Treatment of Fecal Sludge in a Prototype Supercritical Water Oxidation Reactor

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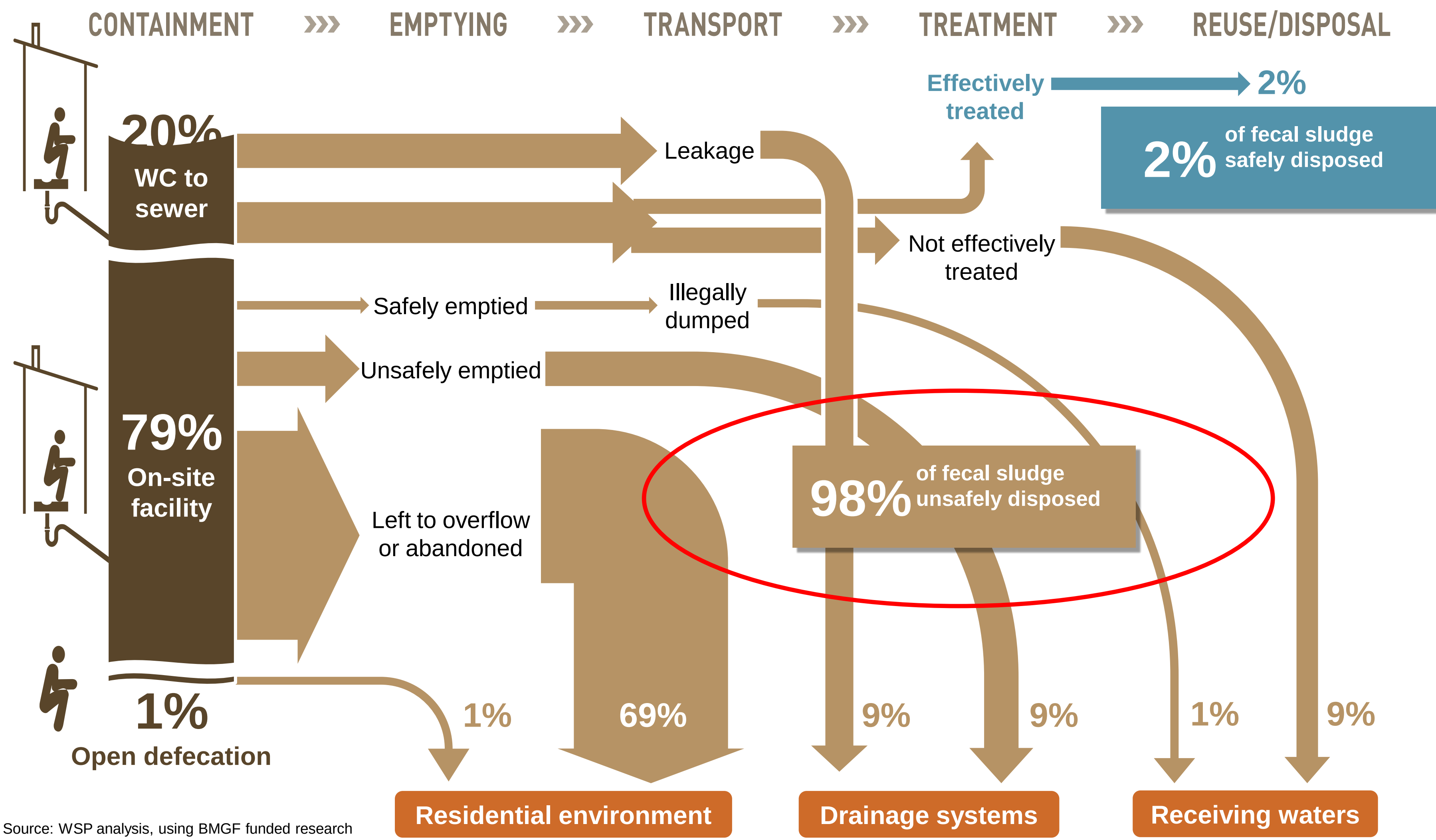
POOR FSM: INSTITUTIONAL OPEN DEFECATION

Untreated sludge ends directly in the environment: no service chain (Dhaka, Bangladesh)



Source: WSP analysis, using BMGF funded research

Content of Fecal Waste

Feces: 70-520 g/(p day) ~ 80% moisture

- Fats (5-25%)
- Carbohydrates (10-30 %)
- Nitrogenous materials (2-3%)
- Minerals (5-8%)
- Bacteria and bacterial debris (10-30%)

Where all pathogens and most of the energy is

~80 g_{dry} , 107 g COD, ~2 g N, **1.6 MJ per day**

Urine: 0.6 – 1.1 L/(p day)

- Organic salts (38%)
- Urea (36%)
- Organic compounds (13%)
- Ammonium salts (13%)

Is where most of the nitrogen is ~7 gN/(p day)

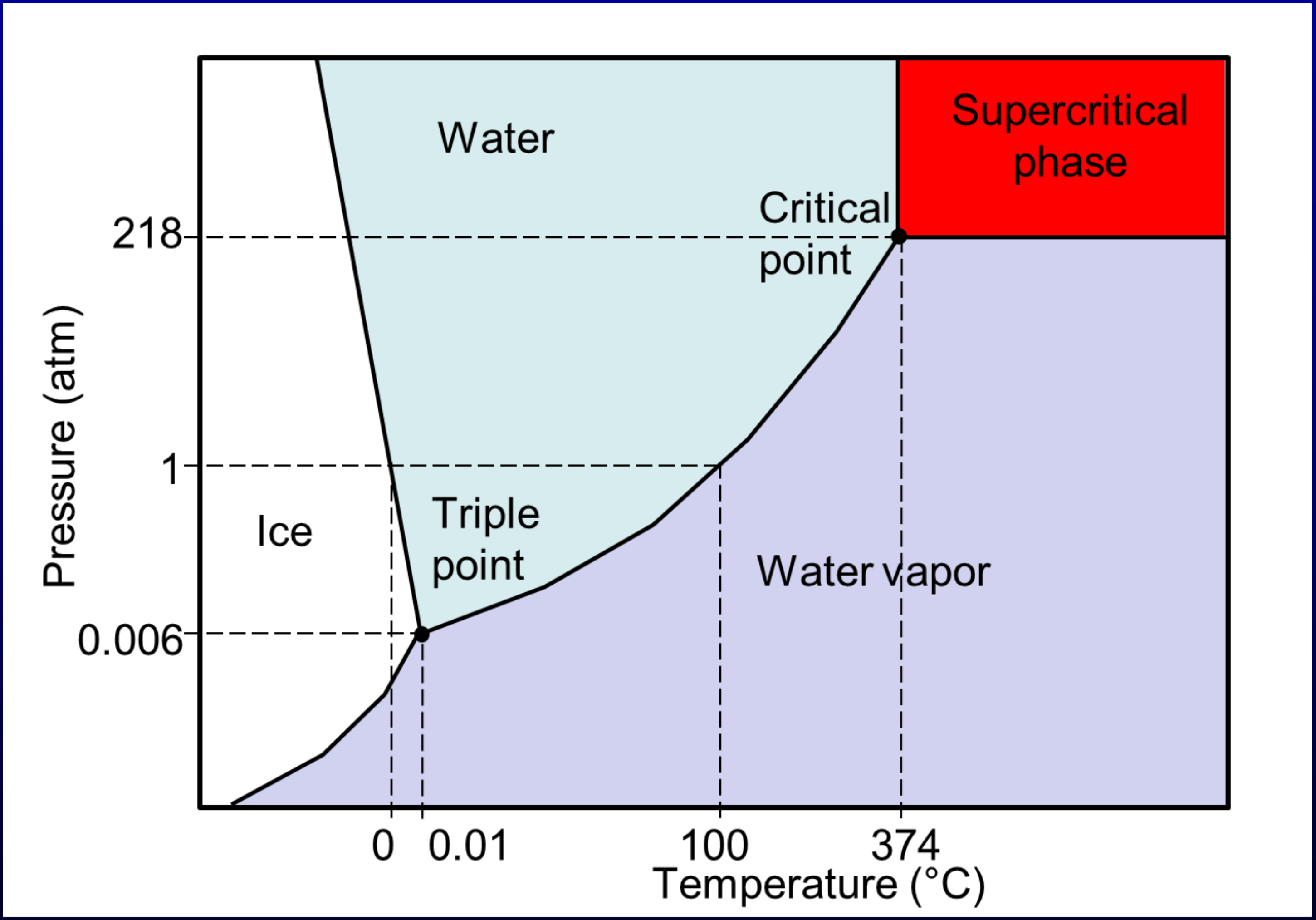
~440 W h/(p d)
1 pig ~ 3 persons


This is a 87 kWh
dump!!!

Omni Processor for Fecal Waste

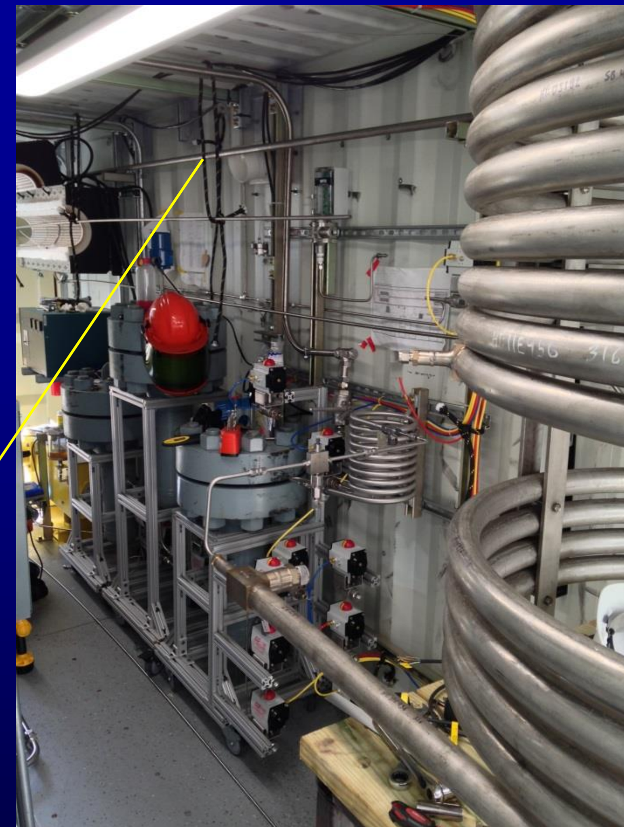
Sanitation for the urban poor using supercritical water oxidation (SCWO). Prototype unit will treat the waste of ~1200 people (~450-530 kWh/d)

In supercritical water, organics are rapidly oxidized (in seconds) resulting in heat, and CO_2



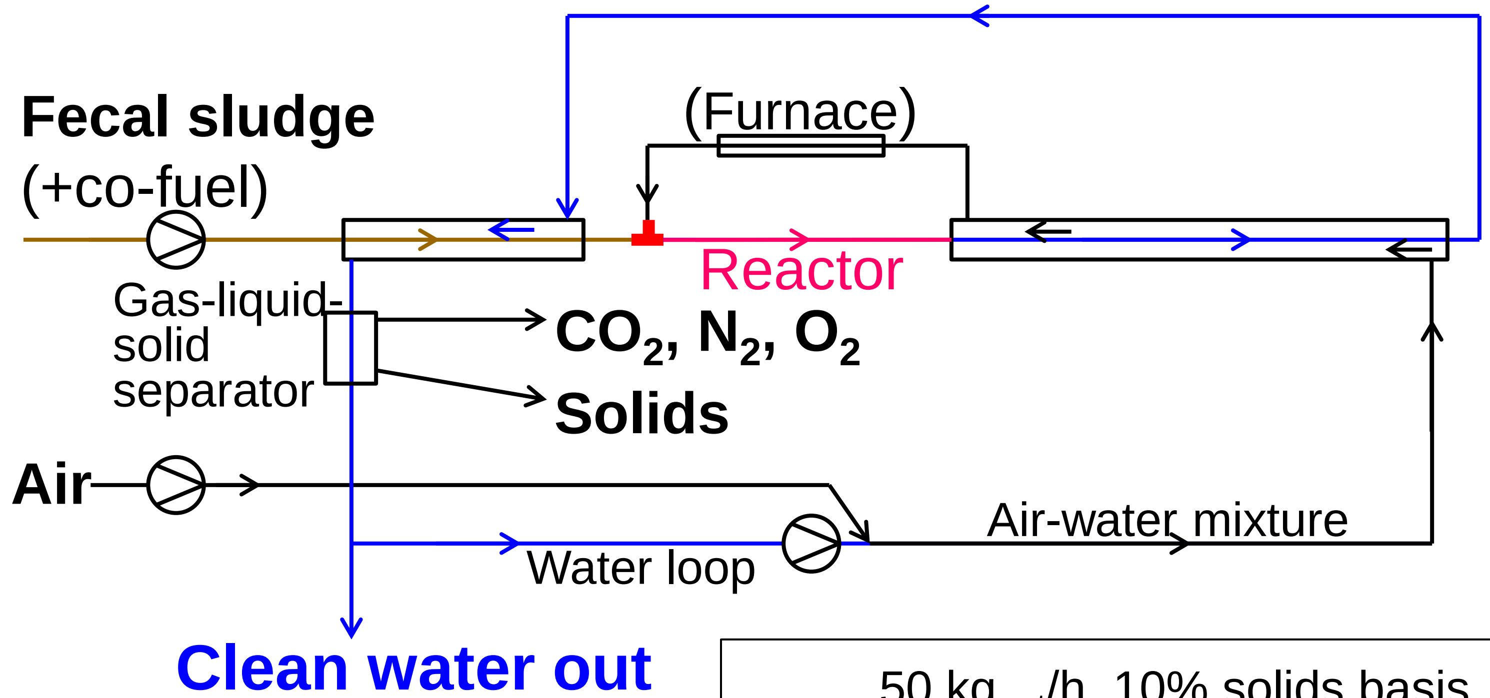
This is a pressure cooker on steroids!

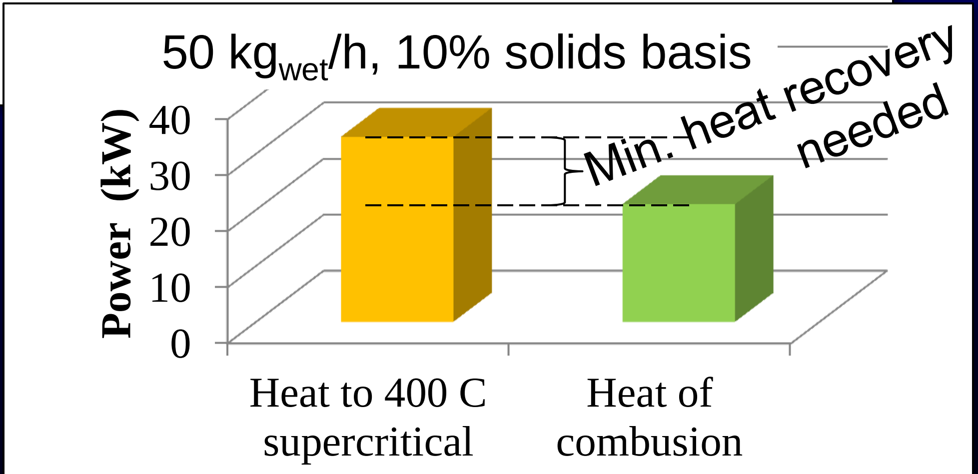
Pilot unit at Duke



- Heat and energy recovery
- Metallurgy and corrosion
- Process control

Process Flow Diagram





System characteristics

Basic characteristics

- 100-150 kg dry/day
- 1-2 m^3/day
- Assume feed ~7-15% solids
- Reactor ID: 19 mm
- Reactor length: 4.0 m
- Heat exchanger length: 39 m
- Reynolds #: 25,000 – 40,000
- Residence time in reaction section = 2.5 to 4.5 seconds!

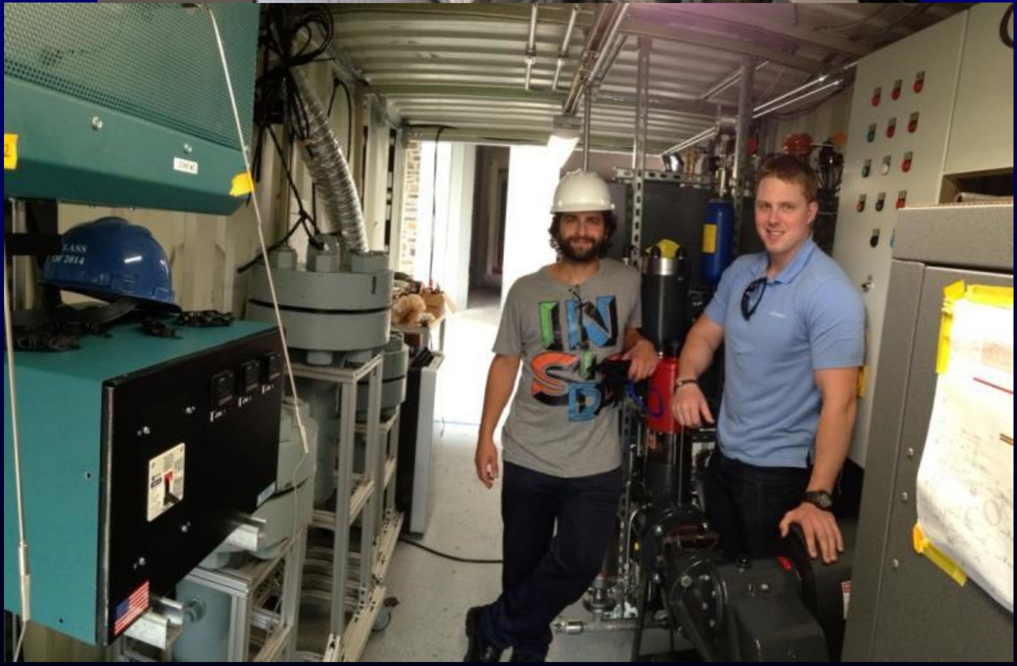
Anti corrosion and plugging measures

- High Re number, slight down slope
- Minimize transition zones
- Reactor and part of heat exchanger in Inconel 625
- Tandem HEPS
- Periodic maintenance

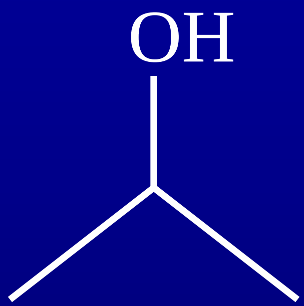
Other

- Startup with IPA
- Use air as oxidant
- Could retrofit to SCW gasification

Pilot unit construction



SCWO Feedstocks Processed



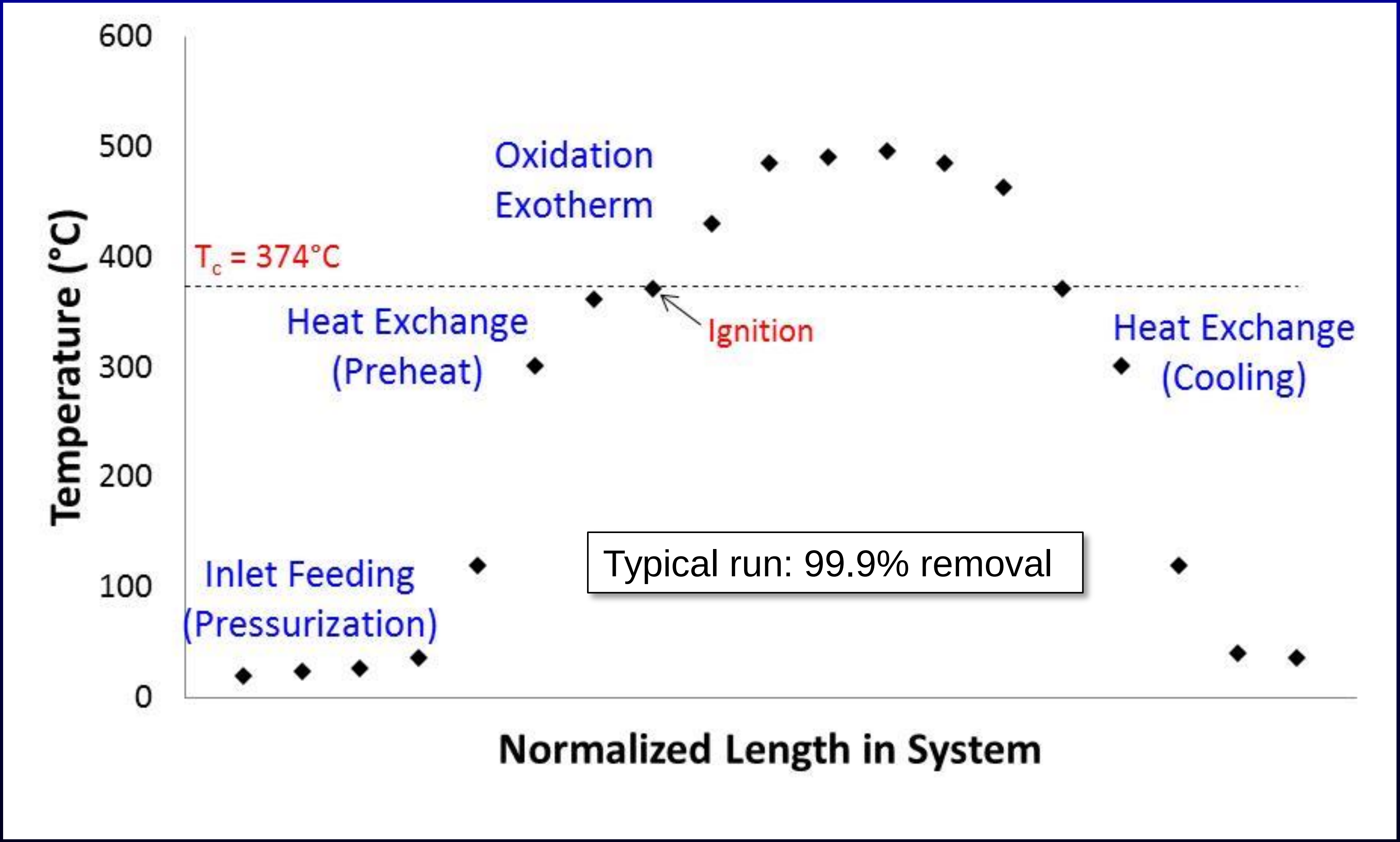
Isopropanol
(IPA)
Starter and
model fuel

Fecal
Simulant
(lab only)

High solids-content
(16%) secondary
sludge

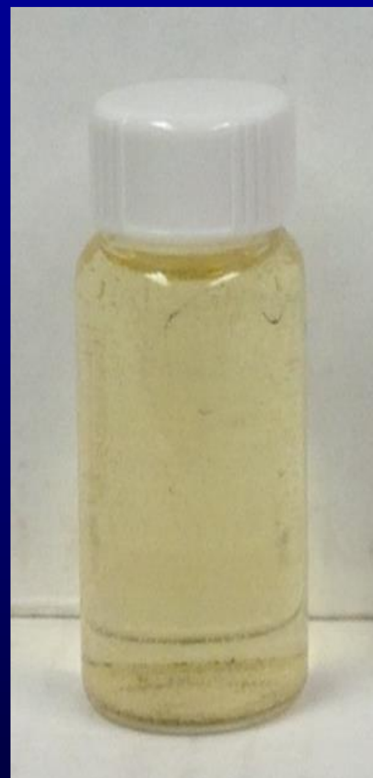
Ash content: 24%
HHV: 15.2 MJ/kg dry

Test run with 1.3% isopropanol



Basic Kinetic Determinations

Feed
(5% solids)

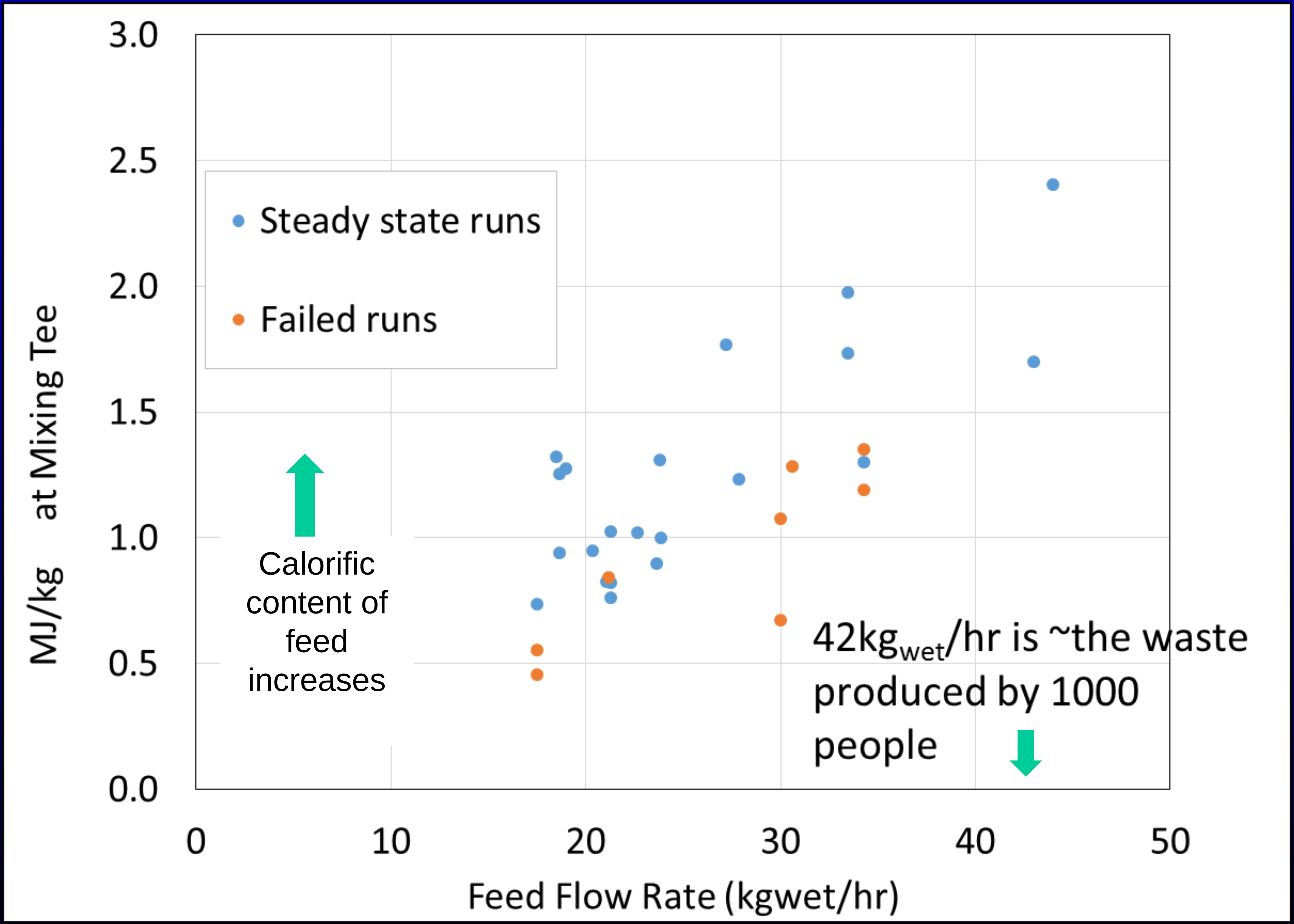


18%
excess O_2

29%
excess O_2

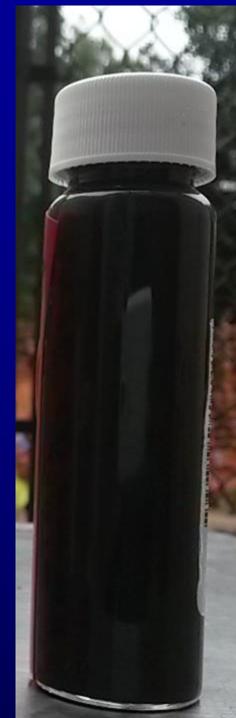
48%
excess O_2

System Characterization with IPA



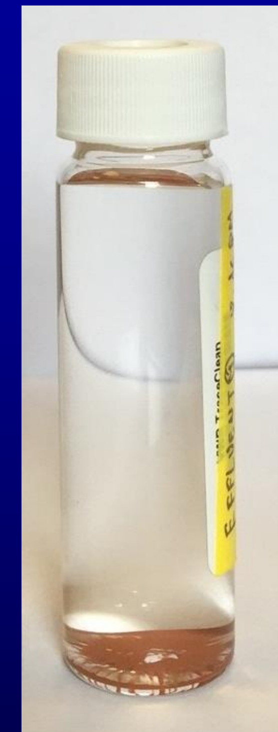
Secondary sludge treatment

Biosolids as received



Feed

Effluent



Effluent After settling

Slurry feed:
4.3% biosolids
9% IPA

Sludge Treatment (with IPA as co-fuel) Summary

Sample	Total Solids (g/kg)	Volatile Solids (g/kg)	Heat of Combustion (MJ/kg)	COD (mg/L)
Raw Sludge	149	46	14.1	107000

	Influent	Effluent		Removal
	3 wt. % sludge + 9% IPA	Transient	Steady State	
COD (mg/L)	214000	43	70	99.97%
Total N (mg/L)	10875	300	200	98.1%
NH_3 (mg/L)	443	133	17.6	
NO_3 (mg/L)	183	51.7	15.9	
NO_2 (mg/L)	14.9	0.2	0.4	
PO_4^{-3} (mg/L)	4930	32.2	67.9	98.6%
pH	6.8	4.3	7.02	
Conductvity (μS/cm)	2560	237	659	

Concluding Remarks: Why I am Optimistic…

- SCWO achieves both waste treatment and pathogen control extremely fast. We can even co-treat hazardous wastes. Process produces clean water, without odor, SOx, or NOx…
- Selling "high value added" by products can be a driver
  Sell a 10 L shower 5-10 cents

  = $1.7-3.4 per kWh!
- Many challenges remain, including slurry pumping, long-term operation (plugging and corrosion), and process economics

Acknowledgments

Gates Foundation for funding

http://sanitation.pratt.duke.edu/

Other projects

Low-tech self-sanitizing latrine
Poster #7
Odor issues and control in FSM
Poster #22