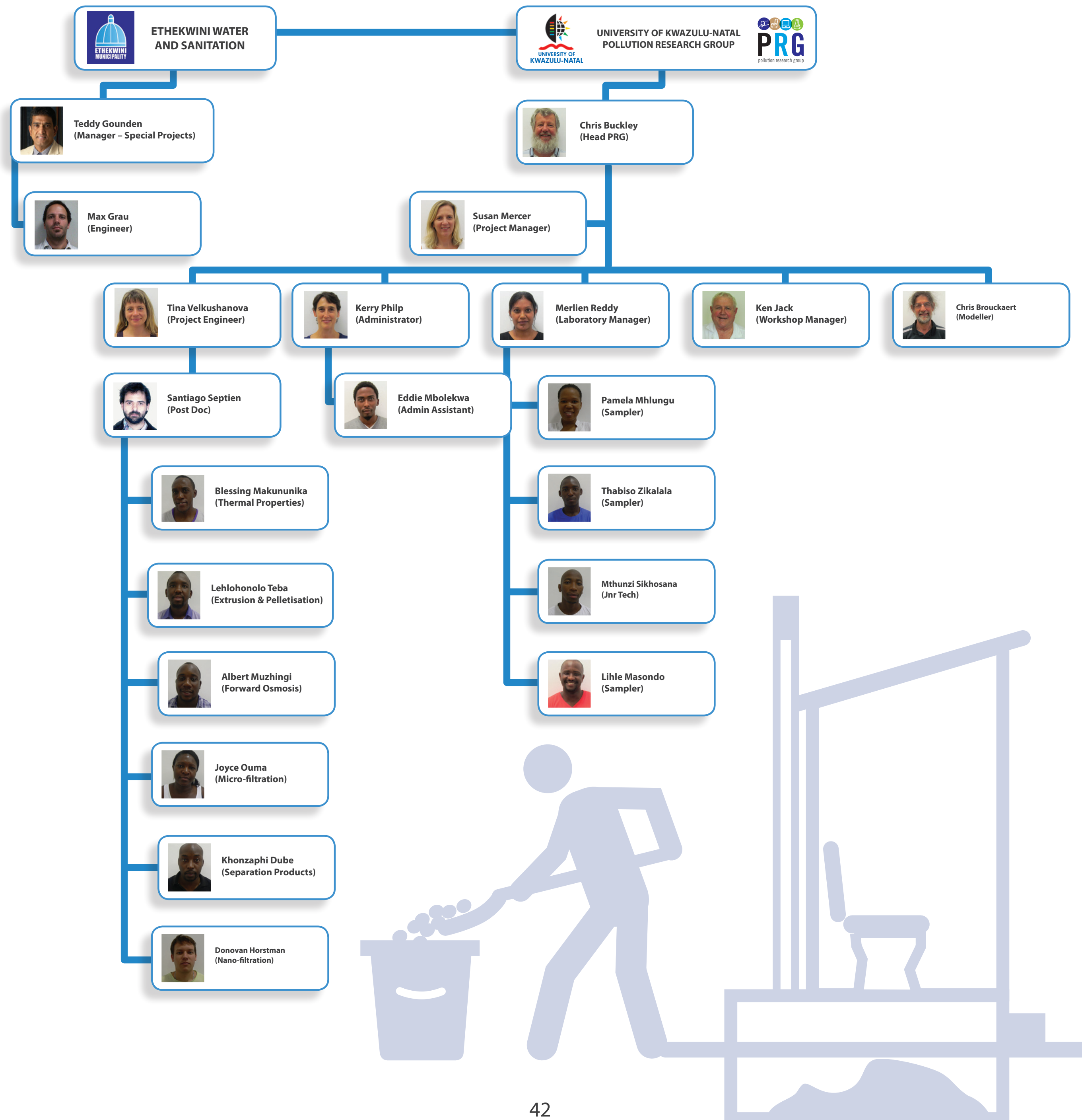
**Key: A=data available on request, F= forthcoming, R=data can be obtained on specific request**

*mg/L

| | | Sludge from dry VIP | Sludge from wet VIP | Sludge from UDT | Sludge from CABs | Sludge from school toilets | Sludge from pou flush toilets | Fresh faeces | Urine | LaDePa Pellets |
|---|---|---|---|---|---|---|---|---|---|---|
| Total solids | (g/g wet solids) | 0.21 | 0.21 | 0.43 | 0.23 | F | 0.33 | 0.24 | 1812* | 0.86 |
| Suspended solids | (mg / L) | 578 | 402 | 246 | 139 | F | R | | R | 0.00 |
| Volatile solids | (g/g dry mass) | 0.58 | 0.54 | 0.45 | 0.49 | F | 0.39 | 0.87 | 855* | 0.16 |
| Moisture content | (g/g wet mass) | 0.79 | 0.79 | 0.57 | 0.77 | F | 0.67 | 0.76 | 0.14 | |
| Ash | (g/g dry mass) | 0.42 | 0.46 | 0.55 | 0.51 | F | 0.61 | 0.13 | | 0.84 |
| Sludge volume index | (ml/mg) | 0.04 | 0.06 | 0.23 | 0.51 | F | R | R | | |
| Nitrates | (mg / L) | R | R | R | R | R | 1.57 | R | A R | |
| VFA | (mg / L) | R | R | R | R | R | R | R | R R | |
| Alkalinity | (eq/L) | R | R | R | R | R | R | R | 1.40 | R |
| pH | | 7.60 | 7.59 | 7.54 | 7.44 | F | 6.28 | 2 | A | 6.37 |
| Total COD | (g/g dry mass) | 0.69 | 0.69 | 0.49 | 0.65 | F | 0.31 | 0.66 | A | 0.10 |
| Filtered COD | (mg/g dry mass) | R | R | R | R | R | 57.97 | R | | R |
| Biodegradable COD | (g/g dry mass) | R | R | R | R | R | F | R | | R |
| Ammonia | (mg/g dry mass) | 12.05 | 1.23 | 5.22 | 3.05 | F | 2.79 | R | A | 7.02 |
| Sodium | (mg / L) | R | R | R | R | R | 0 | R | A | R |
| Potassium | (mg / g dry mass) | R | R | R | R | R | 2.46 | R | A | R |
| TKN | (mg/g dry mass) | 36.15 | 6.14 | 29.62 | 26.77 | F | 21.47 | R | 3.82* | 0.00 |
| Total nitrogen | (mg/L) | | | | | | | | 3075 | |
| Ortho-phosphate | (mg/L) | 0.73 | 0.90 | 1.00 | R | F | 2.55 | R | A | 0.00 |
| Total phosphate | (mg/L) | 3.86 | 2.93 | 3.27 | R | F | 2.27 | R | A | 0.00 |
| Ion conductivity | (µs) | 13.20 | R | R | R | R | R | | A | R |
| Chlorides | (mg/L) | 5.51 | R | R | R | F | R | R | 4680 | R |
| Heat capacity | (J/kg/K) | 2531 | 2422 | 2150 | 3268 | F | 2517 | R | R | 714 |
| Thermal conductivity | (W/mK) | 0.54 | 0.55 | 0.38 | 0.60 | F | 0.57 | 0.73 | R | 0.12 |
| Calorific value | (MJ/kg) | 14.06 | 13.08 | 12.93 | 14.31 | F | 11.33 | 22.64 | R | 4.38 |
| Density | (kg/m3) | 1380 | 1448 | 1450 | 1729 | F | 1562 | 2 | R | 1108 |
| Rheology | | A | A | A | A | A | A | A | R | R |
| Plastic and liquid limits | | A | A | A | R | R | A | F | | |
| Drying behaviour | | F | F | F | F | F | F | F | | |
| Slump tests | | F | F | F | F | | | | | |
| Pathogens / parasites | | A | A | A | A | | A | F | F | A |
| Heavy metals | | A | F | F | F | | F | F | F | F |
| Osmolality | (mOsmol/kg) | A | A | R | R | R | R | R | 560 | R |
| Particle size distribution - shake sieves | | F | F | F | F | F | F | R | | |
| PSD - Malvern master sizer | | A | A | A | A | R | F | F | A | R |
| Anaerobic biodegradability | | R | R | R | R | R | F | R | | |

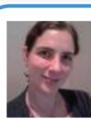
# People

# Reinvent the Toilet Challenge Phase II: Key people



# Students Working on Related Projects

**UKZN Students working on related projects**

- **MScEng students**
  - 
    Aoife Byrne
    MScEng student
    (Pour Flush Toilets)
  - 
    Simon Mirara
    MScEng student
    (LaDePa)
  - 
    Stuart Woolley
    (Mechanical Properties of FS)
  - 
    Lungi Zuma
    (Mechanical Properties of FS)
  - 
    Marietjie Coertzen
    (social studies of UDDTs)
  - 
    Nosipho Mkhize
    (Role of health & hygiene - UDDT)
  - 
    Hope Joseph
    (Logistics of urine collection)
- **PhD Students**
  - 
    Sara Rhoton
    PhD student
    (VUNA)
  - 
    Bjorn Pietruschka
    PhD student
    (DEWATS)

# Other Key Role Players

## Other key role players (PRG – pollution research group)

### University of KwaZulu-Natal – Co-supervisors of students


**Jon Pocock (Chemical Engineering)**


**Aunsha Singh (Chemical Engineering)**


**Deresh Ramjuggernath (Chemical Engineering)**

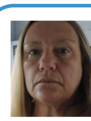

**Myra Taylor (Public Health)**


**Lisa Ramsay (Environmental Science)**

### University of KwaZulu-Natal – University departments contributing to research projects


**Alfred Odindo (Crop Science)**


**Irene Bame (Soil Scince)**


**Colleen Archer (Life Sciences)**


**Nicola Rodda (Life Science)**

### PRG (pollution research group) – Support staff


**Phindi Shezi**

# Further information

## Further Information - Available on request

### Videos

- Data Acquisition and Field Support for Sanitation Projects – an overview of the project awarded to UKZN (PRG) and EWS.
- UN Best practise award (EWS)
- When the Pits are Full

### Supporting Documents

- Sanitation tour document
- Laboratory and equipment manual
- Standard operational procedures manual
- Agricultural trials at Newlands Mashu (fact sheet)
- Overview of Newlands Research Facility (fact sheet)
- Visitor information (fact sheet)
- Lab questionnaire
- Field questionnaire

### Related Documents

- Field note
- Collaborative research projects (2006)
- Innovations (2012)

### Publications

- Various related papers and reports

### Presentations

- Various related presentations

### Photographs

- Various related photographs

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