Solar Disinfection of Anaerobic Digester Effluent from Human Waste Treatment

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Abstract

Anaerobic digestion (AD) is a biological method of treating organic waste in the absence of oxygen. Benefits of a controlled AD system include production of renewable energy (biogas) and a nutrient-rich digested effluent that can be land applied as a biofertilizer for agriculture. Efforts to use AD to help developing countries improve sanitation and increase crop and renewable energy production are ongoing. However, when AD is applied to treat human waste, harmful parasites can persist in the digestate, posing a potential health hazard. The purpose of this project was to develop and evaluate a disinfection stage to follow the AD process: solar sanitation. The conceptual design consists of piping the digestate to holding tanks and harnessing solar energy for thermal inactivation. Temperature conditions necessary for parasite inactivation were determined using *Ascaris* as a model organism since it is among the most resilient and prevalent parasitic helminths in many developing countries. Plastic tanks were filled with water as the test medium, painted black for maximum solar gain, and fitted with solar reflectors and temperature data loggers. The tanks were evaluated in various sizes and temperatures above 50ºC were attained for sufficient time to inactivate the model parasite.

Introduction

AD is a common solution for human waste treatment in developing countries because it is a relatively simple and inexpensive technology that produces valuable end-products of methane and nutrient rich soil amendment. Since most digesters are operated at 35°C, there is a concern over the spread of infectious diseases. *Ascaris* was used as a model in this study to define the parameters required for inactivation since it is one of the most resilient and easily transmissible pathogens found in human waste. *Ascaris* facts:

- The largest intestinal roundworm
- Most common helminth infecting humans worldwide
- Eggs (50 µm in diameter) are found in human feces
- Transmission occurs through ingestion of infective eggs from soil or contaminated food

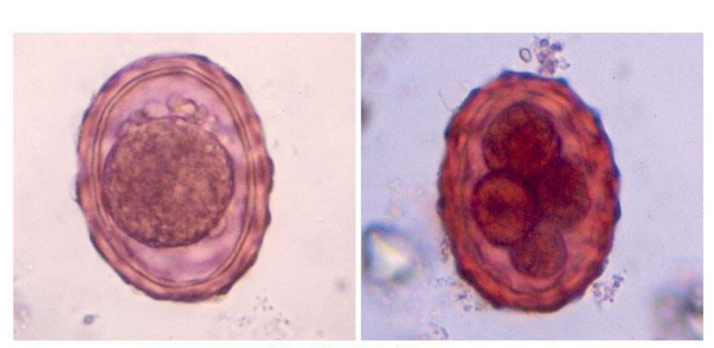

Figure 1. Ascaris in different growth stages

Objectives

A. To determine the conditions required to inactive the model pathogen.
B. Build prototypes for solar collection and determine maximum temperatures that can be achieved.
C. Design an inexpensive system that can be applied to a community-based anaerobic digester in a developing country.

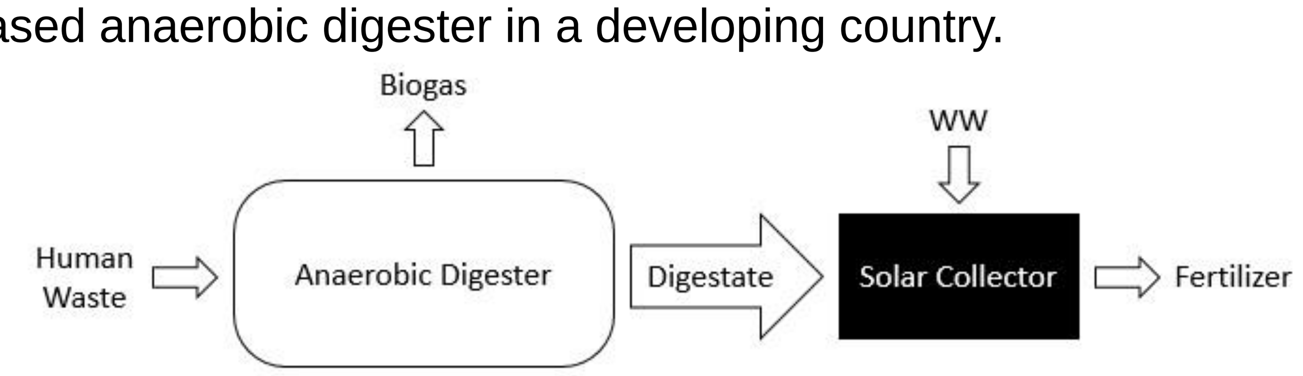

Figure 2. Conceptual Design for AD Solar Disinfection System

Methods

- Literature review to determine conditions for *Ascaris* inactivation
- Build solar collection prototypes
  - Two different sizes - 0.5 gallons and 5.0 gallons
  - Reflective material for experimental prototypes
  - Black paint only for controls
- Install data loggers for temperature monitoring over 24-hr periods
- Compare temperature monitoring results with conditions for inactivation

Results

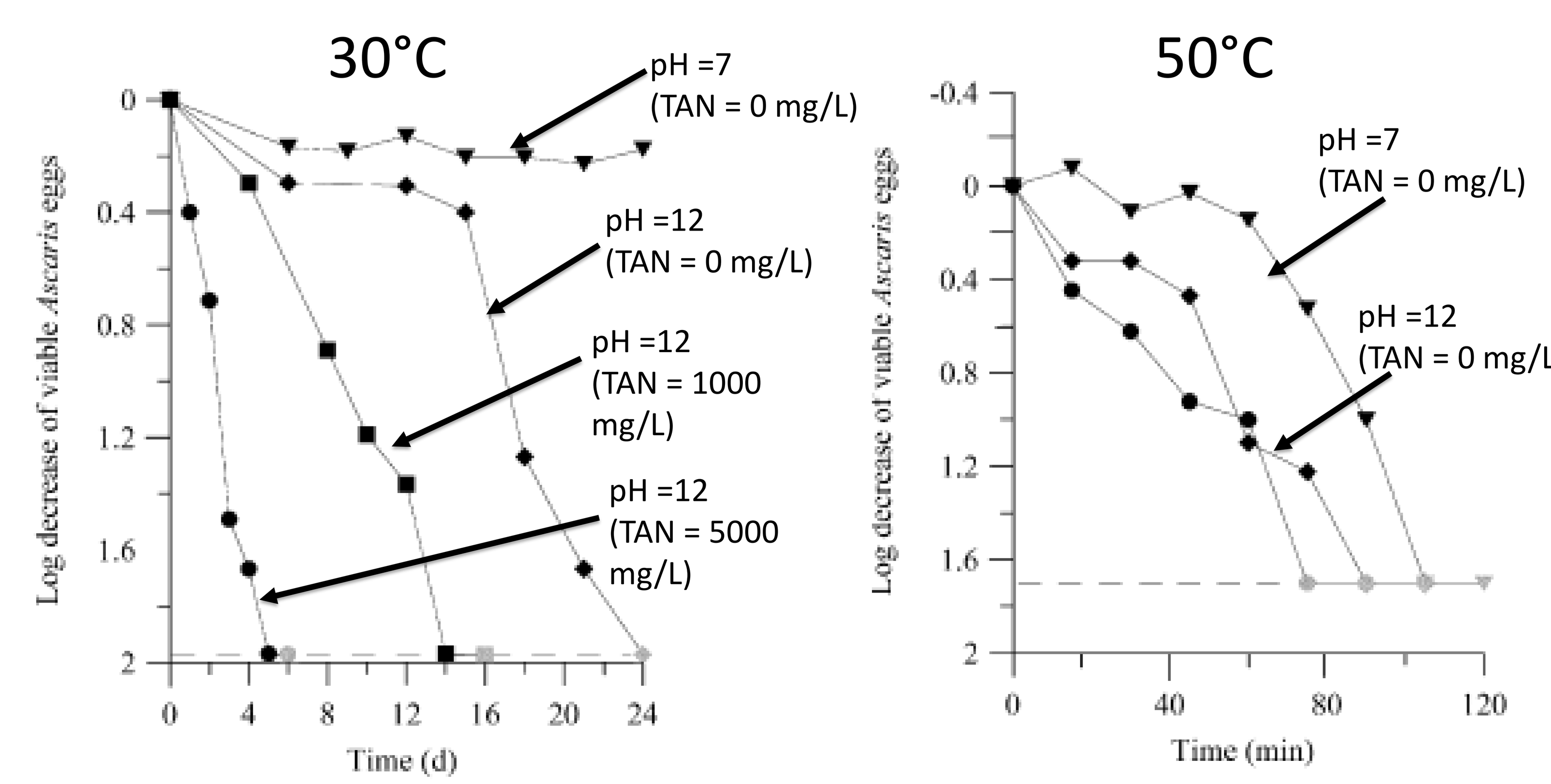

Figure 3. Ascaris Inactivation as a Function of Temperature and Total Ammonia Nitrogen (TAN) Concentrations (Pecson et al., 2007)

Ascaris inactivation is dependent on temperature, pH and total ammonia nitrogen (TAN) concentrations. At a low temperature (30°C), *Ascaris* inactivation (2-log removal) required a pH of 12 for 4 to 24 days depending on the TAN concentration (Pecson et al., 2007). However, at a higher temperature (50°C), *Ascaris* was inactivated within 2 hours without any influence of pH or TAN. Thus, the experimental prototypes were designed to collect sufficient heat for *Ascaris* inactivation.

Figure 4. Experimental Prototype Design for Solar Collector

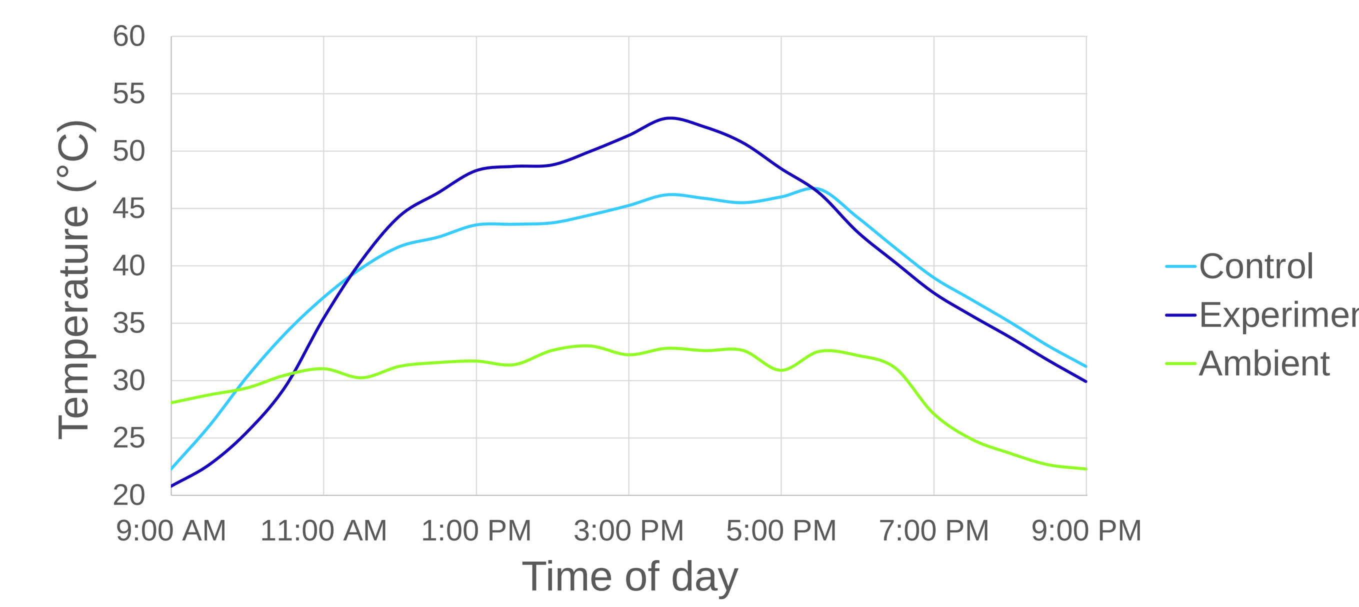

Figure 5. Temperature Data for Small (0.5 gallon) Prototype

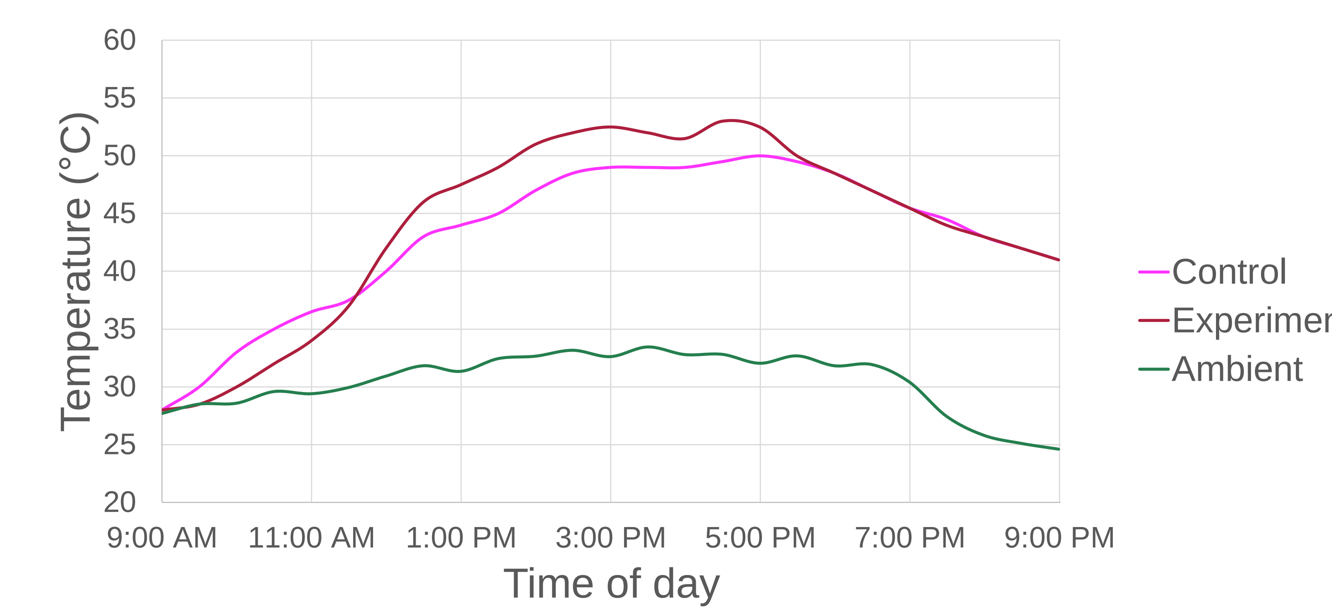

Figure 6. Temperature Data for Large (5.0 gallon) Prototype

The small experimental collector attained temperatures of at least 50°C for 2hr, with a maximum temperature of 52.9°C. The small control volume never exceeded 50°C. The large experimental volume attained temperatures of at least 50°C for 3hr, with a maximum temperature of 53.0°C. The large control volume reached 50°C for 1hr.

Conclusions

- Minimal requirements for *Ascaris* inactivation are 50°C for 2 hrs.
- The experimental prototypes (both small and large) reached conditions for *Ascaris* inactivation within a 12-hour monitoring cycle, while the controls failed to reach those conditions.

Future Work

Further studies should incorporate human and animal waste into the solar collector design to monitor changes in temperature, pH and TAN over variable time intervals to minimize time required for disinfection. In addition, a continuous flow model should be developed for application in developing countries.

References

1. Pecson, B.M., J.A. Barrios, B.E. JimÃ©nez, and K.L. Nelson. 2007. The effects of temperature, pH, and ammonia concentration on the inactivation of *Ascaris* eggs in sewage sludge. Water Res. 41:2893-2902.

Acknowledgements

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