Faecal Sludge Treatment and Utilization by Hydrothermal Carbonization Process

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Hydrothermal Carbonization (HTC) Can be Defined as Carbonization of Biomass in Water to Raise Its Carbon Content, HTC Product is Called “Hydrochar”

Process Condition

- Operation Limited in Subcritical Condition of Water (180-250 °C at About 20-60 bar)
- Reaction Time Varied Between 1 to 12 h.
- Feedstock is Surrounded by Water During the Reactions
- Requiring Closed System Under Saturation Pressures.
Advantages of HTC for Faecal Sludge Treatment:

- Not Require Feedstock Drying
- Convert High Load of Organic Matter into Hydrochar
- Temperature Employed Result in the Destruction of Pathogen
- Hydrochar is a Valuable Product
Applications of Hydrochar

- Solid Fuel
- Soil Amendment
- Absorbent for Water Purification: *Heavy Metal and Micropollutant Removals*
- Energy Storage: Li-ion Battery, Carbon Fuel Cells
- Catalyst: *Supported Catalyst for Selective Hydrogenation*
- CO$_2$ Sequestration
OBJECTIVES

To Identify HTC Products Characteristics
To Investigate Potentials of HTC products Utilization
HTC Experiments

Feedstock:
- Faecal Sludge (FS) of 20% Solid Content

HTC Process Conditions:
- Temperature of 180-250 °C
- Reaction Time of 5 h
- Heating Rate of 6 °C/min
- Cooling Rate of 45 °C/min

HTC Products:
- Hydrochar
- Liquid, Filtrate, Process Water
- Gases
RESULTS & DISCUSSION

Hydrochar Characteristics

SEM Images
(a) Dried FS
(b) Produced Hydrochar at 180 °C
(c) Produced Hydrochar at 220 °C
(d) Produced Hydrochar at 250 °C
Hydrochar Characteristics and Applications

- Energy Content and Atomic Ratios of H/C and O/C of the Hydrochar Were Comparable to Natural Coals
- Hydrochar Could be Use as a **Solid Fuel** in a Typical Combustion Process
### RESULTS & DISCUSSION

#### Hydrochar Characteristics and Applications

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Dried FS</th>
<th>Hydrochar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultimate Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>%wt</td>
<td>37.8-38.1</td>
<td>38.8-39.7</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>%wt</td>
<td>5.0-5.5</td>
<td>4.1-4.5</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>%wt</td>
<td>3.0-3.5</td>
<td>1.9-2.0</td>
</tr>
<tr>
<td>Sulfur</td>
<td>%wt</td>
<td>1.4-1.6</td>
<td>1.2-1.3</td>
</tr>
</tbody>
</table>

- Further Processes to Make It Suitable for Use as an Anode

Anode in Li-ion Battery
The Mean Pore Diameter Was Found in the Range of the Mesopores

- Hydrochar can be used as an adsorbent for Adsorption of Sugar, Heavy Metals and Micro-pollutants
RESULTS & DISCUSSION

HTC Liquid Characteristics

Liquid Products Still Contained High Concentrations of TOC, COD, BOD$_5$, TN and TP.

- pH Was Decreased Due to the VFA Generation From Decomposition of the Hydrolyzed Products During HTC Process

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>FS $^a$</th>
<th>HTC Liquid Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC</td>
<td>g/L</td>
<td>16-40</td>
<td>12-16</td>
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<tr>
<td>COD</td>
<td>g/L</td>
<td>43-50</td>
<td>25-31</td>
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<tr>
<td>BOD$_5$</td>
<td>g/L</td>
<td>3-4</td>
<td>11-14</td>
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<tr>
<td>TN</td>
<td>g/L</td>
<td>5.8</td>
<td>7-8</td>
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<tr>
<td>TP</td>
<td>mg/L</td>
<td>10-15</td>
<td>5-10</td>
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<tr>
<td>pH</td>
<td></td>
<td>6.8-7.2</td>
<td>5.8-6.2</td>
</tr>
<tr>
<td>Phenol</td>
<td>mg/L</td>
<td>Not detected</td>
<td>260</td>
</tr>
<tr>
<td>VFA</td>
<td>g/L</td>
<td>1.0-1.1</td>
<td>5.2-5.4</td>
</tr>
</tbody>
</table>

$^a$ FS at solid content of 20%wt
HTC Liquid Applications and Treatment Options

- Anaerobic Digestion and Biogas Production
  - Bio-Methane Potential (BMP) Test
  - Methane Production Was About 2.8 L-CH$_4$ per kg-HTC Liquid or 2.0 L-CH$_4$ per kg FS
  - The produced biogas could be used as a fuel gas
RESULTS & DISCUSSION

HTC Liquid Applications and Treatment Options

- Recirculation in HTC Process
  - Increasing Hydrochar Yield
  - Increasing Energy Content of the hydrochar
  - Reducing Wastewater Treatment Costs

- Liquid Fertilizer
  - \( \text{NH}_4^+ \text{-N} \) of 2000 mg/L
  - \( \text{P}_2\text{O}_5 \) of 10 mg/L
  - \( \text{K}_2\text{O} \) of 100 mg/L
  - HTC Liquid Products Could be Further Processed to Make It Suitable to Use as a Liquid Fertilizer in Farmlands.
HTC Gas Composition and Treatment Options

- Gases produced from the HTC process were about 10 L-gas/kg-FS

- **Gas Composition**
  - CO₂: 61.9 %V
  - CH₄: 0.7 %V
  - O₂: 1.7 %V
  - N₂: 21.5 %V
  - H₂S: 2.0 %V
  - CO: 1.6 %V
  - VOCs: 3.1 %V
  - Other: 7.5 %V

- **Treatment Options**
  - Activated Carbon Adsorption
  - Absorption With a Wet Scrubber
Energy Contents of the Hydrochar Were Found to be About 19-20 MJ/kg, Comparable to Natural Coals.

HTC Liquid Products Obtained from the HTC Process Contained High Concentrations of Organic Matter, with the BMP Test Suggested the Potential of Methane Production.

These Results Indicated the Technical Feasibility of the HTC Process for Treating FS and Producing Hydrochar for Using as Solid Fuels and Other Value-added Products, Which Minimizing Environmental Problems and Public Health Risk.
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Thank you