Technical and Societal readiness of Nutrient-Recovery Sanitation Systems

in Kampala, Uganda

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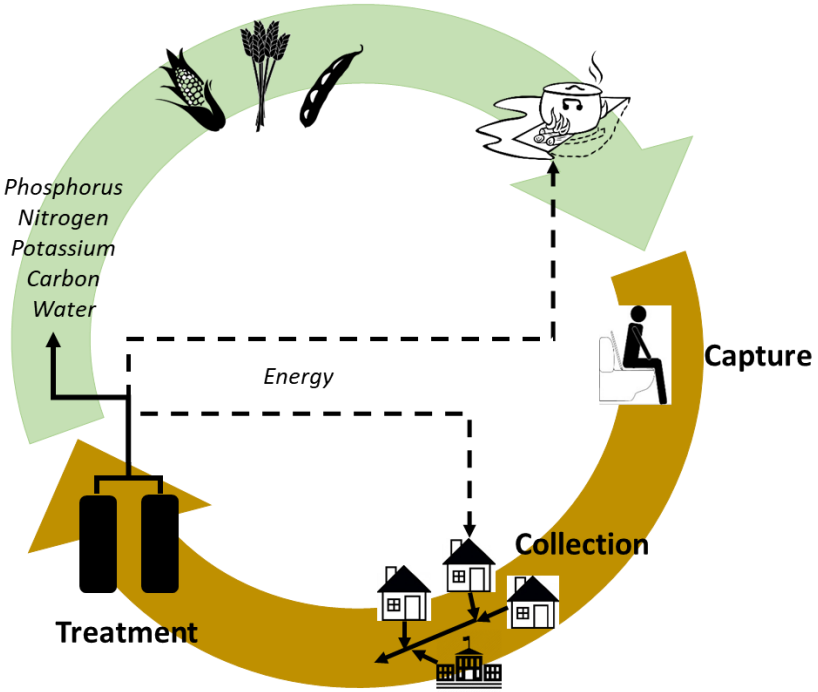
Background – SPANS project

Sanitation Planning for Alternative Nutrient-recovery Systems

- Safely recycle nutrients from excreta and organic waste
- Potential to:
  - *Protect public health*
  - *Increase agricultural productivity*
  - *Recover economic resources*
  - *Decrease fertilizer imports*
- Many emerging technologies



Where to start?

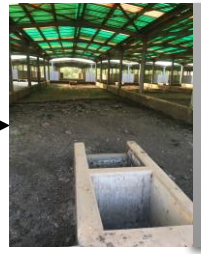
Reference system

FS treatment plant at Lubigi, Uganda

Faecal Sludge

Settling-Thickening Tanks

Supernatant to sewerage treatment (NPK lost)



Unplanted drying beds

Evaporation (N lost)

Soil conditioner

~ 4.6 g P/kg sludge

~ 23 g N/kg sludge

Not meeting WHO guidelines?

Methods

Which FSM systems have the greatest potential for *safe nutrient recycling* in Kampala, Uganda?

1. Systematic mapping of technologies
   - *Database searching 2013-2017*
   - *493 articles used*
2. Pre-selection of feasible treatments
3. Data gathering
4. Multi-criteria analysis (MCA)
   - *Based on local criteria*

Systematic mapping

Nutrient-recovery technologies

Biological	Anaerobic treatment
	Aerobic treatment
	Planted drying beds
	Composting
	Lactic acid fermentation
	Algae production
	Vermicomposting
	Black-soldier fly composting
	Aquaculture
	Microbial cells

Chemical	Precipitation
	Stripping
	Acid leaching
	Ammonia treatment
	Alkaline stabilisation
Thermo	Pyrolysis
	Incineration
	Solar drying
Physio	Membranes
	Adsorption/Filtration

Pre-selection of Treatments

Criteria 1: Recovers NPK

Biological	Anaerobic treatment		*Chemical*	Precipitation	
	Aerobic treatment			Stripping	
	Planted drying beds			Acid leaching	
	Composting			Ammonia treatment	
	Lactic acid fermentation			Alkaline stabilisation	
	Algae production		*Thermo*	Pyrolysis	N lost
	Vermicomposting			Incineration	N lost
	Black-soldier fly composting			Solar drying	
	Aquaculture		*Physio*	Membranes	
	Microbial cells			Adsorption	

Pre-selection of Treatments

Criteria 2: Feasible with Fecal sludge

Biological	Anaerobic treatment		*Chemical*	Precipitation	Not FS
	Aerobic treatment			Stripping	Not FS
	Planted drying beds			Acid leaching	Not FS
	Composting			Ammonia treatment	
	Lactic acid fermentation			Alkaline stabilisation	
	Algae production	Not FS	*Thermo*	Pyrolysis	N lost
	Vermicomposting			Incineration	N lost
	Black-soldier fly composting			Solar drying	
	Aquaculture	Not FS	*Physio*	Membranes	Not FS
	Microbial cells			Adsorption	

Pre-selection of Treatments

Criteria 3: Technical readiness level (TRL) >6

Biological	Anaerobic treatment		*Chemical*	Precipitation	Not FS
	Aerobic treatment			Stripping	Not FS
	Planted drying beds			Acid leaching	Not FS
	Composting			Ammonia treatment	
	Lactic acid fermentation			Alkaline stabilisation	
	Algae production	Not FS	*Thermo*	Pyrolysis	N lost
	Vermicomposting			Incineration	N lost
	Black-soldier fly composting			Solar drying	
	Aquaculture	Not FS	*Physio*	Membranes	Not FS
	Microbial cells	TRL <6		Adsorption	TRL <6

Pre-selection of Treatments

Criteria 4: Feasible at the existing plant

Biological	Anaerobic treatment	Major investment	*Chemical*	Precipitation	Not FS
	Aerobic treatment	Major investment		Stripping	Not FS
	Planted drying beds	Major investment		Acid leaching	Not FS
	Composting			Ammonia treatment	
	Lactic acid fermentation			Alkaline stabilisation	
	Algae production	Not FS	*Thermo*	Pyrolysis	N lost
	Vermicomposting			Incineration	N lost
	Black-soldier fly composting			Solar drying	Major investment
	Aquaculture	Not FS	*Physio*	Membranes	Not FS
	Microbial cells	TRL <6		Adsorption	TRL <6

Pre-selection of Treatments

Criteria 4: Feasible at the existing plant

Biological	Anaerobic treatment	Major investment	*Chemical*	Precipitation	Not FS
	Aerobic treatment	Major investment		Stripping	Not FS
	Planted drying beds	Major investment		Acid leaching	Not FS
	Composting			**Ammonia treatment**	
	Lactic acid fermentation			**Alkaline stabilisation**	
	Algae production	Not FS	*Thermo*	Pyrolysis	N lost
	Vermicomposting			Incineration	N lost
	Black-soldier fly composting			Solar drying	Major investment
	Aquaculture	Not FS	*Physio*	Membranes	Not FS
	Microbial cells	TRL <6		Adsorption	TRL <6

Criteria used for the multi-criteria analysis

Health

1. Pathogen exposure

Institutional

5. Organizational capacity exists

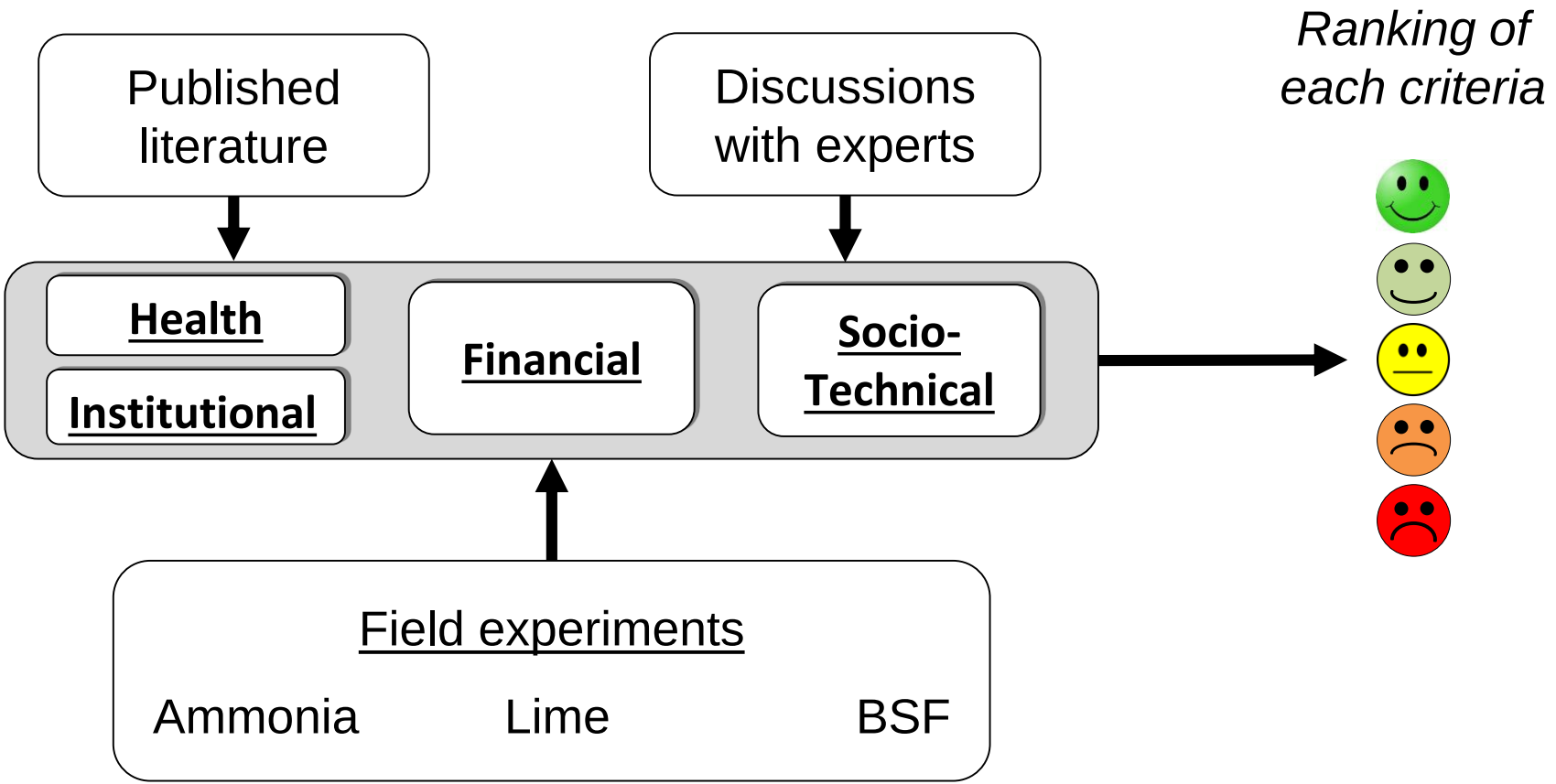
Financial

2. Capital costs
3. O&M costs
4. Nutrient value of product

Socio-Technical

6. Odor (Acceptance)
7. Robustness
8. Volume reduction

Data gathering for MCA



Results – Health risks

Risks for workers will depend how mixing is done!

	Health risks
Current system (storage)	Significant coliform die-off. Ascarsis likely remains.
Lime	
Ammonia	
Lactic Acid Ferm.	
Co-composting	
Vermicomposting	
BSF composting	

Better reduction of pathogens!

Require further treatment

Results – Financial

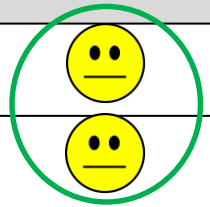
*All <u>safe</u> recovery systems are **more** expensive!*

	Capital costs	O&M costs	Value of product
Current system	Annualized capital investment for FSTP USD$648427	Annual O&M costs for FSTP USD$196001	Sludge contains ca 4,6 g P and 23 g N per kg sludge.
Lime			
Ammonia			
Lactic Acid Ferm.			
Co-composting			
Vermicomposting			
BSF composting			

Expensive additive for NO additional value

Sale of protein feed could off-set additional O&M costs

Results – Institutional

	Organizational capacity
Current system (storage)	Capacity exists
Lime	
Ammonia	
Lactic Acid Ferm.	
Co-composting	
Vermicomposting	
BSF composting	

Results – Socio-technical

	Odor	Robustness	Volume reduction
Current system (storage)	Slightly septic smell	Roofs leak leading to irregular treatment	Total sludge volume reduced ca 85% from incoming sludge.
Lime			
Ammonia			
Lactic Acid Ferm.			
Co-composting			
Vermicomposting			
BSF composting			

Need further studies of acceptance of various products

Recommendations

No obviously better system exists

Alt. 1 Improve existing treatment

- Enforce 6 month storage
- Fix leaking roofs
- Guidelines to farmers
  - *crop restrictions*
  - *handling measures*
- Narrower screens to remove trash

Alt. 2 Combine techniques

BSF  Ammonia

- Ammonia treatment safest at lowest cost
- BSF produce most valuable product
  - But issues with organization & costs
  - Need for new business models!

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