Carbonization of Yerba Mate Stick with Micrometric Pores Using Home-built Kiln

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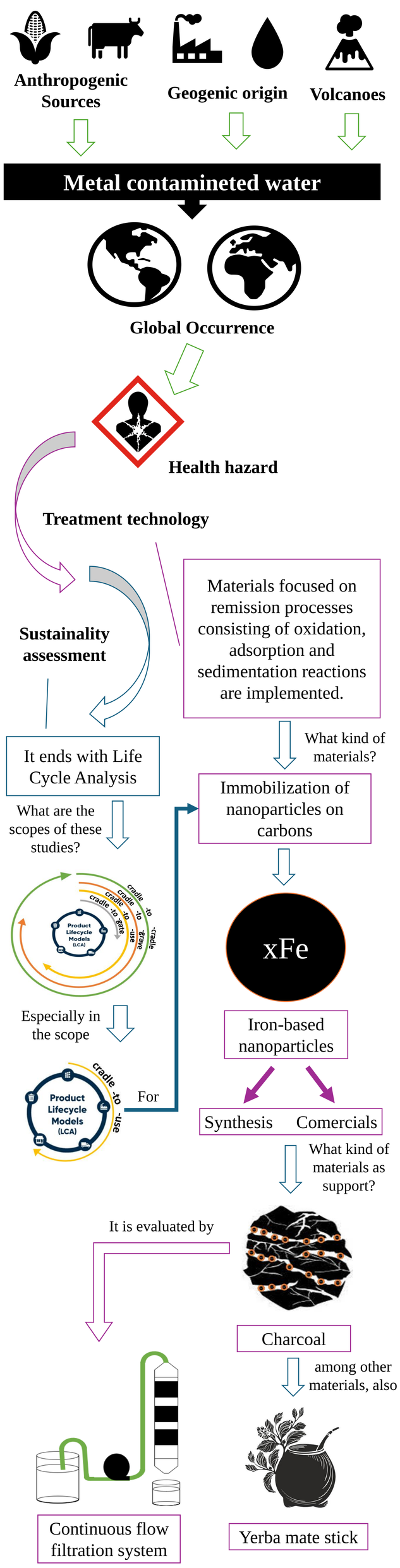
Abstract: Contaminant metals represent a significant threat to global water systems, with severe implications for human health. Treatment technologies utilizing porous materials embedded with nanomaterials offer a promising approach for the effective removal of these contaminants. In this study, charcoal was produced from yerba mate sticks, a form of industrial waste. The raw material, provided by Empresa Rosamonte (Establecimiento Diez Hermanos), was pyrolyzed in a homemade furnace following the methodology reported by Long et al.4 The produced simples were thoroughly characterized using particle size análisis, elemental composition analysis, X-ray diffraction (XRD), and scanning electron microscopy (SEM). The resulting charcoals exhibited cylindrical, parallel pores separated by micrometric walls and interconnected by micropores within the thin walls. A reduction in the average size of yerba mate sticks was observed after pyrolysis, attributed to the contraction and fragmentation of the initial material. The process achieved a yield of 32 ± 1%, corresponding to the production of 170 ± 21 g of charcoal—two orders of magnitude higher than yields typically obtained with laboratory-scale tubular furnaces. This study underscores the potential of utilizing industrial waste for producing functional porous materials with scalable yields, contributing to sustainable solutions for water contamination challenges.

INTRODUCTION



MATERIALS AND METHODS

Synthesis of Charcoal: In a replica of the furnace reported by Long and Arnal (2021), the PYM was carbonized for 3 hours. Three independent syntheses were performed (PYM-C#1, PYM-C#2, and PYM-C#3).

Characterization: X-ray diffraction (XRD) was conducted using a multipurpose Panalytical EMPYREAN model with a Cu-Kα source. Scanning electron microscopy (SEM) was performed on a JEOL JCM-6000 Neo Scope at high vacuum and 15 kV. Elemental analysis of CHNS was carried out using a Carlo Erba EA 1108 (10 mg). Stick size was analyzed using image analysis software ImageJ.

RESULTS AND DISCUSSION

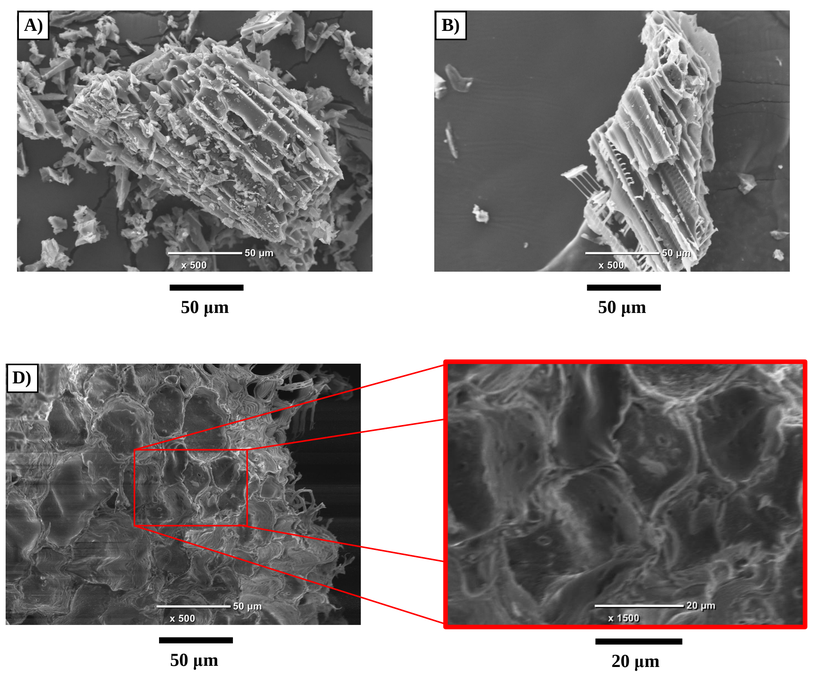


Table 1. Pore size in coal walls

Material	Average pore size diameter (µm)
PYM-C#1	0.193 ± 0.039
PYM-C#2	0.154 ± 0.042
PYM-C#3	0.151 ± 0.055

Figure 1. Scanning Electron Microscopy (SEM) of the materials before and after each carbonization. A) PYM-C#1, B) PYM-C#2, C) PYM-C#3, and D) PYM.

- Cylindrical pore particles were obtained, separated by micrometric walls and interconnected by macropores located in the thin walls..
- The pores located in the thin walls exhibited sub-micrometric sizes.

Replicated furnace from Long & Arnal, 2021.

Table 2. Elemental analysis of the samples before and after carbonization.

Muestra	N (%)	C (%)	H (%)	S (%)	Otros
PYM C#3	0,5	75,5	2,8	ND	21,2
PYM C#2	0,7	61,7	2,7	ND	34,9
PYM C#1	0,5	72,8	3,3	ND	23,4
PYM	0,5	46,5	6,2	ND	46,8

- These results show that the charcoals exhibit a significantly higher C/H ratio compared to the biomass.

Table 3. Shrinkage of biomass after carbonization

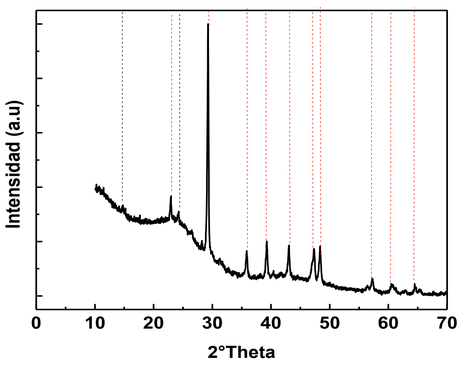
Experiment number	Summation of the total projected area (cm^2) PYM	PYM-C	% shrinkage of charcoal
#1	3.14	2.19	30.17
#2	3.24	2.32	28.36
#3	3.66	2.44	33.50

- The summation of the projected areas shows a decrease after carbonization, indicating a size reduction due to shrinkage.

Table 4. Comparison of Yield and Amount of Charcoal Obtained with References.

Reactor	Raw material	Initial Biomass (g)	Charcoal obtained (g)	Carbonization yield (%)	Reference
Home-built kiln	Yerba Mate Stick	509 ± 60	170 ± 21	32 ± 1	Current study
Home-built kiln	Eucalyptus stick	701 ± 40	200	30 ±1	Long & Arnal, 2021
Tubular furnace	Yerba Mate Stick	3	0.87	29	Jerez & et al.

- This yield is similar to that obtained in the referenced studies. The amount synthesized is two orders of magnitude greater than under typical laboratory conditions using a tubular furnace.



Graph 2. X-ray diffractograms (XRD) obtained from charcoal particles. Calcite (•) and $CaC_2O_4 \cdot H_2O$ (•). a) PYM-C#1, b) PYM-C#2, and c) PYM-C#3.

- Presence of calcium oxalate crystals and their derivative calcite.

CONCLUSIONS

Our work demonstrates that the simple and inexpensive homemade furnace converts yerba mate sticks into charcoal, based on the experimental evidence obtained: SEM, CHNS elemental analysis, XRD, and carbonization yield. A decrease in the average size of the yerba mate sticks was confirmed after pyrolysis as a result of the contraction and breakage of the starting material. The process recorded a yield of 32 ± 1%, corresponding to the production of 170 ± 21 g of charcoal, two orders of magnitude greater than what is usually obtained in laboratory tubular furnaces.

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