Integrated Digestion and Nutrient Recovery to Enhance Value Extraction from Faecal Sludge Treatment

Anna Trego*

C. Rose*, S. Connelly, R. Kennedy-Walker, V.T. Nguyen, D. Hughes, S.G. Shin, C. Patterson, J. Kabika, S. Verdi, A. Parker, K. Kar, B.L. Mehta, D. Raffo, N. Osbert, E. Clifford, J. Amezaga, C.A. Biggs, E. Cartmell and G. Collins

A New Global Agenda

UN, 2016

To achieve ***adequate*** and ***equitable*** sanitation for all and end OD with special attention to women and girls

Integrated Nature of Sustainable Development

Consortium Motivations

Protect water resources & public health

Use *robust & locally appropriate* solutions

Develop *desirable* technologies

Recover *valuable nutrients* from waste

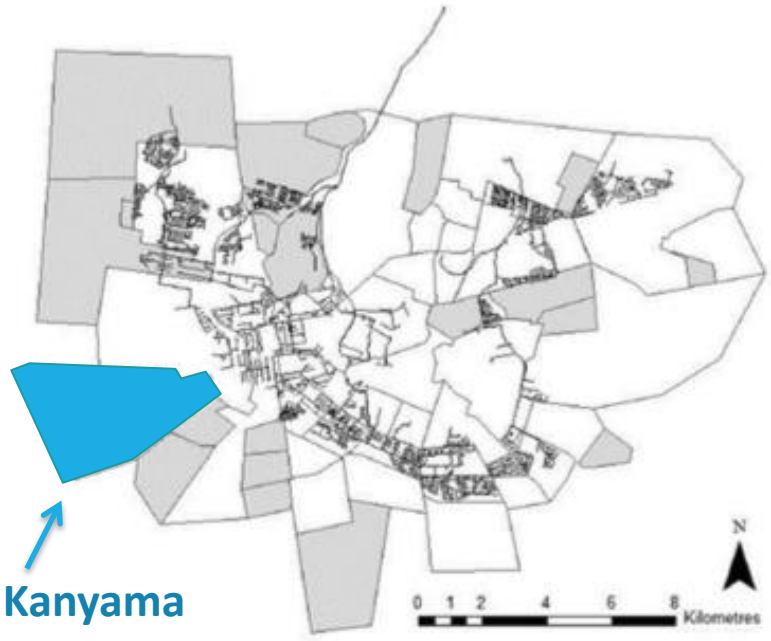
Produce consistent, *high-value products*

Peri-Urban Case Study in Sub-Saharan Africa

The sanitation deficit is largely regional with progress in Sub-Saharan Africa lagging behind

Kanyama, Lusaka, Zambia

Kanyama Compound



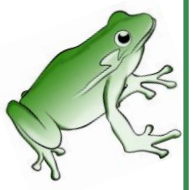
GIS MAP, Lusaka: formal (white) and peri-urban areas (grey), and centralized network (black lines)
(Kennedy-Walker *et al.*, 2015).

- Most populated of Lusaka's PUAs
- 250,000 low-income inhabitants
- Migrant workers – renting
- No centralized sewage connections
- Large deficit in available pit latrines
- Annual flooding – cholera & typhoid outbreaks

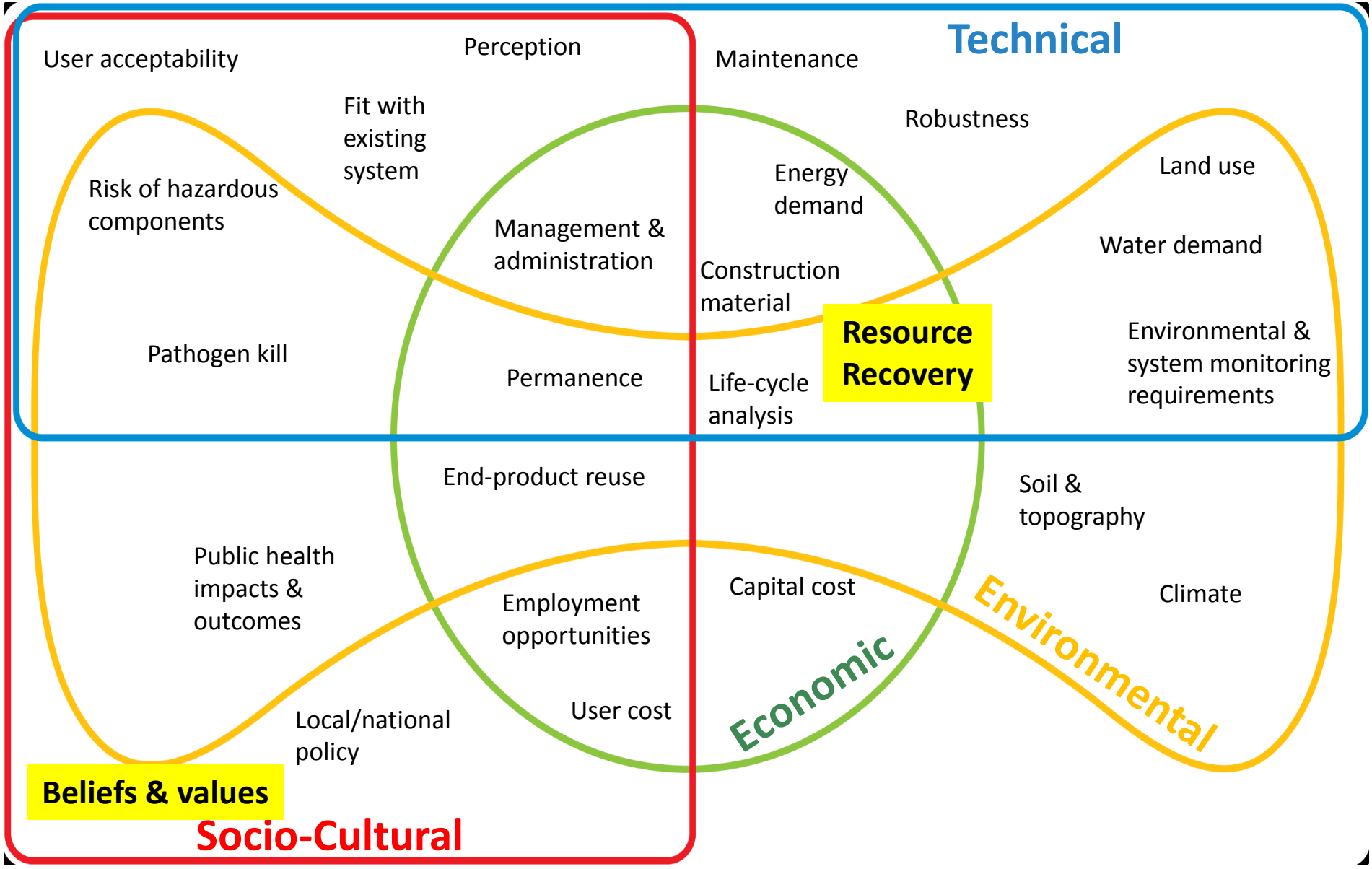
FSM Challenges in Kanyama

Roughly 95% of inhabitants use pit latrines.
When pits are full 41% of households abandon it and build another, while 46% of households bury or dump the waste nearby.

WSUP Baseline Survey, 2012



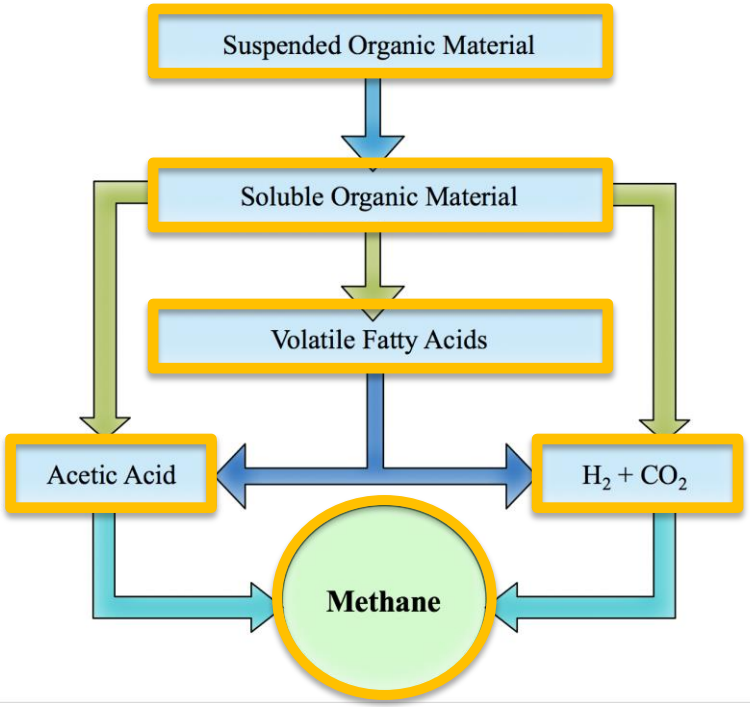
The developing world has an opportunity to **sidestep the costly and inefficient technologies** widespread throughout the developed world and **leapfrog to newer, more sustainable technologies**



Trego *et al.* 2017, submitted

Anaerobic Digestion – A Sustainable Process

= the sequential, and co-operative, action of several groups of microorganisms underpinning breakdown of organics in the absence of oxygen



Transforming FSM in Kanyama

Containment
Pit latrines

Collection
Manual

Transport
Pushcarts

Treatment
Phase 1:
Fixed-dome digestion

Biogas

2° Transport
~25 Km

Treatment
Phase 2: Simple drying beds

One Product:
"Organic fertilizer"

Extracting Value From FSM Treatment

Containment

Pit latrines

Collection

Manual

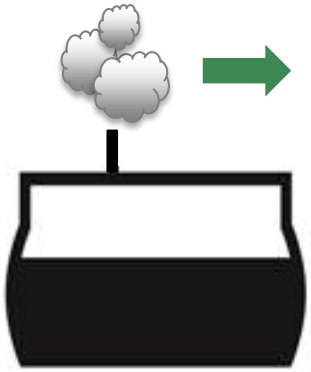
Transport

Pushcarts

Treatment

Phase 1:

Fixed-dome digestion

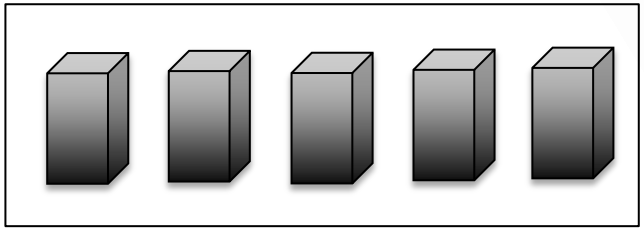


Biogas

Sludge Cake (P)

Blend (N:P)

Material (N)



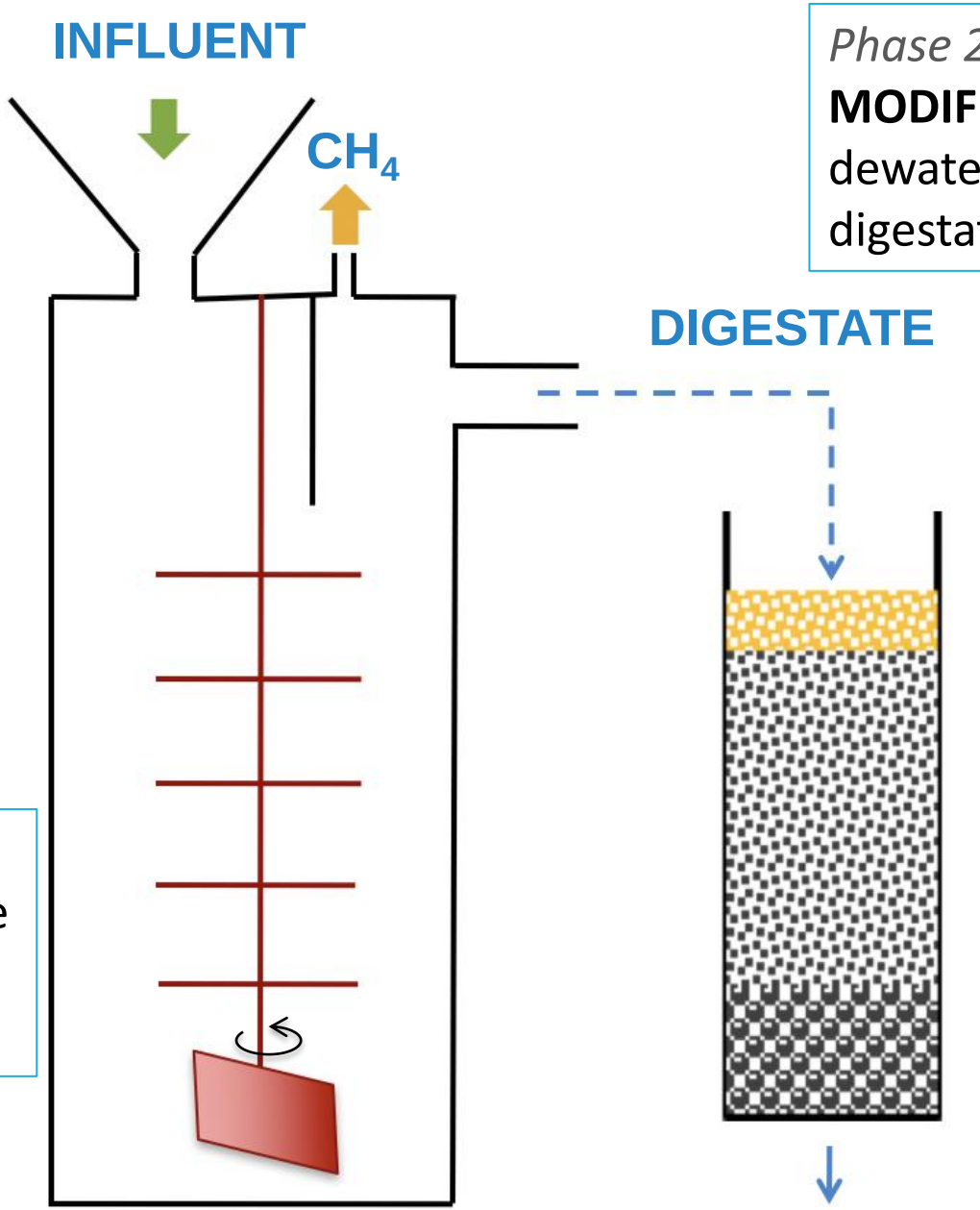
Treatment

Phase 2: Modified drying beds for N & P recovery

FSM4

Lab-Scale Trial

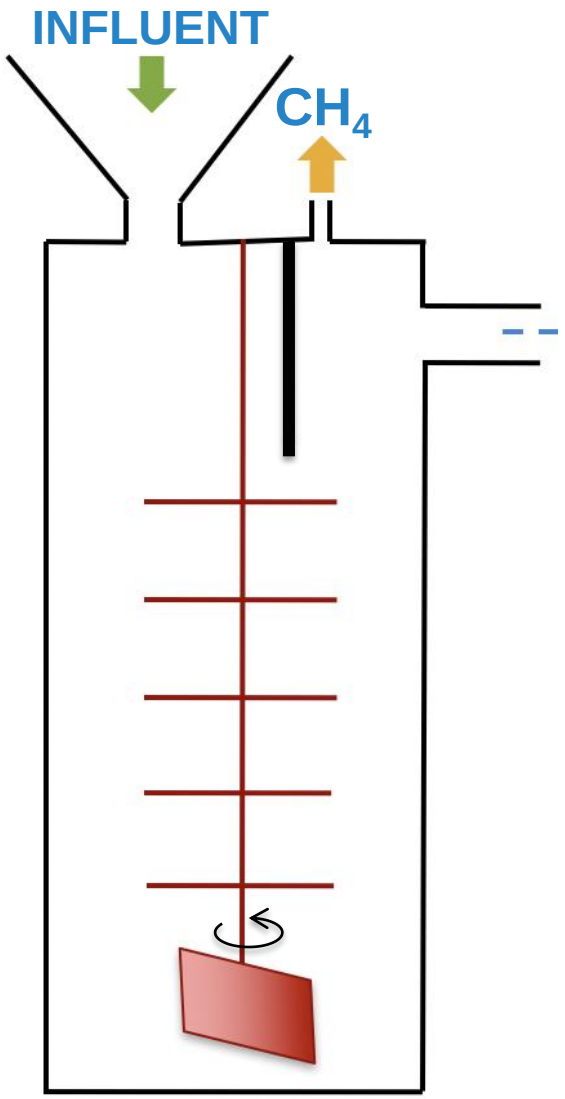
Phase 1 -
DIGESTER: reduce solids content & produce biogas



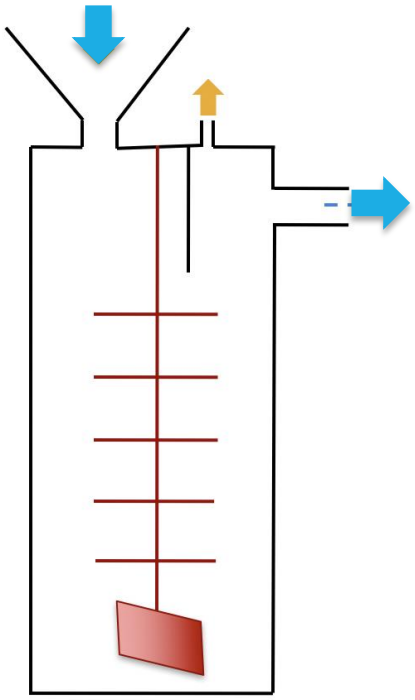
Phase 2 -
MODIFIED DRYING BEDS: dewater anaerobic digestate & recover N & P

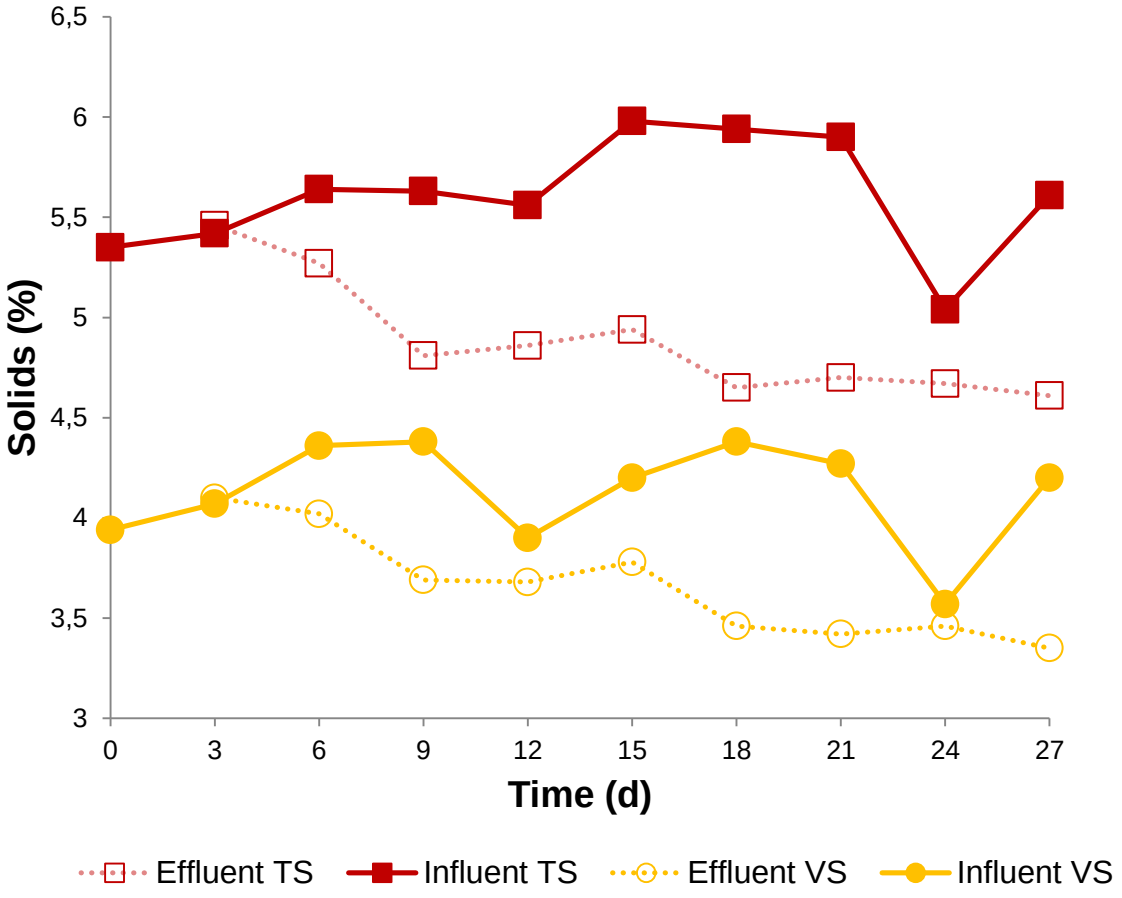
Sequencing Batch Reactor

- **20-L working volume; 37°C**
  - Descending baffle to retain new influent
  - Effluent displaced during feeding
- **Inoculated with cattle slurry**
  - 1:1 ratio based on VS
- **Sequencing batch mode**
  - Fed manually every 3rd day
  - 30-day retention time
- **Intermittently mixed**
  - External mechanical mixer & descending rod
  - 8 times per day for 5-minute durations



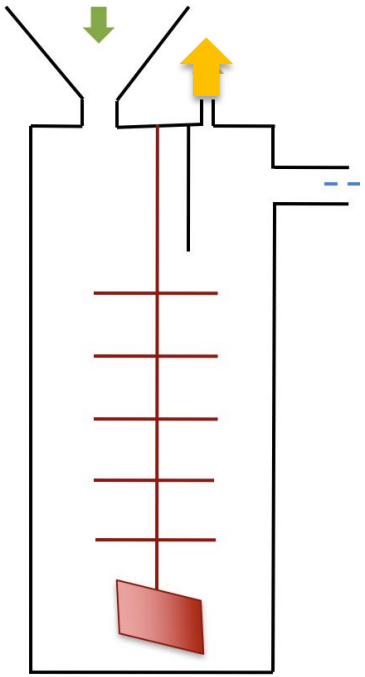
Digester Performance – Solids Destruction

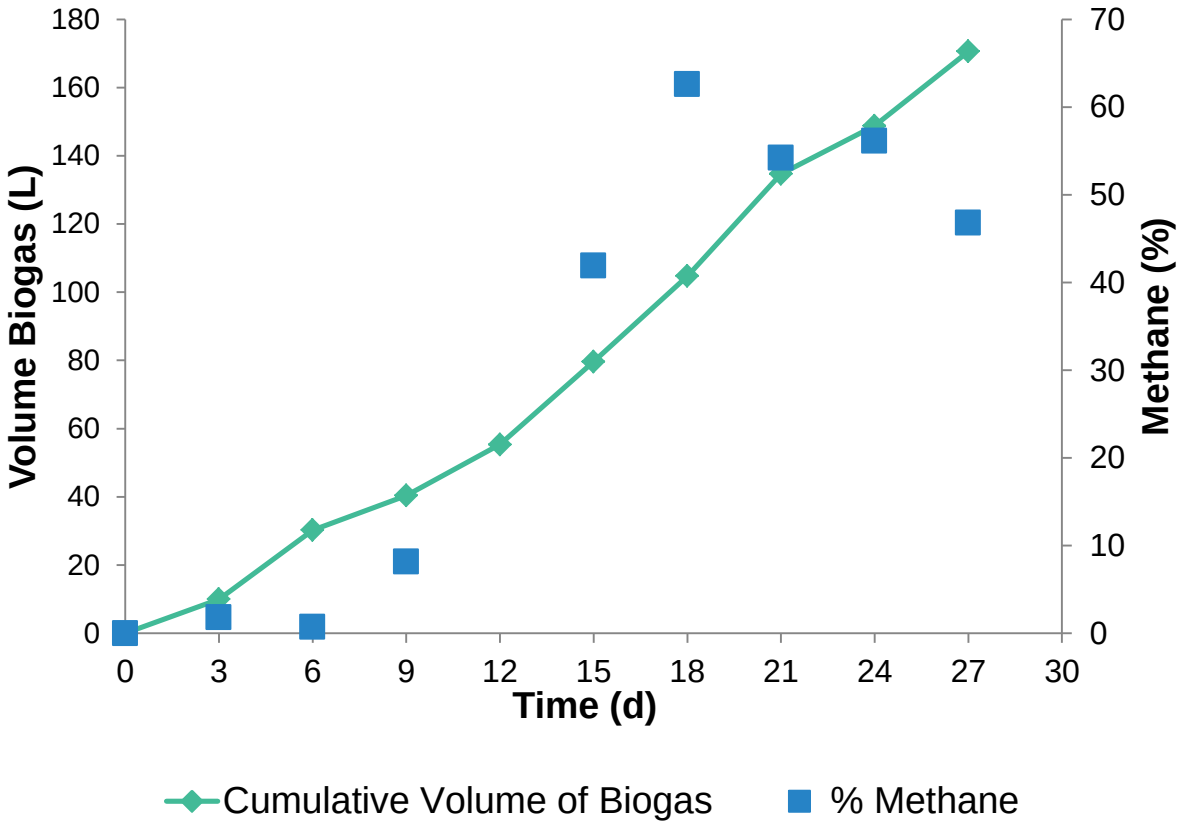




- reduction in total and volatile solids (TS & VS)
- ammonification: 100 mg/L → 500 mg/L

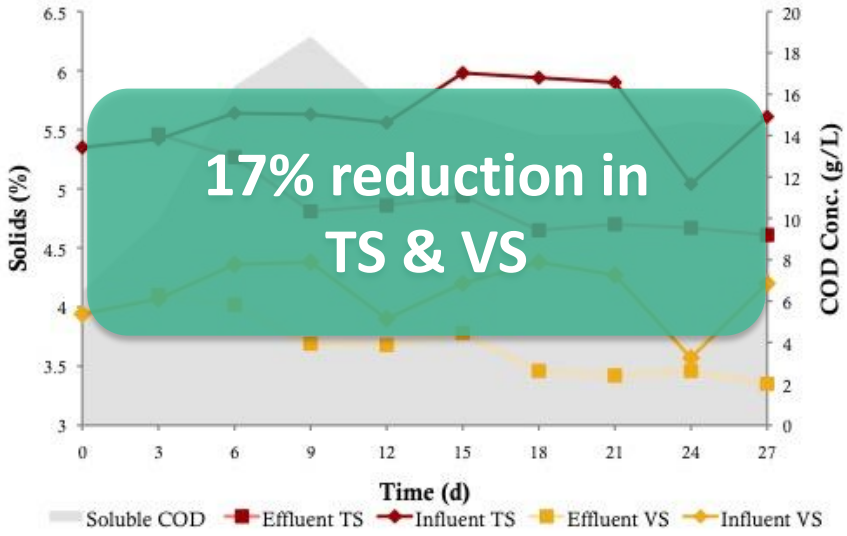
Digester Performance – Biogas Production

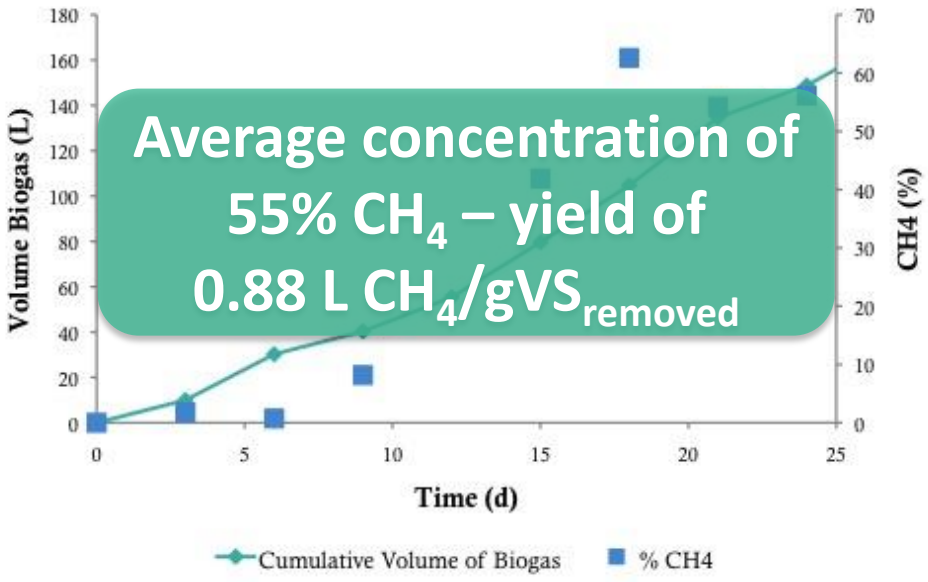




- **Cumulative production of biogas**
- **Increasing CH_4 concentration over time**

Summary Digester Performance





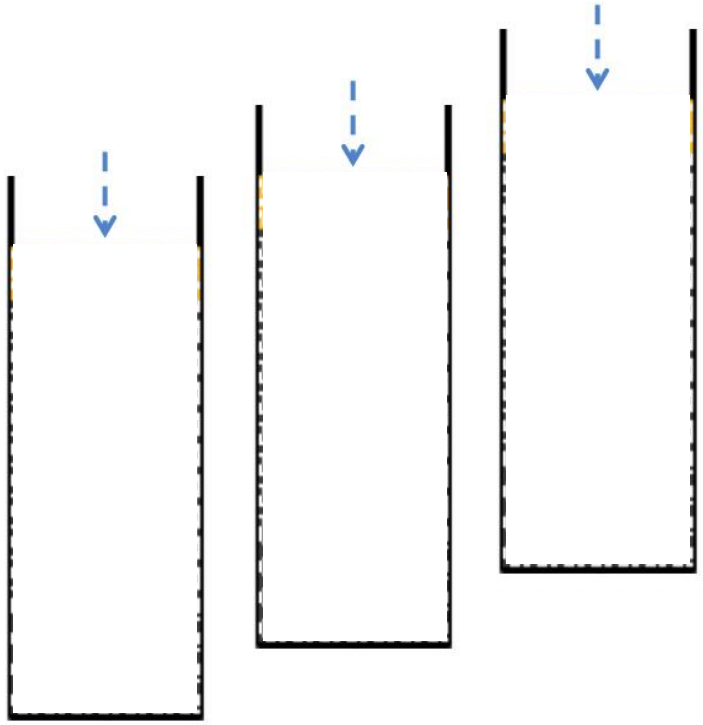
First retention time:

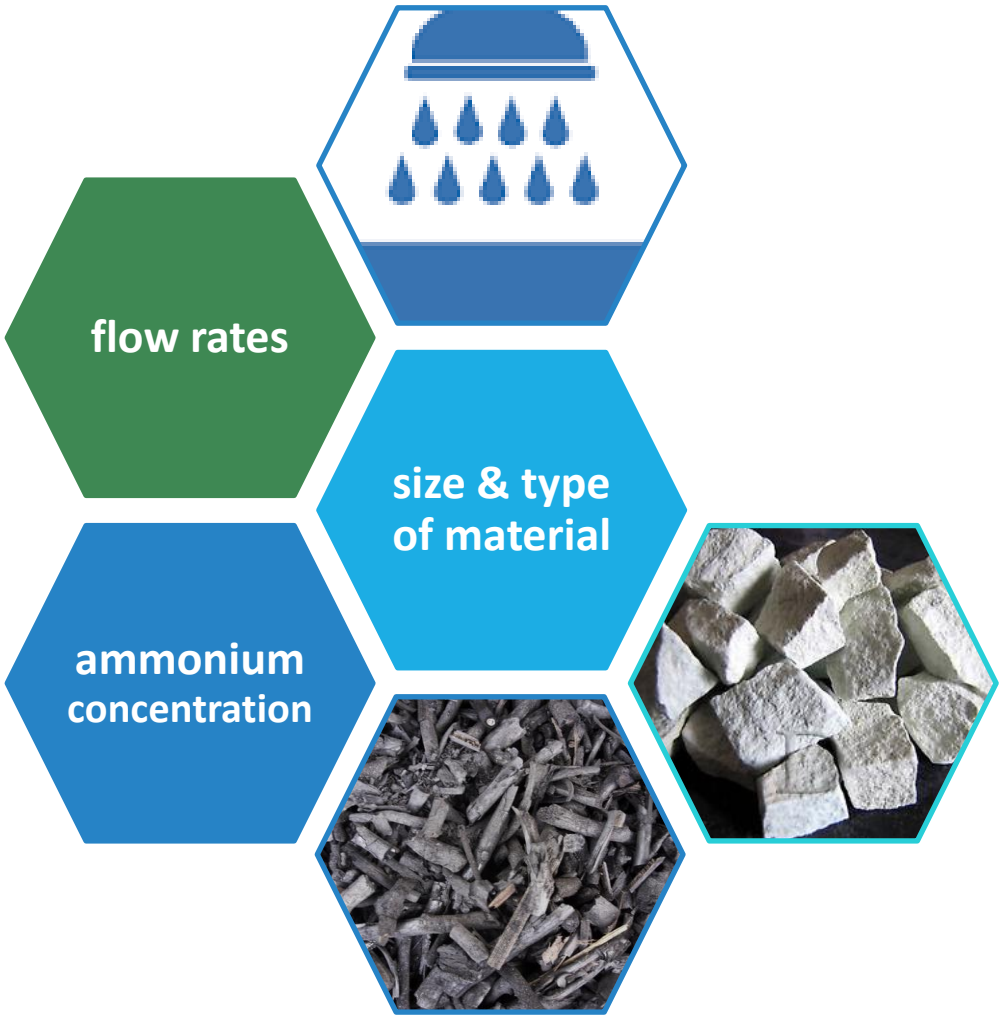
- reduction in total and volatile solids (TS & VS)
- release of soluble COD

- Cumulative production of biogas
- Increasing CH_4 concentration over time

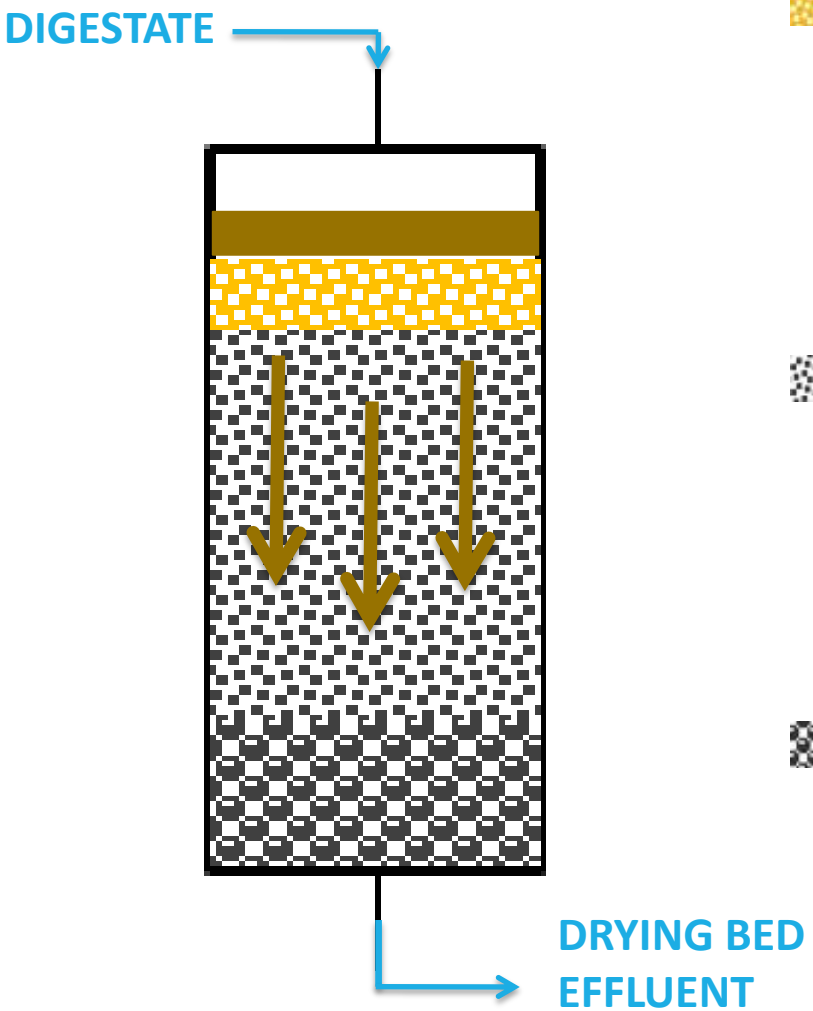
Lab-Scale Dynamic Column Experiments

Phase 2 -
MODIFIED DRYING BEDS:
dewater anaerobic digestate & recover N & P





Modified Sludge Drying Bed Design



Sacrificial Sand Layer – to prevent clogging

- Packing density: 1.8 g/cm^3
- Bed depth: 50 mm
- Particle size: ≤ 1.5 mm

Clinoptilolite Layer – for NH_4^+ recovery

- Packing density: 0.75 g/cm^3
- Bed depth: 220 mm
- Particle size: 2-4 mm

Gravel Layer – to enable drainage

- Packing density: 1.75 g/cm^3
- Bed depth: 50 mm
- Particle size: 6 mm

Clinoptilolite

Zeolite

- Highly porous
- Low-cost
- Can be directly applied as a fertilizer

Ammonium Affinity

- Cation exchange
- Selectivity sequence: $K^{+}>NH_4^{+}>Na^{+}>Ca^{2+}$

Good Performance

- 62-99% removal despite high solids loading
- Capacity of 60 g NH_4-N/kg clinoptilolite
- Provides fertilizer product – grade 5.9 wt.% NH_4-N

Potential Flow Sheet for Sustainable PUA FSM

Containment, Collection & Transport

Outlook – Path Forward

- **POSITIVE**: Developing nations are in unique positions to implement sustainable sanitation technologies, and **AD has clear potential**
- Revenue from **recovery of valuable end-products can underwrite less lucrative stages of FSM**
- Modified sludge drying beds are feasible for **recovery of key macro-nutrients (N, P, K) required in agriculture**. Clinoptilolite has great potential as a non-regenerative medium for drying-beds

Thank you for listening!

Anna Trego
National University of Ireland Galway
a.trego1@nuigalway.ie

Dr. Gavin Collins
National University of Ireland Galway
gavin.collins@nuigalway.ie

NUI Galway
OÉ Gaillimh

Newcastle University

University of Chester

University of Glasgow

UNIVERSITY OF ZAMBIA

Cranfield UNIVERSITY

IDS Institute of Development Studies

The University Of Sheffield.

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