Valorisation of municipal wastes through development of recovered sludge cellulose/biopolymer composites

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Circular economy in the water sector

http://smart-plant.eu/
Cellulose Recovery

- Coarse Screening
- Grit Removal
- Hairs & Organics Removal
- Harvesting Cellulose
- Drying and Pelletising

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The size of coarse screening ranges from 6 mm to 25 mm, that removes all the large particles such as wood and towels.

30 to 80 m³/h waste water is pumped into the SMART Plant pilot plant after coarse screening.

Grit-free wastewater passes through a grit chamber to remove the easily sinkable solids from the wastewater. A transport screw moves the grit (0.004 – 0.037 m³/1000 m³) from the bottom of the chamber to the return stream reaching the aeration tank.

Grit-free wastewater passes onto a rotary screen filter that removes the hairs and organic wastes with particles size larger than 350 microns. A CellCap rotating belt filter with a filter mesh of 350 microns removes the precoat particles up to 90 microns. Automatically controlled belt speed. Lower flux leads to a higher removal, vice versa. Automatic drive operation.
Cellulose Recovery

**Recovered Sludge Cellulose (SC)**

**Cellulose Fibre (CF)**

**Average arithmetic length:**
- 448 μm for CF
- 664 μm for SC

**Average width:**
- 22.5 μm for CF
- 22.4 μm for SC
Composite Development

Incompatible components

Compatible components

PHAs

Phenyl propane monomers in lignin

glucose

xylose
## Composite Development

<table>
<thead>
<tr>
<th>Composites</th>
<th>Polymer matrix</th>
<th>Cellulosic filler</th>
<th>Lubricant and Compatibiliser</th>
<th>Initiator</th>
<th>Coupling agent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PHBV</td>
<td>PE</td>
<td>PLA</td>
<td>SC</td>
<td>WF</td>
</tr>
<tr>
<td>PHBV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MA treated CF-PHBV</td>
<td>52</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>APS treated CF-PHBV</td>
<td>52</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VTMS treated CF-PHBV</td>
<td>52</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The images show the composite development with different treatments and materials, demonstrating the effects on the final product. The table provides a quantitative overview of the components used in each composite.
## Composite Development

<table>
<thead>
<tr>
<th>Matrix/Composite</th>
<th>Tensile stress (MPa)</th>
<th>Tensile strain (%)</th>
<th>Flexural stress (MPa)</th>
<th>Flexural extension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHBV</td>
<td>26.06</td>
<td>2.46</td>
<td>64.62</td>
<td>8.46</td>
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<tr>
<td>PE</td>
<td>23.26</td>
<td>8.61</td>
<td>21.95</td>
<td>11.17</td>
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<tr>
<td>SPC (Untreated)</td>
<td>5.81</td>
<td>0.31</td>
<td>3.73</td>
<td>0.25</td>
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<tr>
<td>SPC (MA treated)</td>
<td>10.17</td>
<td>0.45</td>
<td>8.65</td>
<td>0.40</td>
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<tr>
<td>SPC (VTMS treated)</td>
<td>9.55</td>
<td>0.45</td>
<td>9.54</td>
<td>0.39</td>
</tr>
<tr>
<td>SC-Pe</td>
<td>13.58</td>
<td>1.69</td>
<td>23.91</td>
<td>3.80</td>
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<tr>
<td>WPC</td>
<td>17.15</td>
<td>2.48</td>
<td>24.80</td>
<td>3.40</td>
</tr>
<tr>
<td>WF-PHBV</td>
<td>8.40</td>
<td>0.37</td>
<td>4.25</td>
<td>0.13</td>
</tr>
<tr>
<td>CF-PHBV</td>
<td>15.73</td>
<td>0.67</td>
<td>16.40</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Composite Development

Maleic Anhydride (MA)

Vinyltrimethoxysilane (VTMS)

γ-aminopropyltriethoxy silane (APS)

\[
\text{Maleic Anhydride (MA)} \\
\text{Vinyltrimethoxysilane (VTMS)} \\
\text{γ-aminopropyltriethoxy silane (APS)}
\]
Nanofillers - Nanocellulose

- Elementary unit of crystalline cellulose – typical dimension of 5 nm x 20-200 nm
- Opportunity for chemical modification (surface -OH) – Complimentary
- **Light weight** material, builds network structures
- **Renewable** resource, **Biocompatible** & **Biodegradable**
- **High stiffness** (5-45GPa) & **strength** (3-800MPa)
- High water binding capability
- High Surface Area
- Optical properties
- Self-assembly
Nanofillers - Nanocellulose

Nanocellulose Manufacturing Processes

- Milling
- Steam Explosion
- Ammonia Fibre Explosion
- CO2 Explosion
- Ionic Liquids
- Enzymatic Treatment
- TEMPO Oxidation
- Organosolv.
- Sonication
- Alkaline Hydrolysis
- Acid Hydrolysis

Increasing length
Nanofillers - Nanocellulose

**Diagram Description:**
- **Step 1:**
  - Nanocellulose is treated with NaOH and NaClO.
  - Ultrasonication is applied to both crystalline and non-crystalline regions.
  - Crystalline region is converted to a non-crystalline region.
  - The reaction results in the formation of CO₂, H₂O, and NaCl.

- **Step 2:**
  - Further ultrasonication leads to the production of nanocellulose.

**Graph:**
- Concentration (particles/mL) is plotted against size (nm).
- Various concentration peaks are observed at different size ranges.
Nanofillers – Graphene Oxide (GO)
Thank you very much for your kind attention!

http://smart-plant.eu/
https://www.brunel.ac.uk/civil-engineering