Producing Energy and Fertilizer from Organic Municipal Solid Waste: A novel High Solids Anaerobic Digestion (HSAD) System

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Introduction

The purpose of this project was to develop and test an innovative High Solids Anaerobic Digestion (HSAD) System (Figure 1) for the biological treatment of organic wastes.

This system provides an alternative to composting and landfill by:

- Utilizing a high rate liquid digester to efficiently convert low solids organic waste to methane and produce methanogenic bacteria for seeding of the high solids digester.
- Optimizing operating parameters to accept widely variable ratios of solid and liquid organic wastes.

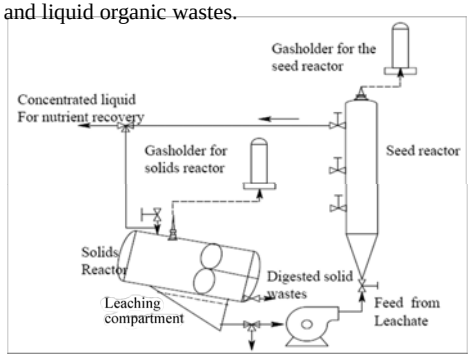

Figure 1: High Solids Anaerobic Digestion Process Flow Diagram

Available Biomass

Washington State produces about 750 thousand dry tons/year of organic wastes that are suitable for HSAD. This system can produce methane by utilizing both the solid and the liquid fractions of these wastes. Full utilization of these wastes (Figure 2) would offset about 730 million kW-h of conventional energy production.

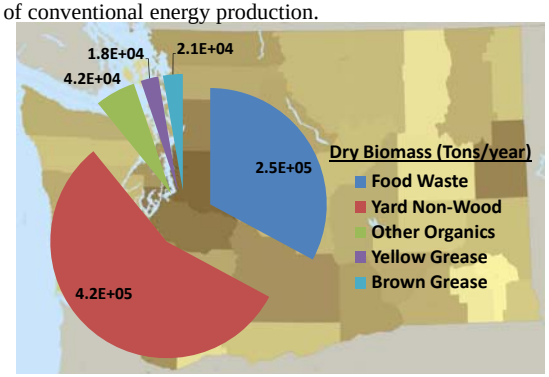

Figure 2: Suitable biomass available for HSAD

HSAD Research Challenges

Anaerobic digestion of high solids organic waste (defined to be total solids content above 10%) is challenging for the following reasons:

- High organic loading rates (inhibiting to methanogenic bacteria)
- High cost of mixing solids (difficult to pump and stir)
- Difficulty in providing adequate residence time for both solids and liquids (volatile liquids generally have shorter stabilization time)

Research Methods

Laboratory-scale experiments

- A batch digester was run to determine baseline performance for food waste.
- A high rate liquid digester was run to determine methanogenic bacterial growth parameters.
- The innovative HSAD system was run to determine operating and design parameters (Figure 3).

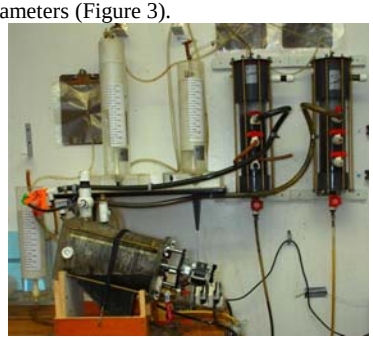

Figure 3: Experimental High Solids Anaerobic Digestion System

Mathematical Modeling

A set of mathematical models was developed using MATLAB® and Simulink® (Figure 4) to define the process kinetics of this system and to:

- Optimize process parameters needed for scale-up design
- Evaluate system economics.

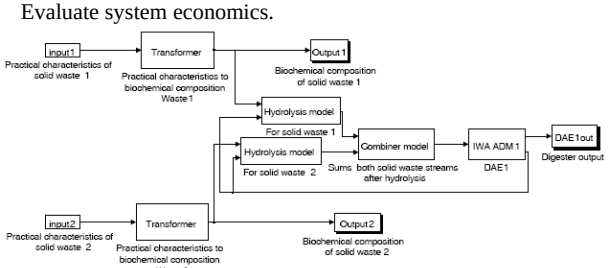

Figure 4: The GISCOD model in Simulink®

Results

The results from both the laboratory-scale experiments and the mathematical modeling point to several key parameters that this innovative HSAD system improves upon compared to existing waste treatment technologies:

- This system produces more methane per digester volume (4.62 m^3/m^3/day), has a higher solids loading rate (0.06 ton/m^3/day), and has a higher volatile organic loading rate (0.04 ton/m^3/day).
- This system demonstrated a 47% chemical oxygen demand (COD) removal and 70% solids removal
- This system produces energy at an estimated $1 kW-h, which is an approximate savings of $0.48 kW-h. This cost is normalized to include capital cost, solids recycle, and liquid recycle--per unit volume of organic waste.
- This system optimizes solids mixing and recycling by decoupling hydraulic retention time (HRT) from solids retention time (SRT). Based on an average solids mixing cost of $4.94/$m^3$, this system will reduce mixing cost by about 75%.
- This system can be coupled to a nutrient recover system to efficiently and economically remove nitrogen and phosphorus from the closed liquid recycle loop. From Food waste alone, it is estimated that 2.1 kg/ton nitrogen and 3.72 kg/ton phosphorus can be recovered in mineralized form.

Public Benefit to Washington State

There are four key benefits to the public from the development of this new system:

1) By building smaller volume digesters with high loading rates, the public can save $75+ million annually for solid waste treatment using this system compared to existing waste treatment technologies.
2) This system significantly reduces the emissions of odors and waste gases by utilizing a closed waste treatment cycle. This will improve air quality compared to existing waste treatment technologies.
3) Excess nutrients can be recovered from the concentrated liquid recycle stream and used as fertilizers. This will improve water quality compared to existing waste treatment technologies.
4) Methane rich biogas is efficiently captured and can be further purified using the nutrient recovery system to provide a renewable source of combined heat and power (CHP).

Acknowledgments

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