Chemical Recycling of Plastic Waste – Pyrolysis and downstream processing of pyrolysis oils

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Development of plastic waste in Germany

- Amount of incinerated plastics increased to more than 50%
- Reasons:
  - Mixed plastics
  - "High-tech" composite material
  - Glass
  - Fibers
  - Metals
  - Flame retardants
  - Pigments
  - Additives
- Feedstock recycling insignificant
Circular Plastics Economy
Connecting Waste Management with Primary Production
Chemical Recycling - an alternative for incineration

- Incinerated plastic waste could be used for chemical recycling
- After depolymerisation, chemicals can be recovered
- Products in virgin quality
- Increased circularity
- Decrease of CO₂ emission

»Green« products
Pyrolysis
From waste to gas, oil and solid products

- Depolymerisation of plastics
- Separation of composites and inorganic material
- Recovery of metals for copper smelters
- Production of aliphatic and aromatic compounds
- Gas for energy self-sufficient operation
- iCycle® pilot plant

- Screw reactor
- Temperature >500 °C
- \( N_2 \) atmosphere
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iCycle® pilot plant (70 kg/h)
Gas and solids

- Gas: energy recovery for a energy self-sufficient process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Sample 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value</td>
<td>MJ/kg</td>
<td>44.87</td>
</tr>
<tr>
<td>CO</td>
<td>Vol.-%</td>
<td>6.31</td>
</tr>
<tr>
<td>CO₂</td>
<td>Vol.-%</td>
<td>2.14</td>
</tr>
<tr>
<td>CH₄</td>
<td>Vol.-%</td>
<td>27.70</td>
</tr>
<tr>
<td>CₓHᵧ</td>
<td>Vol.-%</td>
<td>44.01</td>
</tr>
<tr>
<td>H₂</td>
<td>Vol.-%</td>
<td>17.75</td>
</tr>
<tr>
<td>O₂</td>
<td>Vol.-%</td>
<td>2.09</td>
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</tbody>
</table>
Recycling concept Fraunhofer UMSICHT
Recovery of fibers and metals

- Shredded rotor baldes
- Solid residues
- Pyrolysis oil
- Sieving/flotation/density separation
- Distillation
- Benzene/toluene/styrene
- Phenol
- Polymerisation
- Plastic from recycling material
- Glass fiber
- Carbon fiber
- Foam
- Foam glass
Pyrolysis of complex waste streams
Example: WEEE

Pyrolysis oil:
- High heating value
- Significant lower content of
  - Water
  - Halogens
  - inorganic compounds
- Mainly aromatics → valuable chemicals

<table>
<thead>
<tr>
<th></th>
<th>WEEE</th>
<th>Pyrolysis oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>ma.-%</td>
<td>45,3</td>
</tr>
<tr>
<td>Heating value</td>
<td>MJ/kg</td>
<td>18,7</td>
</tr>
<tr>
<td>Water</td>
<td>ma.-%</td>
<td>2,8</td>
</tr>
<tr>
<td>Ash</td>
<td>ma.-%</td>
<td>39,0</td>
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<tr>
<td>TAN</td>
<td>mg KOH/g</td>
<td>9,3</td>
</tr>
<tr>
<td>C</td>
<td>ma.-%</td>
<td>42,5</td>
</tr>
<tr>
<td>H</td>
<td>ma.-%</td>
<td>5,4</td>
</tr>
<tr>
<td>N</td>
<td>ma.-%</td>
<td>1,4</td>
</tr>
<tr>
<td>S</td>
<td>ma.-%</td>
<td>0,4</td>
</tr>
<tr>
<td>Cl</td>
<td>ma.-%</td>
<td>1,3</td>
</tr>
<tr>
<td>Br</td>
<td>ma.-%</td>
<td>0,1</td>
</tr>
<tr>
<td>Inorganics</td>
<td>ma.-%</td>
<td>17,0</td>
</tr>
</tbody>
</table>

- Styrene 39,2
- Ethylbenzene 16,8
- Toluene 16,2
- alpha.-Methylstyrene 8,3
- Phenol 5,5
- Benzene 2,9

Compounds (area.-%)

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Folie 12
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Closing the value chain
From waste to product

**Waste management**
- Plastic waste

**Chemical Recycling**
- Thermo-chemical conversion of plastic waste
- Direct processing of pyrolysis oil?

**Chemical industry**
- Separation and isolation of recycling based chemicals

**Manufacturing industry**
- »Green« products
# Treatment and cleaning of pyrolysis oil

**Innovative technologies to optimize oil quality**

<table>
<thead>
<tr>
<th>Dehalogenation</th>
<th>Separation of water and salt</th>
<th>Fractionation of Pyrolysis oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrolysis steam (halogen containing)</td>
<td><strong>Pyrolysis oil</strong></td>
<td><strong>Pyrolysis oil</strong></td>
</tr>
<tr>
<td>- Polyolefins as hydrogenation reagent</td>
<td>- Emulsion separation</td>
<td>- Separation of chemicals depending on boiling points</td>
</tr>
<tr>
<td>- halogen reduction</td>
<td>- Product: water and salt free oil</td>
<td>- Concentrates of aromatics</td>
</tr>
<tr>
<td>- oil free of halogenated organic compounds</td>
<td>- Removing of inorganic bounded halogen</td>
<td>- Products: wax, aromatics, aliphatics</td>
</tr>
</tbody>
</table>
Destillation of Pyrolysis oil
seperation of chemicals
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Up-Scale

- Hydrogenation of aliphahtics and heavy boiler
- Extraction, distillation, rectification und hydrogenation in demonstration scale
Closing the value chain
From waste to product

Waste management

Chemical Recycling

Thermo-chemical conversion of plastic waste

Treatment and cleaning of pyrolysis oil

Separation and Isolation of recycling based chemicals

Chemical industry

Manufacturing industry

»Green« products
Thank you for your attention!