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Unravel the structure and reactivity of wood and biowaste biochars

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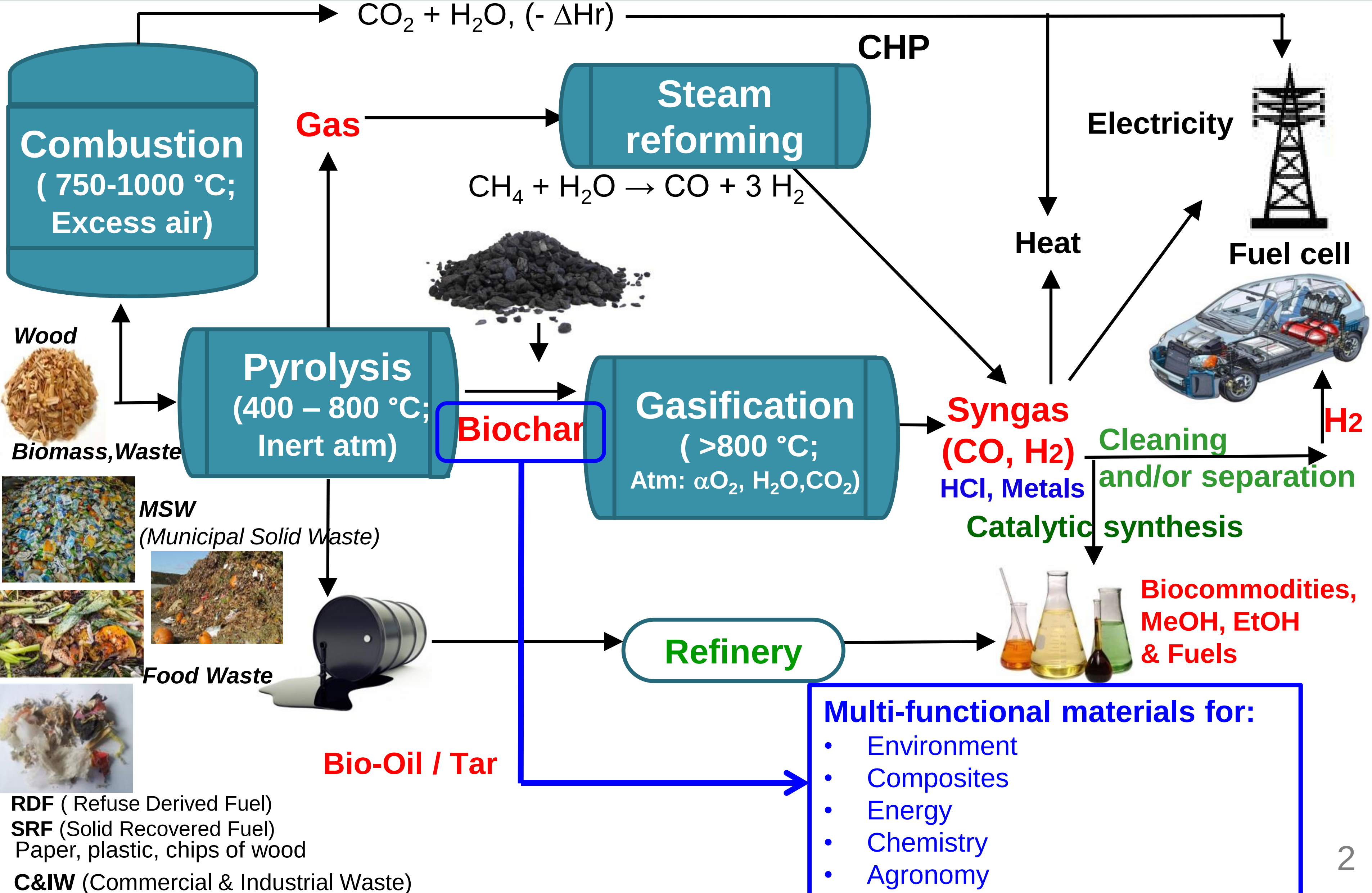
Research field: Alternative feedstocks to energy and multifunctional materials

My group: 16 persons (4 faculties + 8 PhDs and 4post-docs)



OUTLINE

I. Biochar production and utilisation

II. Biochar characterisation and properties

III. Some applications as ceramics for environmental remediation

IV. To take home

I. Biochar production and utilisation

Thermochemical conversion – range of applications

100- 150°C

Drying

A dehydration with the release of light hydrocarbons

GAS

VOC
H_2O

$\Delta H_{v(H2O)}$ = 2.3 MJ/kg at 100°C

250 - 280°C

Torrefaction

a mild form of pyrolysis dedicated only for biomass conversion. Torrefaction leads to obtaining dry product with higher energy content. Main product is biocoal - yield between 70 and 80%

BIOCOAL

300 - 550°C

MT pyrolysis

enables chemical conversion of products like biomass, plastic, or rubber into a solid, liquid or gas phase. Enables valorization to biooil and biochar. Yield of biooil ranges from 30 to 60%.

Yield of biochar 25 to 35%

BIOOIL,
BIOCHAR

600 - 900°C

HT pyrolysis & gasification

conversion most of the feedstock into methane-rich syngas which can be valorized into energy by using it CHP unit or steam boiler. Yield of syngas ranges from 50 and 95%

SYNGAS

$CO+H_2$
SO_x CO_2
CH_4 PAH NO_x

LHV (Low heating value): 8 < Biocoal (MJ/kg) < 22

13 < Biooil (MJ/kg) < 27
10 < Biochar (MJ/kg) < 32

12 <Syngas (MJ/kg) < 20

Reference: LHV H2= 120 MJ/kg LHV CH4= 50 MJ/kg LHV MSW=10 MJ/kg

I. Biochar production and utilisation

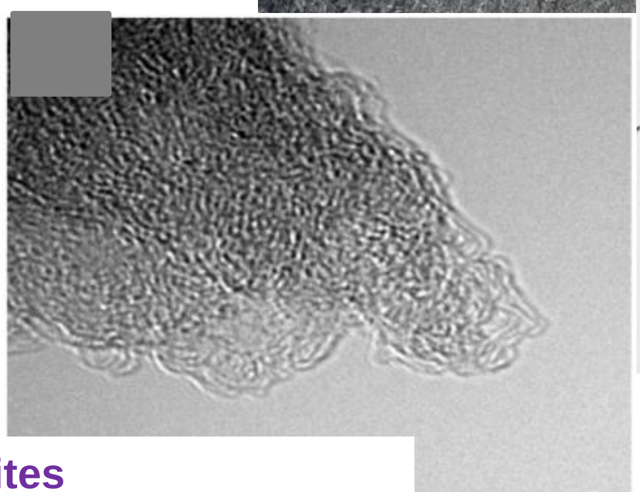
Some current utilisations

Energy
Fuel cells
photovoltaic
Supercapacitors

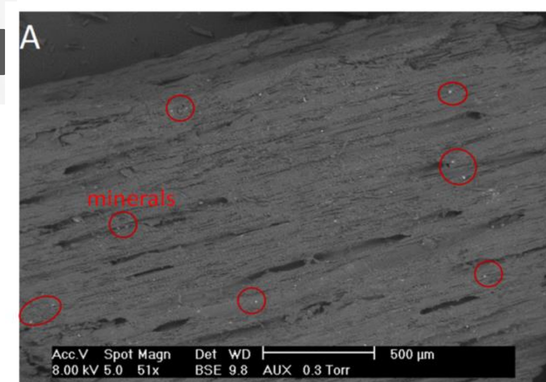
Chemistry
Catalyst
Adsorbent
Water treatment

Carbon fibers
Nanotubes

Environment
Carbon sequestration
CO_2 Storage
Sensors



Agronomy
Water retention
Plant nutrients
Soil conditioner



Composites
Reinforcing materials
in polymer composites.
Biocomposites

Other uses
Biomedical use Pharmaceutical

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II. Biochar characterisation and properties

Raw biomass composition

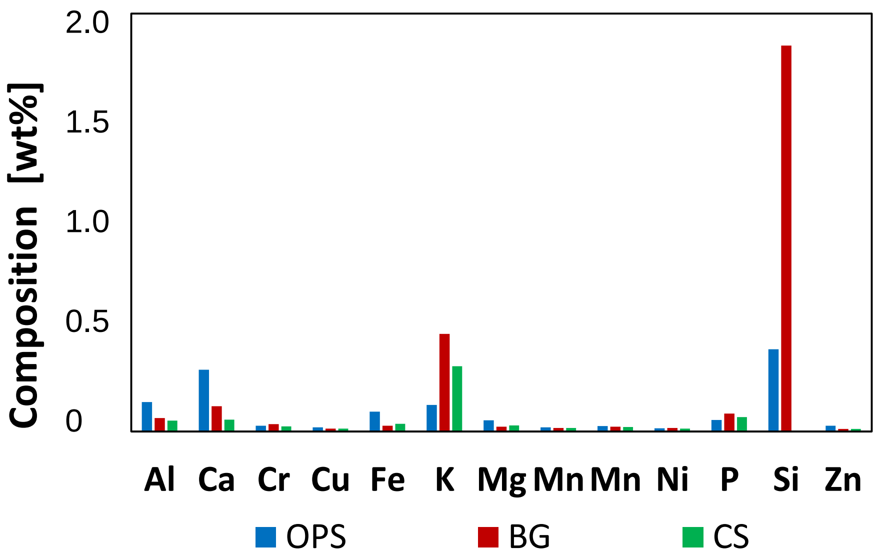
Three tropical biomasses were selected from different agro wastes

Oil Palm Shell (OPS)

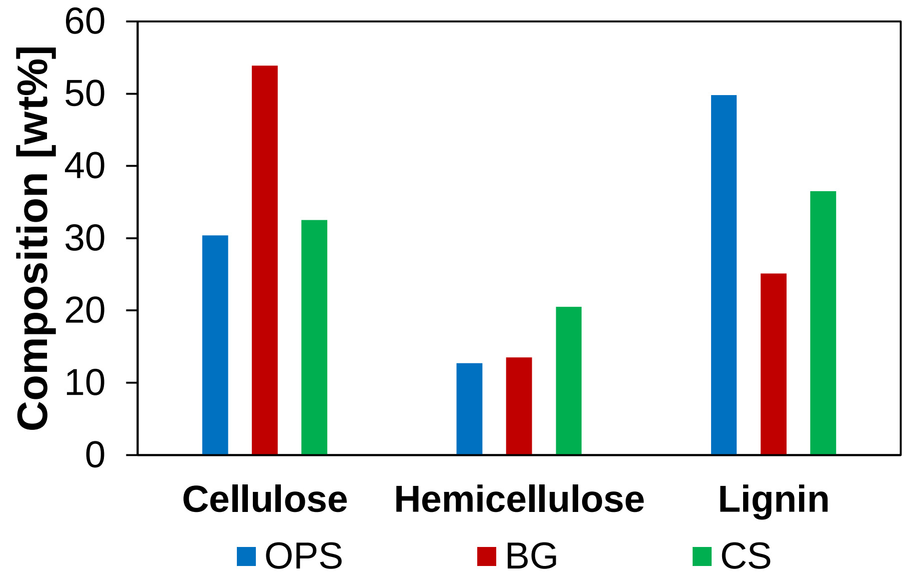
Coconut Shell (CS)

Bamboo (BG)

Inorganic composition



Macromolecular composition



- ✓ Oil palm shells and Coconut shells are endocarps with high lignin content
- ✓ ***Si*** is the most important inorganic constituent of Bamboo guadua
- ✓ ***K*** is the most important inorganic constituent of Coconut shells

L.M. Romero Millan, NZIHOU A., F.E. Sierra Vargas., BioEnergy Research, 10, 832-845, 2017

II. Biochar characterisation and properties

Chemical properties

carbon matrix

- Raman spectroscopy
  → *Carbon structure distribution*
- Transmission Electron Microscopy (TEM)
- X-Ray Tomography
  → *Nanostructure*

O- groups

- Fourier transformed infra red (FTIR)
  → *Nature of O-containing groups*
- Temperature Programmed Desorption (TPD)
  → *Quantification*

minerals

- X-ray fluorescence (XRF)
  → *Elemental analysis*
- X-ray diffraction (XRD)
  → *Structure*
- ESEM analysis
  → *Distribution*

Physical properties

textural properties

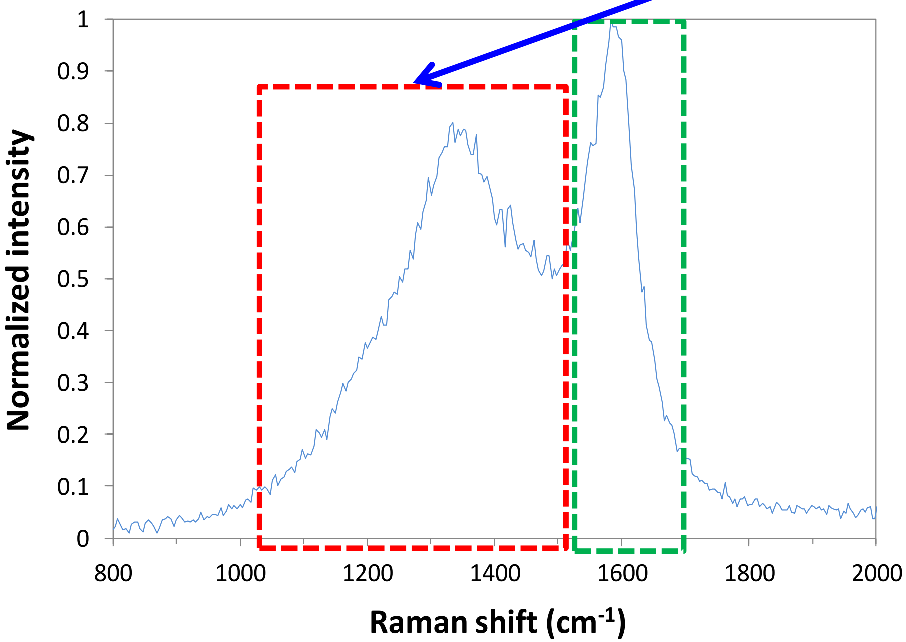
- BET analysis
  → *Specific surface area*
  → *Porosity*

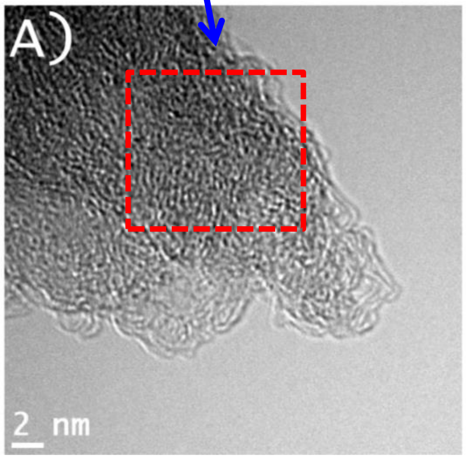
II. Biochar characterisation and properties

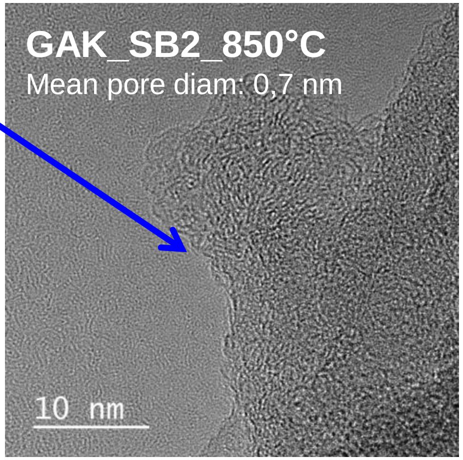
High Resolution TEM spectra

Raman spectrum

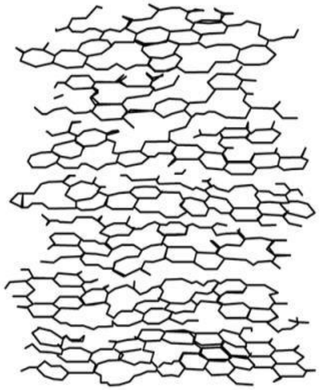
Disordered structure



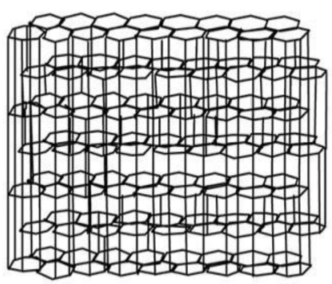




Turbostratic structure



Graphite structure



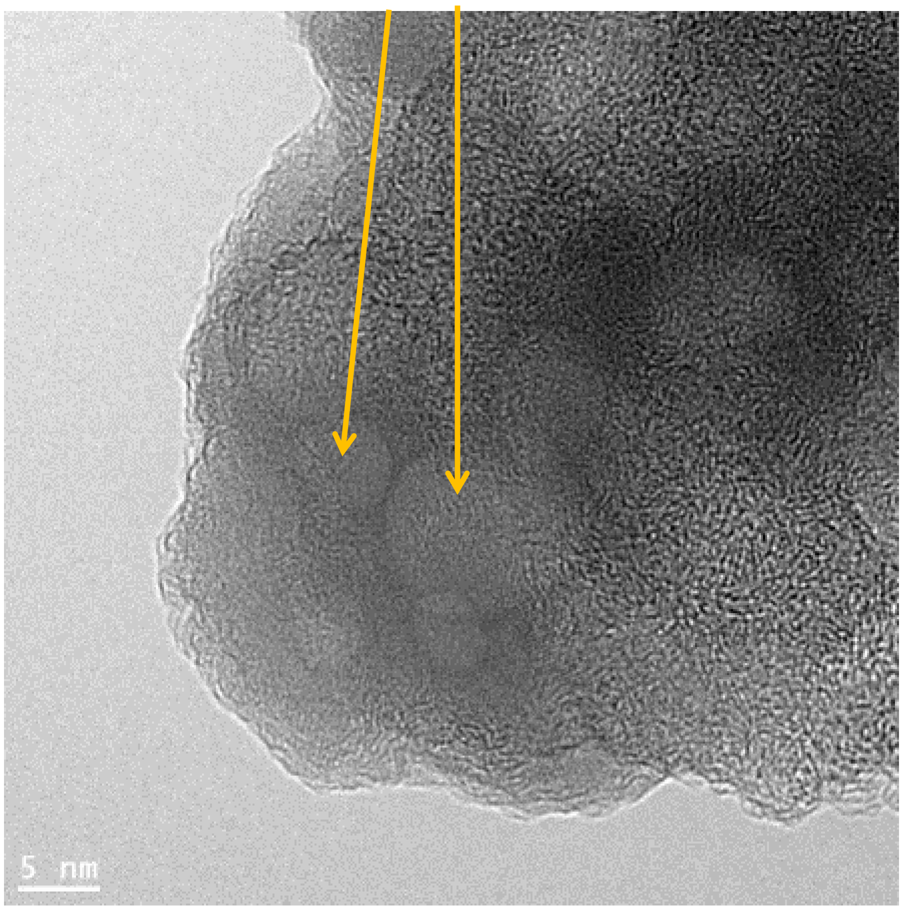
- Raw biochar **complex carbon** containing:
- Ordered structure
- Disordered structure

II. Biochar characterisation and properties

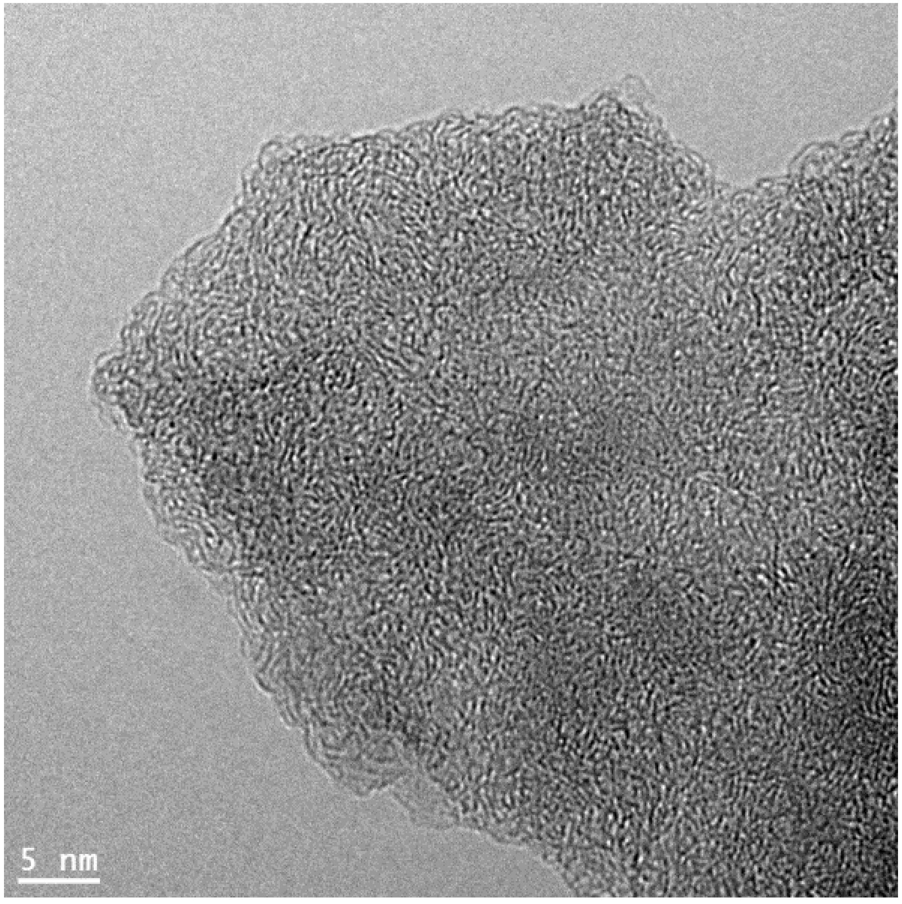
BIOCHAR 700°C

HRTEM

Porosity



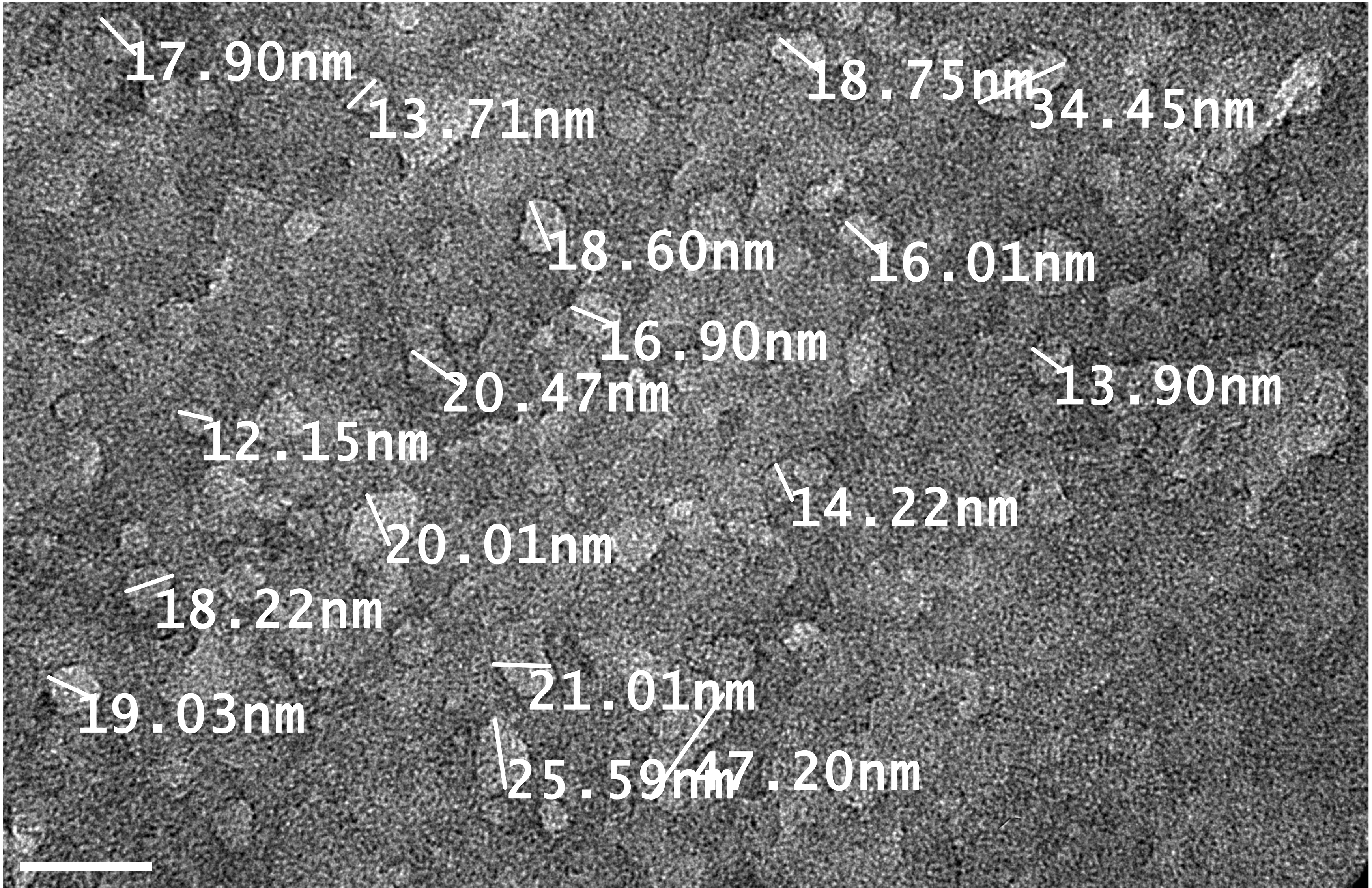
Graphene fringes



II. Biochar characterisation and properties

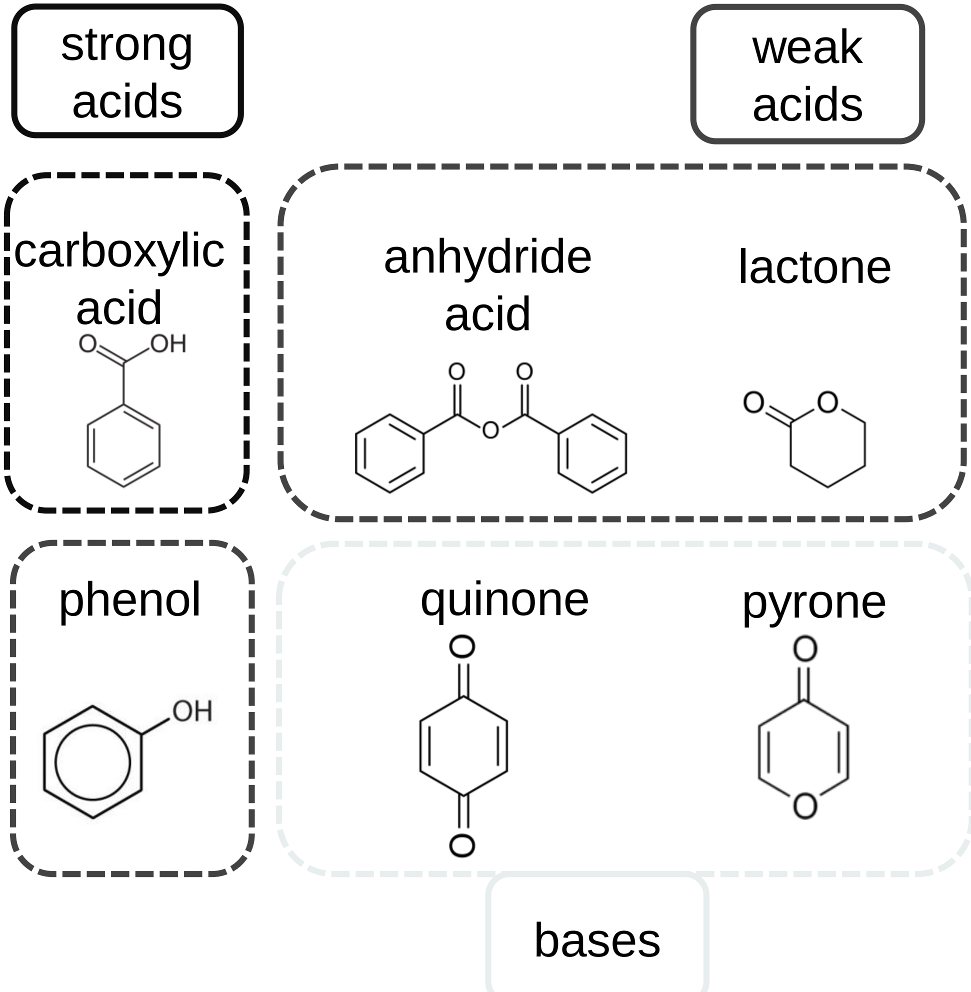
BIOCHAR 400°C

Bright field TEM - nanopores



II. Biochar characterisation and properties

Surface functions determination



TPX (R, O, D)

TPR : reductible species

TPO : oxidable species

TPD : active sites

Chimisorption : dispersion of metals

Titration : acidic and basic sites

Temperature Programmed Desorption (TPD): Thermal desorption spectrometer

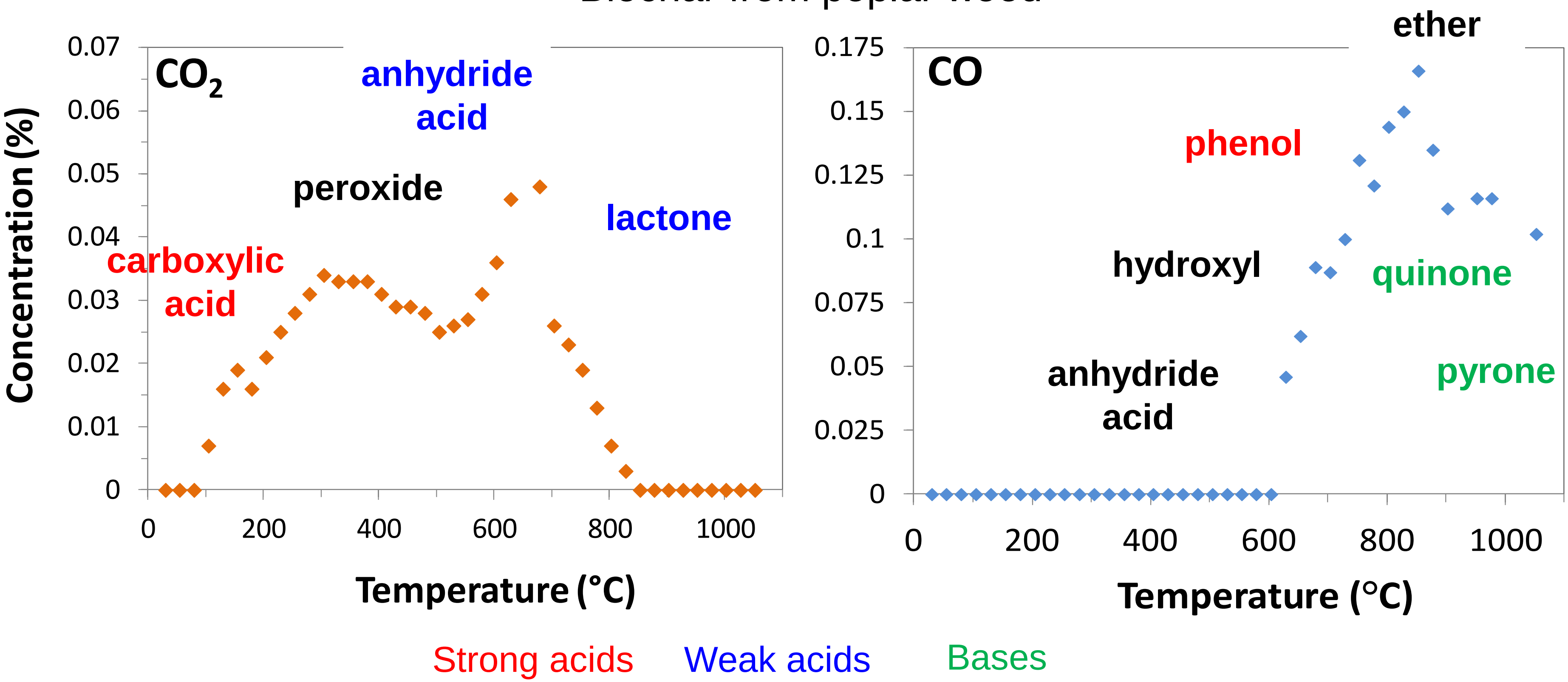
J.L. Figueiredo et al.,Carbon (1999) / I. Salame ,J. of Colloid and Interface Science (2001)

II. Biochar characterisation and properties

Surface functions determination

Temperature Programmed Desorption (TPD)- Gas chromatography

Biochar from poplar wood



M. Ducousso, E. Weiss-Hortala, A. Nzihou, M.Castaldi. Fuel 2015, 159, 491-499

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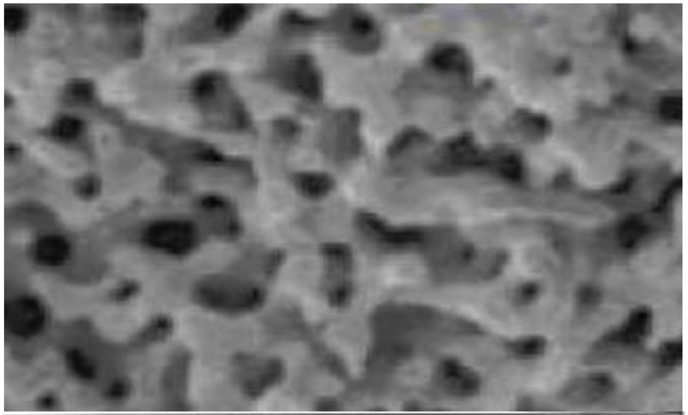
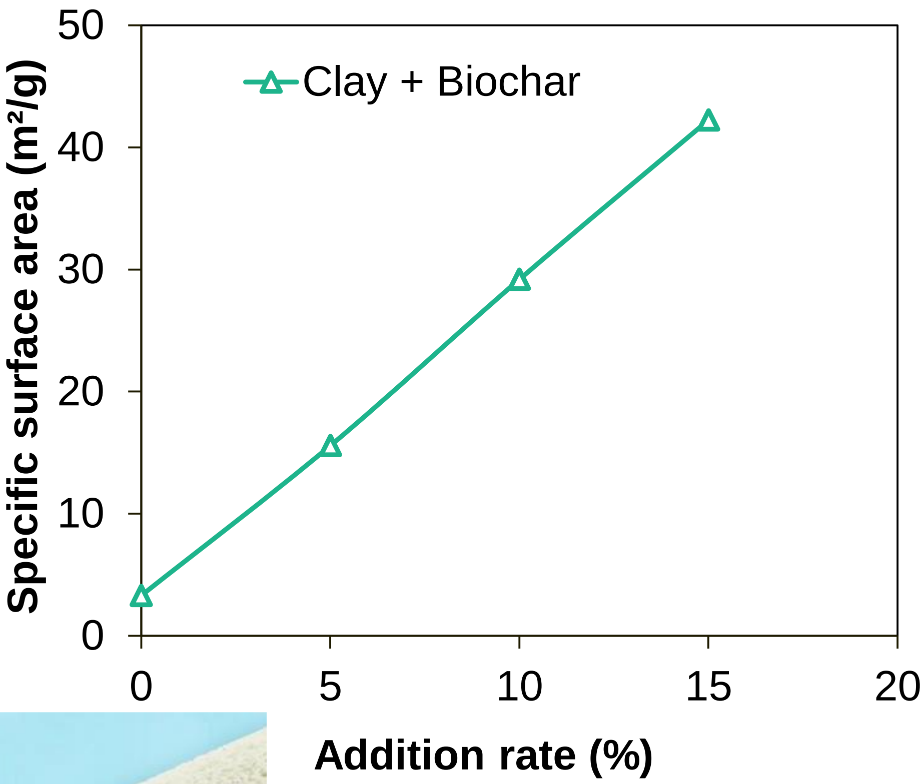
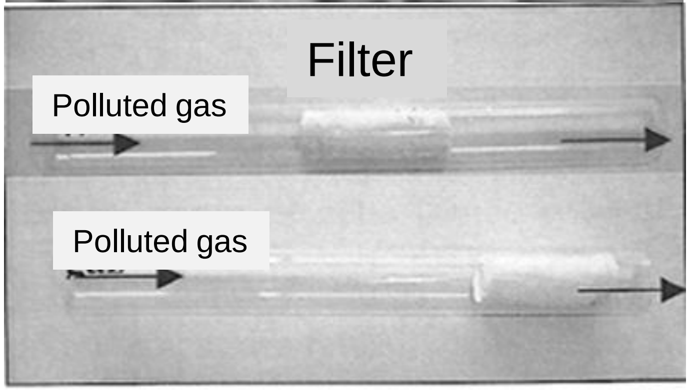
III. Some applications as ceramics for environmental remediation

Clay biochar Composites

- Filters for polluted gas
- Filters for effluents treatment
- Sensors for pollutants removal







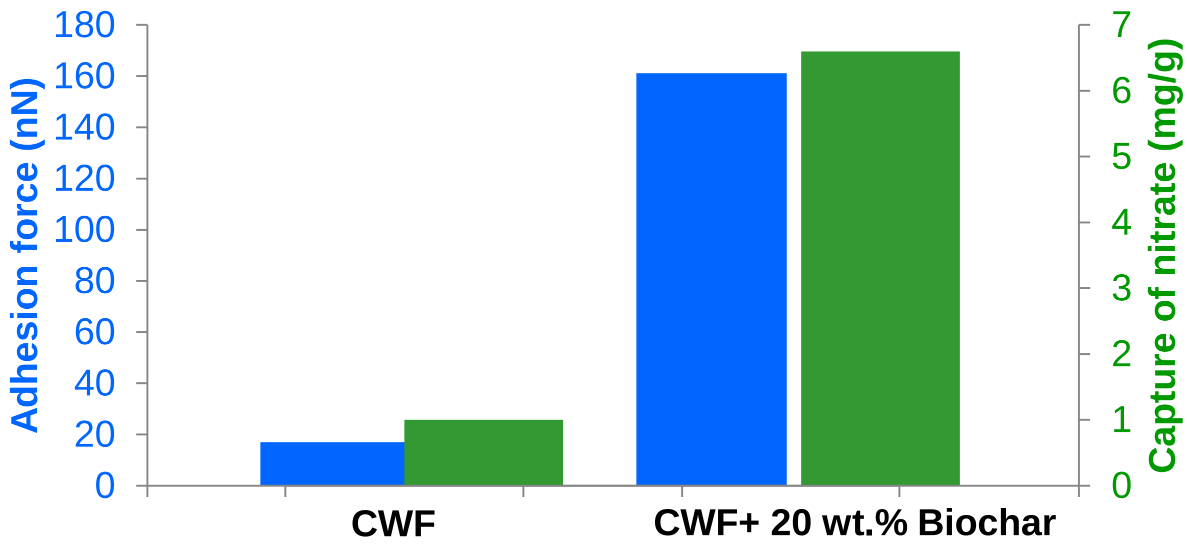
III. Some applications as ceramics for environmental remediation

Wastewater treatment: Denitrification

Sample	Total porosity (%)	Open porosity (vol.%)	Permeability (mD)	Specific surface area (m^2/g)
CWF	34	27	23	0.9
CWF+ 20wt.% biochar	57	52	43	194.7

Data obtained using water absorption (porosity), mercury intrusion porosimetry (permeability) and nitrogen adsorption analysis using the BET method (specific surface area))

Contaminants (nitrate), adhesion forces and capture efficiency of the ceramic water filter (CWF).



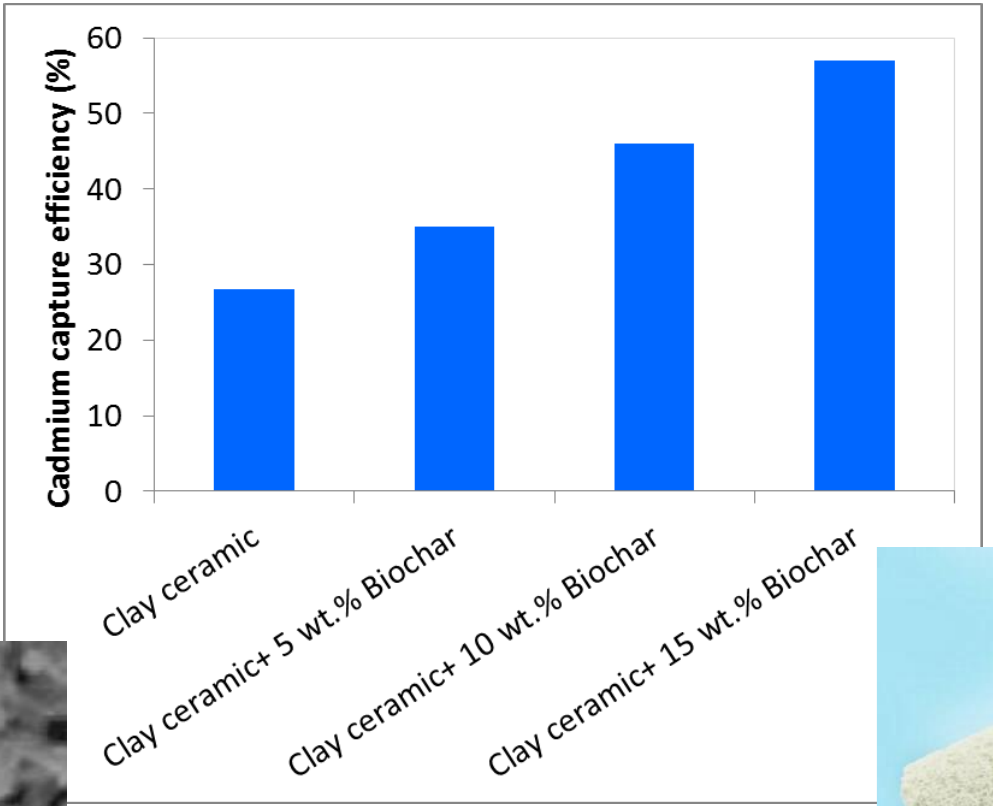
Data obtained using chromatography (IC) and inductively coupled plasma mass spectrometry (ICP-MS)

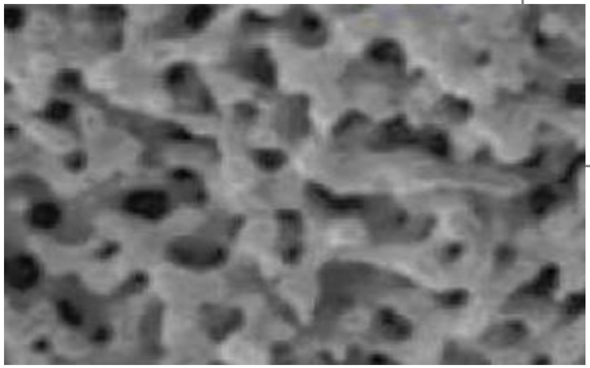
P.M. Nigay et al. J. of Environ. Eng., 2017

III. Some applications as ceramics for environmental remediation

Wastewater treatment: Removal of heavy metals

Dependence of the cadmium capture efficiency of the clay ceramic





P.M. Nigay, A. Nzihou et al. J. of Environ. Eng., 2017

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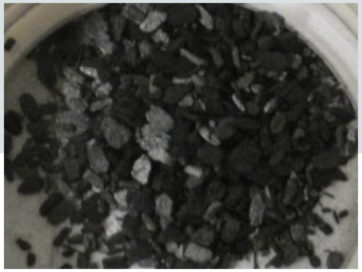

- ✓ Carbonaceous materials such as biochar can derive from renewable resources such as Biomass and Biogenic waste

- ✓ Can be used as a product itself or as an ingredient within a blended product, with a range of potential applications as ceramics

- ✓ Renewable nature
- ✓ Cost effectiveness
- ✓ Tunable: reactivity, thermal and mechanical stability
- ✓ Well adapted for developing Countries

BIOCHAR: A tunable and multi-functional material

ACKOWLEDGEMENTS

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