Sanivation
Sanitation as a Service

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Solar Thermal Powered Feces Heat Exchanger Project Plan

Sanivation Overview

More people in Africa have access to a cell phone than toilet. We're changing that and over the next five years we are planning to serve 1 million people with safe and efficient sanitation services. Simply, we install modern container-based toilets in the homes of the urban poor for free and charge a small monthly fee to service them. Then, instead of dumping the waste, we transform it into a clean burning alternative to charcoal. Our dependable, user-focused, and vertically integrated sanitation services allow families living in urbanizing communities throughout East Africa to live a modern and healthy life.

Our model

Waste treatment Goals

Sanivation uses solar thermal energy to cost effectively inactivate pathogens and render the waste safe for reuse and processing into charcoal briquettes. We have demonstrated our ability to render waste safe for reuse on a small scale with Centers for Disease Control and Prevention and when selling our briquettes at the same price of charcoal, we ran out of supply.

Sanivation's target market for waste treatment is able to safely process waste in urban areas and peri-urban in Kenya. We've identified 17 markets that have populations over 150,000 in which we could work and serve 2,000-20,000 households. Most of these areas have good sun for 10+ months out of the year.

We are currently looking to pilot a system that meets the demand for 500 households~700L a day. The idea here is we are going to continue iterating on the treatment approach as we scale but want something that is cost effective in the short term and give us a strong proof point that we could do this at a scale of 2,000-10,000 toilets.

Our current heat treatment method is to use parabolic trough mirrors to heat-treat batches of feces. This requires heating the feces to 65C for over four hours. This system is too small of scale and we need to scale treatment as we gain more customers.

We want a system in which we have more control and has potential to be backup when it's not sunny. This led us to using a working fluid. We also want a system in which we can input infectious waste and outputs treated waste with little human/worker interaction, which when combined with working fluid/heat exchanger led us to the screw. However maybe there is a better approach?

Project Purpose

We aim to design and pilot a heat treatment system that can treat the human waste produced by 500 toilets. This translates to **750 kg/day** of feces and very roughly **225 MJ/day** of energy. This is assuming the feces starts at 10C and must be heated to 85C and has a specific heat of 4 KJ/kgK.

In order to guarantee pathogen inactivation, the feces depends must be heated above a given temperature for a set amount of time. There are different options for this time-temperature trade off. We propose two possible treatment regimes:

- 65C for 4 hours
- 85C for 1 hour
- 95C for 30 minutes

Summary of Heat Needs: Ability to heat 750kg/d of feces to 85C and keep it above 85C for at least one hour.

Proposed Solution

We will continue to use solar energy and propose installing a 16m^2 parabolic dish that will provide heat to a heating fluid that will then be passed through a heat exchanger to heat the feces.

Parabolic Mirror: Altener Energy Technologies has proposed using a 16m2 parabolic dish to provide heat for the system. The advantage of a dish is that it has a small focal point, so it can heat a smaller area, enabling the larger storage tank to be well insulated. A storage tank will provide a back up supply of heat if the sun goes behind a cloud. The 16m2 dish provides a similar amount to energy as is needed for 500 toilet sized system, so it provides an appropriately sized modular system for Sanivation's scaling goals. The parabolic mirror can be used with water or an oil based heating fluid.

Heat Exchanger: Due to the high viscosity of feces, a traditional heat exchanger is apt to clog. The heat exchanger will be similar to a tube heat exchanger, except the inner-tube will include an Archimedes screw that will facilitate the flow of the feces through the system. The screw will minimize the build up of fouling residue and boundary layer on the tube, which would limit heat transfer. The screw will be attached to a motor and gearbox, which will enable some variation of the rate of feces flow. Being able to control the rate of feces flow is important for providing increased control, and enabling a decrease in flow if full treatment is not being reached.

For the 85C for 1 hour treatment regime, the feces will enter the heat exchanger at about 15C and will need to leave at ~85C. Therefore the heating fluid could possibly be water, but an oil fluid is desirable because it can be heated to higher temperatures, which increases control over the treatment process.

The design of the heat exchanger will be based on existing industry designs. The assumption is that industry designs are optimized to provide the most efficient heat transfer. Scraped surface heat exchangers are designed for viscous and high fouling fluids and are hypothesized to be the best design for fecal sludge. There fore, the geometry and materials of the heat exchanger will be similar to scraped surface heat exchangers.

In addition to needing to heat the feces, we need to keep it above a given temperature for a set residence time. To ensure this, we are considering extending the tube containing the feces beyond the heat exchanger and adding a well-insulated tank that is designed to keep the feces above a set temperature. The length of the insulated tank will be correlated with the expected rate of feces flow, so that the feces stays in the insulated tank for longer than the required residence time.

The following table summarizes relevant values that must be known in order to design the heat exchanger.

Property	Feces	Heating Fluid
Process Data		
Mass Flow Rate	X	Based on industry standard
Inlet Temperature	15C	Depends on Fluid
Outlet Temperature	85-90C	Depends on Fluid
Fluid Properties		
Density	1.27 kg/L	X
Specific Heat	2430 kJ/kgK	X
Thermal Conductivity	0.52 W/mK	X
Viscosity	tbd	X

The figure below shows the proposed design for the heat exchanger. Note this is just a visual schematic and is not to scale. The temperature profile is also just a visual schematic for increased clarity and is not accurate.