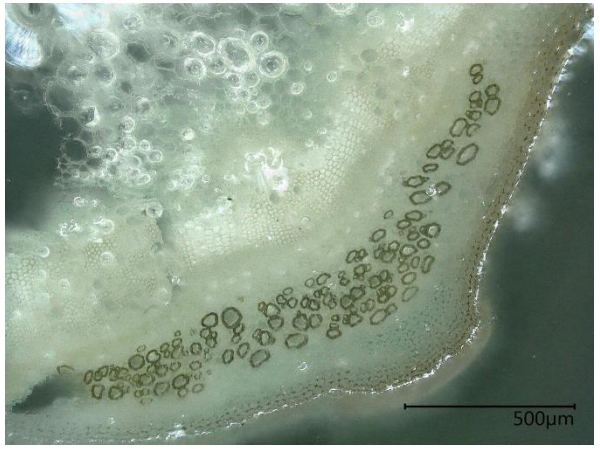
PHYTOFIBER

Valorization of plant fibers from biomass produced on contaminated soils

ADEME

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

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



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FCBA INSTITUT TECHNOLOGIQUE

UNILIN FOR SMART LIVING

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

CHRONO ENVIRONNEMENT

INSTITUT DE RECHERCHE femto-st SCIENCES & TECHNOLOGIES

ICNF 2019 4th International Conference on Natural Fibers Smart Sustainable Solutions

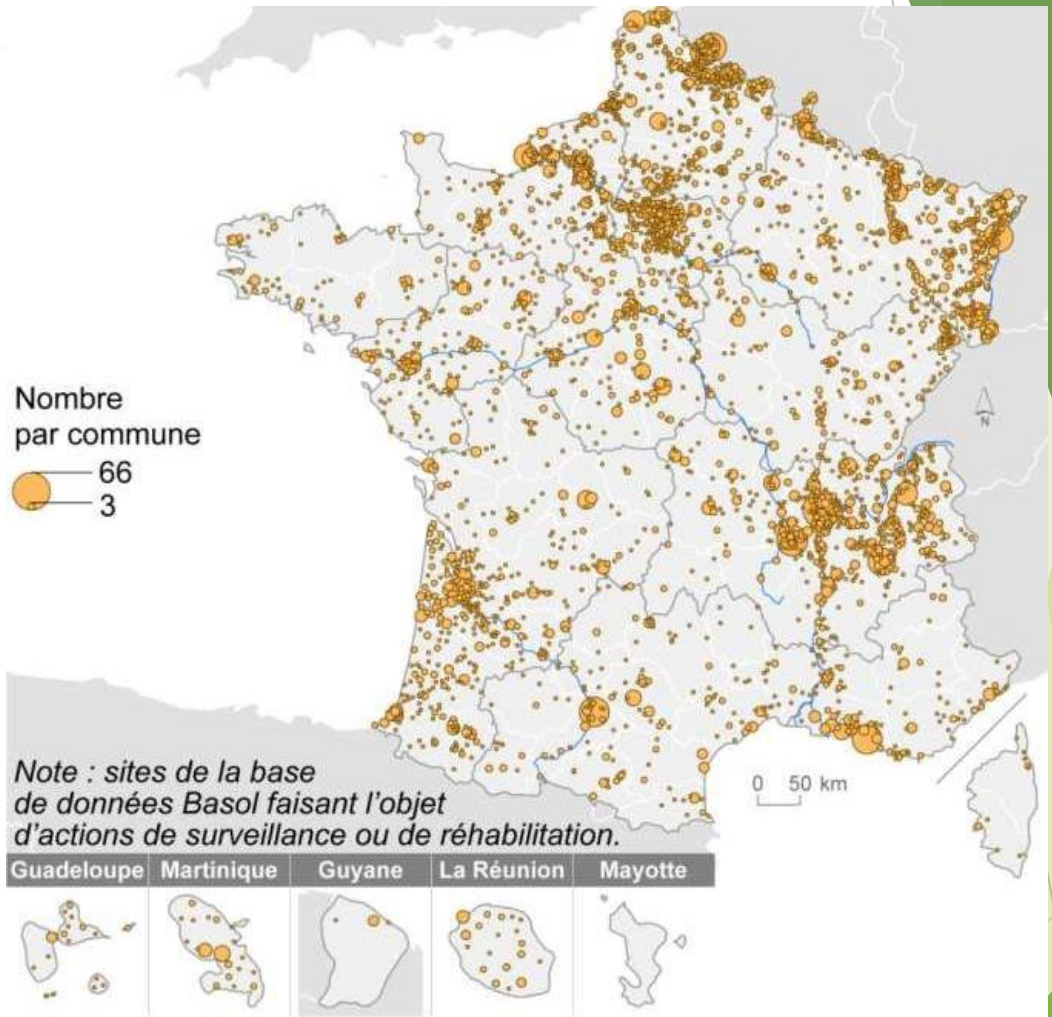
Industrial landfills in France

- 400 000 industrial sites that could be concerned

- 6800 areas with management measures (2018)

↳ No economic function

Opportunity to produce technical fibers for composites industry



Basol database, French Ministry of Environnement (04/07/18)

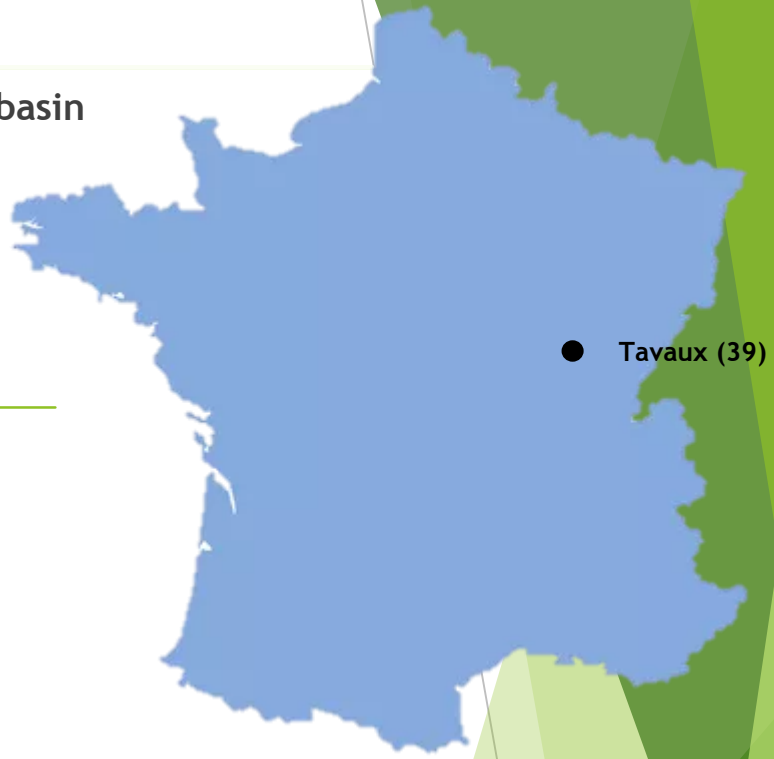
Soil dedicated to produce biomass

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-forestery

Restore and revalorize contaminated industrial landfills

Poplar **plantations** I-214 / Skado

Spontaneous nettle (Urtica Dioica)

Benefits:

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

Multipurpose valorization of the biomass

PHYTOFIBER

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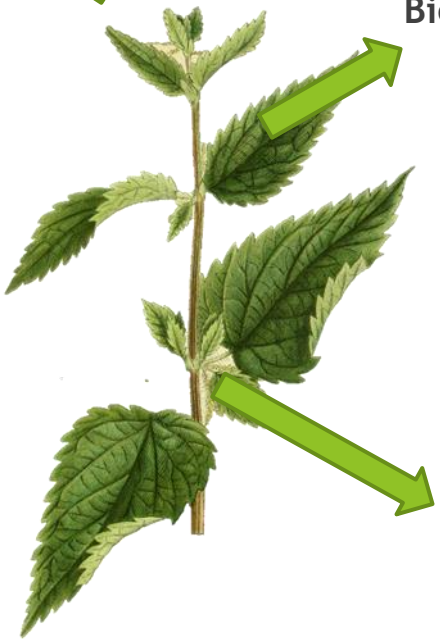
Pulpe paper

Chipboard
MDF, HDF

Bioenergy

Poplar



Spontaneous nettle

Biocosmetcis TE

Medicine

Animals food

? TE

Short fibers,
Non woven

Bio-composites

PHYTOFIBER

Questioning

Are TE contents in fibers lower than the threshold for composites products?

TE contents

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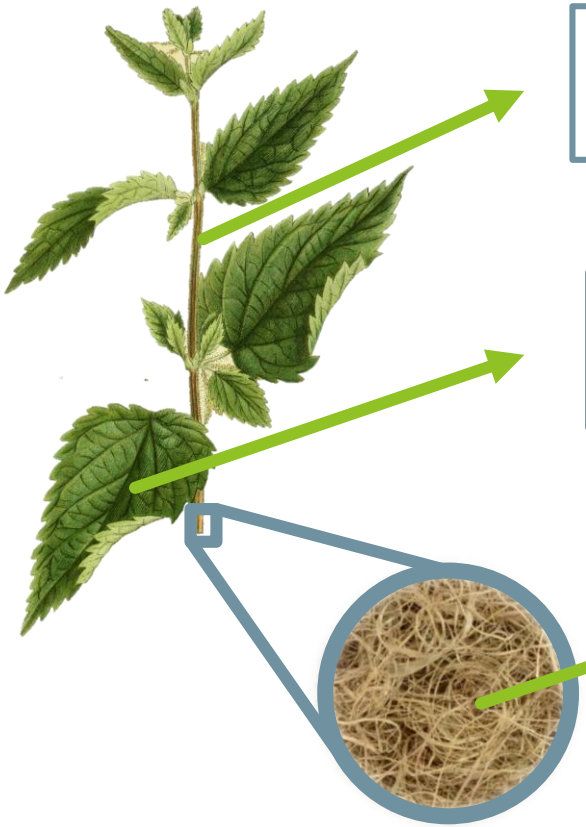


Nettle stems :

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

* Kosta, L., Zelenko, V., Stegnar, P., Ravnik, V., Dermelj, M., & Byrne, A. R. (1974). Fate and significance of mercury residues in an agricultural ecosystem. In *Isotope tracer studies of chemical residues in food and the agricultural environment*.

Questioning

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

Bales with aligned stems

Weighing after 4 month of drying and the leaves were removed

Weighing after fibers extraction

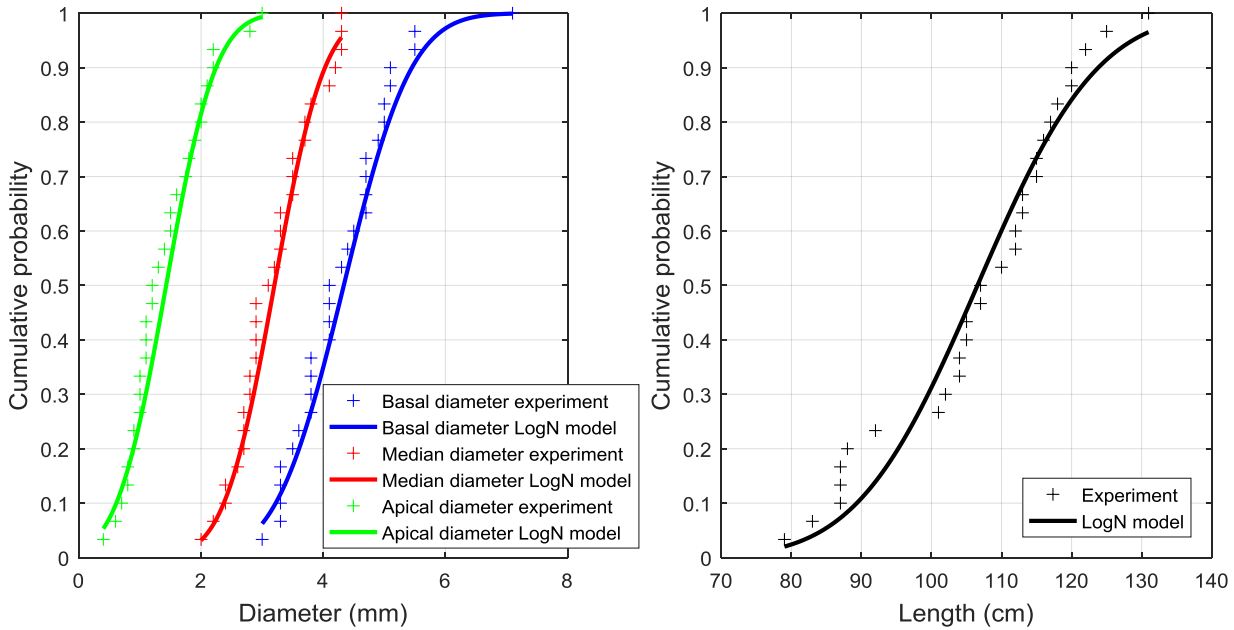
	Dry stem yield ($t.ha^{-1}$)	Bast fibers content (%)	Cultivar
Phytofiber	0.55	9.1	Spontaneous
Lehne and al, 2001*	1.7 - 4.4	12	Clone 13
Hartl and Vogl, 2009**	2.9 - 9.7	10 - 13	Clone 5-9

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

*Lehne, P., Schmidtke, K., Rauber, R., 2001. Ertrag von Fasernesseln im ökologischen Landbau bei unterschiedlicher Nährstoffversorgung. Mitt. Ges. Pflanzenbauwiss 13, 158-159.
**Hartl, A., Vogl, C.R., 2009. Dry matter and fiber yields, and the fiber characteristics of five nettle clones (Urtica dioica L.) organically grown in Austria for potential textile use. American Journal of Alternative Agriculture 17, 195-200.

Stems morphology

Morphological analysis of 30 stems



Stems features	PHYTOFIBER	Bacci and al, 2013*
Mean length (m)	1,06 ± *0,13*	1,7
Mean median diameter (mm)	3,2 ± *0,64*	8,1

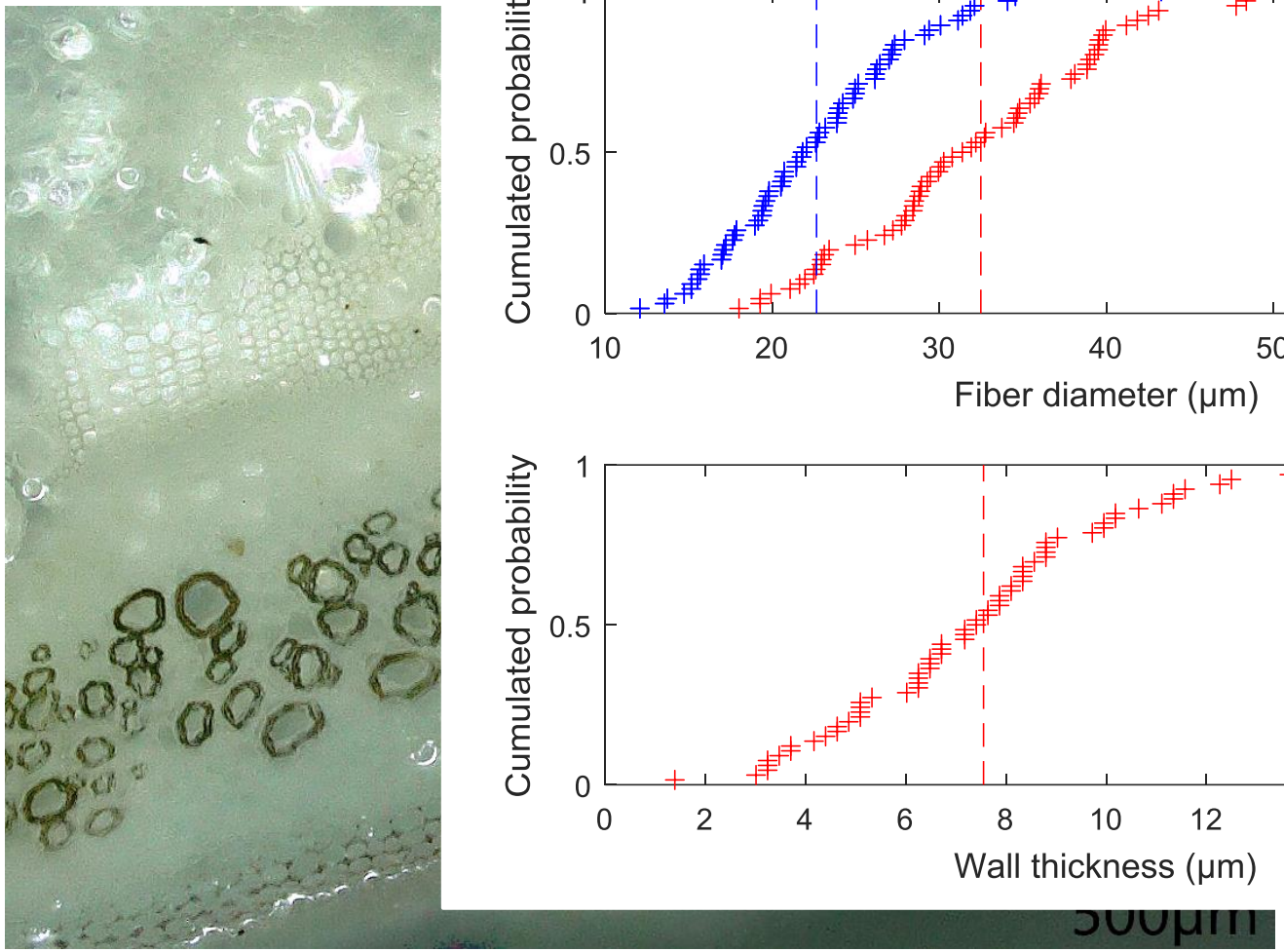
Length and diameters of spontaneous stems lower than when they are cultivated and selected.

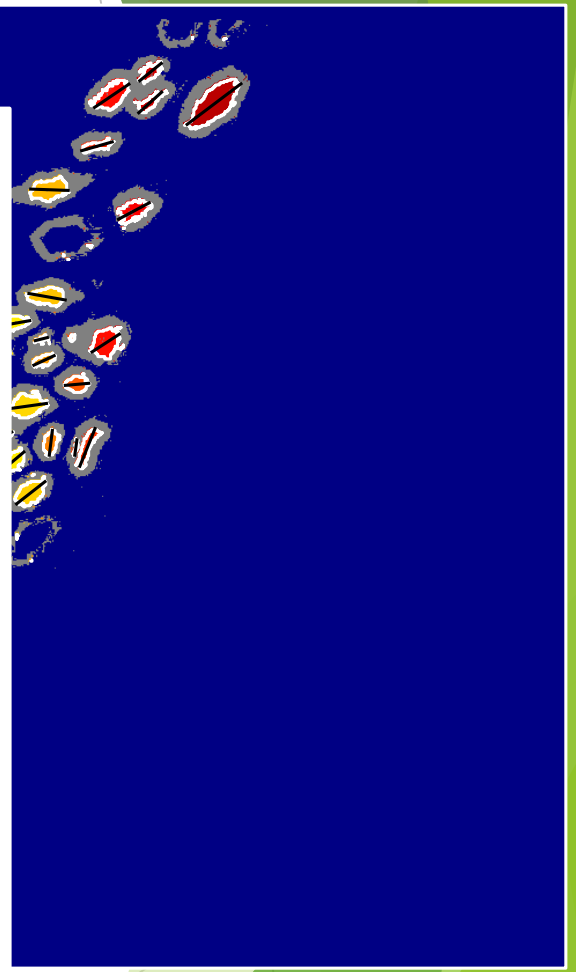
*L. Bacci, S. Baronti, S. Predieri, et N. di Virgilio, « Fiber yield and quality of fiber nettle (Urtica dioica L.) cultivated in Italy », Industrial Crops and Products, vol. 29, no 2-3, p. 480-484, mars 2009.

Cross section view

Pattern recognition

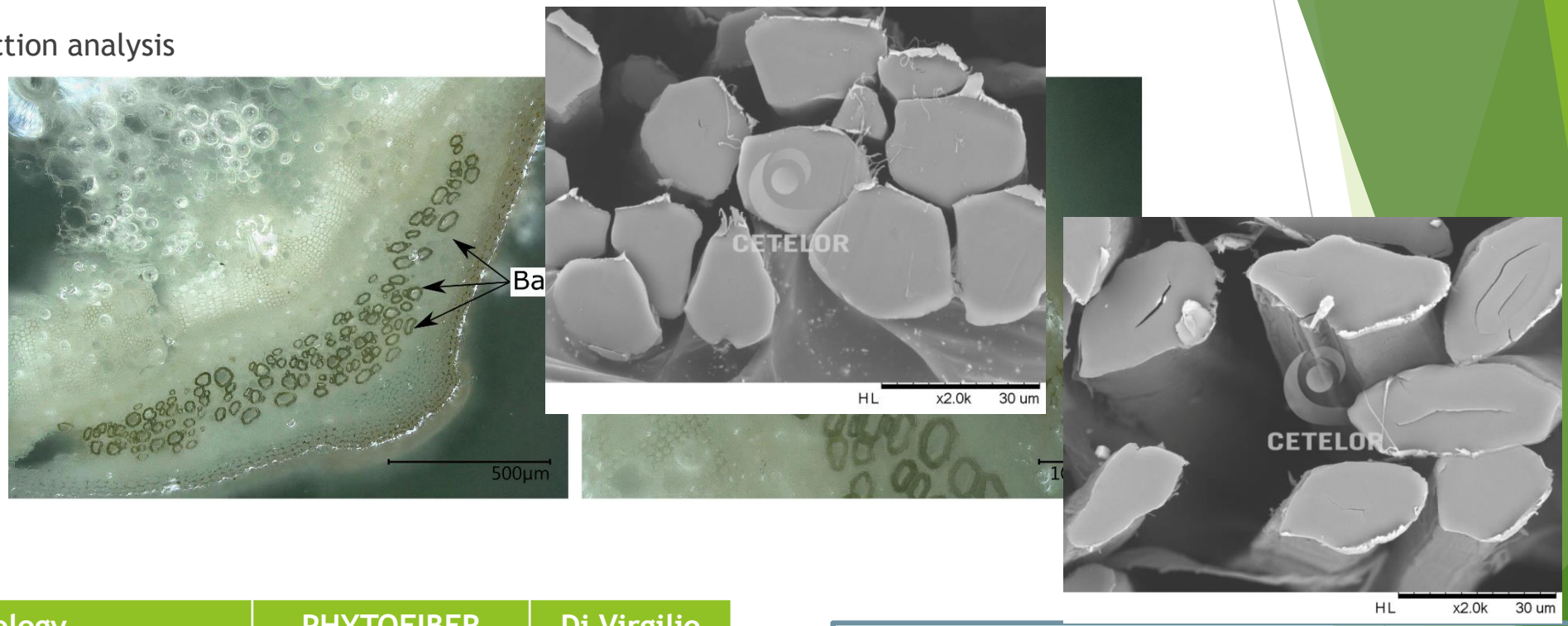
Feret diameters, and wall thickness





Bast fibers morphology

Cross section analysis



Bast fibers morphology	PHYTOFIBER	Di Virgilio and al, 2013*
Mean diameter (µm)	37 ± *11*	19 - 47
Wall thickness (µm)	6,5 ± *2*	-

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

*N. Di Virgilio, « Stinging nettle: a neglected species with a high potential as multi-purpose crop », National Reasearch Council of Italy. Institut of Biometeorology. Catania, Italy, vol. 23, 2013.

Fibers extraction

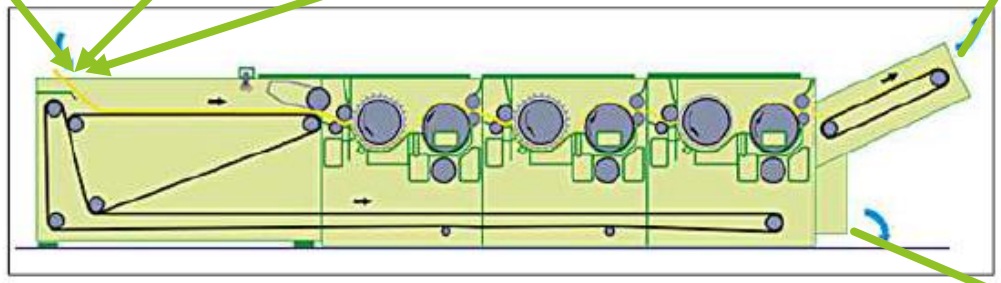
All fibers extraction device

Straw with 3 differents conditionning

C1: without MC=10.4%

C2: sprayed with watter MC=22.0%

C3: soda treatment MC=22.0%



Laroche Cadette 1000 'all fibres' (125 kg/h)

Sample	C1	C2	C3
Fibre lap (%)	11.0	48.4	15.4
Impurities in fibre lap (%)	17.6	36.5	51.0

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

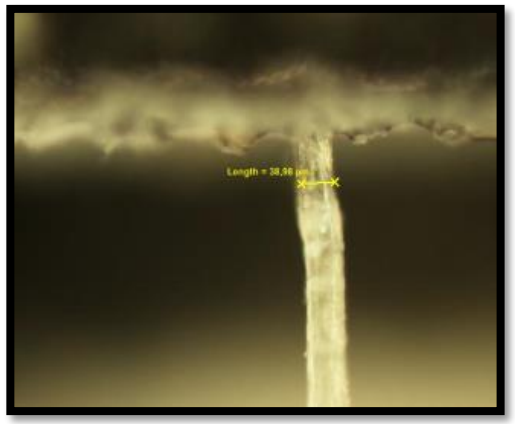
Questioning

Are mechanical properties of nettle fibers high to make composites?

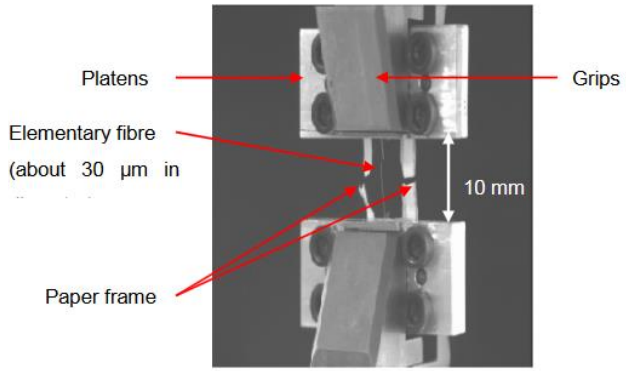
Mechanical properties.

Elementary fiber tensile test: method

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



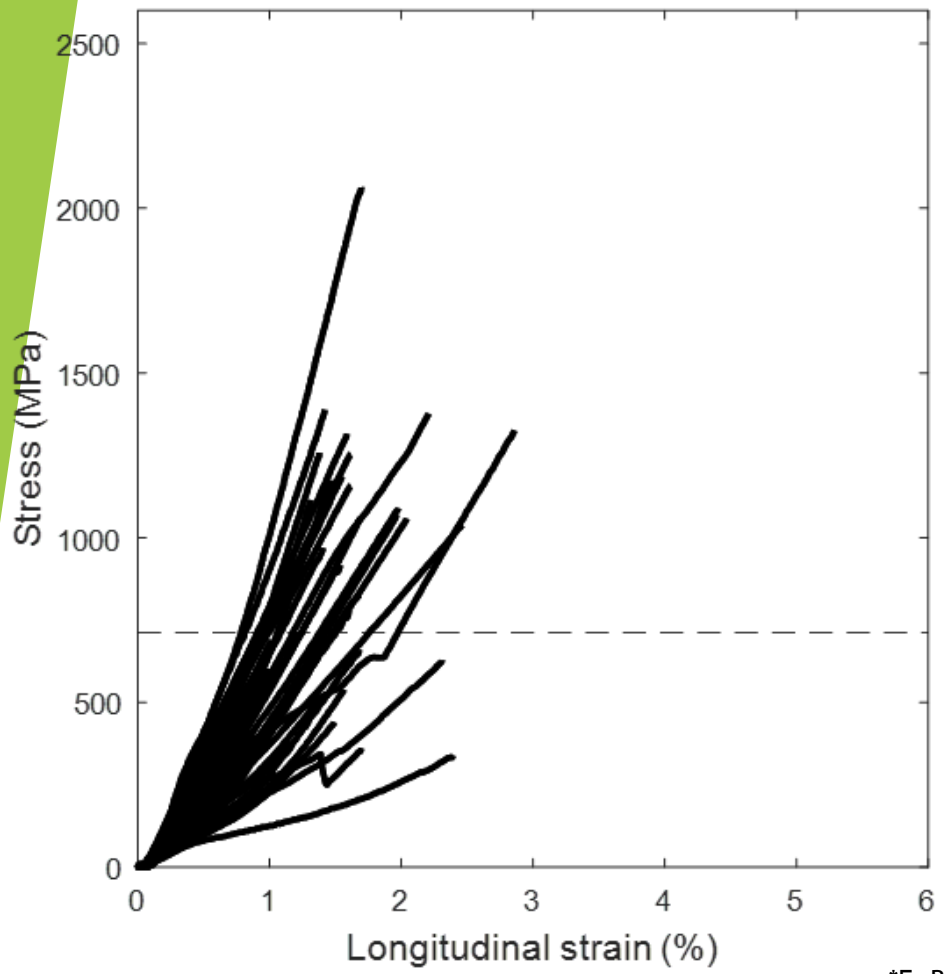
10 measures of the apparent diameter



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.

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.

Elementary fiber tensile test: results



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

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?

*E. Bodros et C. Baley, « Study of the tensile properties of stinging nettle fibres (Urtica dioica) », Materials Letters, vol. 62, no 14, p. 2143-2145, mai 2008.
**G. Lanzilao, P. Goswami, et R. S. Blackburn, « Study of the morphological characteristics and physical properties of Himalayan giant nettle (Girardinia diversifolia L.) fibre in comparison with European nettle (Urtica dioica L.) fibre », Materials Letters, vol. 181, p. 200-203, oct. 2016.

Comparison with other plant fibers

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

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

*Bensadoun, F., Verpoest, I., Baets, J., Müssig, J., Graupner, N., Davies, P., ... & Baley, C. (2017). Impregnated fibre bundle test for natural fibres used in composites. Journal of Reinforced Plastics and Composites, 36(13), 942-957.
**Placet, V., François, C., Day, A., Beaugrand, J., & Ouagne, P. (2017). Industrial Hemp Transformation for Composite Applications: Influence of Processing Parameters on the Fibre Properties. Advances in Natural Fibre Composites, 13-25.

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?

- Interesting 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 Maîtrise de l'Energie

Thanks for your attention

http://phytofiber.fr/