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Sustainable Solid Waste Management

Converting wastes into resources: the repeatability of carbon adsorbents' production from paper mill sludge

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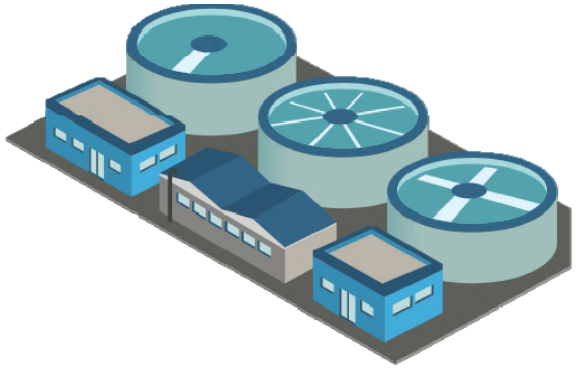
CONTEXTUALIZATION

Why are we producing carbon adsorbents?

Pharmaceuticals
in the environment



Source: FlatIcon

CONTEXTUALIZATION

Adsorption onto **activated carbon (AC)** is considered an **efficient** option for the **removal of pharmaceuticals**, but is poorly economically viable

A challenge exists in what concerns the application of feasible solutions for industrial waste management/valorization

CONTEXTUALIZATION

Pulp and paper industry has **massive water requirements** that result in the generation of a **huge volume of wastewater** which, in turn, create enormous amounts of **sludge**.

Landfills should comply with the requirements of the **European Landfill Directive (1999/31/EC)**

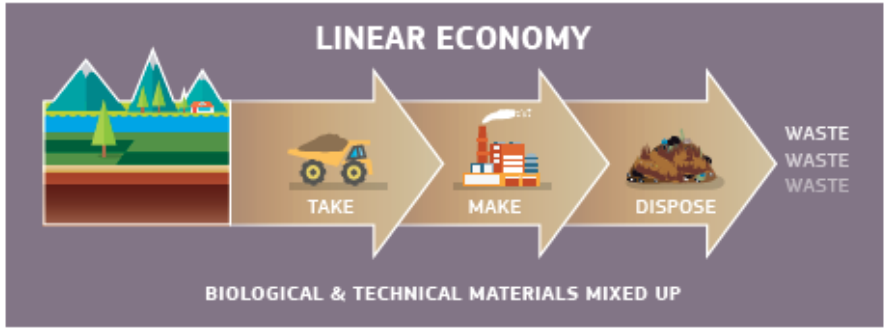
Nevertheless, **landfilling is being discouraged** since it causes environmental problems

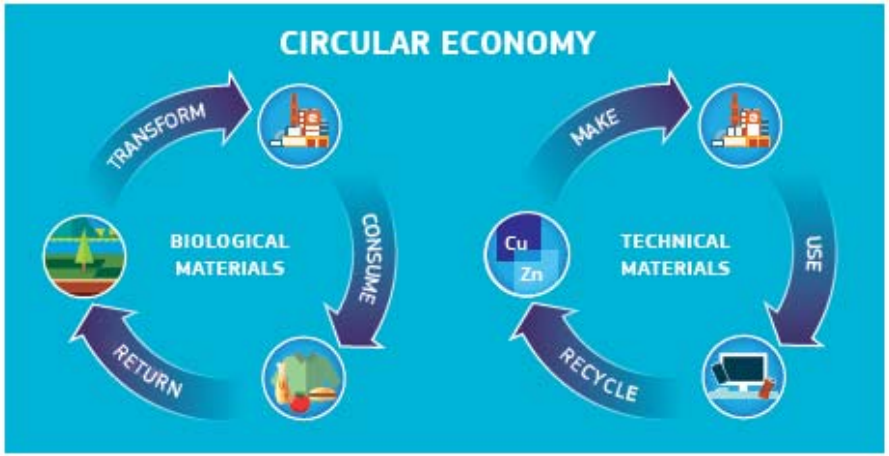
CONTEXTUALIZATION

Pulp and paper industry has **massive water requirements** that result in the generation of a **huge volume of wastewater** which, in turn, create enormous amounts of **sludge**.

Confederation of European Paper Industries (CEPI) supports a complete **ban of landfilling** in the European Union in agreement with the **Waste Framework Directive (2008/98/EC)**

CONTEXTUALIZATION





Source: LIFE and the Circular Economy, European Commission, 2017

Linear economy

"take, make, use and throw away"

Circular economy

restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times

An essential element of the transition to a circular economy is a well-functioning market for secondary raw materials – i.e. recycled materials that can be returned to the economy as new raw materials.

OBJECTIVES

Carry out an **integrated approach** aiming to find:

- a **low-cost** and **waste-based adsorbent** to remediate water, as an **alternative** to traditional ACs, and
- a **sustainable** solution for the **management** of a waste, exploiting its potential **economic value**

Evaluation of the **appropriateness** of **pulp and paper mill sludge as precursor** for the production of **carbon adsorbents**

Consistency and reliability of the raw material, guaranteeing the repeatability of the final product through time and between different origins

EXPERIMENTAL

Factory 1

Factory 2

Several primary (PS) and biological sludge (BS) batches from two paper factories with different operation modes were sampled

1

Both PS and BS were dried (at room temperature, followed by a 12 h period at 105 ºC in an oven), grinded and sieved

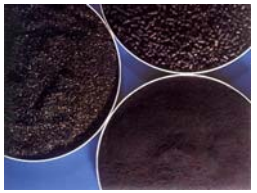
2

Materials were subjected to pyrolysis (800 ºC, 150 min of residence time, under controlled N_2 atmosphere)

3

Part of the produced materials were subjected to an acid washing with 1.2 M HCl

4



All the materials (raw sludge and resulting carbons) were fully characterized by proximate analysis, specific surface area, total organic carbon and attenuated total reflectance Fourier transform infrared spectroscopy

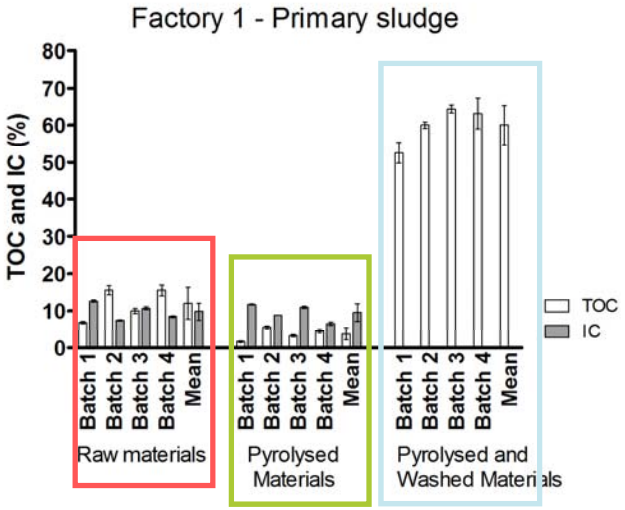
5

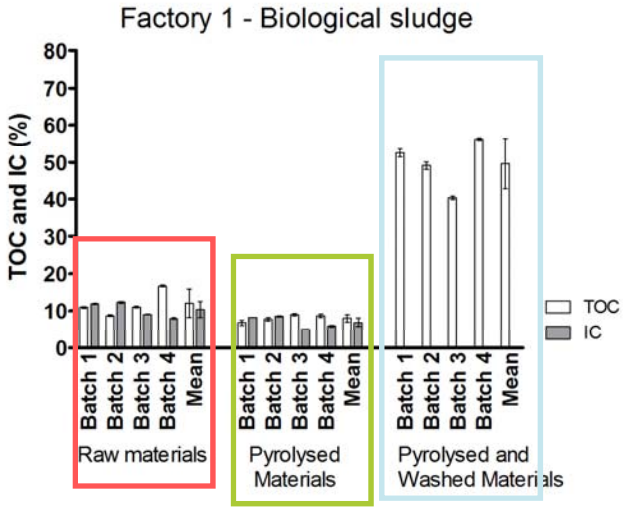
RESULTS: Materials' Characterization

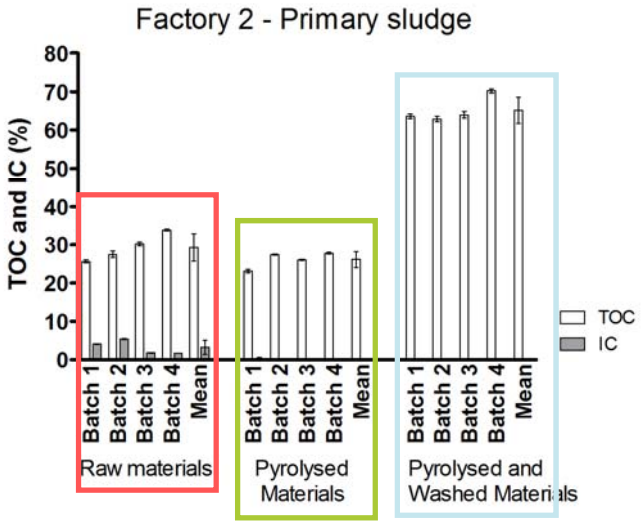
- Total Organic Carbon (TOC) ↑
- Inorganic Carbon (IC) ↓
- Surface área (S_{BET}) ↑
- Ash conten ↓

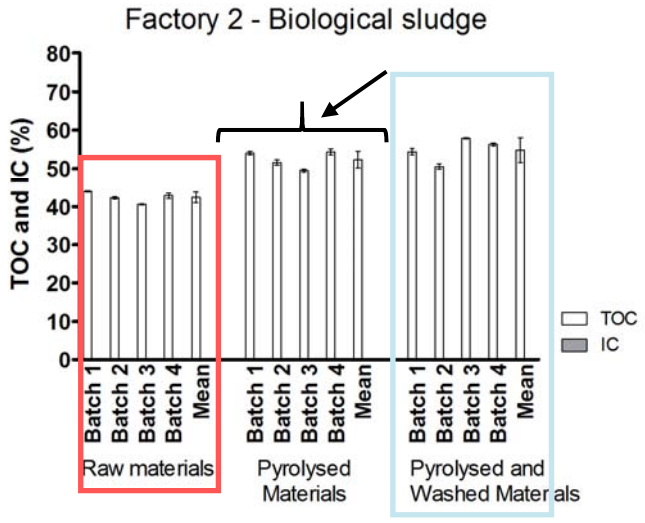
RESULTS: Materials' Characterization

Total Organic Carbon (TOC) and Inorganic Carbon (IC)









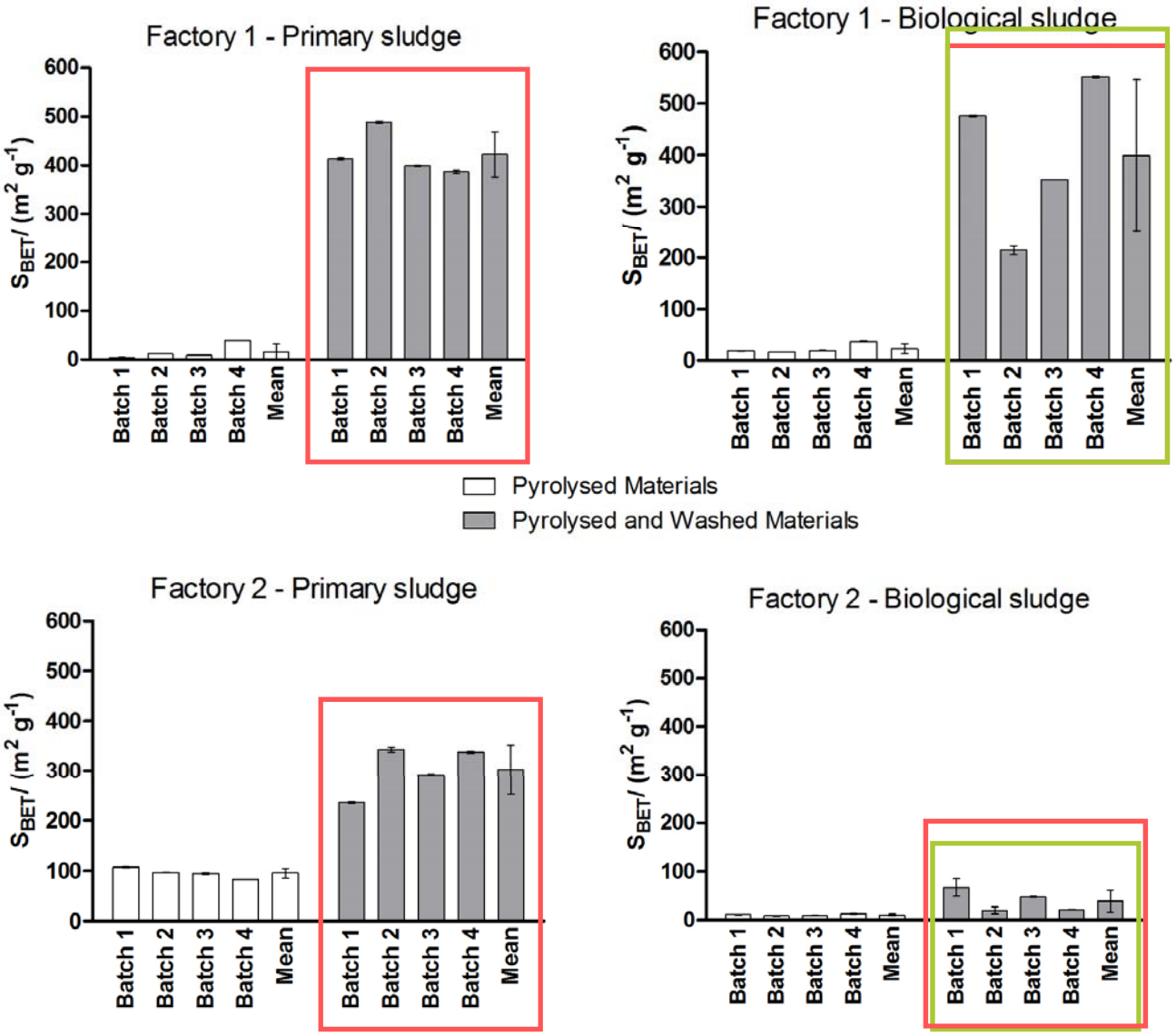
Raw materials from Factory 1:
- higher levels of IC
- TOC significantly lower

Pyrolysis process:
- decrease of TOC, except for BS from Factory 2

HCl washing step:
- significant increase of TOC
- IC fell to negligible values

RESULTS: Materials' Characterization

Specific surface area (S_{BET})



Acid washing resulted in a remarkable increase of the area of pyrolysed materials

In general, BS-PW presented higher variability between batches (RSD of 37% and 58% for Factory 1 and 2, respectively)

PS presented consistent and high S_{BET} values - key features for the production of carbon adsorbents

RESULTS: Variability of the carbon adsorbents' production process

Repeatability of the pyrolysis process

IC: 10.4 ± 0.3 to 11.7 ± 0.4%

TOC: 1.8 ± 0.3 to 1.7 ± 0.2%

S_{BET}: 1.36 ± 0.02 to 4.2 ± 0.4 $m^2\ g^{-1}$

Repeatability of the washing process

S_{BET} $RSD_{60\ min}$: 0.75%

S_{BET} $RSD_{300\ min}$: 0.56%

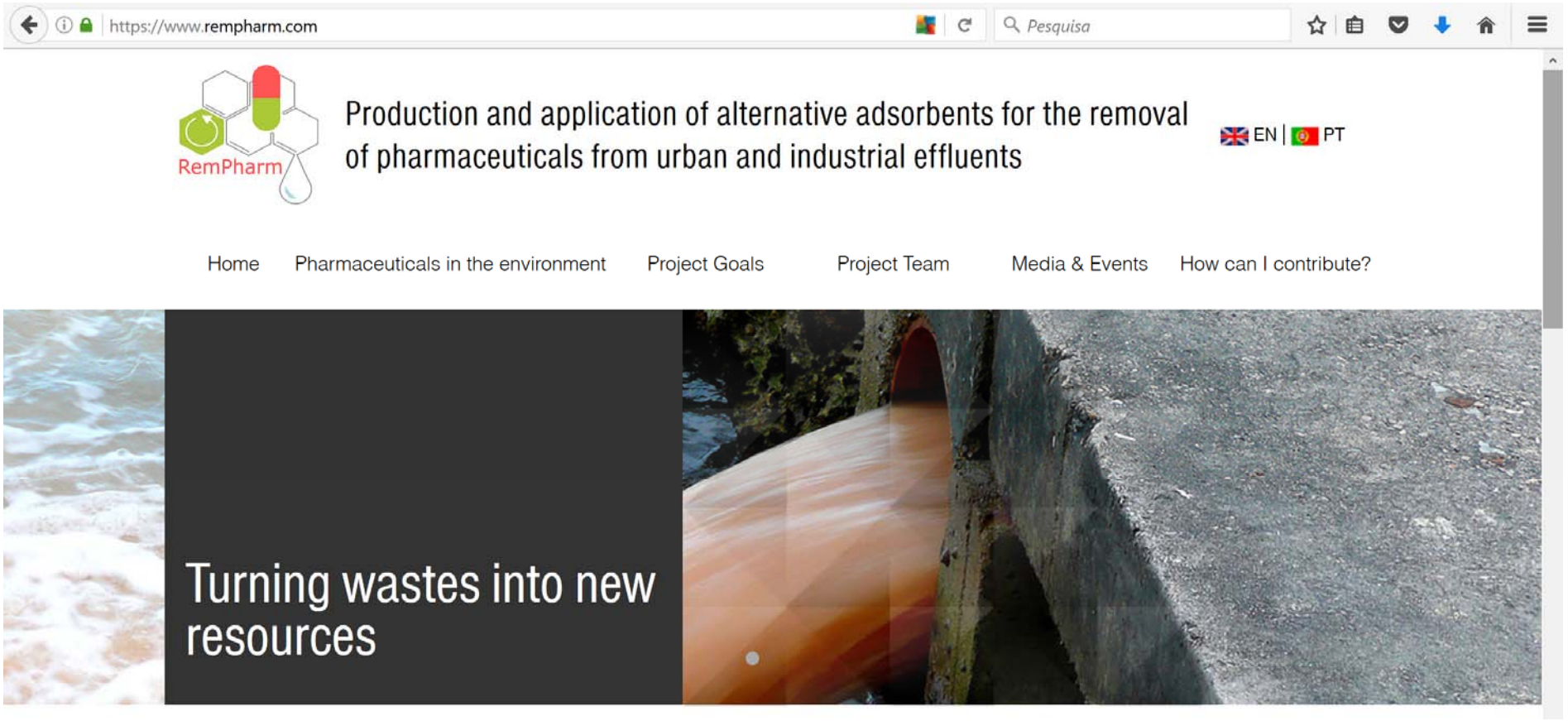
Pyrolysis and washing are not a relevant source of variability in the production of the carbon adsorbents from paper industry sludge

CONCLUSIONS

Use of industrial sludge as a new resource

- **Zero-waste approach**
- **New management option**
- **Potential adsorbent for wastewater treatment**

PROJECT'S WEBSITE



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ACKNOWLEDGMENTS

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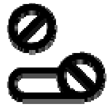






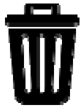


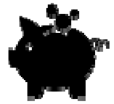




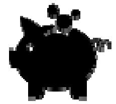

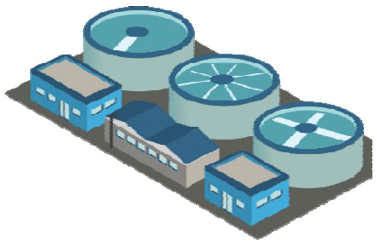
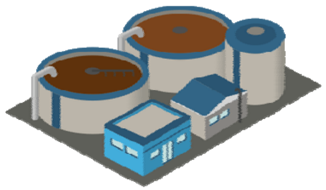

Figure 1. Schematic representation of the use of paper mill sludge as new resource (adapted from http://dx.doi.org/10.1016/j.jenvman.2016.12.004)

Production steps (pyrolysis and washing) did not cause variability in the final carbon materials, however different physico-chemical properties were found between raw materials from different factories, mainly regarding IC. The washing step, performed after pyrolysis, was found to be essential to reduce IC and to considerably increase S_{BET}, yet with high impact in the final production yield. Among the materials produced, PW materials from PS were those having the highest S_{BET} values (387-488 m^2 g^{-1}), which were considered very promising especially considering that materials were not subjected to any type of activation. Still, considering S_{BET}, P and PW materials produced from BS presented relative high variability between batches, while S_{BET} of materials from different batches of PS did not differ by more than 16%. Overall, it was concluded that precursors from different factories might originate final materials with distinct characteristics. It is, therefore, crucial to take into account this source of variability when considering paper mill sludge as a raw material for carbon adsorbents production. On the other hand, low variability was found between adsorbent materials produced from different batches of sludge within each factory, which