Hydrothermal Liquefaction as a Tool to Enable Plastic Circularity

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Plastic circularity is necessary to stop plastic pollution.

Global plastic consumption, production, and waste generation has more than doubled since 2000.

70% of plastic waste is disposed of by traditional methods.

15% of plastic waste is collected for recycling, while 9% of plastic is recycled successfully.

Remaining plastic eludes waste management and ends up incinerated or dumped into the ecosystem.
Innovative feedstocks improve sustainable industry

Only 7 petrochemicals are used as feedstocks for 90% of chemical processes.

In 2012, petrochemical feedstock processing accounted for roughly 60% of the energy consumed in the chemicals sector.

Energy for chemical processing could be lowered by creating value-added products or feedstocks from recycled plastics.
Hydrothermal liquefaction effectively breaks down plastics.

Conversion of polyethylene waste into clean fuels and waxes via hydrothermal processing (HTP)

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\textsuperscript{c} Department

Influence of reaction parameters on thermal liquefaction of plastic wastes into oil: A review

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\textsuperscript{a} Department of Chemical Engineering, Universiti Teknologi Malaysia, 81310 Banting, Selangor, Malaysia
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Characteristics of polyethylene cracking in supercritical water compared to thermal cracking

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Hydrothermal liquefaction uses water to degrade plastic

Hydrothermal liquefaction is a thermal depolymerization process that converts organic waste, biomass, and other macromolecules, into value added products under moderate-extreme temperature and high pressure.

Hydrothermal liquefaction uses subcritical and supercritical water as a universal reaction media.

Features of supercritical water:

- Low dielectric constant
- Low viscosity
- High diffusivity
- Very low ionic product
- Acts as both solvent and catalyst
- Suitable for free radical reaction

<table>
<thead>
<tr>
<th>Features</th>
<th>Normal Water</th>
<th>Sub-critical water</th>
<th>Super-critical water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>25</td>
<td>250</td>
<td>400</td>
</tr>
<tr>
<td>Pressure (MPa)</td>
<td>0.1</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Relative static dielectric constant (ε)</td>
<td>0.997</td>
<td>0.8</td>
<td>0.17</td>
</tr>
<tr>
<td>pK_w</td>
<td>78.50</td>
<td>27.10</td>
<td>5.90</td>
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<tr>
<td>Thermal Conductivity (mW/mK)</td>
<td>0.89</td>
<td>0.11</td>
<td>0.03</td>
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<tr>
<td>Dynamic viscosity (mPAs)</td>
<td>608</td>
<td>620</td>
<td>160</td>
</tr>
</tbody>
</table>

Normal Water
Sub-critical water
Supercritical water
Tunable parameters offer a high level of reaction design.

Environment
- Stability
- Phase Behavior
- Longevity
- Sintering
- Supercritical water
- Acid-base behavior

Catalysts
- Type
- Preparation
- Characterization

Process
- Reactor Design
- Operating Mode
- Condition

Products
- Product Distribution
- Selectivity
- Yield

Reactants
- Compounds
- Oxidants
- Behavior
- Reaction Mechanism
- Reaction Kinetics
- Kinetic Models
- Catalytic Effect

Stability
- Phase Behavior
- Longevity
- Sintering
We investigated the influence of reaction parameters on LDPE breakdown.

Starting material: LDPE

Hydrothermal liquefaction

- Temperature
- Pressure
- Reaction time
- Ratio of water to feedstock
- Catalytic influence

LDPE breakdown
We investigated the influence of reaction parameters on LDPE breakdown.

Starting material: LDPE

• Temperature
• Pressure
• Reaction time
• Ratio of water to feedstock
• Catalytic influence

Hydrothermal liquefaction

LDPE breakdown
Reaction products vary from solids to oils

Starting material: LDPE

LDPE breakdown

Hydrothermal liquefaction
The majority of LDPE was converted to alkanes

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<th>Feedstock LDPE</th>
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<tr>
<td>23</td>
<td>425 °C</td>
<td>60 min</td>
<td>25g</td>
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<td>Med</td>
<td>Low</td>
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<tr>
<td>24</td>
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Water content, feedstock:water ratio, and temperature influence average chain length.
We investigated the influence of catalysts on LDPE breakdown.

Starting material: LDPE

Hydrothermal liquefaction

- Temperature
- Pressure
- Reaction time
- Ratio of water to feedstock
- Catalytic influence

LDPE breakdown
Catalyst promotes aromatic production under supercritical conditions

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Conclusions

Degrading chemically resistant plastics can be challenging. Hydrothermal liquefaction is a promising technology for degrading and re-functionalizing plastic waste.

The reaction parameters for hydrothermal liquefaction can be tuned to change products and physical properties. Use of catalysts increases the variety of products available using hydrothermal liquefaction.

Currently, the influence of reaction parameters, catalysts, and solvent selection is being used to investigate hydrothermal liquefaction of different plastics and mixed waste.
Thank you for your time!
Extra slides
PE degradation mechanism & insight

- Bockhorn *et al* suggest mechanism for PE decomposition is radical chain mechanism
- Initial polymer chain random cracking will form alkenes by b-scission and hydrogen abstraction
- The alkene/alkane ratio is determined by the contribution of b-scission and intermolecular hydrogen reaction

- Alkene/alkane ratio and selectivity of alkadienes increase with increasing b-scission
- The product distribution helps narrow down which pathway our reaction is taking
- Zhang suggests in flow reactor primary radicals surrounded by flowing SCW reduces hydrogen abstraction and enhances unimolecular b-scission
Type of plastic
Ratio of plastic to solvent
Solvent selection
Temperature
Pressure
Reaction time
Type of reactor
Gas product
Liquid Product
Solid Product