ENHANCED ANAEROBIC DIGESTION AS A SANITATION AND ENERGY RECOVERY TECHNOLOGY

Faecal Sludge Management Conference (FSM2)

Durban, South Africa

October 29-31, 2012

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Introduction

- 2.6 billion people lack access to basic sanitation (WHO and UNICEF 2005)
- 2.2 million people, mostly children, die every year (WHO and UNICEF 2000)

Source: GiZ

Introduction (Cont.)

- Current sanitation systems are not effective
  - Fail to kill pathogenic microorganisms
  - Contaminate drinking water supplies
  - Serve as breeding grounds for insects
  - Generate noxious odors
  - Resource recovery is very difficult

- Reliable, inexpensive and sustainable waste treatment technologies

Challenges

- Engineering/technical
- Financial
- Social
- Cultural
- Political
- …

Engineering/Technical Challenges

- Energy content of human excreta is low
  - 90 g COD per capita per day (USEPA 1999)

    ≈ 50 L biogas per capita per day

    ≈ 25% of the cooking energy demand for a household of 5 people (1000 L/household, GiZ 2010)

- Energy recovery must be enhanced

Engineering/Technical Challenges (Cont.)

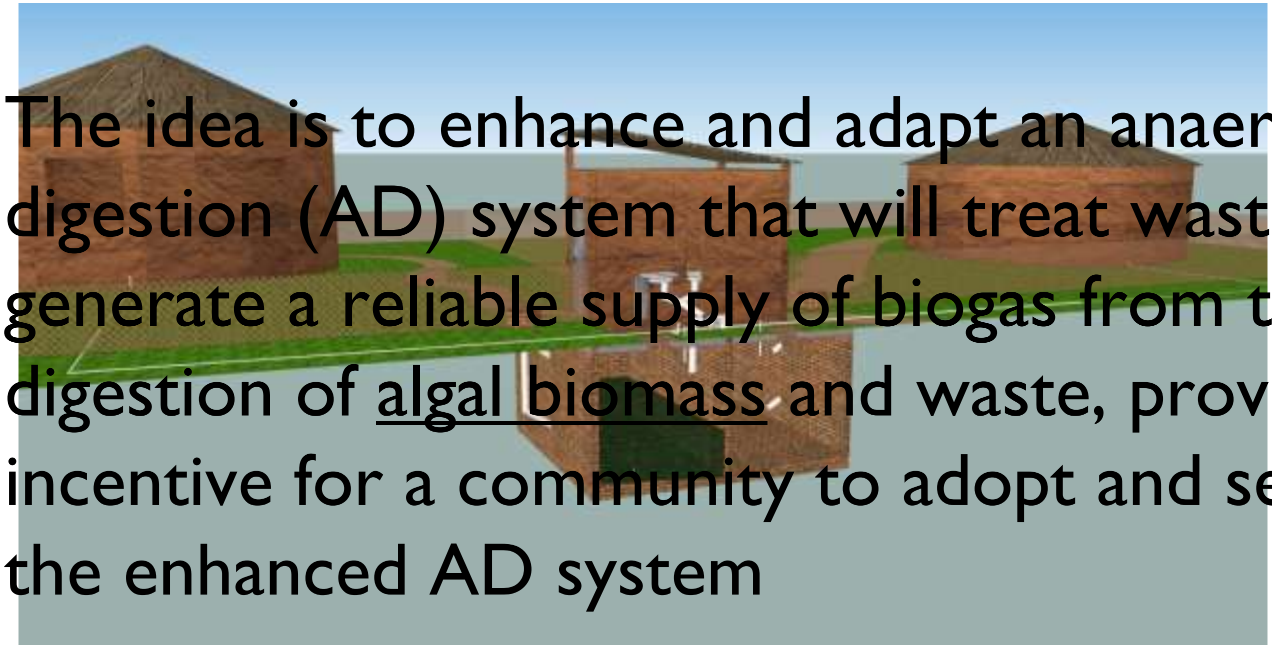
- Impractical to control operating parameters
  - pH
  - Temperature
  - Alkalinity
  - Organic loading rates
  - …
- Design and operating parameters should be established based on anticipated field conditions

Engineering/Technical Challenges (Cont.)

- Operated and maintained by the local
  - Use locally available resources
  - Require minimal training
  - Not require complex monitoring equipment

Proposed Technology

- We propose a novel enhancement to an existing technology



- The idea is to enhance and adapt an anaerobic digestion (AD) system that will treat waste and generate a reliable supply of biogas from the co-digestion of algal biomass and waste, providing an incentive for a community to adopt and self-sustain the enhanced AD system

Why Algae?

$$C_{107}H_{174}O_{26}N_{10}P + 60.75H_2O$$
$$\downarrow$$
$$\cdots$$
$$\downarrow$$
$$\cdots$$
$$\downarrow$$
$$65.625CH_4 + 41.375CO_2 + 10NH_3 + H_3PO_4$$

- Excellent source bioenergy compared other energy crops

Why Algal? (Cont.)

- 650 L CH_4/ kg VS digested for *Chollera vulgaris (C. vulgaris)*

  ≈ 93% of the cooking energy demand for a household (70% of biogas is CH_4)

  ≈ 6.0 kWh/kg of VS digested for *C. vulgaris*

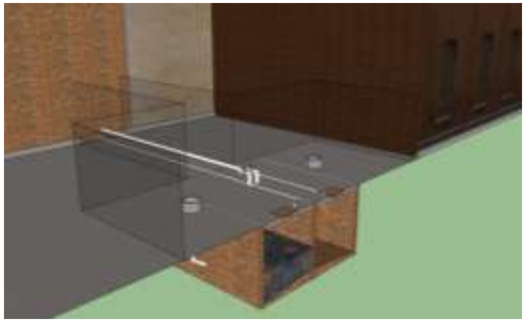
- This is the maximum potential yield

➢ The <u>actual</u> yield must be determined experimentally

Objectives

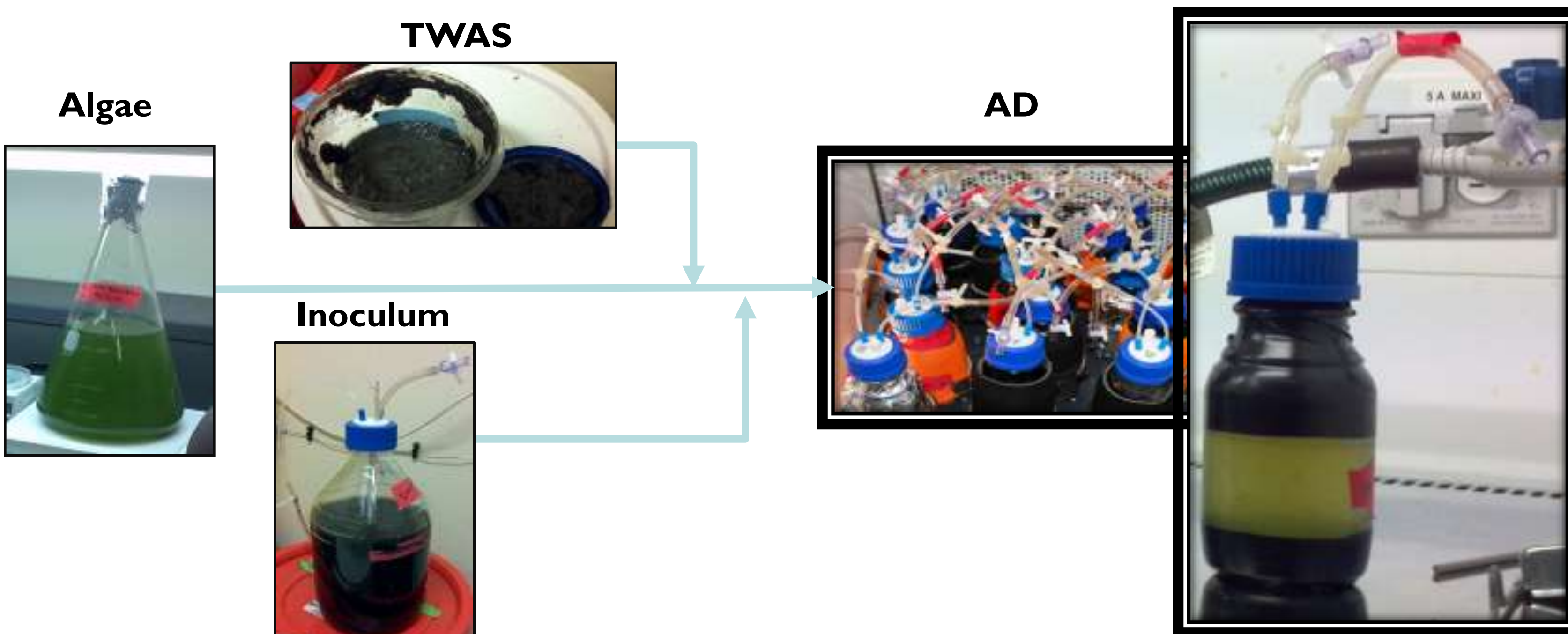
- Investigate the potential of algal biomass as a supplementary feedstock to generate a reliable supply of biogas

- Evaluate the effects of operational parameters for the enhanced AD system pertaining to developing countries



Experimental Approach

- Lab-scale anaerobic digesters were set-up
  - Thickened waste activated sludge (TWAS)
  - *C. vulgaris*
  - Inoculum (seed bacteria)



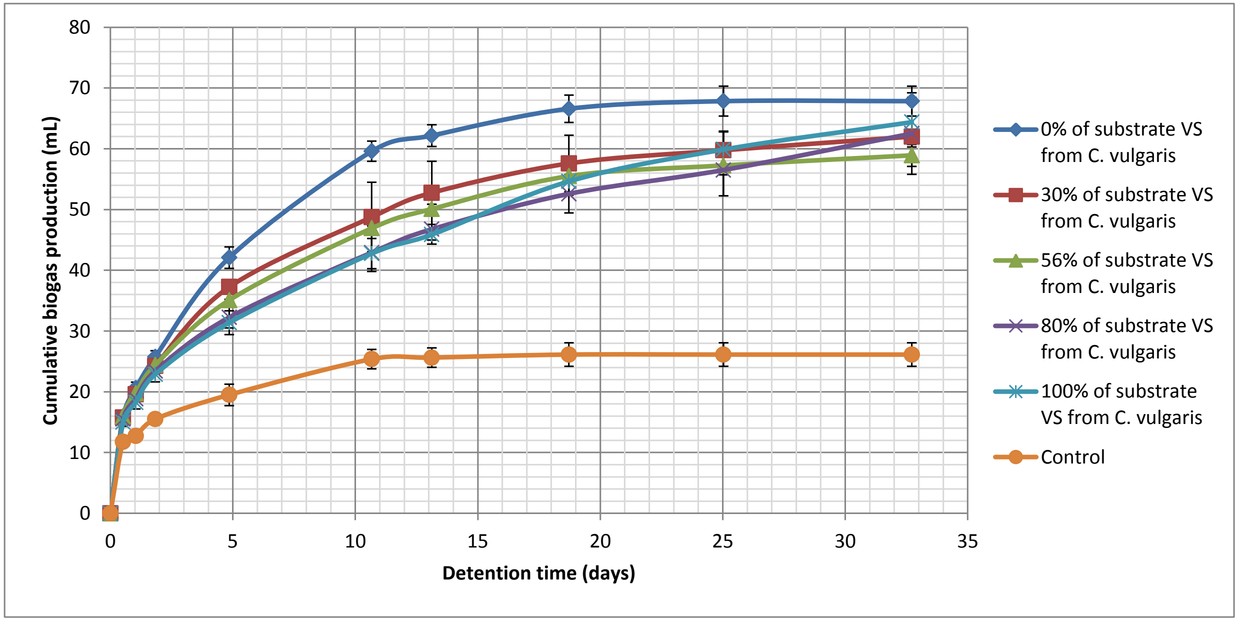
Preliminary Studies

- Determine the ideal substrate (*C. vulgaris* + TWAS) to inoculum ratio
  - 0.5:1, 1:1, and 1.5:1
  - 1:1
- Establish the appropriate substrate VS loading
  - Low – 400 mg per digester or 2 mg/L
  - High – 1500 mg/L per digester or 7.5 mg/L
  - 2 mg/L

Experimental Conditions

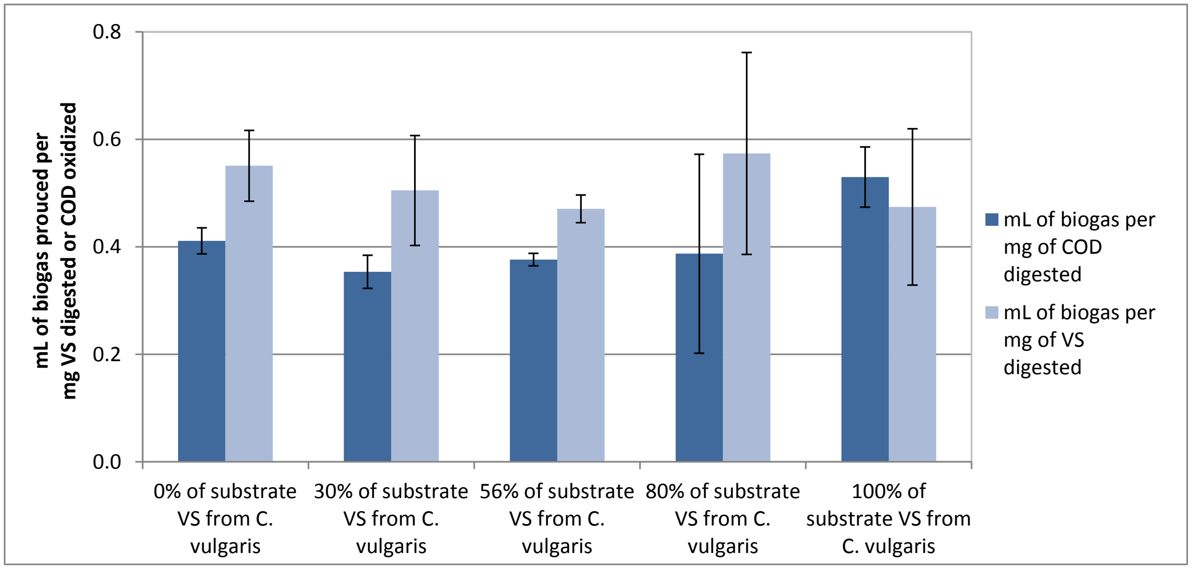
- Contribution *C. vulgaris* to total substrate VS
  - 0, 30, 56, 80, and 100%
- Effect of temperature
  - 10, 20, and 35°C
- Effect of alkalinity
  - 70, 1600, and 3200 mg/L as $CaCO_3$

Potential of Algae as a Supplementary Feedstock



- ANOVA for an $\alpha = 0.5$ ➔ $F = 0.43$, $F_{crt} = 2.53$
  - No significant difference between TWAS and algae as a feedstock

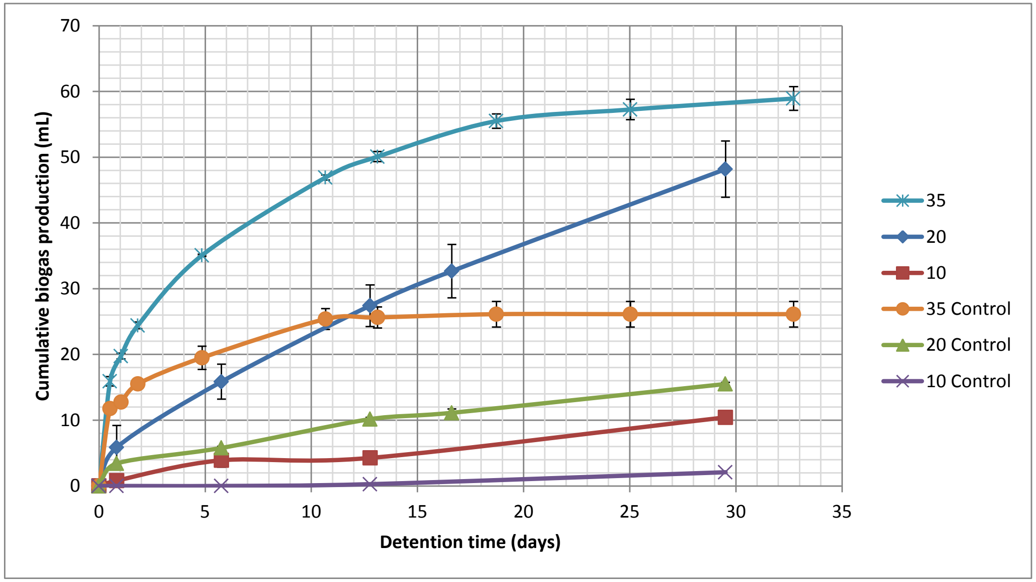
Volume of Biogas Produced per Mass of VS Digested and COD Oxidized



- 0.47 to 0.57 mL biogas per mg VS digested ≈ 0.33 to 0.40 mL CH_4 per mg of VS digested
  - Theoretical yield ~ 0.65 L CH_4/ kg VS digested

Effect of Temperature

- Biogas production decreased with a decrease in temp
- Biogas production at 20°C is almost same as at 35°C
- Biogas production at 10°C is 80% less than at 20°C



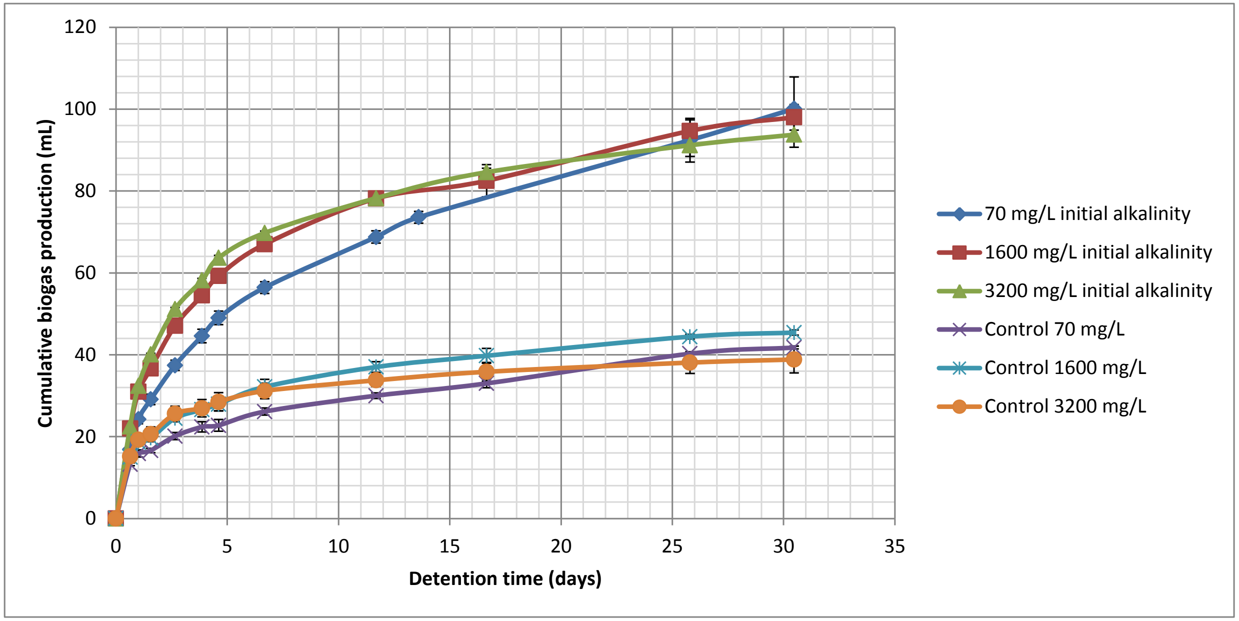
Effect of Alkalinity

- ANOVA

  $\alpha = 0.5$

  $F = 0.23$

  $F_{crt} = 3.28$



- No significant difference

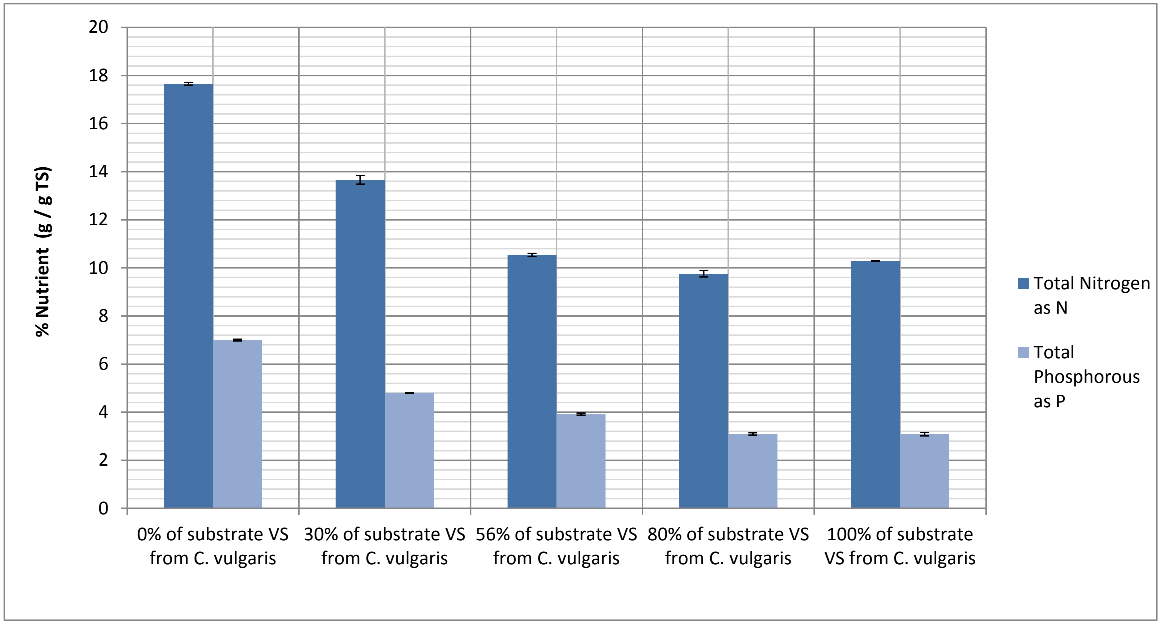
- The alkalinity level increased to 670, 2100, 3450 mg/L as $CaCO_3$

Effect of Alkalinity (Cont.)

- The increase could be due to ammonification
  - $\Delta Alk = 3.57 \Delta N_{am}$
- Algae may also serve as a source of alkalinity
- Ammonia is known to inhibit anaerobic microorganisms

Composition of Residual

- TN varied from 9 to 17% as N (g/g TS)
- TP varied from 3 to 7% as P (7 to 16% as P_2O_5)
- Commercial fertilizer
  - Up to 82% as N
  - Up to 48% as P_2O_5



Reductions in TS, VS and COD

	0% of substrate VS from C. vulgaris	30% of substrate VS from C. vulgaris	56% of substrate VS from C. vulgaris	80% of substrate VS from C. vulgaris	100% of substrate VS from C. vulgaris
Initial TS (mg/L)	1700	1900	2100	2300	2400
Initial VS (mg/L)	1200	1300	1300	1400	1400
Initial COD (mg/L)	2100	2100	2200	2200	2200
% TS reduction	42	33	30	25	31
% VS reduction	49	51	48	42	51
% COD reduction	40	45	37	39	29

- A VS reduction of 38% or higher was achieved, and therefore, the residuals meet vector attraction reduction requirements for land application

Reductions in Total and Fecal Coliforms

	0% of substrate VS from C. vulgaris	30% of substrate VS from C. vulgaris	56% of substrate VS from C. vulgaris	80% of substrate VS from C. vulgaris	100% of substrate VS from C. vulgaris
Initial TC (CFU/g TS)	$7.3x10^6$	$5.6x10^6$	$4.1x10^6$	$2.8x10^6$	$1.8x10^6$
Initial FC (CFU/g TS)	$2.4x10^6$	$1.7x10^6$	$1.1x10^6$	$5.8x10^5$	$1.7x10^5$
Final TC (CFU/g TS)	$2.8x10^6$	$5.0x10^5$	$7.9x10^4$	$1.2x10^5$	$2.5x10^5$
Final FC (CFU/g TS)	$3.2x10^3$	$3.2x10^4$	$1.8x10^4$	$5.1x10^3$	$1.3x10^4$
% TC reduction	67.61	69.84	73.12	79.26	90.17
% FC reduction	99.89	93.58	76.90	95.82	94.97

- Residuals meet the EPA requirements for pathogen reduction (FC < $2x10^6$ CFU/g TS) for land application

On-going and Future Works

- Conduct addional experiments for extended detention times
- Size the AD systems with multiple capacities on the basis of pupation served [Preliminary]
- Validate the bench-scale data with pilot-scale testing

The Potential

- The enhanced AD process can be designed to **collect**, **contain** and **treat** waste in the same reactor, making it suitable for rural and urban communities with no sewer connections
- It can be built from locally available materials
- Unlike conventional AD systems, the enhanced AD system can be operated and managed by individuals with minimal training and does not require complex monitoring equipment

The Potential (Cont.)

- It is versatile and the design can be modified to fit for communities of all income levels
- Furthermore, it can be scaled to treat waste at any size facility, from a group of households at rural communities to a high rise building in big cities

Concluding Remarks

- The enhanced AD has the potential to be developed into a reliable, inexpensive, and sustainable waste treatment technology with several benefits such as:
  - an increase in access to improved sanitation facilities,
  - a reduction in the release of untreated waste to the environment,
  - reduction in deaths from diseases contracted from food and water tainted with fecal matter, and
  - the recovery of valuable resources – biogas and biosolids.

Acknowledgements

BILL & MELINDA GATES foundation

SAN ELIJO JOINT POWERS AUTHORITY

Thank you!

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