Smoldering and catalytic conversion for fecal sludge
Reinvent the toilet project

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Automated & integrated household processing unit
Treatment processes

- Solid waste combusted by smoldering
  - Oxygen limited
  - Analogous to a burning cigarette
- Liquid waste is heated to over 75°C for 20 minutes for pasteurization
  - At 70°C, residence time in order of few minutes is sufficient to kill 6 logs of Helminth eggs
Challenges of household scale solution

- Low processing rate
- Variability proportionately more pronounced at small scale
  - E.g. wedding scenario
- Energy efficiency
- Users, not operators or maintenance workers
Self sustaining processing rates

- Primary control parameter is airflow
- 10-200 g/h processing rates demonstrated
  - Required rate of 3 g/h pp
- Accommodates variability in input rates
Continuous smoldering
Continuous cyclic operation

Repeatability and does not require additional heat

Smoldering zone (°C)

Temperature probes

Heater OFF

Time (Hr)
Continuous cyclic operation
Catalyst module

Heat exchanger

Catalyst module wrapped around reactor
Catalytic oxidation of flue gases

- $T \uparrow$ by up to 300°C across catalyst
- $\text{CO/CO}_2 < 0.003$
- $[\text{CO}]$ between 100 to 300 ppmv
No pre-drying step for human feces processing
Liquids treatment

Demonstrated to reach 78°C
Challenges of household scale solution

- Low processing rate & variability in fuel input
  - Demonstrated 10-200g/h operating range with easy controllability

- Energy efficiency at smaller scale
  - Reduce energy consumption
  - Maximize heat generation and its effective use to process human feces without pre-drying

- Users, not operators or maintenance workers
  - Automated process control with one button startup and shutdown
  - Periodic ash removal
Questions?
Extra slides
Energy efficiency summary

- Incineration of solids through continuous smoldering
- Catalytic oxidation of smoldering by-products
- In situ drying of untreated human feces
- Radial heat transfer used to treat Liquid waste
### Daily material flow per person

<table>
<thead>
<tr>
<th></th>
<th>mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feces</strong></td>
<td>300</td>
</tr>
<tr>
<td><strong>Dry solids</strong></td>
<td>75g</td>
</tr>
<tr>
<td><strong>Fecal water</strong></td>
<td>225g</td>
</tr>
<tr>
<td><strong>Urine</strong></td>
<td>1500</td>
</tr>
<tr>
<td><strong>Wash water</strong></td>
<td>1000 to 3000</td>
</tr>
<tr>
<td><strong>Total solids</strong></td>
<td>75</td>
</tr>
<tr>
<td><strong>Total liquid</strong></td>
<td>2725 to 4725</td>
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<tr>
<td><strong>Working value for design</strong></td>
<td>3500</td>
</tr>
</tbody>
</table>
Emissions Before and After Catalyst

Diagram showing emissions before and after catalyst bypass.
Liquids treatment

Heat Exchanger

Heating Coil

Temperature (°C)

Time (Hr)

- Water Out [1]
- Water In [2]
- Insulation [3]
Liquids treatment

- Liquids treated through pasteurization
  - At 70°C, residence time in order of few minutes is sufficient to kill 6 logs of Helminth eggs