From Waste to Power: Smart Atomization for a Sustainable Future

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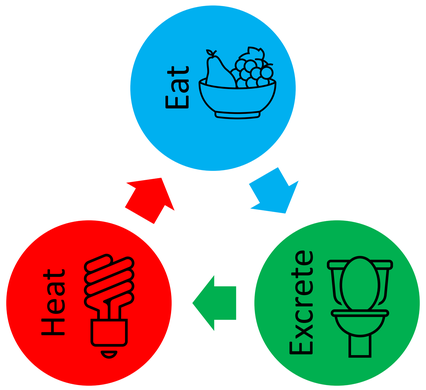
Background

Challenges and opportunity for the modern world: two major challenges are ever-increasing production of human waste and enormous energy needs. Both issues can be addressed with waste-to-energy conversion technology.

Current technology: digestion, gasification, pyrolysis. Deficiencies: long waits, dilution, drying operations.

Importance: New, efficient energy conversion technology can address numerous global issues including fossil fuel scarcity, clean air, clean water shortage, food safety, and disease control.

Goal: Sustainable Energy Cycle



Introduction

Objective: efficient waste-to-energy conversion via direct spray injection of highly concentrated biosludge into boiler for combustion

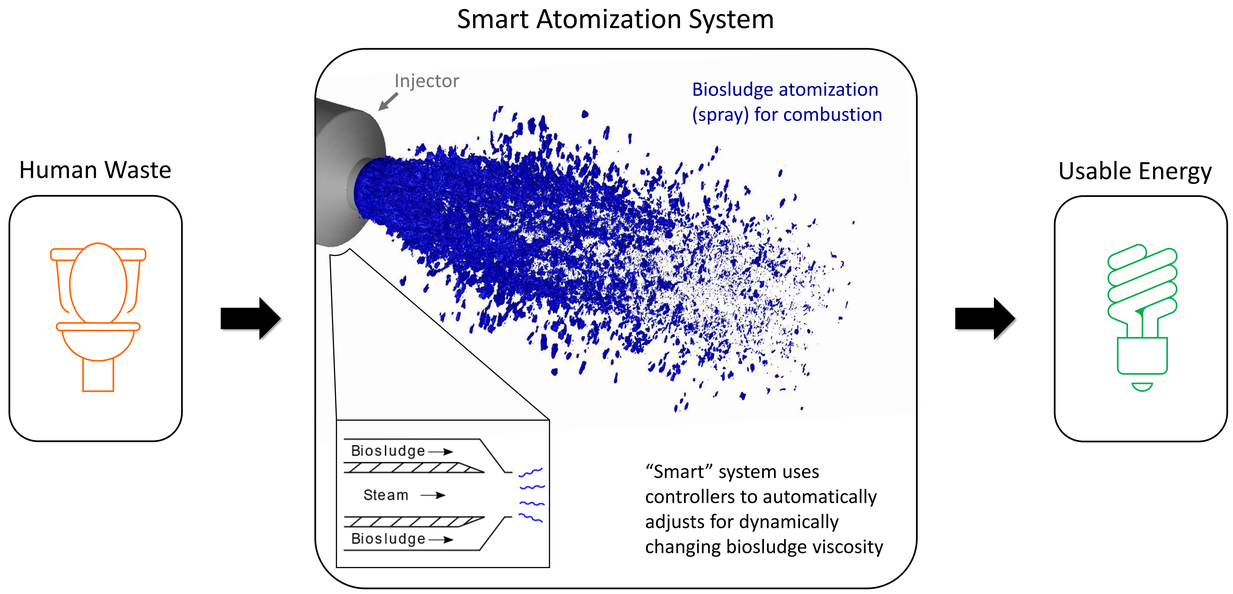
- *Biosludge:* human waste sludge
- *Boiler:* energy harvesting equipment
- *Spray (atomization):* high surface-area-to-volume ratio for drying and combustion

Difficulty: viscosity of biosludge varies widely

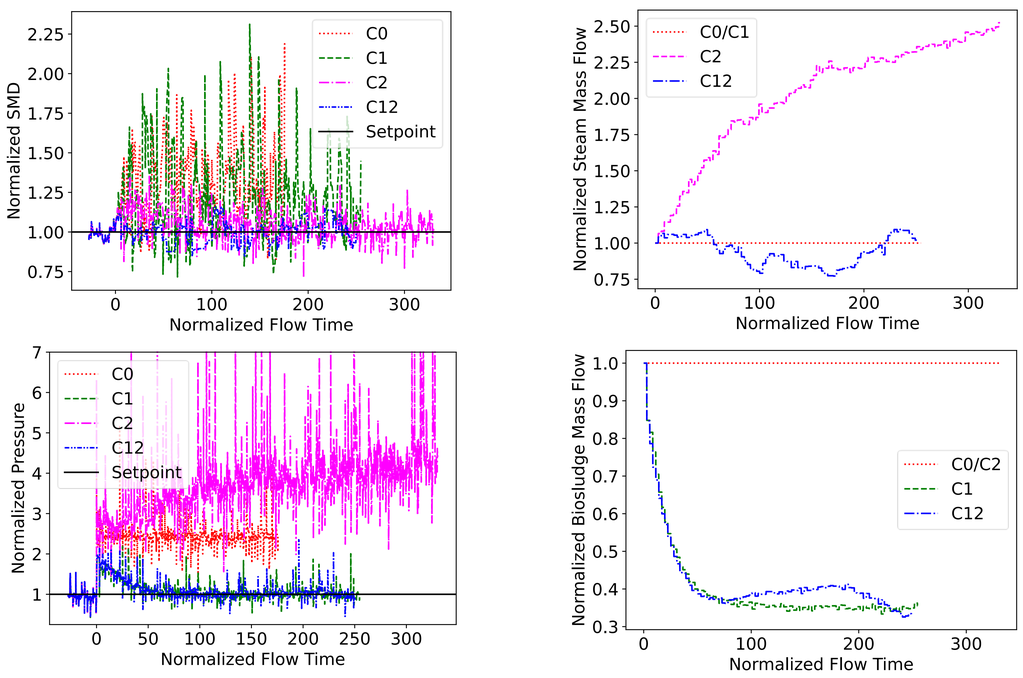
- High viscosity → large pressure drop restricts flow → poor atomization quality

Smart atomization: self-corrects to account for dynamically changing biosludge viscosity using 2 proportional integral derivative (PID) controllers

"Smart atomization" could enable **new waste-to-energy conversion technology** by effectively spraying **variable-viscosity** biosludge into a boiler for combustion



Initial tests demonstrate **efficacy of a coupled controller smart atomization system** through a 100-fold increase in biosludge viscosity



Figures 1-4. *Pressure and SMD controller responses to a 100-fold increase in biosludge viscosity at Normalized Flow Time = 0 demonstrating 1) the efficacy of the coupled controller system and 2) the need for* ***both*** *C1 and C2.*

Methods

Approach: use CFD to simulate smart biosludge atomization with steam-assisted, twin-fluid atomizer and 2 PID controllers

1. Biosludge flow controller (C1)
   Automates flow of biosludge to maintain constant biosludge pump requirement (pressure) for varying viscosity
2. Steam flow controller (C2)
   Automates flow of steam to maintain consistent droplet size (quantified by SMD) for varying viscosity

CFD = computational fluid dynamics
SMD = Sauter Mean Diameter (representative droplet size)

Results

Controller tests: controller performance was evaluated for four scenarios across a 100-fold increase in biosludge viscosity (0.05 → 5 kg/m-s at Normalized Flow Time = 0)

- C0 = no controllers
- C1 = only C1 controller
- C2 = only C2 controller
- C12 = C1 + C2 coupled controller system

Pressure results:

- C0 → pressure increases by 150%
- C2 → pressure increases by 320%
- C1, C12 → flow adjusts, pressure returned to setpoint

SMD (droplet size) results:

- C0 → SMD increases by 40%
- C1 → SMD increases by 20%
- C2, C12 → flow adjusts, SMD returned to setpoint

Conclusions

1. Initial tests demonstrate 1) the efficacy of the coupled controller system and 2) the need for *both* C1 and C2.
2. Smart atomization is a feasible means for direct spray injection of variable-viscosity biosludge into a boiler for efficient waste-to-energy conversion.