Gasification of Municipal Wastewater Primary Sieved Solids in a Rotary Drum Reactor

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Presentation Structure

New concepts for energy recovery from wastewater

The microscreen process for removal of primary solids

Ultra high temperature (uht) gasification

Primary fine-sieved solids to syngas

Conclusions and future plants
New Concepts for Energy Recovery from Wastewater

- Employ energy efficient design
- Use heat pumps to recover energy from sewage
- Use fine cloth screen as replacement for primary sedimentation at wastewater treatment plants
- Use fine cloth screen within the collection system to recover energy constituents
- Recover energy from dried solids by combustion, pyrolysis or gasification and generation of electricity
At 0.03 €/kWh Energy Efficiency was not an Issue. Example: Excessive Headloss (Energy Loss) at Primary Sedimentation Tank Weir
Heat recovery from sewage
Microscreen - Operating principle
Microscreen

a. Microscreen with open housing

b. Belt Scraper and Screw Auger

c. Microscreen cloth (350μm openings)
Primary Fine-Sieved Solids

- Solids removed right after the headworks at a wastewater treatment plant.
- Composition (mainly): tissue paper, food waste, feces particulate, mixed plastics.
- May be dewatered mechanically to over 40% solids, due to high cellulose content.
- May be used as a feedstock to generate energy.
- Removing solids at the beginning of the plant will increase treatment capacity, improve biology kinetics and reduce or eliminate secondary sludge.
Microscreen Installations:  (a) Adelanto, CA  
(b) Fontana, CA  
(c) Woodsville, NH
Microscreen (Patra, Greece)
Primary Fine-Sieved Solids Proximate Analysis

- Adelanto
- Woodsville
- Fontana

Sample Location

% by Weight, Dry Basis

- Volatile Solids, %
- Fixed Carbon, %
- Ash, %
Btu value of dry woodchips is about 8000 Btu/pound
Biosolids management for energy production

**Anaerobic digestion**
- Converts only a fraction of carbon to methane
- Produces sludge as byproduct
- Bioprocess, and thus susceptible to instability
- Well received by the public

**Direct combustion**
- May produce harmful byproducts
- Production of solid residue (with tar)
- Incomplete conversion of carbon to gaseous species
- Not well received by the public

**Gasification**
- Production of clean combustible gas
- Production of solid residue (no tar)
- Technology still under development
- Complete conversion of carbon to gaseous species
- Confused with combustion by the public
Biosolids: Gasification versus anaerobic digestion*

Net electrical energy production per 1000 m$^3$ of raw wastewater

<table>
<thead>
<tr>
<th>Wastewater treatment energy requirements per 1000 m$^3$ (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upfront solids removal process</td>
</tr>
<tr>
<td>150-230</td>
</tr>
<tr>
<td>Activated sludge process</td>
</tr>
<tr>
<td>330-660</td>
</tr>
</tbody>
</table>

450 kWh  
237 kWh

* P. Gikas, 2014, Environmental Technology, 35(17), 2140-2146
Main types of gasifiers

- Updraft
- Arc plasma
- Downdraft
- Rotary drum
- Fluidized bed
- Entrained flow
Ultra High Temperature (UHT) Gasification

- Standard sizes: 5 tpd or 25 tpd
- Rotating cylindrical nickel-chromium or molybdenum alloy reactor with impregnated heat resistant coating and proprietary electric heating element
- Operating temperatures of 1100°C to 1500°C
- Air tight operation to prevent nitrogen dilution
- Complete thermal decomposition of all organic matter into syngas, typically 62% H₂ and 31% CO (depending upon feedstock and reactor temperature range)
The Pyromex UHT gasification process

(1) input material storage tank
(2) rotation valves
(3) feed auger
(4) Reactor
(5) raw syngas pipe
(6) inert residue outfeed
(7) inert residue silo
(8) condenser
(9) scrubber
(10) cyclone
(11) clean syngas pipe to storage tank
25 ton/d UHT Pyromex Gasifier

Munich, Germany
25 ton/d UHT Pyromex Gasification Cylinder

Munich, Germany
25 ton/d UHT Pyromex Syngas Striping
Electric Generator using Syngas
UHT Pyromex Gasifier
(Used in the Experiments)

Munich, Germany
Feedstock

a. Primary fine sieved solids partially dried

b. Primary fine sieved solids after size reduction
### Overall Inlet and Outlet from the Gasifier

<table>
<thead>
<tr>
<th>Run No</th>
<th>PF-S solids (kg)</th>
<th>Moisture (%)</th>
<th>Temp. (°C)</th>
<th>CO (%)</th>
<th>CO₂ (%)</th>
<th>CH₄ (%)</th>
<th>H₂ (%)</th>
<th>Other gases (%)</th>
<th>Ash (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run1</td>
<td>8.15ᵃ</td>
<td>17</td>
<td>1050</td>
<td>29.87</td>
<td>2.63</td>
<td>1.79</td>
<td>62.96</td>
<td>2.75</td>
<td>0.52ᵇ</td>
</tr>
<tr>
<td>Run2</td>
<td>8.15ᵃ</td>
<td>17</td>
<td>950</td>
<td>29.86</td>
<td>4.14</td>
<td>2.92</td>
<td>62.18</td>
<td>0.90</td>
<td>0.52ᵇ</td>
</tr>
</tbody>
</table>

ᵃ: Combined weight of infeed charge for Run1 and Run2  
ᵇ: Total measured weight of ash from both Run1 and Run2 combined

**Syngas production → 1.56 m³ / kg (17% wet basis)**

**Energy production → 12.63 kJ / kg (17% wet basis)**
Syngas composition and production rate

a.
Run 1: Maximum temperature = 1050 °C

b.
Run 1: Maximum temperature = 950 °C
Reactor Temperature versus Time

![Graph showing reactor temperature over time with three lines representing Inlet, Middle, and Outlet, with markers indicating start and stop of material in Run 1 and Run 2.](image-url)
Ash from the UHT Pyromex Gasifier
Mass and Energy Balance (Combined Runs)

Energy produced: 18.15kg PFS (17% H₂O) → 12.75m³ syngas = 160.9MJ

Energy consumed (electrical): 12 kW for 90min = 66.2MJ

Energy yield: 160.9 MJ / 66.2 MJ ~ 2.4
Conclusions - Future Work

- MicroScreen Primary Fine-Sieved Solids provide a high Btu value, suitable for gasification
- Ultra High Temperature gasifier produces a high calorific value syngas from Fresh Solids
- Moisture content of gasification feedstock may be regulated by the addition of tire crumb rubber
- Energy yield of more than 2.4 (MJ produced /MJ consumed) is feasible
- The use of mixture of Primary Solids with Secondary Sludge should be investigated
Thank you for your attention