Chemical process design of solid waste management for use in railway rolling stock

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Rolling stock after 1988 have been fitted with CET for managing sewage on trains.

- **Challenges**
  - Train unavailability
  - High associated costs of emptying
  - CET filling up leading to toilet shut down

- **Solutions**
  - BIOREACTORS
    - Long processing Timeframe
    - Secondary disposal of improper sludge

- **Overall Gap:**
  - Need for a novel method for the on-site FSM
  - Lack of research on energy consumptions
  - Rare literature on emissions
  - Unassessed conversion efficiencies
  - Few information on operational reliabilities

- **Unsuccessful practices for the on-site faecal sludge management (FSM)**

- **Energy Conversion Methods**
  - COMBUSTION
  - GASIFICATION
  - PYROLYSIS
  - Char
  - Gas
  - Syngas
  - Tar
  - Biomass
  - Oil
  - CO₂
  - H₂O
  - Ash
  - O₂
  - Agent
Approach

Overall aim:
Design and optimisation of a novel pyrolysis system delivering suitable products for rapid combustion and heat recovery as a new method for the on-site faecal sludge management.
Approach

- Contributing information on the inorganic extraction through drying
- Drying efficiencies and temperature effects on volatile extraction
- Prolonged biomass/gas RT on the yield and composition, contaminant contribution
- Contribution of water from initial feedstock and reactions to the bio-oil fractions
- Shedding light on the species having impact on the boiling point of the bio-oil (i.e., Saccharides, polyphenols)
- Contributing information on the species leading to the formation of coke (phenol-aldehydes)

Partially dried feedstock (30-40-50 and 60 MC%)

Quantification of CO, H₂, CH₄, C₂-C₃, and CO₂
# Findings

<table>
<thead>
<tr>
<th>Sample</th>
<th>MC</th>
<th>Ash</th>
<th>V&lt;sub&gt;m&lt;/sub&gt;</th>
<th>FC</th>
<th>C</th>
<th>H</th>
<th>N</th>
<th>O</th>
<th>CV</th>
<th>S</th>
<th>Cl</th>
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<td>91</td>
<td>5</td>
<td>82</td>
<td>13</td>
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<td>43</td>
<td>18</td>
<td>960</td>
<td>3450</td>
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<td>2</td>
<td>90</td>
<td>4</td>
<td>83</td>
<td>13</td>
<td>42</td>
<td>7</td>
<td>1</td>
<td>47</td>
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<td>18</td>
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<tr>
<td>4</td>
<td>92</td>
<td>6</td>
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<td>13</td>
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<td>1</td>
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<td>17</td>
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</tr>
<tr>
<td>5 (DE)</td>
<td>92</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>48</td>
<td>7</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>TT</td>
<td>6</td>
<td>2</td>
<td>89</td>
<td>9</td>
<td>42</td>
<td>5</td>
<td>0</td>
<td>51</td>
<td>17</td>
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MC%: Moisture content, V<sub>m</sub>: Volatile matter, FC: Fixed carbon, DE: Drying experiments, TT: Train tissue, CV: Calorific value

## Activation Energy

<table>
<thead>
<tr>
<th>Sample</th>
<th>Activation Energy (KJ/mol^-1)</th>
<th>Log&lt;sub&gt;10&lt;/sub&gt;(K&lt;sub&gt;c&lt;/sub&gt;)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>153 - 212</td>
<td>9 - 14.5</td>
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<tr>
<td>4</td>
<td>164 - 245</td>
<td>12 - 16</td>
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<tr>
<td>TT</td>
<td>171 - 201</td>
<td>11.5 - 14</td>
</tr>
</tbody>
</table>
Findings

1. Unstable temperature profile

2. Stable temperature profile

- Channel 1
- Channel 2
- Channel 3
- Channel 4
Findings

**HHT Vs DE (Constant 0.2RPM, 100g)**

**RPM Vs DE (Constant 150°C, 100g)**

**Flowrate Vs DE (constant 150°C, 0.1 RPM)**
## Findings

Waste dried at 150°C and 0.1 RPM

Vapour collected from drying

<table>
<thead>
<tr>
<th>Zone</th>
<th>SU</th>
<th>IN</th>
<th>SU</th>
<th>IN</th>
<th>SU</th>
<th>IN</th>
<th>SU</th>
<th>IN</th>
<th>SU</th>
<th>IN</th>
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<th>IN</th>
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<td>C</td>
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<td>41</td>
<td>55</td>
<td>50</td>
<td>43</td>
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</tr>
<tr>
<td>H</td>
<td>7</td>
<td>6.99</td>
<td>8.58</td>
<td>7.97</td>
<td>7.31</td>
<td>7.45</td>
<td>8.02</td>
<td>7.46</td>
<td>7.20</td>
<td>7.40</td>
<td>7.31</td>
<td>7.45</td>
</tr>
</tbody>
</table>
Findings

Yield of syngas (wt%)

Residence time (min)

Screw Speed (RPM)

Temperature (°C)

Calorific Value (MJ/Kg)

Temperature (°C)
Conclusion

My contribution to knowledge is going to be:

1. Developing a new method for on-site FSM enabling robust operation for complete destruction and disposal of the waste
2. Complete understanding of the moisture content handling in terms of the internal relation in a pyrolysis system implemented for these application
3. Comprehensive contribution to the characteristics and challenges involved with the conversion of such waste materials
4. Providing knowledge on the relation between process parameters and emissions from these specific waste materials never analysed to the best of our knowledge
5. Highlighting the implementation of auger pyrolysis reactors and their efficiencies due to these application’s constraints
6. Contribute to a complete industry revolutionizing technology for mobile applications
7. Drying efficiencies of ~70% are achievable while the emissions stay negligible within such dryer.
8. The sizing of such dryer can accommodate the feedstock volumes specified for this application (ranging from 100-400g on various trains)
9. In order to provide a better insight on the emissions, COD of the resultant vapour could be determined. However, no limits/regulations are defined for these applications to the best of our knowledge
10. Extensive research is suggested for future work on the flash point and ignition properties of the bio-oil fraction. This includes the simultaneous combustion with the syngas.
Thanks for listening