Life cycle assessment of biological and mechanical processes of valorization of absorbent hygiene products

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Absorbent hygiene products AHPs

In Italy are produced, consumed and disposed 1.2 Mt/y

AHP are made of valuable material

Landfill or Incineration

- GHGs emission;
- Space consumption;
- Economic issues.
From problem to resource

AHP are made up of **valuable materials** that can be recovered according to Circular Economy principles applying the concept of urban mining. The **sustainability** of these actions is evaluated through **Life Cycle Assessment**.

The **aim** of this study is the evaluation of the **life cycle assessment** of AHP products from cradle to grave with particular focus on five different waste to value management scenarios.
Life Cycle Assessment of Absorbent Hygiene Products

FU = 1 t of AHP

- **Feedstock**
  - Cellulose
  - Super absorbent polymer
  - Plastic

- **Production and delivery**
  - Production of AHPs
  - Stock
  - Delivery
  - AHPs

- **Use and waste collection**
  - Use of AHPs
  - Collection, transport, and stock
  - Used AHPs

- **Waste treatment**
  - Biological treatment;
  - OMPECO technology
  - Fater technology
  - Incineration with energy
  - Fater technology
Life Cycle Inventory Assessment of AHPs

**Biological treatment:**
The treatment was carried out with the fungus *Pleurotus Ostreatus*, which can bio-degrade cellulosic matter. The data of collection and transport are based on primary data, whereas the data about the treatment are based on the study of (M.Liza et al. 2019).

### Data for Life Cycle Inventory

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
<th>Amount/Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection</td>
<td>Transport (km) Euro 5</td>
<td>47</td>
</tr>
<tr>
<td>Washing and sterilization</td>
<td>Pump (kWh)</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>H$_2$O (t)</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>H$_2$O$_2$ (t)</td>
<td>0.1</td>
</tr>
<tr>
<td>Comminution</td>
<td>Energy (kW/t)</td>
<td>5.14</td>
</tr>
<tr>
<td>Inoculum</td>
<td>Seed of fungi (g)</td>
<td>533</td>
</tr>
<tr>
<td>1$^{\text{st}}$ step of fungi growth</td>
<td>time (d)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>temperature (°C)</td>
<td>25–29</td>
</tr>
<tr>
<td></td>
<td>humidity (%)</td>
<td>70–80</td>
</tr>
<tr>
<td></td>
<td>Growth condition</td>
<td>darkness</td>
</tr>
<tr>
<td>Aspiration</td>
<td>electricity (kW/t)</td>
<td>0.35</td>
</tr>
<tr>
<td>2$^{\text{nd}}$ step of fungi growth</td>
<td>time (d)</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>temperature (°C)</td>
<td>22–25</td>
</tr>
<tr>
<td></td>
<td>humidity (%)</td>
<td>70–80</td>
</tr>
<tr>
<td></td>
<td>Growth condition</td>
<td>light</td>
</tr>
<tr>
<td>Aspiration</td>
<td>electricity (kW/t)</td>
<td>0.35</td>
</tr>
<tr>
<td>Fungus</td>
<td>Fungus (kg)</td>
<td>225</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>Amount (t)</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>transport (km)</td>
<td>0</td>
</tr>
</tbody>
</table>

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M. m. Liza, “Use of oyster mushroom (*pleurotus ostreatus*) to degrade used diapers and sanitary pads in selected estates in thika, kiambu county, kenya a thesis submitted in partial fulfilment of the requirements for the award of the degree of master of science (microbiology) in the school of pure and applied sciences of kenyatta university,” 2019.
OMPECO technology:
Ompeco S.r.l (Turin, Italy) patented the Converter technology, which is based on the principle of mechanical to thermal energy transformation, hence the machines can reach an optimal sterilization temperature of 150°C, without high pressure, and with low water consumption.

Data for Life Cycle Inventory Collection
- Transport (km) Euro 5: 47
- H₂O (kg): 5
- electricity (kWh/kg): 0.5
- Wastewater treatment:

Ompeco, Available: https://www.ompeco.com/
Life Cycle Inventory Assessment of AHPs

**Fater technology:**
Fater S.p.A technology was developed by FaterSMART (Sustainable Materials and Recycling Technologies), and Contarina S.p.A and it consists of stabilization and elimination of the organic matter and possible pathogenic compounds of AHPs waste through the autoclave exploiting the pressure steam.

![Diagram of the Fater technology process](Image)

**Data for Life Cycle Inventory**

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategory</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection</td>
<td>Transport</td>
<td>(km) Euro 5</td>
</tr>
<tr>
<td>Sterilization + desiccator +</td>
<td></td>
<td>H₂O (kg) 500</td>
</tr>
<tr>
<td>mechanical separation</td>
<td></td>
<td>Primary energy (MJ/ton) 1870</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sludge (kg) 2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovered cellulose (kg) 354</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovered plastic (kg) 146</td>
</tr>
<tr>
<td>Transport of plastic matter</td>
<td></td>
<td>Euro 5 (20t) (km) 2.7</td>
</tr>
<tr>
<td>Recovery of plastic matter</td>
<td></td>
<td>Plastic (kg) 146</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primary energy (MJ/t) 6500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avoided plastic (kg) 110</td>
</tr>
<tr>
<td>Transport of cellulosic matter</td>
<td></td>
<td>Efficiency (%) 75 %</td>
</tr>
<tr>
<td>Recovery of cellulosic</td>
<td></td>
<td>waste (kg) 76</td>
</tr>
<tr>
<td>material</td>
<td></td>
<td>Euro 5 (20t) (km) 9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose (kg) 354</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Primary energy (MJ/t) 9919</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avoided virgin fibers (kg) 283</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Efficiency (%) 80%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>waste (kg) 71</td>
</tr>
<tr>
<td>Waste disposal</td>
<td></td>
<td>Waste from the recycling of plastic (kg) 36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waste from the recycling of cellulose (kg) 71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total waste (kg) 107</td>
</tr>
</tbody>
</table>

Life Cycle Inventory Assessment of AHPs

Current management of AHPs waste:

The distances of landfill and incineration from the collection center are respectively stated according to the waste management centers in the Nord-West part of Piedmont.

<table>
<thead>
<tr>
<th>Process</th>
<th>Avoided products</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN Incineration scenario</td>
<td>Steam and electricity</td>
</tr>
<tr>
<td>Thermovalisation</td>
<td></td>
</tr>
<tr>
<td>Landfill scenario</td>
<td></td>
</tr>
<tr>
<td>Landfill</td>
<td></td>
</tr>
</tbody>
</table>

Data for Life Cycle Inventory

<table>
<thead>
<tr>
<th>Process</th>
<th>Avoided products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection Transport (km) with Euro 5</td>
<td>47</td>
</tr>
<tr>
<td>Incineration with energy recovery</td>
<td></td>
</tr>
<tr>
<td>LHV of AHPs (MJ/ton)</td>
<td>10360</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>23</td>
</tr>
<tr>
<td>Produced energy (MJ/ton)</td>
<td>2383</td>
</tr>
<tr>
<td>Produced heat (MJ/ton)</td>
<td>1072</td>
</tr>
<tr>
<td>Produced electricity (kW/h)</td>
<td>834</td>
</tr>
<tr>
<td>Landfill Transport with Euro 5 (20 t) km</td>
<td>16.2</td>
</tr>
</tbody>
</table>
Life Cycle Impact Assessment of AHPs

The CED method was employed to evaluate the energy impact of the proposed AHPs valorization treatments considering the total energy required and saved in the whole process especially for the evaluation of mechanical processes.

ReCiPe Midpoint (H) method 20216
- Global Warming Potential (kg CO₂ eq);
- Human Toxicity (kg 1,4-DBeq),

Because the attention was focused both on the environmental quality and human health.

Cumulative Energy Demand (CED).

Database Ecoinvent 3.3
Life Cycle Assessment of AHPs: results

- **Global Warming Potential**
  - Bar chart showing kg CO₂ eq/t for different processes.

- **Human toxicity**
  - Bar chart showing kg 1,4-DBeq/t for different processes.

- **Cumulative energy demand**
  - Bar chart showing GJ/t for different processes.
Life Cycle Assessment of AHPs: results

- Biological treatment
  - GWP (kg CO2 eq/t)
  - HT (kg 1,4-DB eq/t)
  - CED (GJ/t)
- Fater treatment
  - GWP (kg CO2 eq/t)
  - HT (kg 1,4-DB eq/t)
  - CED (GJ/t)
- Ompeco treatment
  - GWP (kg CO2 eq/t)
  - HT (kg 1,4-DB eq/t)
  - CED (GJ/t)
The first sensitive analysis was performed varying kilometers of collection, transport, and disposal of AHPs waste in a range ± 10 km since recent that biomass yield density (t/hay) varied with biomass supply distance (km) from refinery plant location. In detail, the study according to (R. Golecha and J. Gan, 2016).
Life Cycle Assessment of AHPs: results sensitivity analysis II

The second sensitivity analysis for the LCA section was applied to change the efficiency of the proposed technologies in a range of ± 5% according to (M. J. Somers, et al. 2021).

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Conclusion and future perspectives

- The study evaluated the environmental impacts of Absorbent Hygiene Products (AHPs), through Life Cycle Assessment (LCA) from cradle to grave, with particular focus on the end-of-life scenarios.

- The five the end-of-life scenarios included three innovative treatments: one biological and two mechanical processes and two baseline scenarios the incineration with energy recovery and the landfill.

- AHPs composition represented the highest environmental impact contribution equal to 50-65% of the total impact due to the consumption of raw material.

- The high environmental impact of the mechanical treatments was due to the absence of avoided products and high energy requirement and due to the low recovery rate of the product.

- By combining the results achieved for GWP, HT, and CED, the rank is:
  - Biological process;
  - Fater process;
  - Ompeco process;
  - Incineration with energy recovery;
  - Landfill.
Thank you for the attention