Transforming Municipal Solid Waste into Geopolymers: A Sustainable Solution

More information

Ana Paula Ferreira da Silva

anapaula.silva@ipb.pt

Supervisor(s): Jose L. Diaz de Tuesta T[1,2,3], José Alcides S. Peres[4], Helder T. Gomes[1,2]

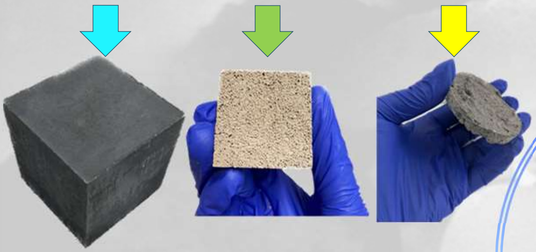
1. Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança (IPB), Campus de Santa Apolónia, 5300-253 Bragança, Portugal;
2. Laboratório Associado para a Sustentabilidade e Tecnologia em Regiões de Montanha (SusTEC), IPB;
3. Department of Chemical and Environmental Technology, ESCET, Rey Juan Carlos University, Móstoles, Spain;
4. Centro de Química de Vila Real (CQVR), Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801, Vila Real, Portugal.

MIT Portugal 2023 Annual Conference

Geopolymer

Geopolymers are a class of inorganic materials that are formed through a chemical process known as geopolymerization. They are typically produced by activating source materials rich in alumina and silica, such as fly ash (used in this work), slag, or metakaolin, with alkali activators. This process creates a three-dimensional network of covalent bonds, resulting in a strong and durable material.

Geopolymers have gained significant attention due to their eco-friendly nature, as they can be synthesized using industrial by-products, reducing the need for raw materials and mitigating waste disposal issues. Their versatility and potential for sustainable development make geopolymers a promising candidate in advancing environmentally conscious and resource-efficient materials. They can be valued in products such as geopolymer concrete, adsorbent, foams, and zeolite-like geopolymers or incorporate other high value-added materials into its matrix (activated carbon, carbon nanotubes).



Production

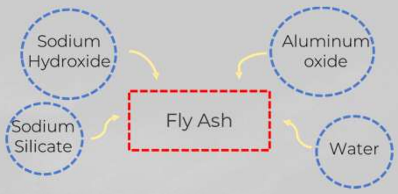
To produce geopolymers, both as adsorbents and as concrete, an experimental design was developed using the Box-Behnken Design methodology. Also, structural characterizations of geopolymers were conducted, encompassing surface area, acidity and basicity assessments, FTIR (Fourier-transform infrared spectroscopy) analysis, XRD (X-ray diffraction), and SEM (scanning electron microscopy). These analyses provided valuable insights into the material's properties and composition.

Adsorbent

Factor	Original Factor (x)	Levels -1	0	1
Si/Al	x_1	1.50	2.00	2.50
NaOH (M)	x_2	5.00	7.50	10.0
Na_2SiO_3/NaOH	x_3	1.00	1.75	2.50

Concrete

Factor	Original Factor (x)	Levels -1	0	1
NaOH (M)	x_1	4	10	16
Na_2SiO_3/NaOH	x_2	1.5	2	2.5
Alkali Solution/Fly-ash)	x_3	0.35	0.525	0.7



Geopolymer Application

The adsorption capacities for phenolic compounds were in the range of 75.8 mg/g and 58.1 mg/g, respectively. And this material can be applied as an adsorbent in the treatment of leachate water.

As for the geopolymeric concrete, a compressive strength of 25 mPa and a flexural strength of 11 mPa were obtained. And this material can be applied as a substitute for Portland Cement, in civil construction.

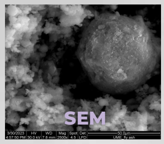
Characterization

Fly-ash

ICP-OES

Element	wt (%)
Ca	27.5
Si	12.2
Al	9.6
K	2.9
Fe	2.1
Mg	1.9
Zn	0.4
Cu	0.1
Mn	0.1

- The fly ash contains sufficient amounts of Si and Al, making it a valuable source of aluminosilicate.



- The structure of FA is intricate and multifaceted, characterized by an amalgamation of independent and agglomerated particles that appear round and spherical but vary in size and shape.

Geopolymers

Surface area

	FA	GP-2	GP-6	GP-10	GP-11	GP-13
BET surface area (m^2/g)	11	35	30	30	30	61
Total pore volume (cm^3/g)	1.4E-02	6.7E-02	6.2E-02	7.7E-02	7.7E-02	1.1E-01
Average pore width (nm)	1.8	1.8	1.8	1.8	1.8	2.3

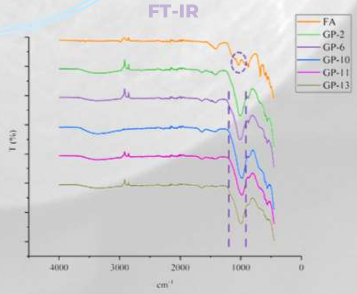
- GP-13 exhibited an increase in pore volume compared to the other GPs;
- Increase in the surface area of all the GPs compared to the precursor material, which is attributed to their higher porosity;
- Increase in the total pore volume, indicating the role of geopolymerization in enhancing pore formation within the geopolymer matrix.

Acid-Base Characterization

GP	pH_{PZC}	pH_{ads}	Basicity (mmol/L)	Acidity (mmol/L)
GP-2	8.1	7.8	12.3	1.00
GP-6	8.8	7.9	15.3	0.75
GP-10	8.7	8.1	13.0	0.30
GP-11	8.6	8.0	9.80	0.55
GP-13	8.2	7.8	10.5	1.40

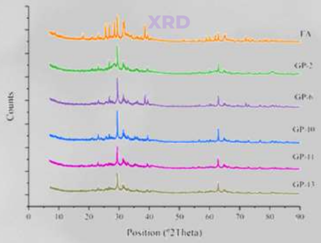
- Predominantly basic character;
- The pH_{PZC} value for all the GPs analyzed was found to be in the range of 8;
- The pH values during the adsorption process for all GPs were lower than their pH_{PZC} values, indicating that the adsorbents were positively charged.

FT-IR



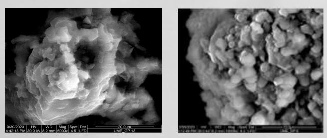
- 1037 cm^{-1}: asymmetric stretching vibrations of Si-O T (T-tetrahedral Al or Si) in FA;
- 1000 - 980 cm^{-1}: asymmetric stretching vibrations of Si-O-T (T-tetrahedral Al or Si) in GPs;
- Changes in the length and angle of the Si-O-Si bonds in the gel.

XRD



- Calcite ($CaCO_3$) is the most prominent phase observed;

SEM



- The GPs exhibits a homogeneous structure with fewer unreacted FA particles;

Funded by: FCT Fundação para a Ciência e a Tecnologia; Centro de Investigação de Montanha CIMO; MIT Portugal; UTAD Universidade de Trás-os-Montes e Alto Douro; IPB Instituto Politécnico de Bragança

The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) for financial support through national funds FCT/MCTES (PIDDAC) to CIMO (UIDB/00690/2020 and UIDP/00690/2020) and SusTEC (LA/P/0007/2020). Ana Paula Silva is supported by the doctoral Grant SFRH/BD/151346/2021 and PRT/BD/153090/2021 financed by FCT and with funds from NORTE2020, under MIT Portugal Program. Jose L. Diaz de Tuesta acknowledges the financial support through the program of Atracción al Talento of Comunidad de Madrid (Spain) for the individual research grants 2020-T2/AMB-19836 and 2022-T1/AMB-23946.

under the Doctoral Grant PRT/BD/153090/2021 | Sustainable Cities