"IMPROVED ON-SITE SANITATION – FROM SCIENCE TO TECHNOLOGY DEVELOPMENT"

DR KONSTANTINA (TINA) VELKUSHANOVA

POLLUTION RESEARCH GROUP, UNIVERSITY OF KWAZULU-NATAL

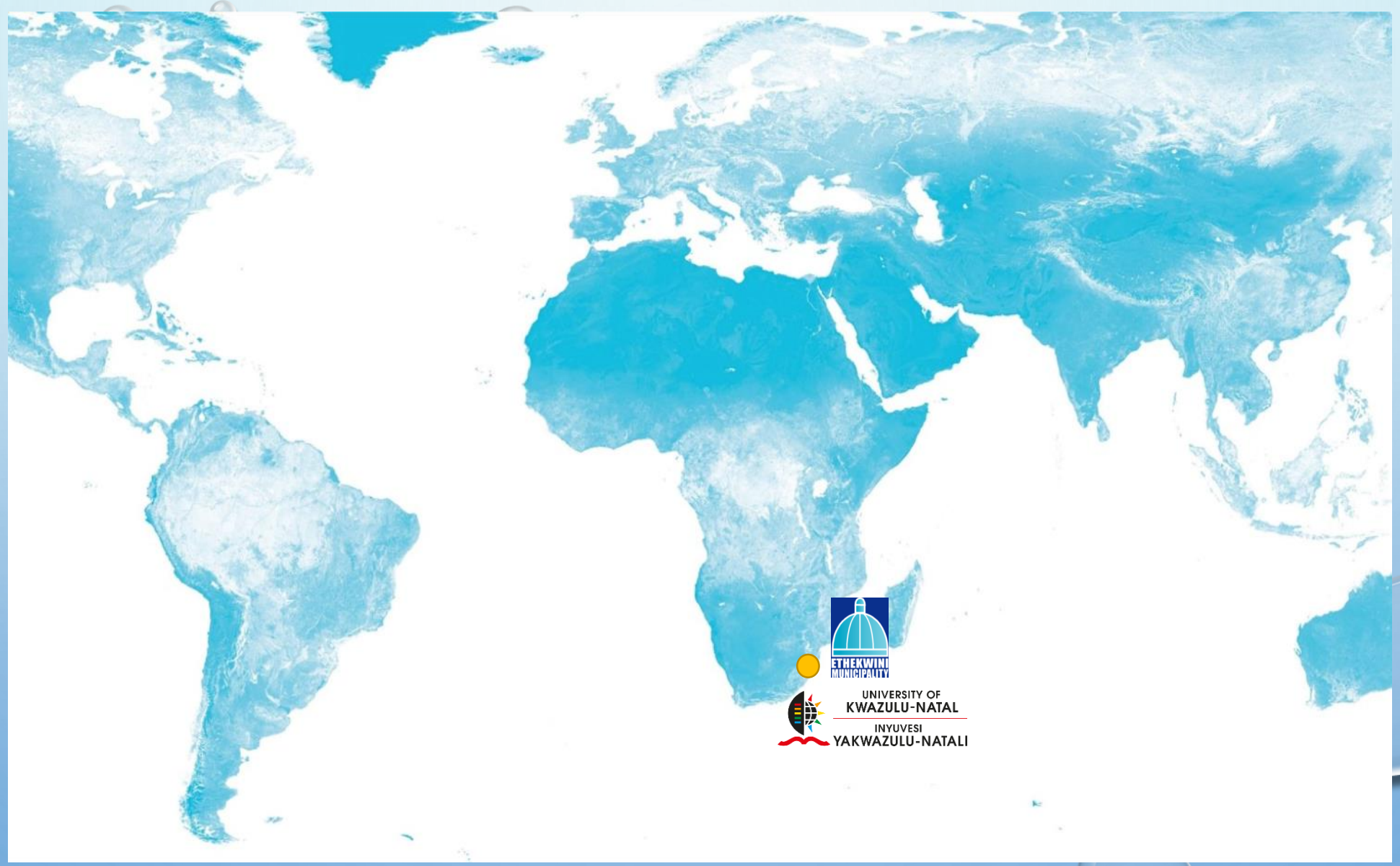
SOUTH AFRICA

PRG
pollution research group

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

OUTLINE

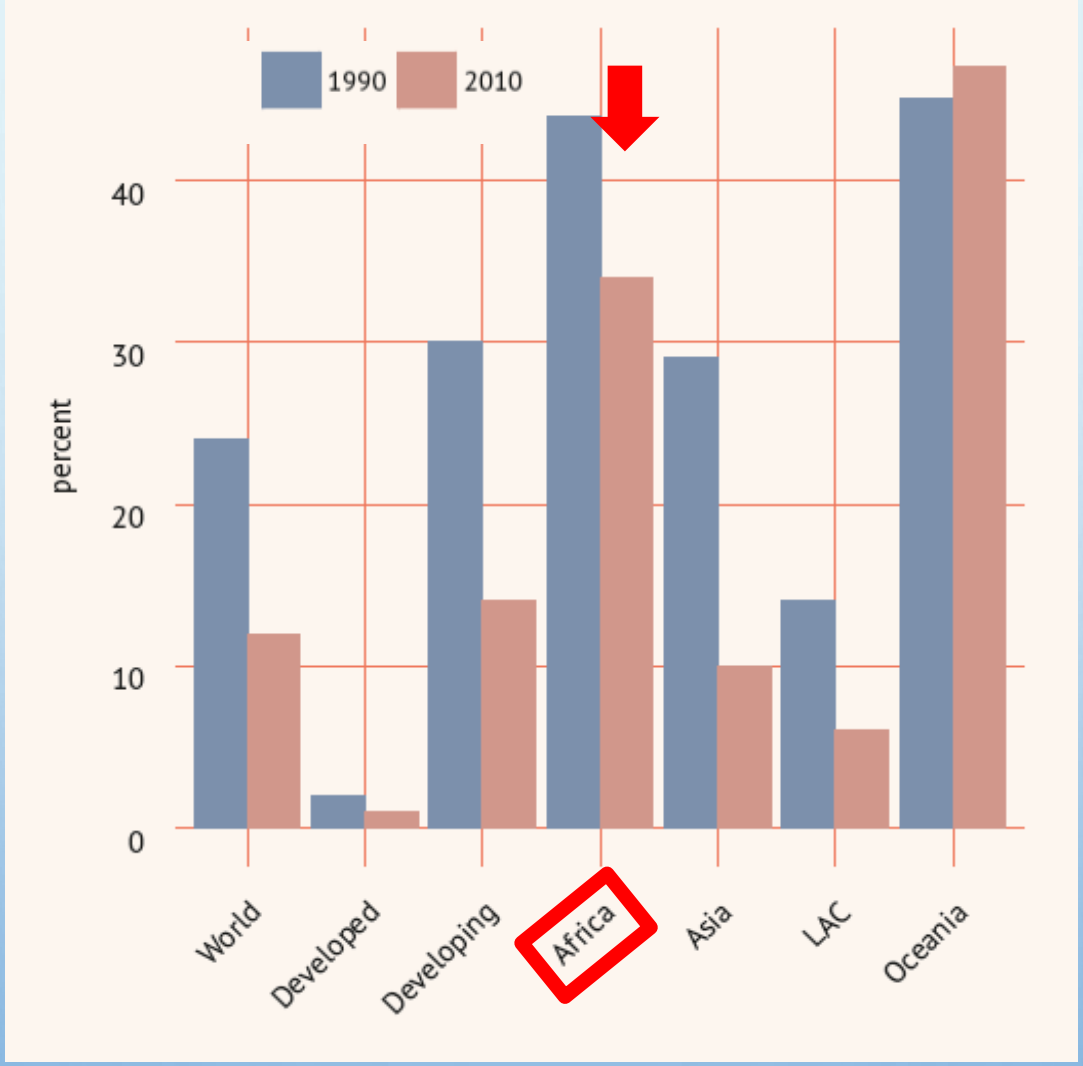
- WATER AND SANITATION IN AFRICA
- WATER AND SANITATION IN SOUTH AFRICA
- ETHEKWINI – DURBAN
- POLLUTION RESEARCH GROUP'S ROLE


ETHEKWINI
MUNICIPALITY
UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

AFRICAN REALISATIONS

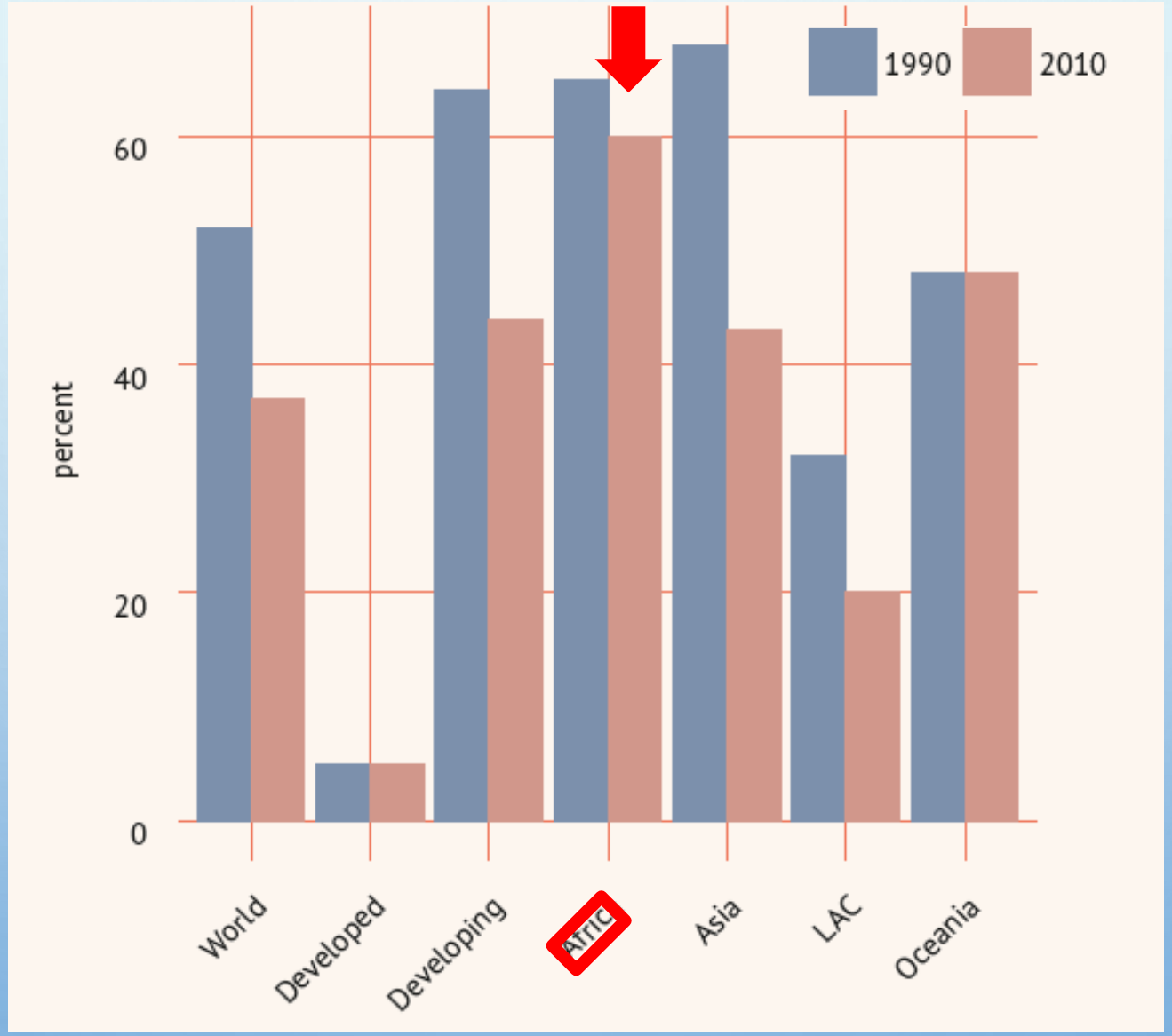
- **FAST GROWING INFORMAL POPULATION**
- **WATER SCARCITY**
  - BASIC WATER AS A ***HUMAN RIGHT***
  - TECHNICAL METHODS OF MANAGING WATER USE
- **SANITATION PROVISION**
  - LARGE BACKLOG
  - WATER BORNE SANITATION SERVICE TOO EXPENSIVE AND SLOW
  - MULTIPLE DELIVERY MODES
- **VULNERABLE POPULATION**
  - FOOD
  - EMPLOYMENT
  - HOUSING
- ***ASSIMILATIVE CAPACITY OF AGRICULTURE***

POPULATION WITHOUT REASONABLE ACCESS TO IMPROVED WATER SOURCES (2010)



FAO STATISTICAL YEARBOOK, 2013. World Food and Agriculture
http://www.fao.org/docrep/018/i3107e/i3107e00.pdf

POPULATION WITHOUT REASONABLE ACCESS TO IMPROVED SANITATION (2010)



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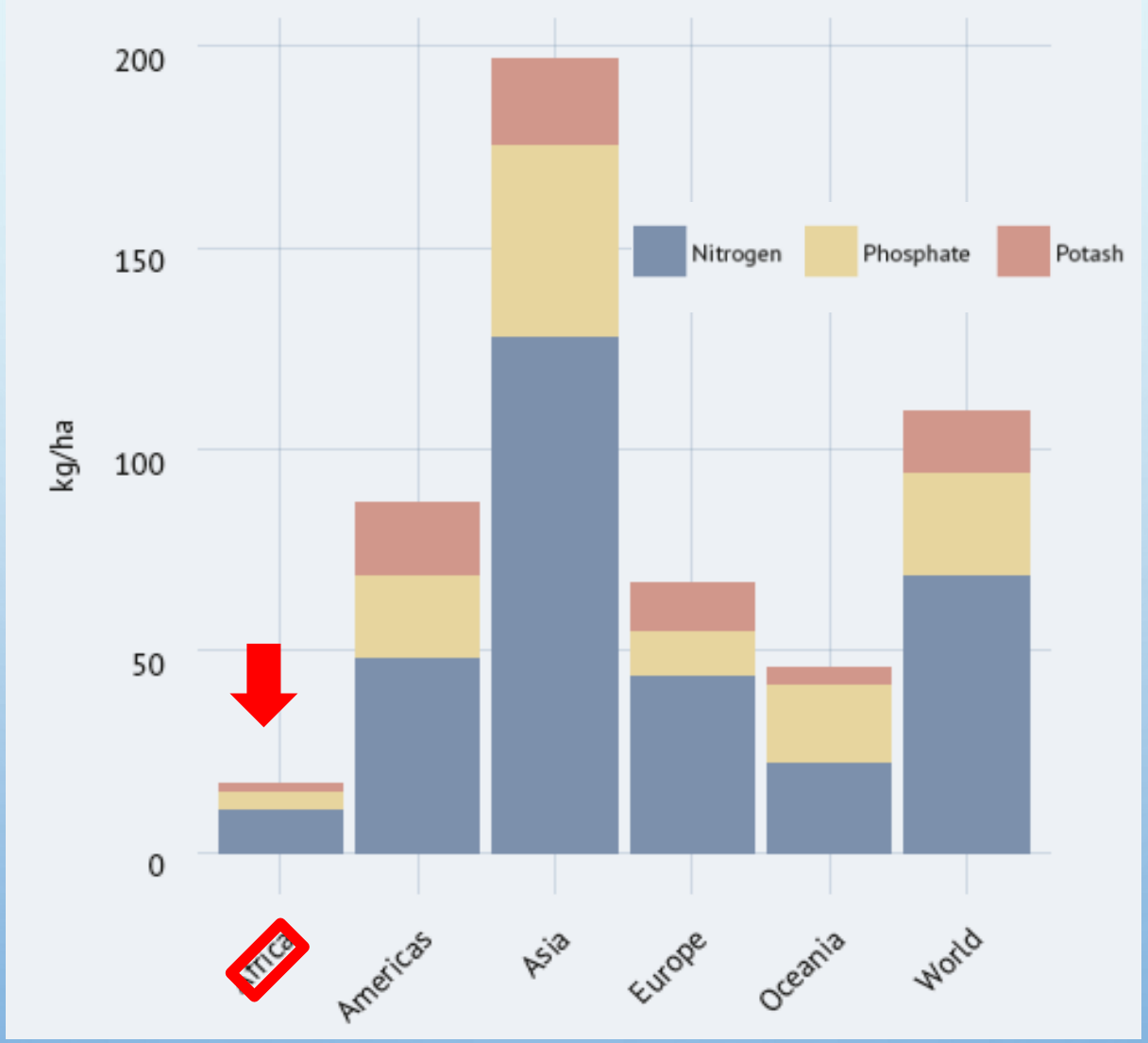
FERTILISER CONSUMPTION PER HA ARABLE LAND



FAO STATISTICAL YEARBOOK, 2013. World Food and Agriculture http://www.fao.org/docrep/018/i3107e/i3107e00.pdf

SOUTH AFRICA - FACTS

- Area 1,221,037 km^2
- Population 51,770,560
- Density 42.4/km^2
- Access to improved water sources 91%
- Access to improved sanitation 79%
- Water scarce country

(Census 2011)

WATER AND SANITATION LEGISLATION

- **1994 NEW SOUTH AFRICA**
- **1994** WHITE PAPER ON WATER SUPPLY AND SANITATION POLICY
- **1996 CONSTITUTION OF THE REPUBLIC OF SOUTH AFRICA**
  - ***"EVERYONE HAS A RIGHT TO AN ENVIRONMENT THAT IS NOT HARMFUL TO THEIR HEALTH OR WELL-BEING"***
  - ***"EVERYONE HAS THE RIGHT TO HAVE ACCESS TO (…) SUFFICIENT FOOD AND WATER".***
- **1997 WATER SERVICES ACT 108**
  - PROVIDING FOR THE RIGHT OF ACCESS TO BASIC WATER SUPPLY AND SANITATION NECESSARY TO SECURE SUFFICIENT WATER AND AN ENVIRONMENT NOT HARMFUL TO HUMAN HEALTH AND WELL-BEING
  - ***"RIGHT TO BASIC SANITATION."***
- **1998 NATIONAL WATER ACT 36**
- **2000 FREE BASIC SERVICES (FBS) POLICY**
  - ***FREE BASIC SERVICES FOR THE POOR INCLUDING WATER SUPPLY, SANITATION, REFUSE REMOVAL AND ELECTRICITY***
- **2002** SANITATION TECHNOLOGY OPTIONS
- **2003 STRATEGIC FRAMEWORK FOR WATER SERVICES**
  - ***WATER IS LIFE SANITATION IS DIGNITY***
- **2004 NATIONAL WATER RESOURCE STRATEGY**
- **2005 NATIONAL SANITATION STRATEGY**
- **2009 FREE BASIC SANITATION (FBSAN) IMPLEMENTATION STRATEGY**
  - ***"PROVIDING ALL CITIZENS WITH FREE BASIC SANITATION BY 2014"***
- **2013 NATIONAL WATER RESOURCE STRATEGY (UPDATE FROM 2004)**

WATER SERVICE INSTITUTIONS

- **WATER SERVICE AUTHORITY (WSA)**
  - ANY MUNICIPALITY ENSURING ACCESS TO WATER SERVICES IN THE ACT
  - CAN PERFORM AS A WATER SERVICE PROVIDER
  - MAY FORM A JOINT VENTURE WITH ANOTHER WATER SERVICES INSTITUTION
  - MUST PREPARE A WSDP TO ENSURE EFFECTIVE, EFFICIENT, AFFORDABLE AND SUSTAINABLE ACCESS TO WATER SERVICES
  - WSDP IS A LINK BETWEEN WATER SERVICES PROVISION AND WATER RESOURCES MANAGEMENT

WATER SERVICE INSTITUTIONS

- **WATER SERVICE PROVIDER (WSP)**
  - TO PROVIDE WATER SERVICES IN ACCORDANCE WITH THE CONSTITUTION, THE WATER SERVICES ACT AND BY-LAWS OF THE WATER SERVICES AUTHORITY
  - WSA MAY PERFORM THE FUNCTIONS OF THE WATER SERVICE PROVIDER
- **WATER BOARDS**
  - GOVERNMENT OWNED
  - KEY ROLE IN THE SOUTH AFRICAN WATER SECTOR
  - PROVIDE TECHNICAL ASSISTANCE TO MUNICIPALITIES
  - REPORT TO THE DEPARTMENT OF WATER AFFAIRS
  - 15 WATER BOARDS IN SA
  - THE THREE LARGEST ARE RAND-WATER; UMGENI WATER; OVERBERG WATER
  - PROVIDE WATER SERVICES TO WSA'S
- **WATER RESEARCH COMMISSION (WRC)**

KEY STAKEHOLDERS

- NATIONAL GOVERNMENT – DEPARTMENT OF WATER AND SANITATION
- WATER BOARDS
- MUNICIPALITIES
- BANKS, THE PROFESSIONAL ASSOCIATION WISA, WRC AND CIVIL SOCIETY

ON-SITE SANITATION

- **VENTILATED IMPROVED PIT (VIP) LATRINE IS THE STANDARD FOR BASIC SANITATION IN SOUTH AFRICA**
- PROBLEMS IN ENSURING LEGALLY COMPLIANT DISPOSAL OF FS'S
- A SERIES OF *GUIDELINES FOR THE UTILISATION AND DISPOSAL OF SLUDGE* BETWEEN 2006-2009
  - *POST WORLD SUMMIT ON SUSTAINABLE DEVELOPMENT, SA, 2003*
  - *TOWARDS SUSTAINABLE DEVELOPMENT BY UTILISING THE ENERGY OR NUTRIENTS AVAILABLE IN SLUDGE*

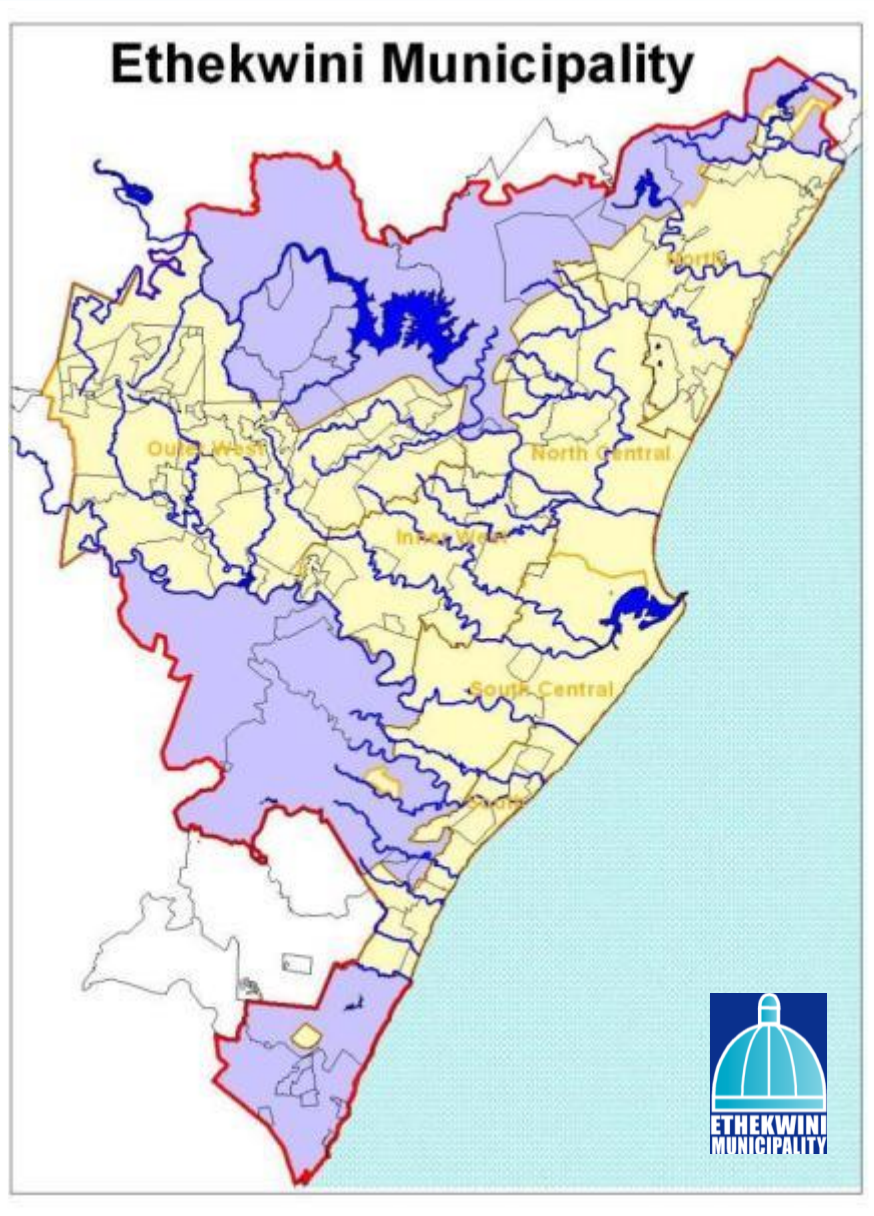
CLASSIFICATION OF SLUDGE

Microbiological class	**A: Unrestricted use** **(<1000 FC; <0.25 viable helminth ova/g dry)**	**B: General use** **(1x10^6 FC; <1 HO)**	C: Limited use (1x107; 4 HO)
Stability class	**1: Stable**	**2: Partially stabilised**	**3: Unstable**
Pollutant class	**a: Minimal restriction**	**b: Moderate restriction**	**c: High restriction**

MANAGEMENT OPTIONS AND LIMITATIONS FOR PIT SLUDGE

- **AGRICULTURE AND OTHER BENEFICIAL OPTIONS**
  - REQUIRE PRE-TREATMENT OF THE SLUDGE
- **SLUDGE APPLICATION METHODS**
  - SURFACE APPLICATION
  - SHALLOW INCORPORATION
  - INJECTION
  - DEEP ROW ENTRENCHMENT

DURBAN TO ETHEKWINI MUNICIPALITY



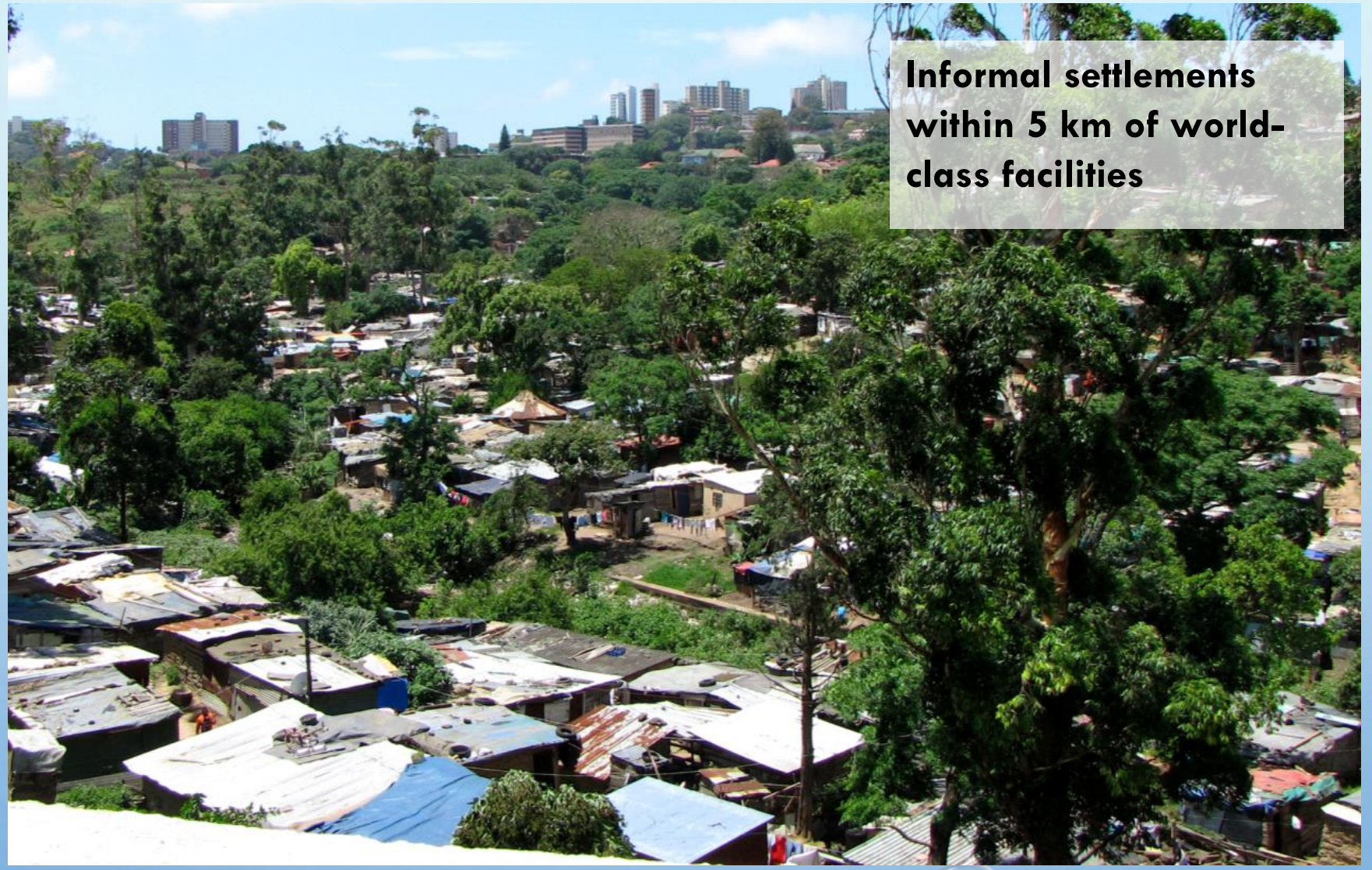
- OLD METRO
  - 1 366 KM^2
  - POPULATION 2.5 MILL
- UNICITY
  - 2 297 KM^2
  - POPULATION 3.5 MILL
- 1 MILL LIVE IN INFORMAL SETTLEMENTS AND TOWNSHIPS

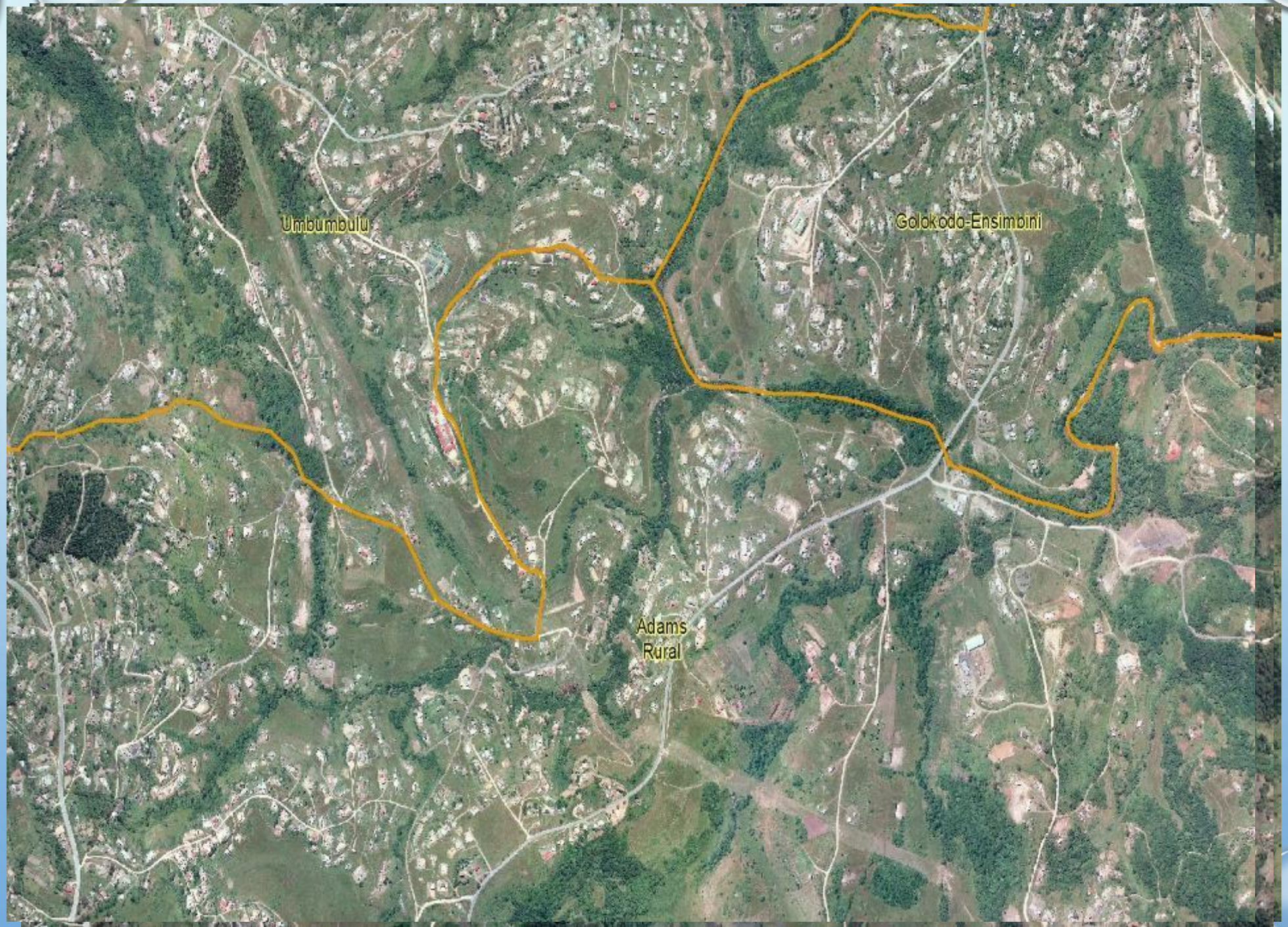
- Committed to
  - recovery of nutrients in excreta
  - dry on-site sanitation
  - innovative delivery

Durban: City of contrasts

- Second largest industrial hub
- Fastest growing urban area
- Major tourist destination
- South Africa's major port

Durban: City of contrasts




Umbumbulu
Golokodo-Ensimbini
Adams
Rural


Shallcross
Burlington Heights
Crossmoor
Woodhurst

CONVENTIONAL SEWAGE TREATMENT NOT ALWAYS A FEASIBLE OPTION + HIGH ENERGY CONSUMPTION

EXCRETA PLUS FLUSH WATER

	Units	Black water (urine + faeces)	Black water + Flush water
wet mass	kg/person.y	**610** →	**18,000**
dry mass	kg/person.y	40	**40**
nitrogen	kg/person.y	4.5	**4.5**
phosphorus	kg/person.y	0.5	**0.5**

all pathogens are in the water!

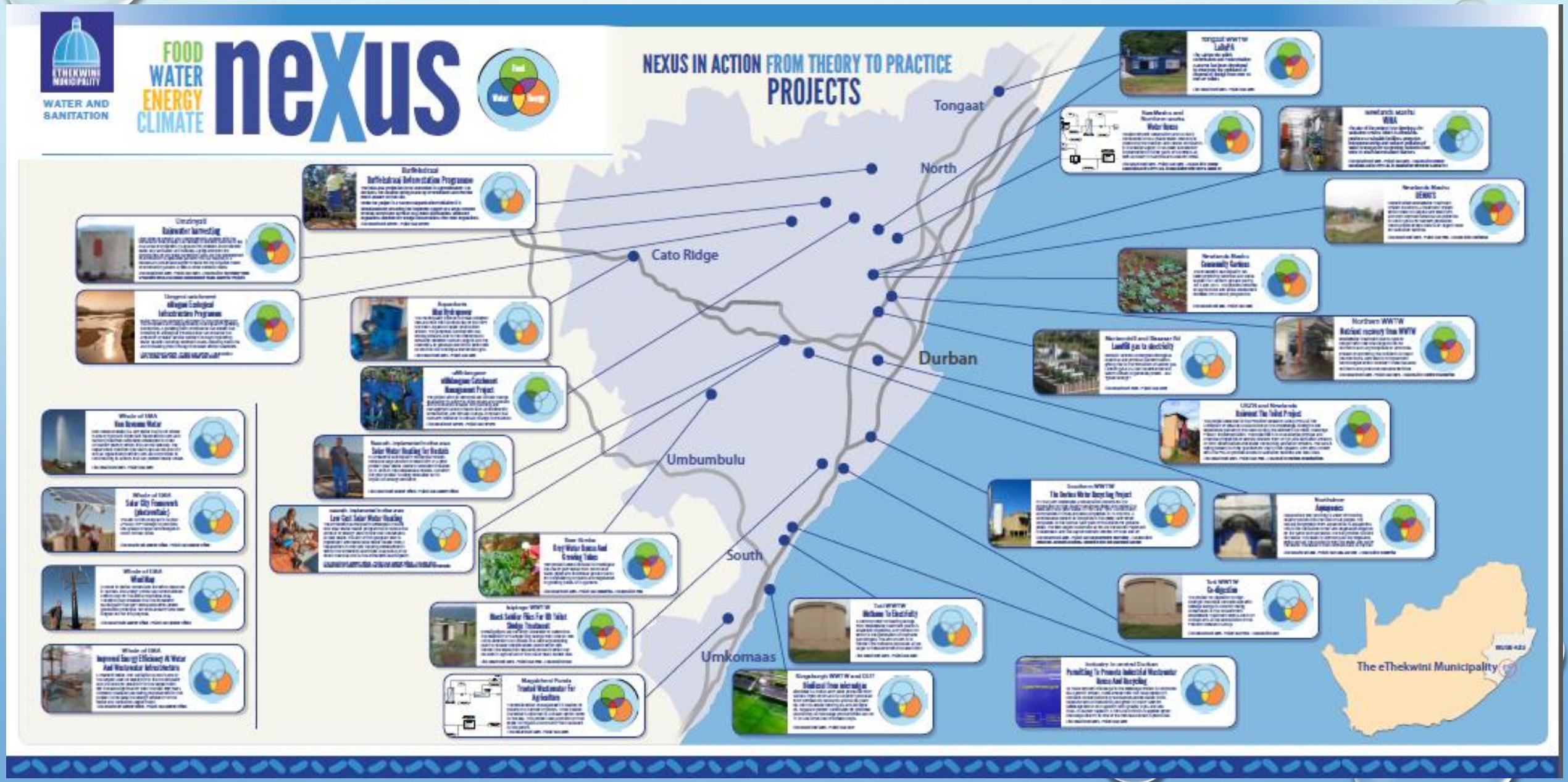
NEXUS APPROACH

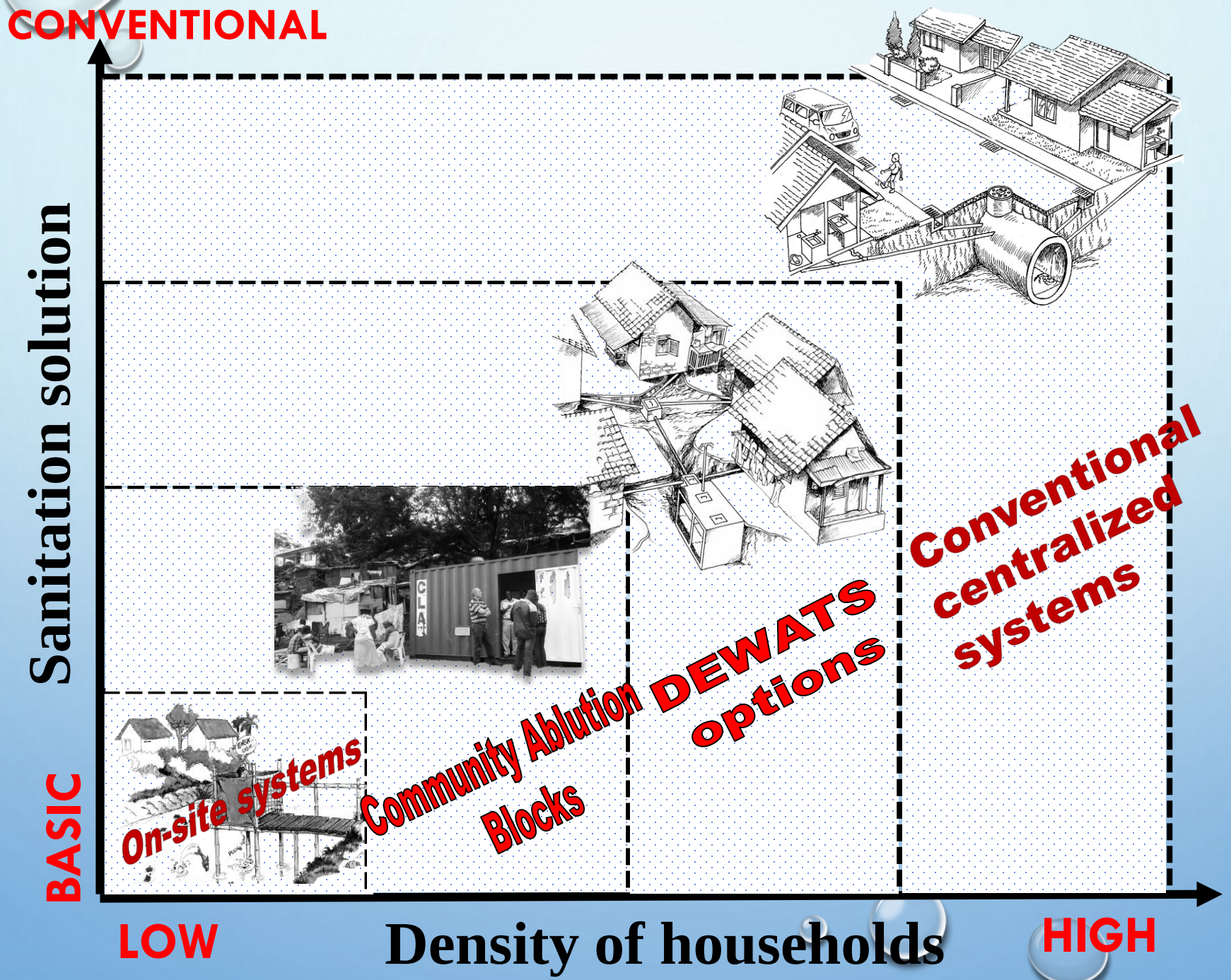
Water – Sanitation – Food - Energy

- THROUGH THE TREATMENT OF FS/WW:
  - RECOVERING WATER FOR REUSE
  - PROVIDING SAFE AND AFFORDABLE SANITATION
  - RECOVERING NUTRIENTS FOR FOOD SECURITY
  - RECOVERING ENERGY

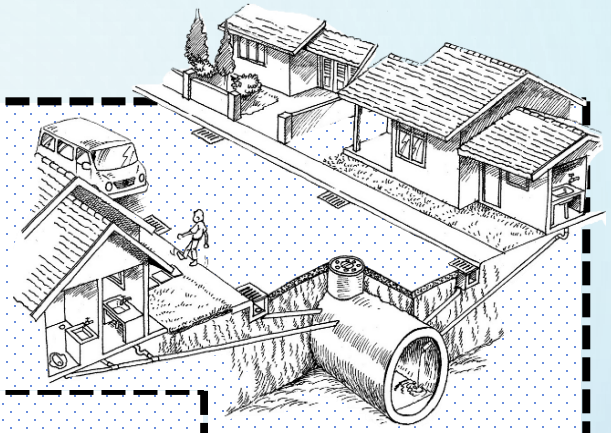
- RESPONSIBILITIES
  - PROVISION OF W&S SERVICES TO ALL CUSTOMERS IN THE MUNICIPALITY
  - PUBLIC HEALTH IS THE OBJECTIVE
  - SANITATION SYSTEM IN HARMONY WITH WATER SUPPLY
  - ALL WATER TO BE ADSORBED ON-SITE UNLESS FORMAL SEWERS PROVIDED

THE MUNICIPALITY

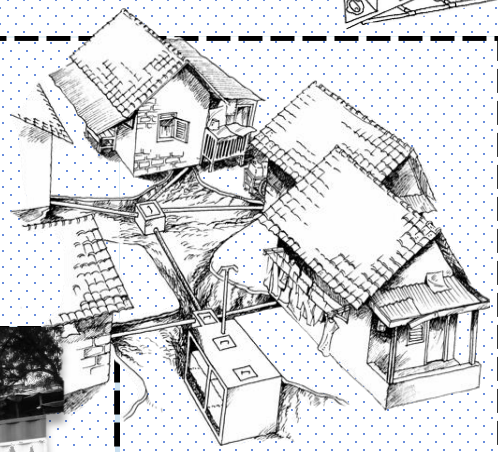



CONVENTIONAL
Sanitation solution
BASIC
LOW
Density of households
HIGH
On-site systems
Community Ablution Blocks
DEWATS options
Conventional centralized systems

EXPENSIVE!



Cost



Conventional centralized systems

DEWATS options

Community Ablution Blocks

On-site systems

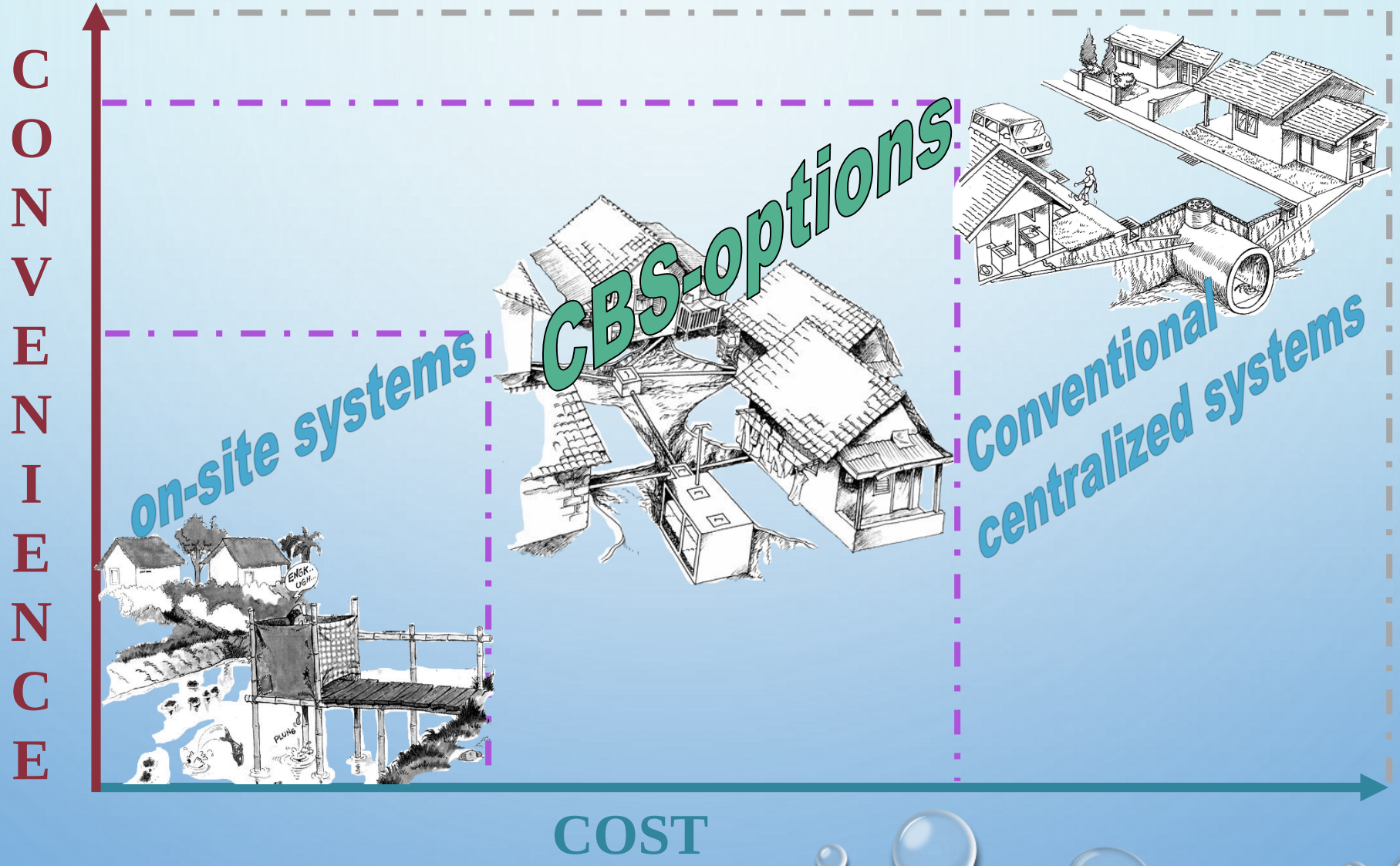
CHEAP

LOW

Density of households

HIGH

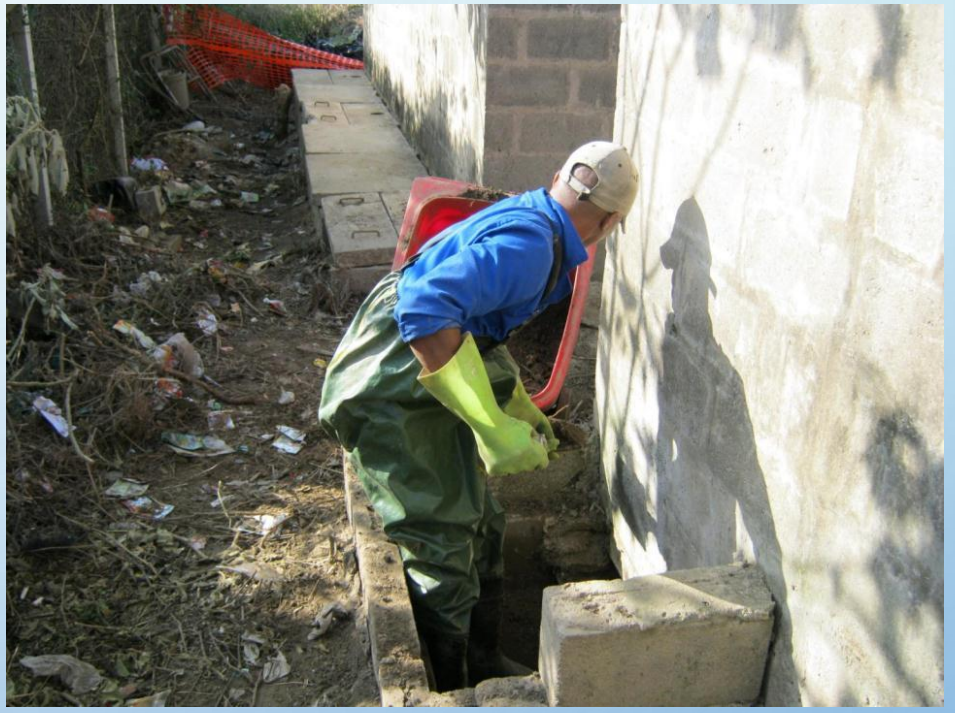
Filling the gap: ww treatment >5 up to 5,000 p



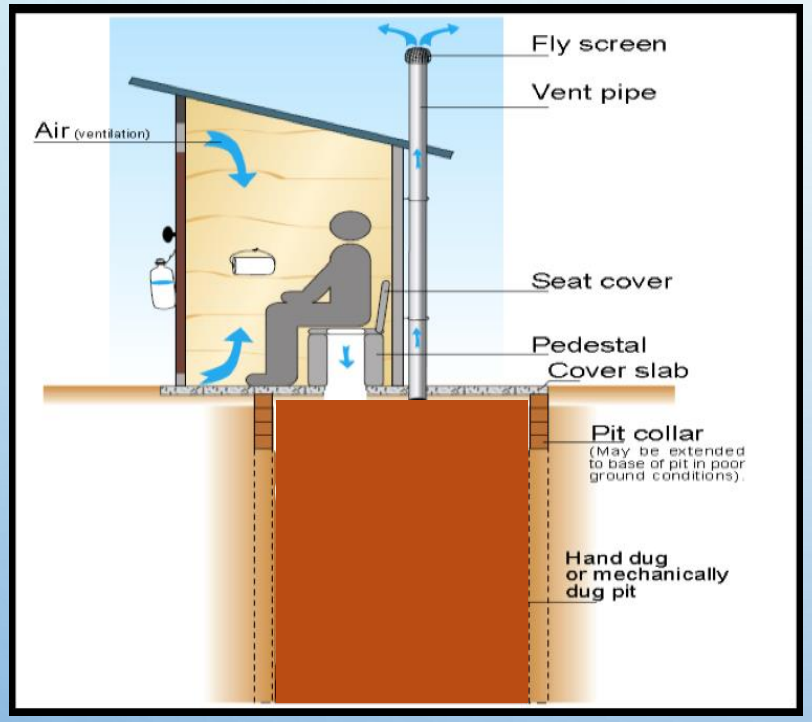
Current Situation – eThekwini

- 1 mil people in informal settlements and townships
- 35 000 VIPs
  - Need regular emptying
  - Entrepreneurs empty pits safely
  - LaDePa – dry, pasteurised pellets
- 80 000 UDDTs
  - BSF treatment
- 360 Community Ablution Blocks
  - central area – sewered or VIP
- DEWATS
- Conventional sewer

VIPs



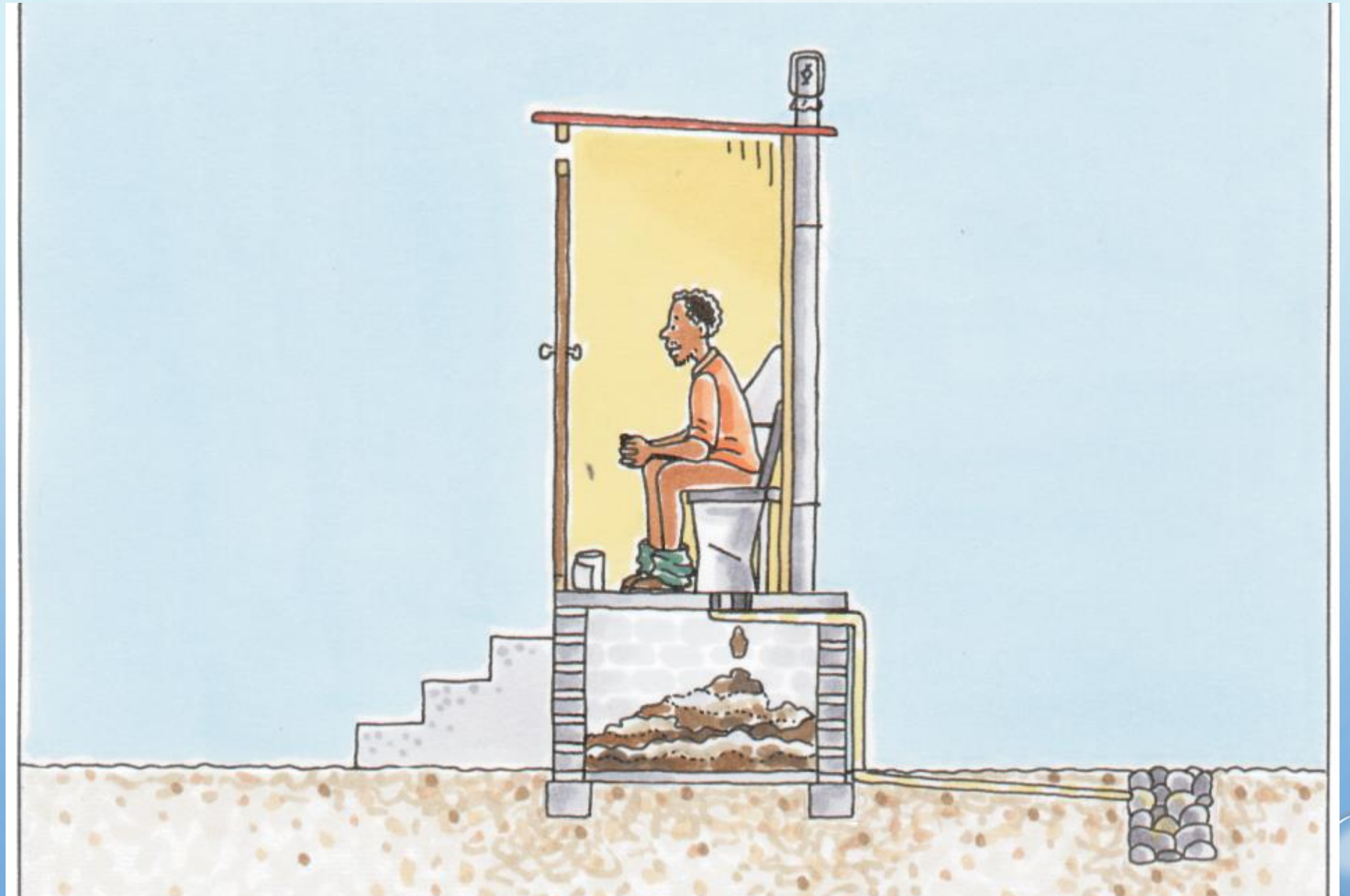
PIT EMPTYING



COMMUNITY ABLUTION BLOCKS

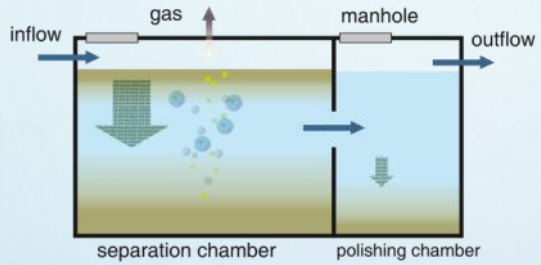
URINE DIVERSION TOILETS

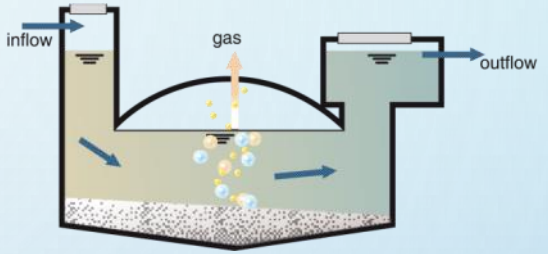
URINE DIVERSION TOILET



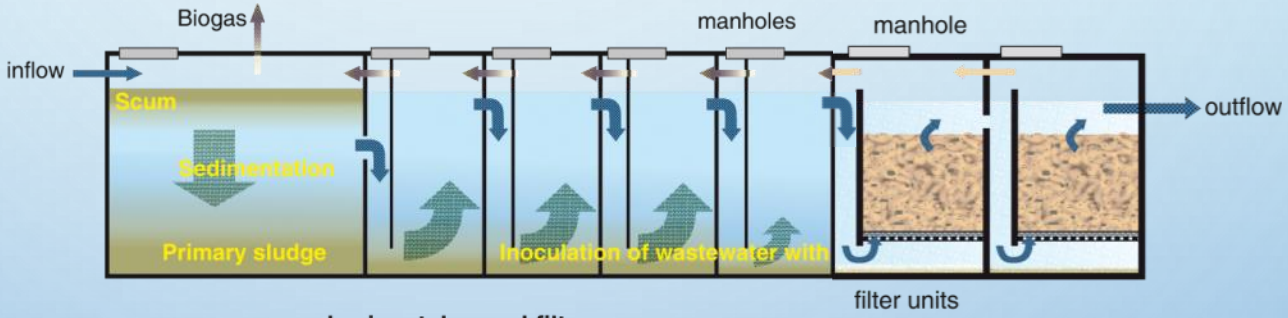
Decentralised Wastewater Treatment Systems

Sedimentation

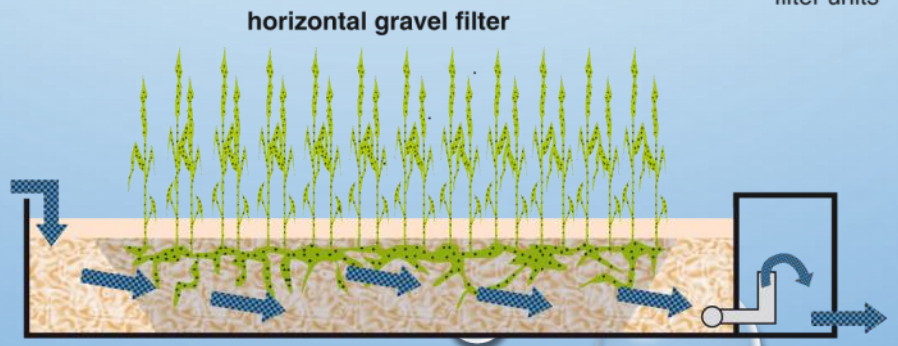




Anaerobic digestion



Aerobic and facultative decomposition



No energy input, low skill requirements for O&M,
Modular and partly standardized

POLLUTION RESEARCH GROUP – PRIMARY ACTIVITIES

- CONTRACT RESEARCH
- EXTENSIVE BACKGROUND IN THE WASH FIELD
- CUSTOMER FOCUSED
- POST GRADUATE STUDENTS
- FUNDING
  - ETHEKWINI MUNICIPALITY
  - WATER RESEARCH COMMISSION
  - BILL & MELINDA GATES FOUNDATION
  - BORDA (INGO)
- WIDE COLLABORATION
  - HEALTH, SCIENCE, AGRICULTURE, SOCIAL SCIENCE, ENGINEERING

FACILITIES AND ACTIVITIES OFFERED BY THE PRG TO SUPPORT FAECAL SLUDGE RESEARCH

- ACCESS TO DIFFERENT SANITATION SYSTEMS
- SANITATION (REFERENCE) LABORATORY
- MECHANICAL WORKSHOP
- FIELD TESTING
- SYSTEMS AND PROTOTYPES TESTING
- TRAINING AND SHARING

ACCESS TO SANITATION SYSTEMS

- PARTNERSHIP WITH ETHEKWINI WATER AND SANITATION
  - VIP LATRINES
  - URINE DIVERSION TOILETS
  - COMMUNITY ABLUTION BLOCKS
  - POUR-FLUSH TOILETS
  - BLACK SOLDIER FLIES
  - CONVENTIONAL SYSTEMS

- Orientation for city leaders and officials
- Social and technical orientation
- Sampling and data gathering

→ Sanitation tours at eThekwini
Sanitation safari in Africa

SANITATION TOURS


CLA


ETHEKWINI
MUNICIPALITY
ELECTRICITY

FIELD TESTING - NEWLANDS MASHU SITE

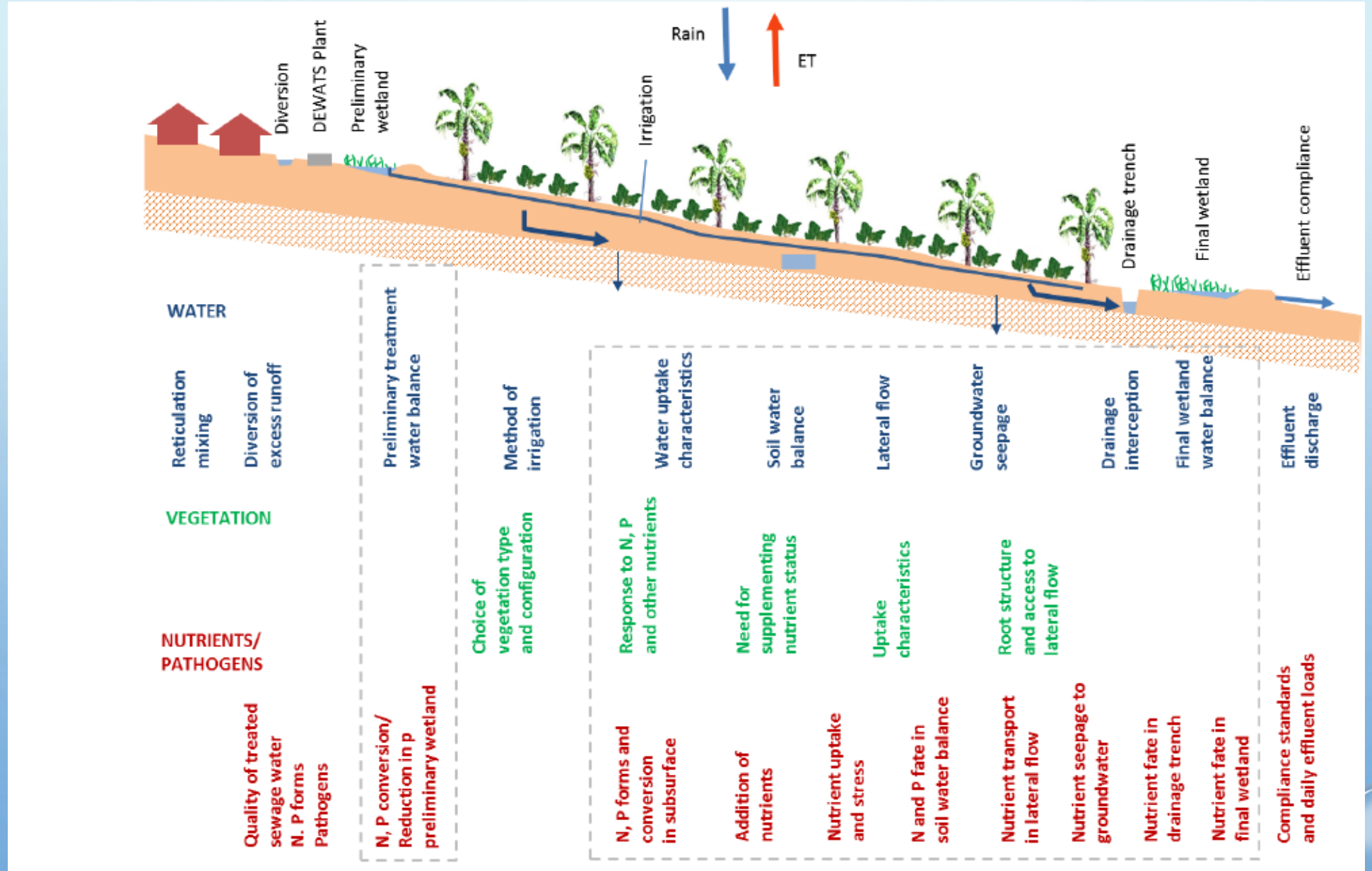
- AGRICULTURAL TRAINING CENTRE
- BORDA DEWATS ANAEROBIC BAFFLED REACTOR
- CONSTRUCTED WETLANDS
- AGRICULTURAL RESEARCH
  - FIELD TRIALS
  - POT TRIALS
  - MICROBIAL RISK ASSESSMENT
  - URINE PRODUCT EVALUATION (STRUVITE, VUNA PROJECT)
- LABORATORY


NP 139-802

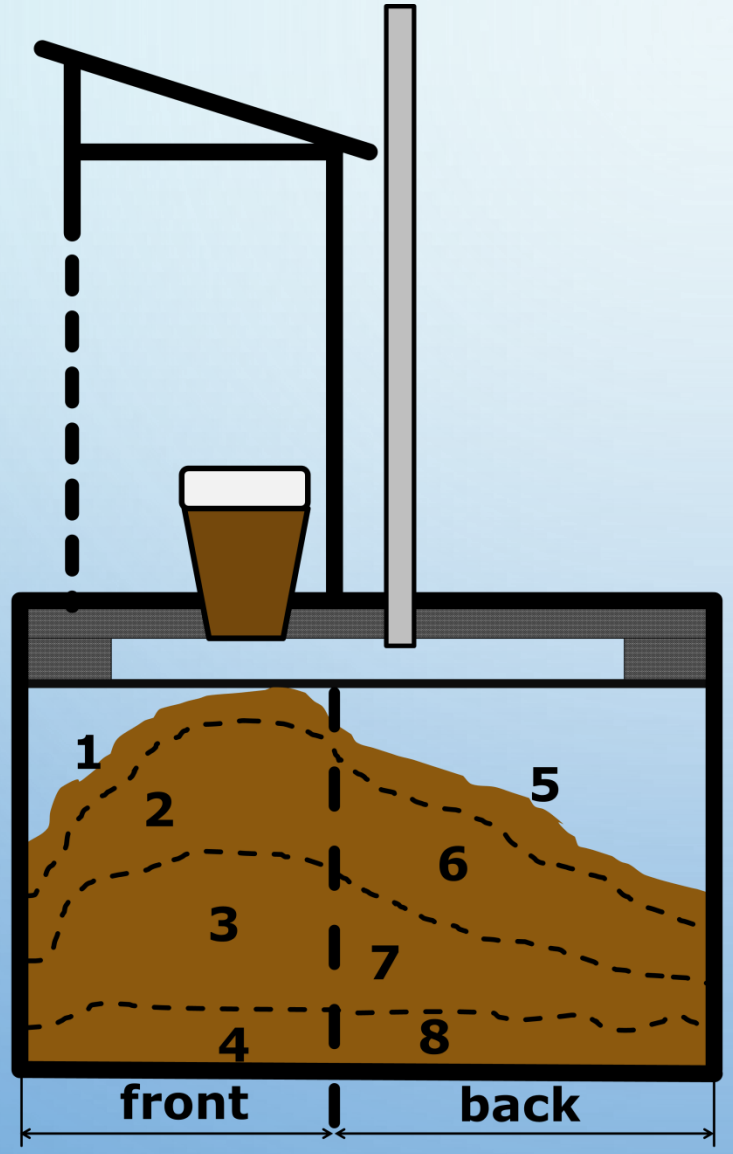

ETHEKWINI WATER
NDM 9856

NEWLANDS MASHU

AGRICULTURAL TRIALS AND MODELS



FIELD TESTING - PIT EMPTYING AND SAMPLING



Field testing - LaDePa - Faecal sludge drying and pasteurisation

Volume and mass reduction

Transport cost decrease

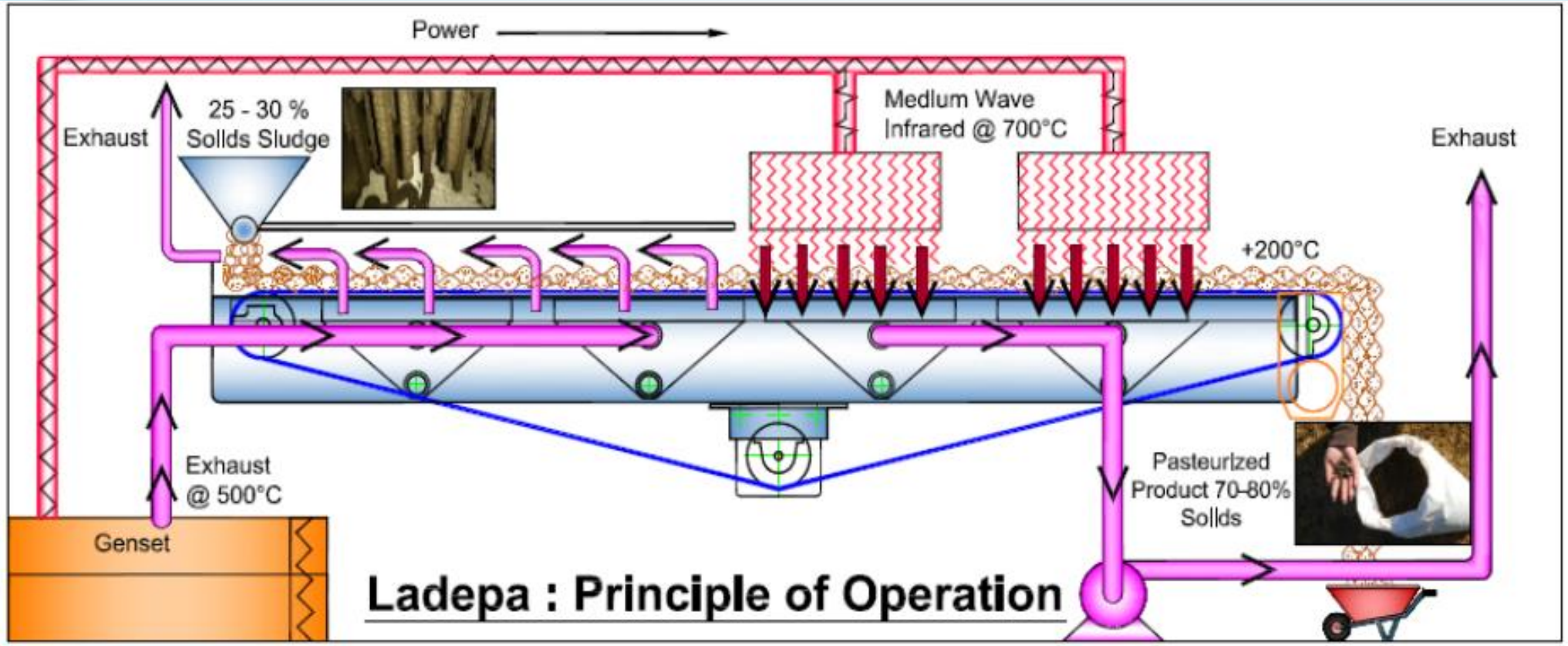
Pasteurization

Low moisture content + Organic content

Biofuel

Agriculture use

LADEPA (LATRINE DEHYDRATION AND PASTEURISATION)



WATER RESEARCH COMMISSION

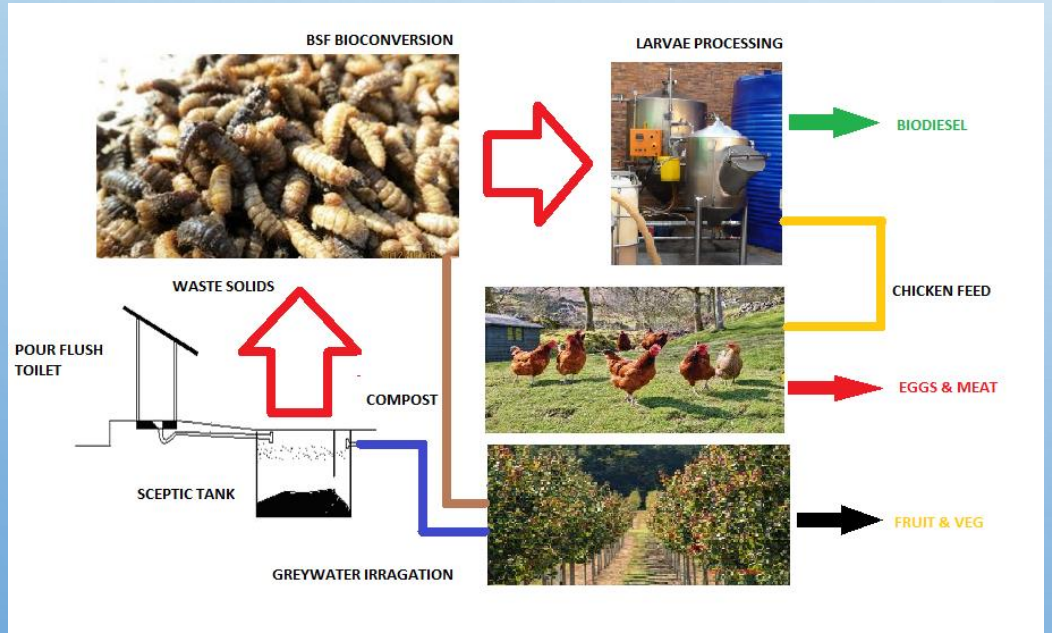
ETHEKWINI MUNICIPALITY

SLUDGE PASTEURISATION AND AGRICULTURAL REUSE

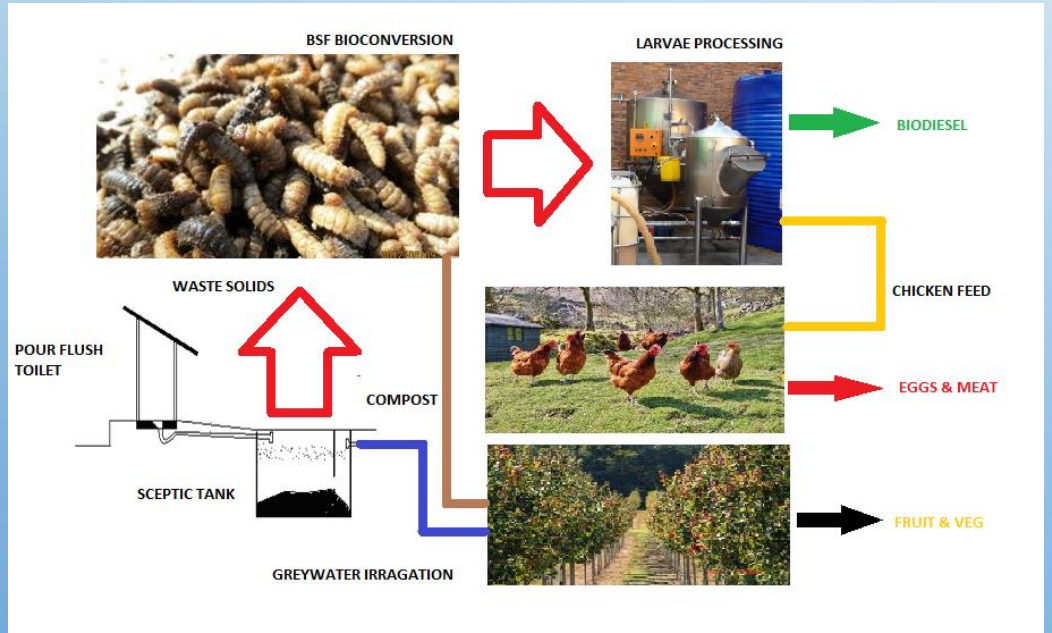
Pit + LaDePa

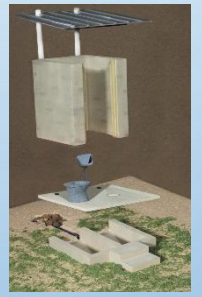

SLUDGE TREATMENT JOINT VENTURE:
PATENT REGISTRATION NUMBER: 2010/02800
ETHEKWINI MUNICIPALITY
TREATMENT JOINT VENTURE:
PSS
PARTICLE SEPARATION TECHNOLOGIES (PTY) LTD
GEHL

Pit + LaDePa; UDDT+black soldier fly



Pit + LaDePa; UDDT+black soldier fly+VUNA

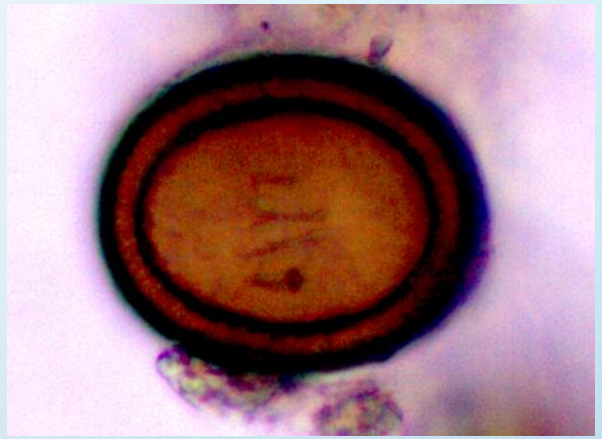


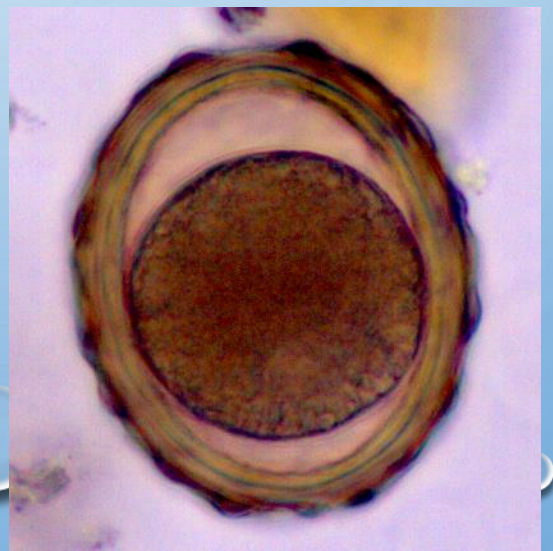


LABORATORY

- HEALTH AND SAFETY FOR ANALYSING FAECES AND URINE
- COMPREHENSIVE EQUIPMENT FOR FAECAL SLUDGE CHARACTERISATION
- PREPARATION FOR EXTERNAL SPECIALISED ASSAYS
- MULTIPLE SAMPLES AND REPLICATES
- TRAINED TECHNICIANS AND RESEARCHERS
  - PHYSICAL, CHEMICAL, MICROBIOLOGICAL, AGRICULTURAL
- STANDARD OPERATING PROCEDURES (SOPS)
- LAB-SCALE PILOTING

SPECIALISED SANITATION LABORATORY



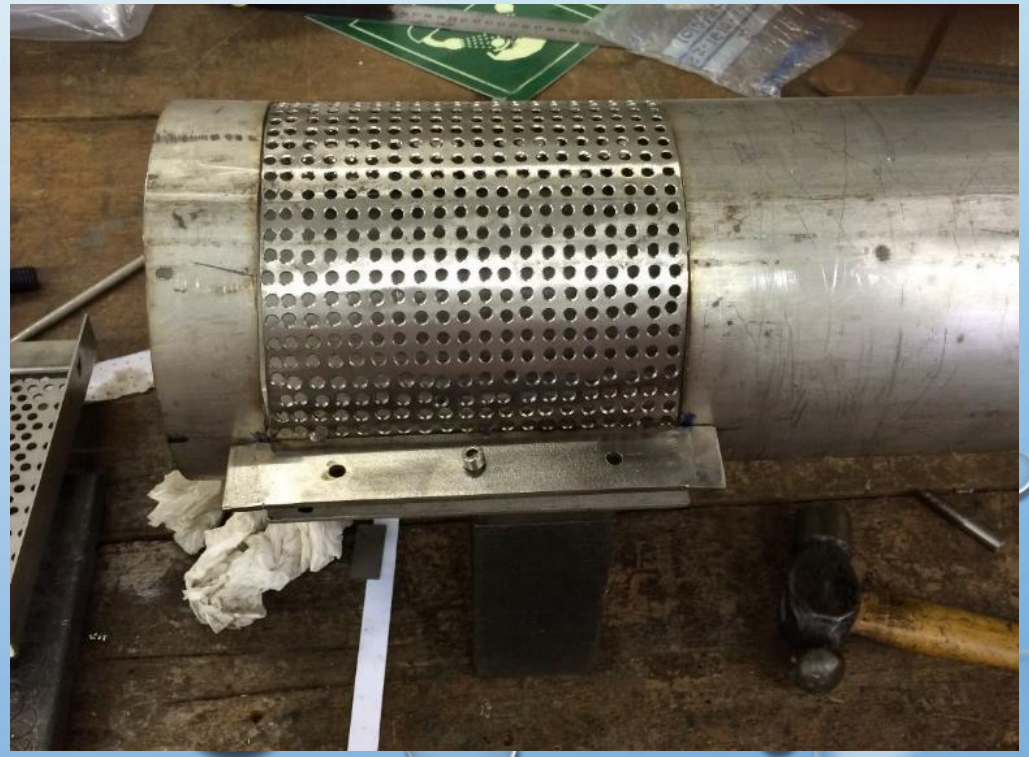


MECHANICAL WORKSHOP

- EQUIPMENT CONSTRUCTION
- MODIFICATION

Viscous heater

Hydraulic ram

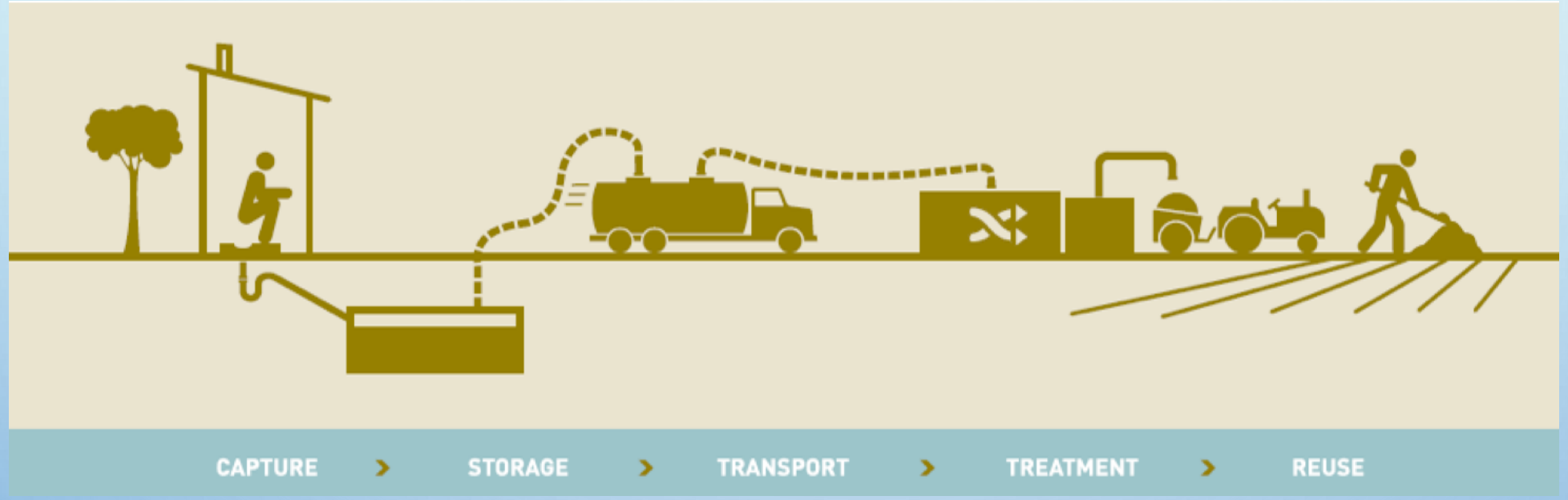


SYSTEMS AND PROTOTYPES TESTING

BMGF PROJECTS:

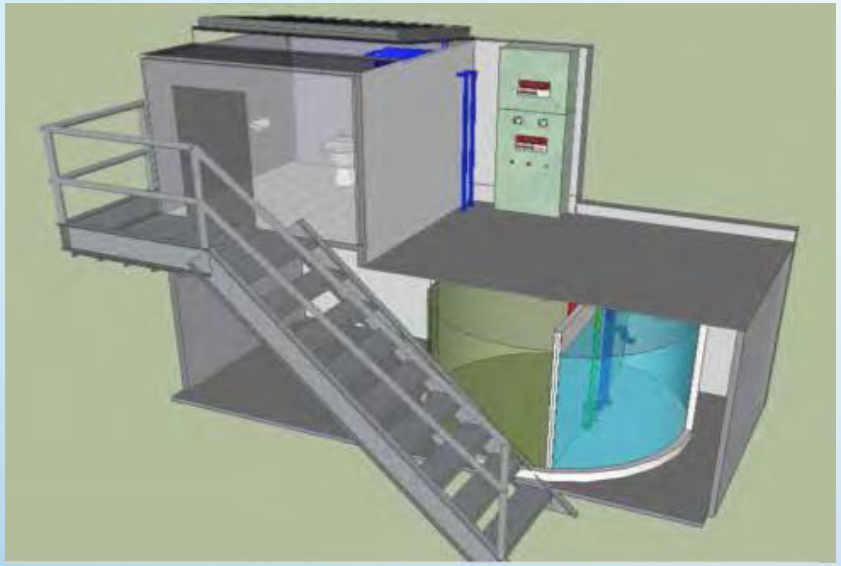
- REINVENT THE TOILET CHALLENGE
- PHASE I
- PHASE II DATA ACQUISITION AND FIELD SUPPORT FOR SANITATION PROJECTS
- MECHANICAL PROPERTIES OF FAECAL SLUDGE
- CAPACITY GRANT: EQUIPMENT AND HEALTH AND SAFETY MODIFICATIONS REQUIRED FOR DEVELOPING THE CAPACITY TO SUPPORT GRANTEES FIELD TESTING IN DURBAN, SA

REINVENT THE TOILET CHALLENGE

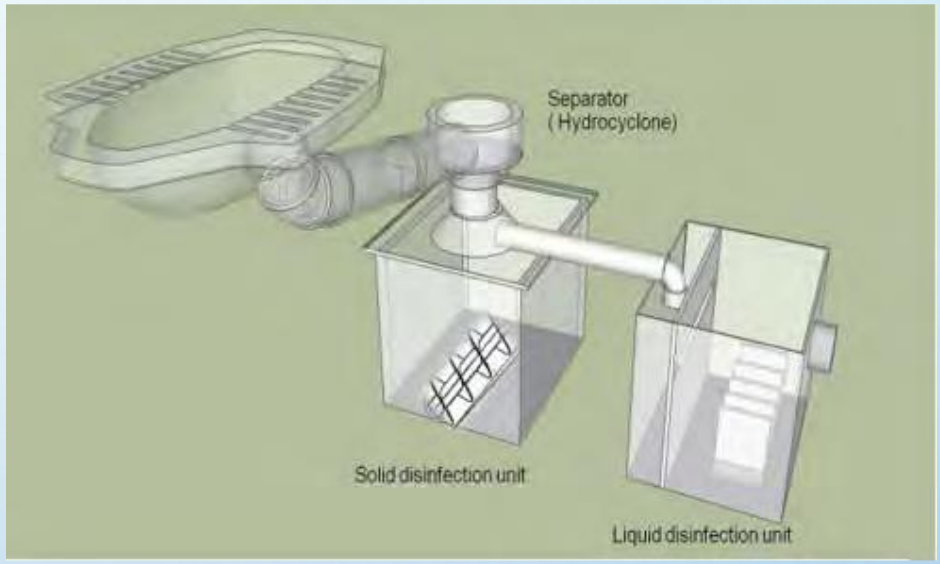


REINVENT THE TOILET FAIR: INDIA 2013

ASIAN INSTITUTE OF TECHNOLOGY



Solar septic tank



Hydrocyclone toilet

JANICKI INDUSTRIES

OMNI-PROCESSOR

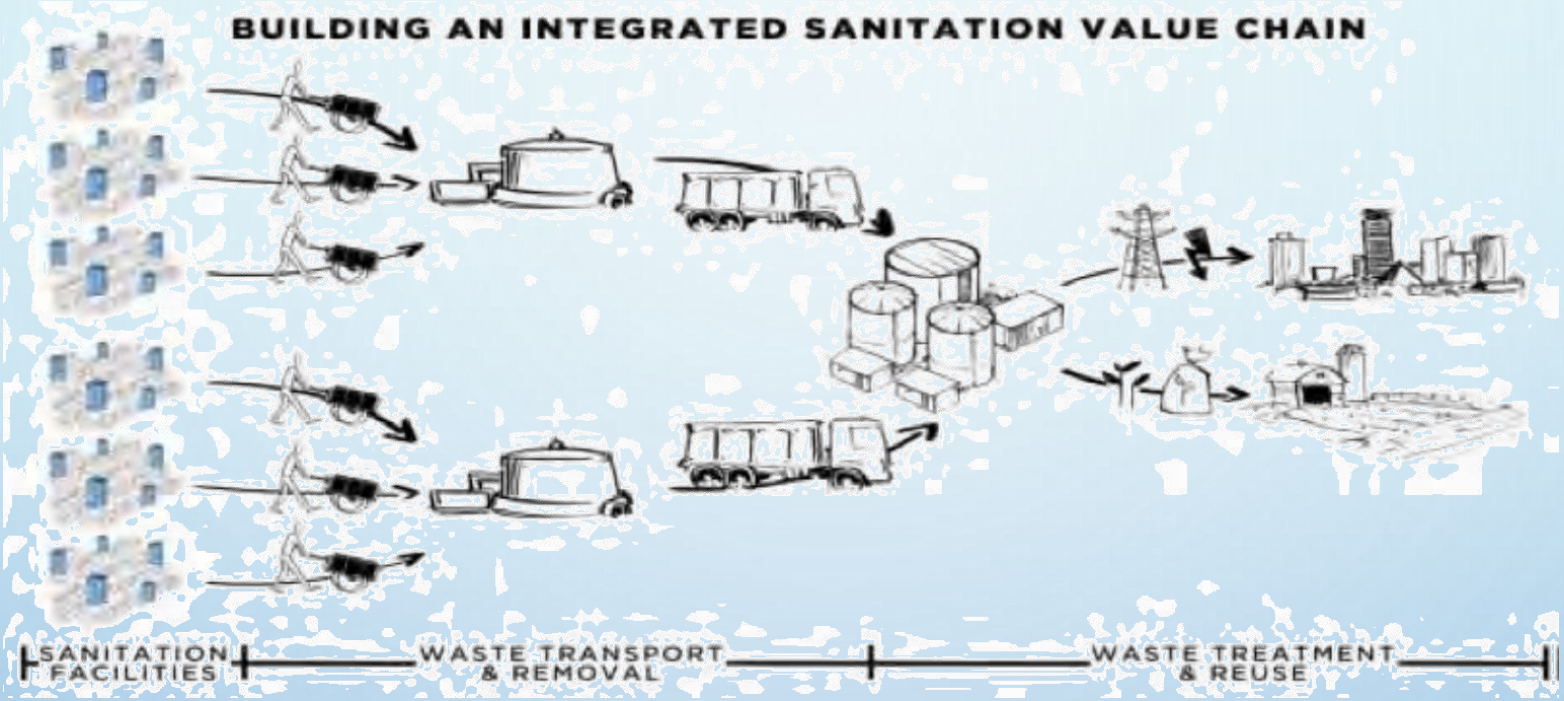
FSOI DEVELOPMENT FIRMS

THE FECAL SLUDGE OMNI-INGESTOR (FSOI) AND OTHER PIT EMPTYING DEVICES

NORTH CAROLINA STATE UNIVERSITY

HYGIENIC PIT EMPTYING USING A MODIFIED AUGER – "THE EXCREVATOR"

SANERGY

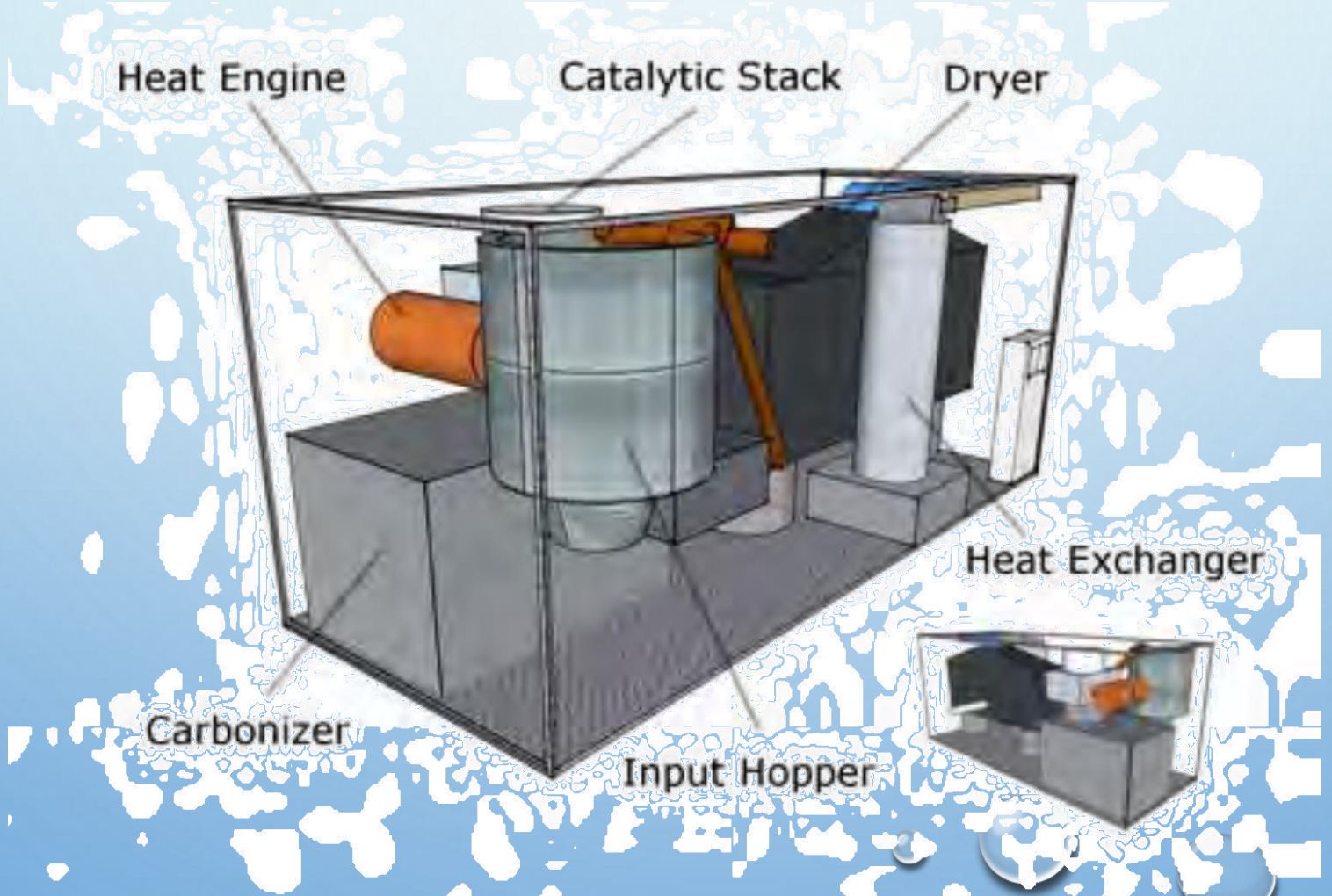

BUILDING AN INTEGRATED SANITATION VALUE CHAIN
SANITATION FACILITIES
WASTE TRANSPORT & REMOVAL
WASTE TREATMENT & REUSE


CHOO
CHOO
Fresh Life
WATU WAZIMA
5
WATOTO
2


Fresh Life
Fresh Life

CLIMATE FOUNDATION

CONVERSION OF HUMAN WASTE INTO BIOCHAR USING PYROLYSIS AT COMMUNITY SCALE FACILITY



CRANFIELD UNIVERSITY

The Nano Membrane Toilet

DELFT UNIVERSITY OF TECHNOLOGY

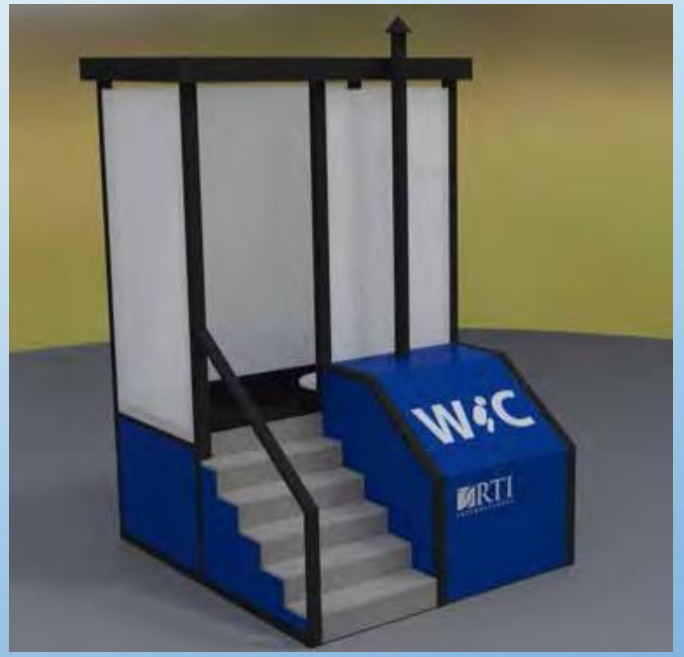
SANIR: UPGRADING HUMAN WASTE WITH PLASMA-DRIVEN GASIFICATION

OKLAHOMA STATE UNIVERSITY

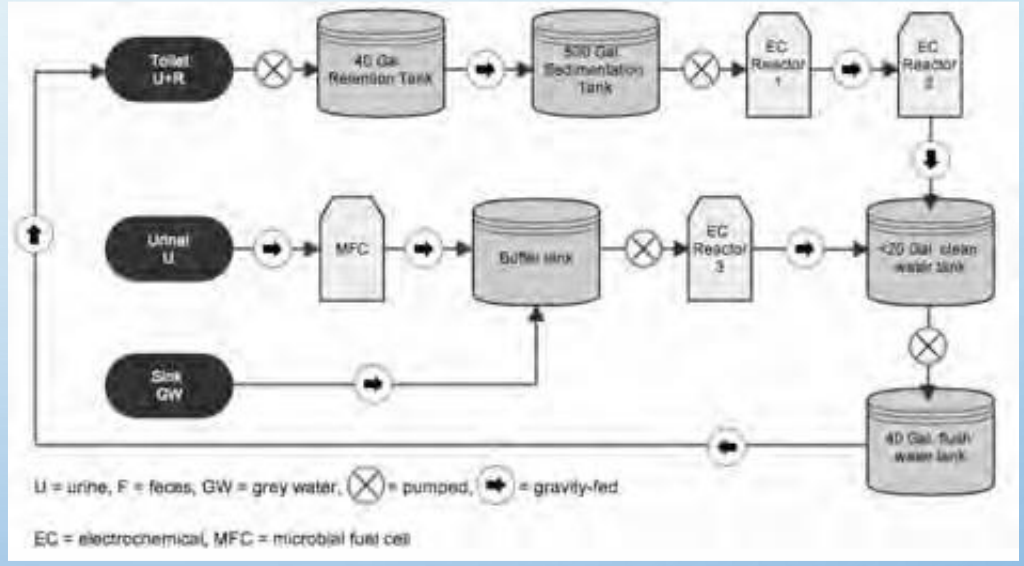
Viscous heater for pathogen inactivation in faecal sludge

RTI INTERNATIONAL

AN INTEGRATED ON-SITE WASTE TREATMENT AND TOILET SYSTEM.



CALIFORNIA INSTITUTE OF TECHNOLOGY (CALTECH)



DUKE UNIVERSITY AND THE UNIVERSITY OF MISSOURI

NEIGHBORHOOD-SCALE TREATMENT OF SEWAGE SLUDGE BY SUPERCRITICAL WATER OXIDATION

EAWAG (SWISS FEDERAL INSTITUTE OF AQUATIC SCIENCE AND TECHNOLOGY), DESIGN BY EOOS

BLUE DIVERSION TOILET

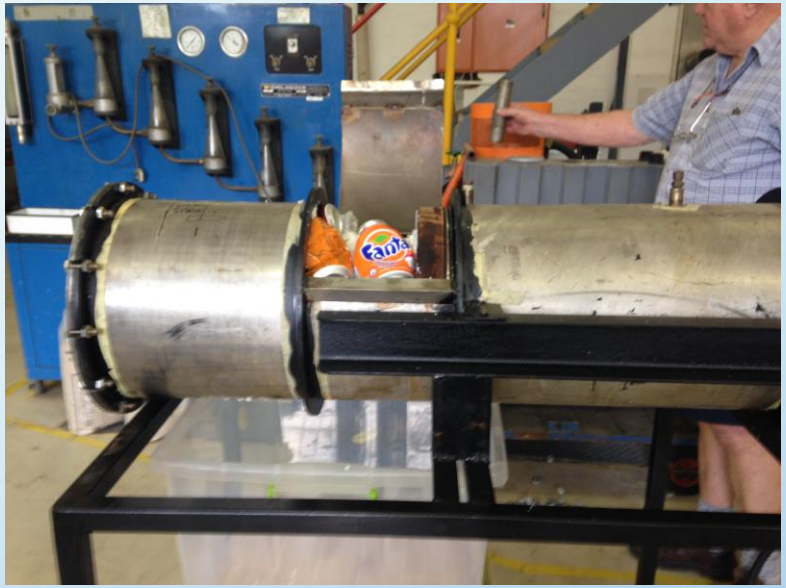
LOUGHBOROUGH UNIVERSITY

REINVENTEDTOILET@LBORO

TRAINING AND SHARING

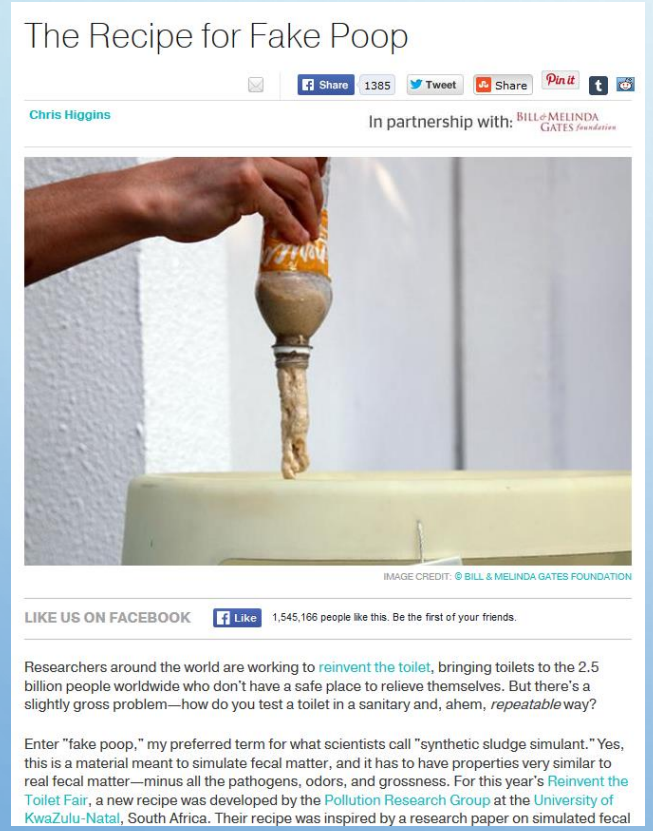
- TRAINING (IN SITU OR REMOTELY)
  - LAB TRAINING
  - SAMPLING
  - POSTGRADUATE STUDENTS AND INTERNS
  - FSM ONLINE COURSE
- DEVELOPMENT OF SOPS
- HOST RESEARCHERS (SHORT / LONG TERM)
- DATA DISSEMINATION
  - DATA BASE ON FS AND URINE CHARACTERISTICS
  - UNDERTAKE DATA COLLECTION ON SPECIFIC REQUESTS

HYDRAULIC RAM FOR TRASH SEPARATION FROM FS



DEVELOPMENT OF FS SIMULANTS

- TOILET FAIR INDIA 2013



The Recipe for Fake Poop

Share 1385 Tweet Share Pin it

Chris Higgins

In partnership with: BILL & MELINDA GATES foundation

IMAGE CREDIT: © BILL & MELINDA GATES FOUNDATION

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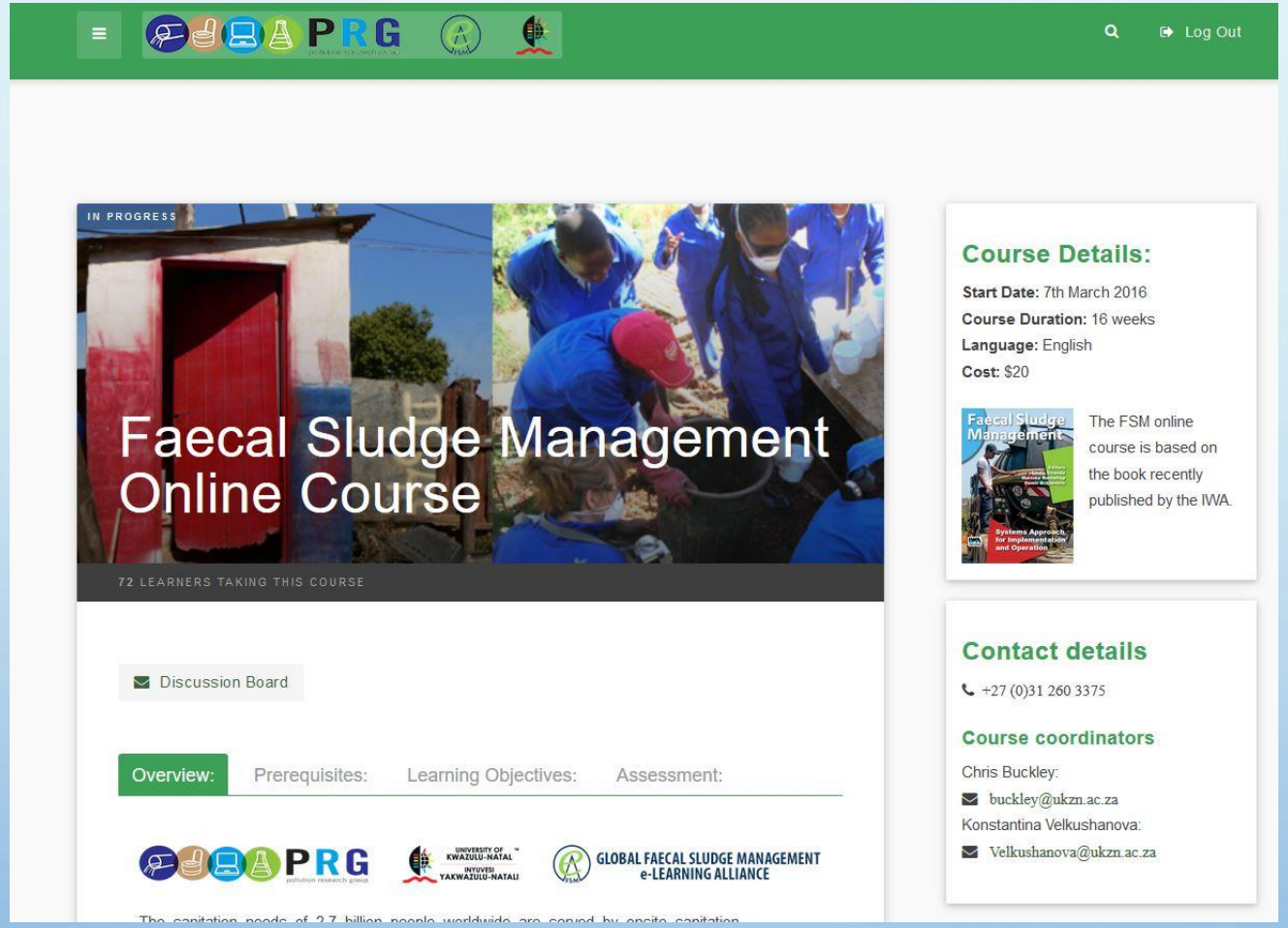
Researchers around the world are working to reinvent the toilet, bringing toilets to the 2.5 billion people worldwide who don't have a safe place to relieve themselves. But there's a slightly gross problem—how do you test a toilet in a sanitary and, ahem, *repeatable* way?

Enter "fake poop," my preferred term for what scientists call "synthetic sludge simulant." Yes, this is a material meant to simulate fecal matter, and it has to have properties very similar to real fecal matter—minus all the pathogens, odors, and grossness. For this year's Reinvent the Toilet Fair, a new recipe was developed by the Pollution Research Group at the University of KwaZulu-Natal, South Africa. Their recipe was inspired by a research paper on simulated fecal

http://mentalfloss.com/article/56003/recipe-fake-poop

Radford, JT; Underdown, C; Velkushanova, K; Byrne, A; Smith, DPK; Fenner, RA; Pietrovito, J; Whitesell, A;
"Faecal sludge simulants to aid the development of desludging technologies" Journal of Water, Sanitation and Hygiene for Development",5,3,456-464,2015,IWA Publishing

FSM ONLINE COURSE



https://prg-durban.org.za/course/faecal-sludge-management

K5/2414 Household Sanitation Technology Assessment and Evaluation Protocol (Water Research Commission SA)

- Desktop review
- Field verification
- Laboratory verification
- Overall technology assessment

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LESSONS LEARNED AND CONSIDERATIONS

- ✓ It is ideal for reviewer to be involved in selection of the site(s) to visit.
- ✓ Supplier should describe the toilet operation in detail on-site. This captures nuanced items that may be neglected in initial forms and brings clarity.
- ✓ Try to get input from other people on site in particular users



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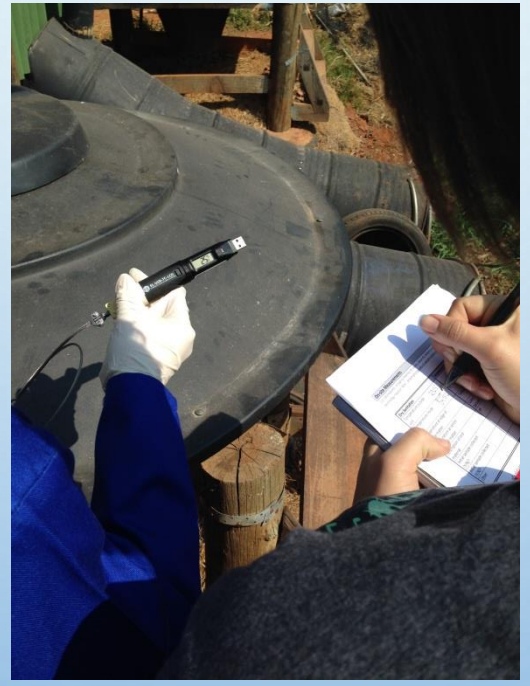
LESSONS LEARNED AND CONSIDERATIONS

- ✓ Check all components thoroughly – really get inside the system
- ✓ Check for dead zones and short circuiting
- ✓ Take good notes and report back



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REPUBLIC OF SOUTH AFRICA

MICROWAVE DIGESTER TECHNOLOGY (UNESCO-IHE) – PROTOTYPE TESTING

INTERACTIONS WITH OTHER ORGANISATIONS - PROVISION OF DATA, HOSTING VISITORS, ASSISTANCE ON RESEARCH PROJECTS, TESTING OF PROTOTYPES AND EXCHANGE OF INFORMATION

- AGRI PROTEIN (SOUTH AFRICA)
- ASIAN INSTITUTE OF TECHNOLOGY (THAILAND)
- BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY (BUET)
- BATH UNIVERSITY (UK)
- BEAUMONT (USA)
- BILL & MELINDA GATES FOUNDATION
- BORDA
- BRISTOL ROBOTICS LAB (UK)
- CALIFORNIA POLYTECHNIC UNIVERSITY (USA)
- CENTRE OF SCIENCE AND ENVIRONMENT (INDIA)
- CLIMATE FOUNDATION (USA)
- CRANFIELD UNIVERSITY (UK)
- DUKE UNIVERSITY (USA)
- EAWAG (SWITZERLAND)
- ETHEKWINI WATER AND SANITATION (SOUTH AFRICA)
- FIRMENICH (SWITZERLAND)
- INRA (FRANCE)
- JANICKI INDUSTRIES (USA)
- LOUGHBOROUGH UNIVERSITY (UK)
- MOTT MACDONALD (UK)
- NORTH CAROLINA STATE UNIVERSITY (USA)
- NORTH-WEST UNIVERSITY, UNIT FOR ENVIRONMENTAL SCIENCE AND MANAGEMENT, POTCHEFSTROOM CAMPUS
- OKLAHOMA STATE UNIVERSITY (USA)
- PLYMOUTH MARINE LABORATORY (UK)
- RESEARCH TRIANGLE INSTITUTE (USA)
- SAN DIEGO STATE UNIVERSITY (USA)
- SANERGY (KENYA)
- STOCKHOLM ENVIRONMENT INSTITUTE
- SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES
- SYNAPSE
- TECHNICAL UNIVERSITY OF DELFT (TU DELFT, NETHERLANDS)
- UNESCO-IHE (NETHERLANDS)
- UNILEVER (UK)
- UNIVERSITÉ LAVAL (CANADA)
- UNIVERSITY COLLEGE, LONDON (UK)
- UNIVERSITY OF COLORADO (USA)
- UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
- UNIVERSITY OF KWAZULU-NATAL
- UNIVERSITY OF TORONTO (CANADA)

AFRICAN ORGANISATIONS

- KHANYISA PROJECTS
- PARTNERS IN DEVELOPMENT (PID)
- AFRICAN MUNICIPALITIES
- BOTSWANA GOVERNMENT
- JIMMA UNIVERSITY, ETHIOPIA
- EGERTON UNIVERSITY, KENYA
- MAKERERE UNIVERSITY, UGANDA
- UNIVERSITY, OF MALAWI, MALAWI
- UNIVERSITY OF ZAMBIA, ZAMBIA
- UNIVERSITY OF BOTSWANA, BOTSWANA
- WATER FOR PEOPLE, UGANDA
- MZUZU UNIVERSITY, MALAWI
- RHODES UNIVERSITY, RSA
- INTERNATIONAL INSTITUTE FOR WATER & ENVIRONMENTAL ENGINEERING (2IE), BURKINA FASO

THANK YOU!

Velkushanova@ukzn.ac.za