2014-2015

Emergency Sanitation

Malawi Field trials

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This handout on the treatment of faecal sludge for emergency situations by WASTE Advisers is part of the Emergency Sanitation Project (ESP) and the S(P)EEDKITS Project. The ESP project is funded by the US Office for Foreign Disaster Assistance (OFDA) and is a consortium of the International Federation of Red Cross and Red Crescent Societies (IFRC), WASTE and Oxfam GB. S(P)EEDKITS has received funding from the European Unions seventh Framework Programme (FP7/2007-2013) under grant agreement No 284931. The activities were executed in close cooperation with the Technical University of Delft, Unesco-IHE in Delft, Blantyre City Council (Malawi).

Malawi Field Trials

Preliminary results

January-April 2014

Pit Latrine → Pit Emptying → Treatment

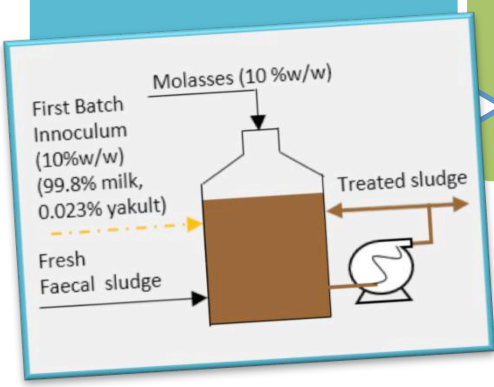
Bangwe Market Pit Latrine
Users per day: 50-100 people
Sludge age: 2weeks - 1month

Pit Latrine Emptying
High Pressure Fluidisation
Vacuum pump

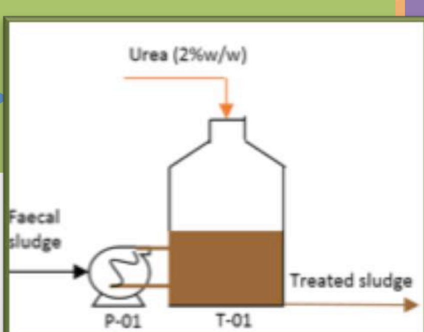
Sochi Treatment Plant: Experiment Site
50L Plastic Drum Reactors

Emergency Sanitiation Field Trials using readily available resources for the treatment of Faecal Sludge from pit Latrines

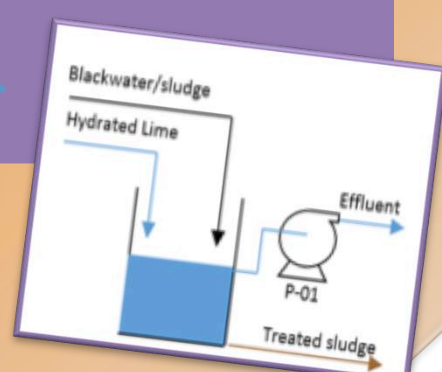
Lactic Acid



Urea



Lime



Emergency Faecal Sludge Treatment

Field Trials Jan – Apr 2014 in Blantyre, Malawi

Three Emergency Faecal Sludge Treatment Options have been investigated through small scale experiments using Fresh Faecal Sludge over 3 months (Jan–April 2014) in Blantyre, Malawi. Preliminary testing has indicated that based on the small-scale field trials, Urea Treatment, Hydrated Lime Treatment and Lactic Acid Fermentation are promising low-tech faecal sludge treatment technologies and are all potentially applicable to emergency situations.

The sludge used in the trials was sourced from Bangwe Market Pit Latriens and extracted using a desludging technique involving high pressure fluidization and a vaccuum pump. The characteristics of the Faecal sludge collected from the Bangwe Market Pit Latrines each week varied considerably reflecting the heterogeneous nature of faecal sludge as well as the influence of external factors such as climatic conditions.

Based on the small-scale field trials all three treatment processes are able to satisfy the key safety, sanitation and robustness criteria for emergency faecal sludge treatment processes

Faecal Sludge Characteristics

Temperature	21-27°C
pH	6.0-7.6
COD	50-150 g COD/L
Ammonia	1.2-1.5 g NH_3-N/L
Total solids	4-15 %[a]
Volatile Solids	45-68 % dry wt (2-10% wet wt)
Ecoli	3x 10^6 -4x10^7 CFU/100ml

- Adhere to the safety, health and environmental norms and standards during operation and maintenance

Safety ✓

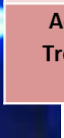
- Produce treated sludge compliant with the WHO guideline limit of 10^3 E-coli CFU /100ml

Sanitisation ✓

- Can treat both liquid and solid sludge
- Effective under challenging physical conditions such as unstable soils, high water tables and flood-prone areas

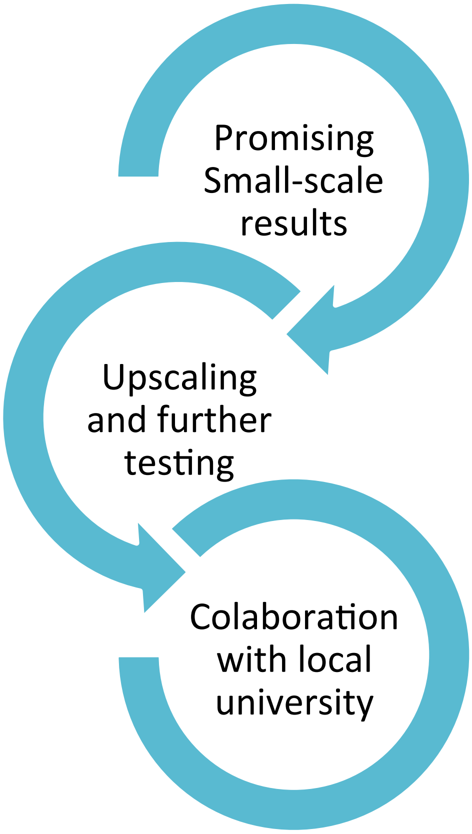
Robustness ✓

Criteria	Lactic Acid	Ammonia	Lime
Technology	Biological Treatment	Chemical Treatment	Chemical Treatment
Sanitisation time	7-15 days	4-8 days	2 hours
End pH of Faecal Sludge	3.8-4.2	9-9.5	11-12
Chemical Use	Sugar Additive	Urea	Hydrated Lime
Chemical Use	2g simple sugar/kg sludge 10% w/w pre culture (Pre-culture: 0.2% Yakult, 99.8% Milk)→ 30g/L Lactic Acid	2%w/w Urea (20g Urea/kg Sludge – 9g TAN/kg Sludge)	17-30g Hydrated Lime / kg Sludge
Chemical cost per m³ faecal sludge[1]	€2.20/m³ (100L Molasses) €31.20/m³ (Pre culture: 100L Milk, 0.2L Yakult)	€16/m³ (20kg Urea)	€12/m³ (25kg Lime)
Limitations	Temperature dependence for Lactic Acid Bacteria fermentation	Homogeneous mixing required Air-tight container	Homogeneous mixing required
Additional Treatment/ Re-use	Drying bed/ inoculum for subsequent batches	Drying bed/ fertilizer	Drying bed/ soil conditioner for acidic soils



[1] Note chemical costs are based on product costs sourced from Malawi originally in Malawian Kwacha.

On-going Research in Malawi



Based on the small-scale field trials, Urea Treatment, Hydrated Lime Treatment and Lactic Acid Fermentation are promising low-tech faecal sludge treatment technologies and are all potentially applicable to emergency situations

Further upscaling and scientific testing is required to ensure that these treatment methods can consistently meet sanitation requirements and a robust procedure that safeguards public health during an emergency situation can be established.

In collaboration with the University of Malawi- the Polytechnic , further research into off-site and on-site faecal sludge treatment methods will be undertaken over the coming year. Two Master of Philosophy Students have been idenitifed to conducted the proposed future research in Blantyre, Malawi

Upscaling off-site Treatment Processes

Urea

Lime

On-site Treatment Field Trials

Lime: Pit Latrine Additive

Lime in Desludging process

Lactic Acid Pit Latrine Additive

Worm Toilet

Terra Preta Toilet

Off-site Treatment : Lime

Primary Objective:

To determine the optimum dosage of hydrated lime($Ca(OH)_2$) as well as the physical treatment conditions required to achieve the WHO guideline limits for faecal sludge.

Key research results

- Total Treatment time
- Extent of Sanitisation
- Extent of Stabilisation
- Required Resources (e.g. Chemical & Energy usage)
- Upscalability of the treatment process

Stage 1: Small Scale Testing : Key Objectives	
1. pH/ Hydrated Lime dosage	1a. Determine optimum pH for pathogen removal 1b. Determine required hydrated Lime dosage to achieve optimum pH 1c. Determine pH requred to prevent regrowth
2.Mixing Conditions	2. Determine the required mixing time and intensity
3. Storage Conditions	3. Determine the minimum storage time required to produce a safely sanitised sludge product
4. Additional Treatment	4. Determine additional treatment required to produce a stabilised sludge product

Stage 2: Large Scale Testing : Key Objectives	
1. Upscalability of Lime dosage and pH conditions	1a. Using the results of the small scale experiments determine if the relationship between lime dosage and pH can be upscaled to the large scale testing situation.
	1b. Determine if the optimum pH resulting from the small scale experiments deactivates pathogens on a large scale with no regrowth occuring.
2. Batch Size and Mixing Conditions	2a. Determine the optimum batch size (tank or pit size) for lime treatment of faecal sludge.
	2b.Determine if adequate mixing can be achieved through pumping and recirculation the sludge using a diaphram pump.
	2c.Determine the optimum mixing time.
3. Storage Conditions	3. Determine the minimum storage time required to produce a safely sanitised sludge product on a large scale
4. Additional Treatment	4. Determine additional treatment required to produce a stabilised sludge product

Measured Parameters

- pH
- Tempearture
- E-coli Count
- Total Solids
- Volatile Solids

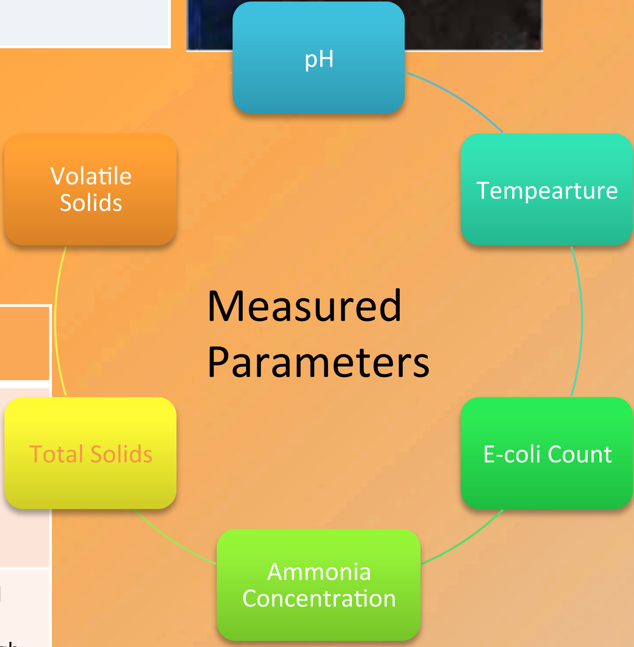
Off-site Treatment : Urea

Primary Objective:

To determine the optimum dosage of Urea as well as the physical treatment conditions required to achieve the WHO guideline limits for faecal sludge. Key outcomes of the research included: determination of 1. total treatment time; extent of sanitization and stabilization; required chemical and energy resources and up scalability of the treatment process.

Stage 1: Small Scale Testing : Key Objectives

1. Urea dosage	1a. Determine optimum urea dosage based on sludge weight for pathogen removal 1b. Determine required pH and temperature
2.Mixing Conditions	2. Determine the required mixing time and intensity
3. Storage Conditions	3. Determine the minimum storage time required to produce a safely sanitised sludge product
4. Additional Treatment	4. Determine additional treatment required to produce a stabilised sludge product



Stage 2: Large Scale Testing : Key Objectives

1. Upscalability of urea dosage	1. Using the results of the small scale experiments determine if the relationship between urea dosage , ammonia concentration, treatment time and pathogen deactivation can be upscaled to the large scale testing situation.
2. Batch Size and Mixing Conditions	2a. Determine if the bladder is a suitable reactor vessel for ammonia treatment of faecal sludge. 2b.Determine if adequate mixing can be achievd through pumping and recirculation. 2c.Determine the optimum mixing time.
3. Storage Conditions	3. Determine the minimum storage time required to produce a safely sanitised sludge product on a large scale
4. Additional Treatment	4. Determine additional treatment required to produce a stabilised sludge product

Large Scale Urea Testing with Bladder

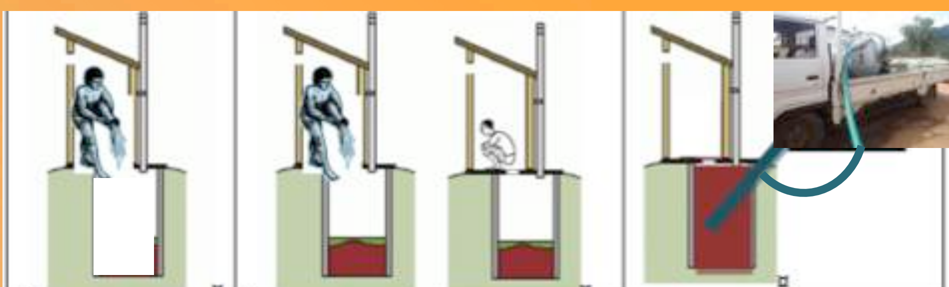
On-site Treatment : Lactic Acid

Primary Objectives:

To determine if the procedure for lactic acid treatment of faecal sludge established through small scale experiments can be upscaled to on-site treatment in a pit latrine

a) To determine if a sanitised sludge can be produced through on-site treatment with lactic acid.

b) To determine if treated sludge can be used as the innoculum for the subsequent treatment process.



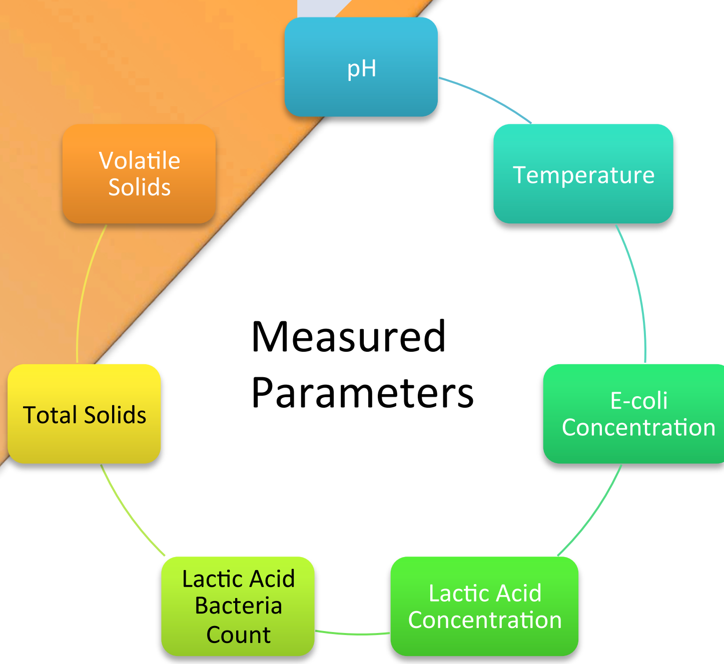
Innoculum containing lactic acid bacteria is added to the empty pit latrine

Sugar solution (e.g. Molasses) is added weekly whilst the pit latrine is in use

The sludge contained within the pit latrine is removed using a vaccuum pump and sludge samples taken

Innoculum Options

Yakult + Milk	Treated Sludge
	
Requirement : 20-30 g/L Lactic acid	

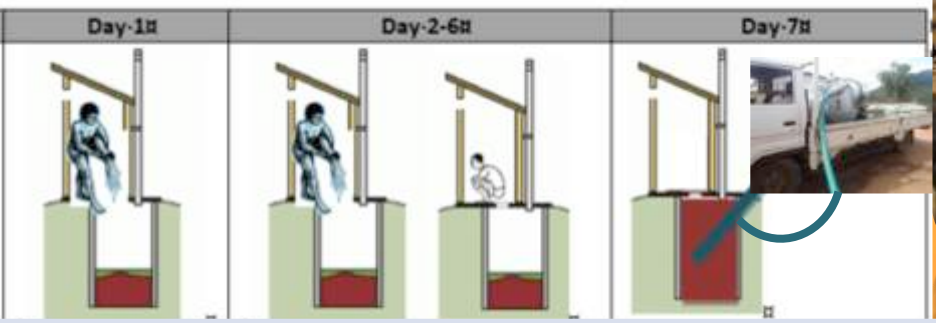


On-site Treatment : Lime

A. Daily Hydrated Lime Addition to Latrine

Primary Objectives

1. To determine if a sanitized sludge can be produced by adding lime periodically into the latrine whilst the public pit latrine is in use
2. To determine if mixing via the desludging process is sufficient to provide a consistently sanitized sludge



1kg Hydrated Lime is mixed with 6L of water and poured into the pit latrine

Hydrated Lime solution is added daily in the morning. The Latrine is in used during the day

The sludge contained within the pit latrine is mixed during the fluidisation process and removed using a vaccuum pump and sludge samples taken

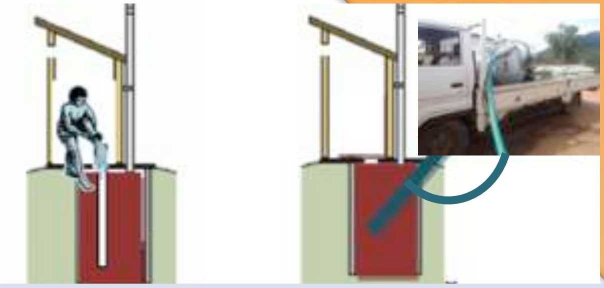
Measured Parameters

- pH
- Tempearture
- E-coli Count
- Total Solids
- Volatile Solids

B. Lime Treatment during Fluidisation (desludging)

Primary Objective

To determine if a consistently sanitized sludge can be produced by adding Lime during the fluidization process of desludging a pit latrine.



Hydrated Lime is added to the water tank on the desludging truck and injected into the pit latrine during the fluidization process

The Pit Latrine is emptied using the vaccuum pump and sludge samples taken

On-site Treatment Systems

Primary Objectives

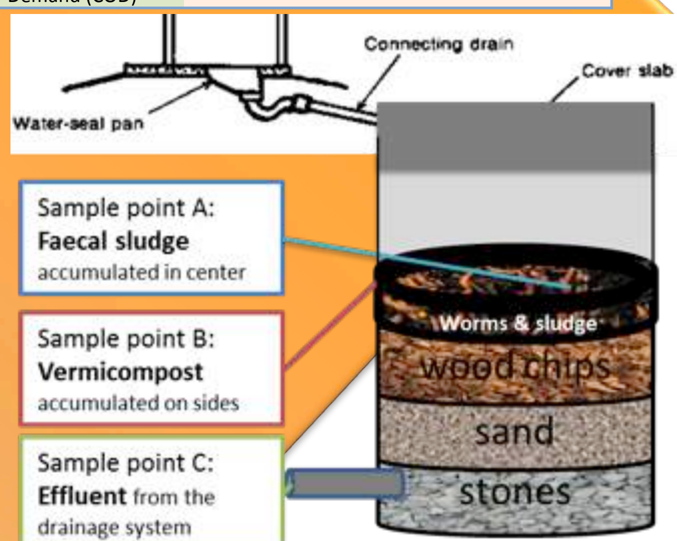
- Investigate the functionality of the on-site sanitation systems; quantifying the process efficiency in terms of stabilization, sanitization and useful by-product generation.
- Determine the impact of climate, seasonal and environmental factors on system performance
- Devise the process conditions required for Pit Latrine Sludge Treatment to achieve the WHO guideline sanitation requirements.
- Compare and contrast each of the on-site sanitation systems using a multi-criteria analysis

Foreground: Worm toilet
Background: Terra Preta Toilet
photo taken at Crown Ministries, Malawi

Worm Toilet

The worm toilet utilizes worms to digest the faecal matter and produce vermicompost suitable for agriculture. The produced vermicompost is volumetrically less than the consumed faecal matter, therefore a key advantage of this system is reduced pit volume.

Monitored Parameters to Assess WormToilet and Terra Preta Toilet		
Sanitisation	Stabilisation	Useful By-product Generation
Pathogen reduction E-coli count	**organic conversion** Chemical Oxygen Demand (COD)	**Fertilizer Quality of Vermicompost/ sludge** Ammonia Concentration, pH, Temperature

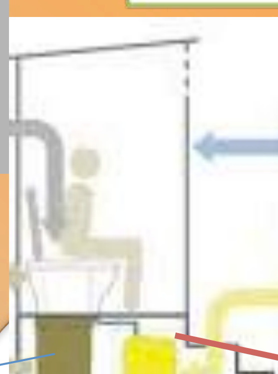


Terra Preta Sanitation

Terra Preta Sanitation (TPS) is a low-cost dry sanitation system based on urine diversion and the addition of charcoal that produces lasting and highly fertile soils. Through natural processes of lacto-fermentation (silage) and vermicomposting fecal material is converted into Terra Preta like soils that can be utilized in (urban) agriculture and act as a carbon sink

Charcoal mixture added to faeces

Pyorolysis Stove
-used to create charcoal from corn cobs, bamboo and other waste material



Lactic Acid Bacteria innoculum added for lacto-fermentation
(0.2%w/w Yakult to Milk. 10%w/w sludge
Lactic acid concentration: 30g/L)

UDDT toilet

Sample point A:
Lacto-fermented sludge

Sample point B:
Urine

Technology Summary

Technology	Description	Sanitation Mechanism	Potential By-products
On-site Sanitation Systems			
Lactic Acid Fermentation	Lactic Acid Bacteria convert simple sugars(molasses) into Lactic Acid which sanitises the sludge by lowering the pH and being toxic to pathogens. Small scale experiments have been conducted and the potential to use treated sludge as an innoculum has been suggested. The next step is to test this theory within a pit latrine.	Lacto-fermentation, reduction of pH to below pH 4.	Fertilizer
Worm Toilet	This toilet utilizes worms to digest the faecal matter and produce vermicompost suitable for agriculture. A key advantage of this system is reduced pit volume.	Biological Treatment	Vermicompost (fertilizer)
Terra Preta Sanitation Toilet	Terra Preta Sanitation (TPS) is a low-cost dry sanitation system based on urine diversion and the addition of charcoal that produces lasting and highly fertile soils. Through natural processes of lacto-fermentation (silage) and vermicomposting fecal material is converted into Terra Preta like soils that can be utilized in (urban) agriculture and act as a carbon sink	Lacto-fermentation, reduction of pH to below pH 4.	Highly fertile soil
Off-site Sanitation Systems			
Lime Treatment	The addition of Calcium hydroxide (Lime) to pit latrine sludge is known to sanitize the faecal matter. Small-scale experiments have been undertaken and the next step is to upscale these results for treatment for three applications: 1. Within the pit latrine, 2. during desludging and 3. at a pilot-scale decentralized treatment facility	Increase of pH to above pH 11.	Soil conditioner/ Fertilizer
Ammonia Treatment	The addition of urea to pit latrine sludge under anaerobic conditions has been proven to release ammonia which sanitizes the sludge. Small-scale experiments have been undertaken and the next step is to upscale these results for treatment for three applications: 1. Within the pit latrine, 2. during desludging and 3. at a pilot-scale decentralized treatment facility	Ammonia Toxicity ($pH > 9$)	Fertilizer

University of Malawi
Emergency Sanitation Project
WASTE advisers on urban environment and development
SPEEDKITS