Anaerobic Digestion Pasteurization Latrine - Two Year Study of an Innovative Fecal Sludge Treatment System in Eldoret, Kenya

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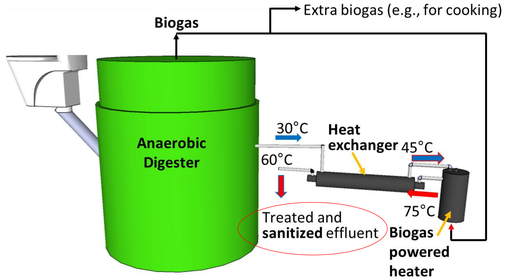
Background

The overall objective of the Anaerobic Digestion Pasteurization Latrine (ADPL) is to provide self-contained and energy neutral on-site sanitation using anaerobic digestion of human wastes to generate biogas, and then use the biogas to pasteurize the treated effluent.



The concept was investigated in the lab with a 17 L floating dome anaerobic digester treating simulant feces and urine. An efficient biogas-powered pasteurization system was also developed. Key findings were that anaerobic digestion of undiluted human waste yields sufficient biogas to maintain continuous operation of the pasteurization at 75 °C, within the 55-75 °C range known to provide several log reductions of bacteria, virus, and helminth ova. (see Colon, Forbis-Stokes, Deshusses; Energy Sustain. Dev., 2015)

Parameter	Value
Organic Loading Rate, OLR ($kg_{COD}/(m^3 d)$)	1.78
Total N_{in} (mg/L)	5,200
Biogas Yield (m^3_{biogas}/kg_{COD})	0.42
CH_4 (% vol.)	63.0
COD Removal (%)	71.1
NH_3-N out (mg/L)	3,800
pH	7.6

Objectives & Methods

The goal of the demonstration was to prove the concept's success in the lab would translate to field conditions. Demonstration partners at the University of Eldoret (UoE, School of Environmental Sciences) and Wataalamu Repair & Maintenance were in engaged for study implementation. UoE students monitored system operation daily and provided data for gas production and heating temperature. These values determine if digestion provides sufficient energy to maintain temperatures between our target 65-75 °C. Sample collection and laboratory analysis would provide additional information on digestion operation.

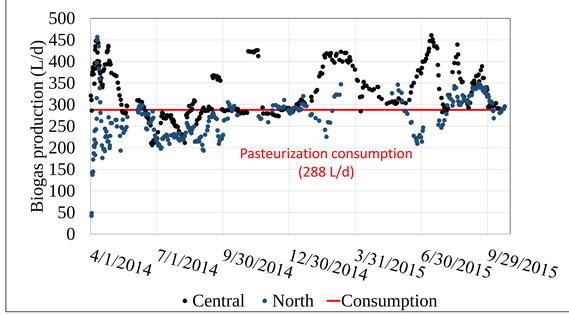
Study Site

In June 2013, three systems were installed in a peri-urban area outside of Eldoret, Kenya, near UoE. Each system was comprised of 3 toilets built above a floating dome digester and heating system, using gravity-induced flows, on a 3m × 3m footprint. Site characteristics were compounds with shared pit latrines and borehole water well. Sites designated as "North," "Central," and "South" had 17, 35, and 24 residents, respectively (shown on map, top left).

Adoption at two sites was successful, and residents reported that the system (compared to their pit latrines) is easier to keep clean, has little to no odor or flies. They were interested in the possibility of excess biogas and effluent reuse. Toilet usage at the third site (South) was unsatisfactory. It is believed to be due to disinterest of site owner and perceived inconvenience of users to ascend stairs to the toilets. However, usage has increased since August 2015 with new tenants at this location.

Results

Biogas production was determined daily (see Figure below). Biogas production at Central consistently remained above the consumption rate, except for June-August. The majority of residents are university students, and were away from campus during this period which may explain decrease in production. North experienced a production shortage during this period as well as in June 2015. The excess biogas amount at North was lower than that of Central.



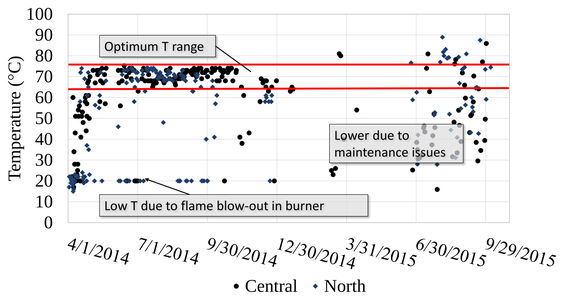
Results

Average digester operational values (with standard deviations) are displayed below. Due to the difficulty of obtaining representative samples in the digester inlet, inlet values are estimated based on complete toilet usage by all residents at each site and adding 1 L pour flush water per defecation event.

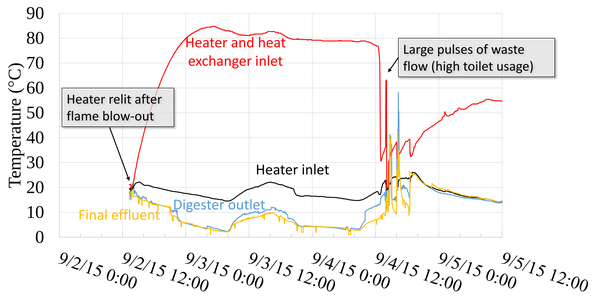
Parameter	Inlet	Outlet Central	Outlet North
COD (mg/L)	42,100-42,500	5,560 (3,740)	4,540 (2,550)
BOD (mg/L)	-	3,910 (2,301)	2,050 (1,310)
TSS (mg/L)	4,060-4,520	3,570 (2,300)	2,130 (1,620)
NH_3-N (mg/L)	3,030-4,200	4,760 (1,090)	2,420 (510)
pH	6.1	7.3 (0.1)	7.1 (0.6)
Biogas prod. (L/d)	-	332 (125)	287 (136)
Yield (m^3_{biogas}/kg_{COD})	-	0.09	0.17

Biogas yield was much lower than found in lab studies. This may be due to under-reporting biogas production when storage capacity is exceeded and biogas leaks (often at Central) and/or overestimation of toilet usage leading to erroneous inlet load.

Daily temperature measurements taken in the heating tank show that during May-December 2014, temperatures remained within the desired range 87% and 58% of the days at Central and North, respectively.



Continuous temperature data collection at North over 2.5 days is shown below.



Discussion

Though biogas production was consistently sufficient for energy demand, temperatures often were not in the appropriate range. The majority of temperature failures were found to be due to hardware or operating issues such as flame blow-out, or burner corrosion and clogging stopping the heat supply. This stimulated implementation (in November 2015) of low-cost microcontrollers to ensure the flame is lit, heating tank operation at 65-75 °C at all times, and will save biogas by cutting supply when not needed. Further, the heating system hardware has a lifespan of 2-3 years as shown by increased failures in July 2015 indicating the need for replacement parts.

Additional applications

The ADPL has also been implemented in Toledo, Cebu, Philippines (left & center), and Chennai, India (right). These two units are designed to serve 10 and 50 users, respectively.

Each of these units has proven to be able to provide sufficient energy from anaerobic digestion to power its own pasteurization as seen in the table below.

Parameter	Lab	Kenya	Philippines	India
Number of users	0.3	25	10	50
Digester volume (L)	17	1,500	450	2,000
COD removal (%)	71	88	-	99
pH	7.6	7.2	7.9	7.0
Biogas production (L/d)	12.7	330	240	362
Yield (m^3_{biogas}/kg_{COD})	0.42	0.13	0.32	0.29
Biogas consumption (L/d)	-	288	144	360

Conclusions

The ADPL concept of using anaerobic digestion of human waste to power its own sterilization has been successful in both laboratory and field conditions. The system is simple, requires no outside energy or moving parts, applicable in many contexts, and low-cost. All materials for installations were locally purchased or fabricated, and the total cost of initial installation is roughly $2000 for 20-30 users. Maintenance needs are low. With a 10 year life for the digester and 2-3 years for the heat sterilization system, cost comes to 2.1 to 3.2 cents per user per day (without factoring energy/fertilizer benefits).

Acknowledgements: Funding by the Bill & Melinda Gates Foundation (GCE Round 7 and follow on funds), Duke Global Health Institute, Tesari Foundation.

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