Are nettle fibers produced on metal-contaminated lands suitable for composite applications?

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Industrial landfills in France

- 400,000 industrial sites that could be concerned
- 6,800 areas with management measures (2018)

No economic function

Opportunity to produce technical fibers for composites industry

Basol database, French Ministry of Environment (04/07/18)
Soil dedicated to produce biomass

Description: Storage area which contain sediments from the adjacent sedimentation basin
Process: Chlorine extraction from NaCl using electrolysis
Contamination: Hg
Concentration: 6±3 mg.kg\(^{-1}\) (guide: 1 mg.kg\(^{-1}\))

Phytomanagement: Agro-forestry

Restore and revalorize contaminated industrial landfills

Poplar plantations I-214 / Skado

Benefits:

- Restore ecosystems
- Limit the diffusion of contaminants
- Produce valuable resources

Spontaneous nettle (Urtica Dioica)
Multipurpose valorization of the biomass

Poplar

Spontaneous nettle

Pulpe paper

Chipboard
MDF, HDF

Bioenergy

Pulpe paper

Chipboard
MDF, HDF

Bioenergy

Biocomposites

Short fibers, Non woven

Animals food

Bioenergy

Biocomposites

Short fibers, Non woven

Animals food

http://www.herboristerie-grenoble.com
http://www.ecorenove.fr
https://e-rse.net
Are TE contents in fibers lower than the threshold for composites products?
TE contents

Nettle stems:
0.01 ± 0.004 mg/kg D Wt

Nettle leaves:
0.03 ± 0.01 mg/kg D Wt

Nettle fibres:
0.008 ± 0.004 mg/kg D Wt

Background [Hg] food plants:
0.001-0.1 mg/kg D Wt

Threshold for agronomics crops:
0.2 mg/kg D Wt

Industrial use of nettle fibers in materials application is not a problem

Can nettle fibers be a suitable source for materials applications?

Morphology and yields of stems and fibers.
Nettle and fibers yields

A plot of 50m² was harvested at the edge of the poplar SRC.

Interesting yields at the edge of the poplar coppice without any chemical fertilization and clone selection.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Dry stem yield (t.ha⁻¹)</th>
<th>Bast fibers content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytofiber</td>
<td>0.55</td>
<td>9.1</td>
</tr>
<tr>
<td>Lehne and al, 2001*</td>
<td>1.7 - 4.4</td>
<td>12</td>
</tr>
<tr>
<td>Hartl and Vogl, 2009**</td>
<td>2.9 - 9.7</td>
<td>10 - 13</td>
</tr>
</tbody>
</table>


Stems morphology

Morphological analysis of 30 stems

<table>
<thead>
<tr>
<th>Stems features</th>
<th>PHYTOFIBER</th>
<th>Bacci and al, 2013*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean length (m)</td>
<td>1,06 ± 0,13</td>
<td>1,7</td>
</tr>
<tr>
<td>Mean median diameter (mm)</td>
<td>3,2 ± 0,64</td>
<td>8,1</td>
</tr>
</tbody>
</table>

Length and diameters of spontaneous stems lower than when they are cultivated and selected.

Cross section view
Pattern recognition

Feret diameters, and wall thickness
Bast fibers morphology

Cross section analysis

<table>
<thead>
<tr>
<th>Bast fibers morphology</th>
<th>PHYTOFIBER</th>
<th>Di Virgilio and al, 2013*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean diameter (µm)</td>
<td>37 ± 11</td>
<td>19 - 47</td>
</tr>
<tr>
<td>Wall thickness (µm)</td>
<td>6,5 ± 2</td>
<td>-</td>
</tr>
</tbody>
</table>

Bast fibers diameters in agreement with the literature. Large lumen area compared to other European crops (hemp, flax).

Fibers extraction

An industrial device can be used to extract fibers from the straw. No preliminary treatment is required before fibers extraction.

<table>
<thead>
<tr>
<th>Sample</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre lap (%)</td>
<td>11.0</td>
<td>48.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Impurities in fibre lap (%)</td>
<td>17.6</td>
<td>36.5</td>
<td>51.0</td>
</tr>
</tbody>
</table>

Laroche Cadette 1000 ‘all fibres’ (125 kg/h)

Straw with 3 different conditioning:
- C1: without MC=10.4%
- C2: sprayed with water MC=22.0%
- C3: soda treatment MC=22.0%
Are mechanical properties of nettle fibers high to make composites?

Mechanical properties.
Elementary fiber tensile test: method

Manual separation and gluing on paper frame
Gauge length: 10mm

Tensile test of 50 fibers or small bundles of fibers. The stress was calculated using the applied force and the evaluated initial cross section (lumen area neglected). Apparent Young modulus calculated between 0.2% and strain at failure.

Tensile test on a BOSE Electroforce 3230 machine. Cross head speed 0.01 mm.s\(^{-1}\). Strain measure with grips displacement. Load cell of 20N.
Elementary fiber tensile test: results

<table>
<thead>
<tr>
<th>Mechanical properties of fibres</th>
<th>Phytofiber</th>
<th>Bodros and al, 2007*</th>
<th>Lanzilao and al, 2016**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre extraction</td>
<td>Mechanical</td>
<td>Manual</td>
<td>Manual</td>
</tr>
<tr>
<td>Diameter (µm)</td>
<td>28.2 ±6</td>
<td>19.9 ±4</td>
<td>24 ±15.9</td>
</tr>
<tr>
<td>Stress at failure (MPa)</td>
<td>711 ±427</td>
<td>1594 ±640</td>
<td>2196 ±801</td>
</tr>
<tr>
<td>Elastic modulus (GPa)</td>
<td>53 ±24</td>
<td>87 ±28</td>
<td>79 ±29</td>
</tr>
<tr>
<td>Strain at failure (%)</td>
<td>1.37 ±0.53</td>
<td>2.11 ±0.91</td>
<td>2.8 ±0.9</td>
</tr>
</tbody>
</table>

Mechanical properties of fibers from spontaneous nettle lower than those measured on cultivars. Is it due to the mechanical extraction process? Is it influenced by the maturity of the plant?


Comparison with other plant fibers

<table>
<thead>
<tr>
<th>Mechanical properties of fibres</th>
<th>Phytofiber</th>
<th>Bensadoun and al, 2017*</th>
<th>Placet and al, 2017**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Nettle</td>
<td>Flax</td>
<td>Hemp</td>
</tr>
<tr>
<td>Fibre extraction</td>
<td>Mechanical</td>
<td>Mechanical</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Diameter (µm)</td>
<td>28.2 ±6</td>
<td>19 ±3</td>
<td>25.4 ±6</td>
</tr>
<tr>
<td>Stress at failure (MPa)</td>
<td>711 ±427</td>
<td>791 ±319</td>
<td>685 ±590</td>
</tr>
<tr>
<td>Elastic modulus (GPa)</td>
<td>53 ±24</td>
<td>57 ±13</td>
<td>19.1 ±11.3</td>
</tr>
<tr>
<td>Strain at failure (%)</td>
<td>1.37 ±0.53</td>
<td>1.8 ±0.5</td>
<td>2.5 ±1.06</td>
</tr>
</tbody>
</table>

After industrial extraction, mechanical properties of fibers from spontaneous nettle are high compared to flax or hemp.


Are TE contents in fibers lower than the threshold?

- Te contents are lower than thresholds: material use of nettle fibers for industrial application is possible.

Can nettle fibers be a suitable source for materials applications?

- Interestingly yields at the edge of the poplar coppice without any chemical fertilization and clone selection.

Are mechanical properties of nettle fibers interesting to make composites?

- Industrial extraction of fiber in ‘all fiber device’ can be used without preliminary treatment of the straws.
  - Bast fibers of spontaneous nettle have high mechanical properties despite an important lumen area.
Prospect

Evaluate the potentiality of other landfills.

- Fresnes-sur-Esacaut (59)
  TE: Cd, Zn, As and Pb

Can cropping of selected nettles improve nettle yields and mechanical properties?
Thanks to ADEME, France, under grant n°1772C0018, PHYTOFIBER project.

ADEME

Agence de l'Environnement
et de la Maitrise de l'Energie

Thanks for your attention

http://phytofiber.fr/