



Hydrothermal valorisation of residual hibiscus biomass waste for facile synthesis of hydrochar/TiO₂ nanocomposite

Stephen Sunday Emmanuel and Shepherd M. Tichapondwa

Department of Chemical Engineering, Sustainable Environmental and Water Utilisation Processes Division, University of Pretoria, South Africa



Introduction

The transition towards nanotechnology and circular economy has become imperative in contemporary discourse, driven by the urgent need for environmental sustainability. Thus, this research work aims to explore the hydrothermal valorisation of residual hibiscus biomass waste (HWH) for facile synthesis of HWH/TiO₂ nanocomposite. The inherent characteristics of the nanocomposite were objectively investigated using SEM, EDS, TEM, FTIR, as well as BET, and in the end, interesting potential areas of application were suggested.

Elemental analysis

Table 1: Percentage of major elements

Material	Carbon (%)	Oxygen (%)	Titanium (%)
HWH/TiO ₂	41.00	27.20	29.70
HWH	60.70	29.10	Not detected
TiO ₂	Not detected	50.40	49.30

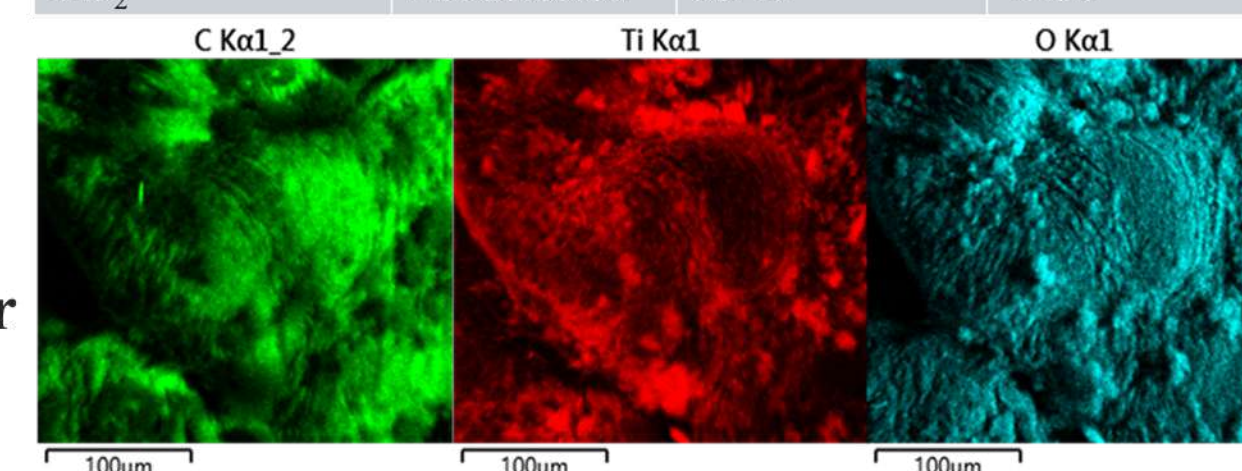


Figure 1: EDS image for HWH/TiO₂

Functional group analysis

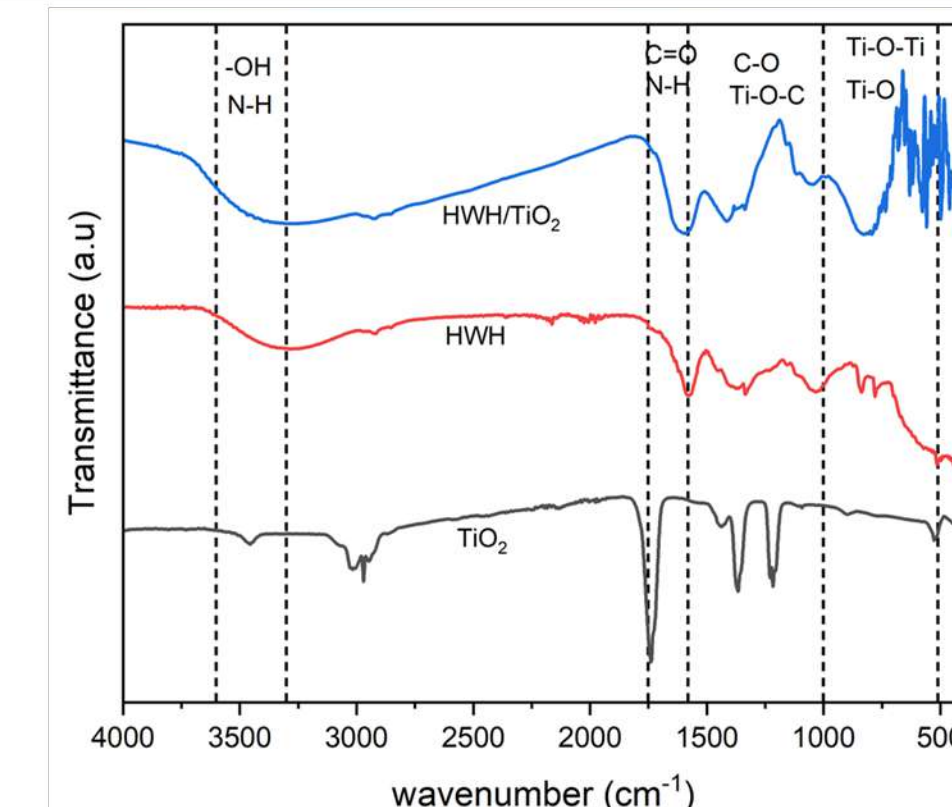


Figure 2: FTIR spectral

HWH/TiO₂ synthesis protocol

The hydrochar was prepared from hibiscus biomass waste at 180°C for 6 h in an autoclave. Secondly, TiO₂ nanoparticles were synthesized using sol-gel method from titanium tetra-isopropoxide and calcined at 500 °C. Then, the HWH/TiO₂ nanocomposite was fabricated using a ball milling approach for ~1 hr with ethanol as a control agent.



Figure 3: Synthesis synopsis

Morphological and textural properties

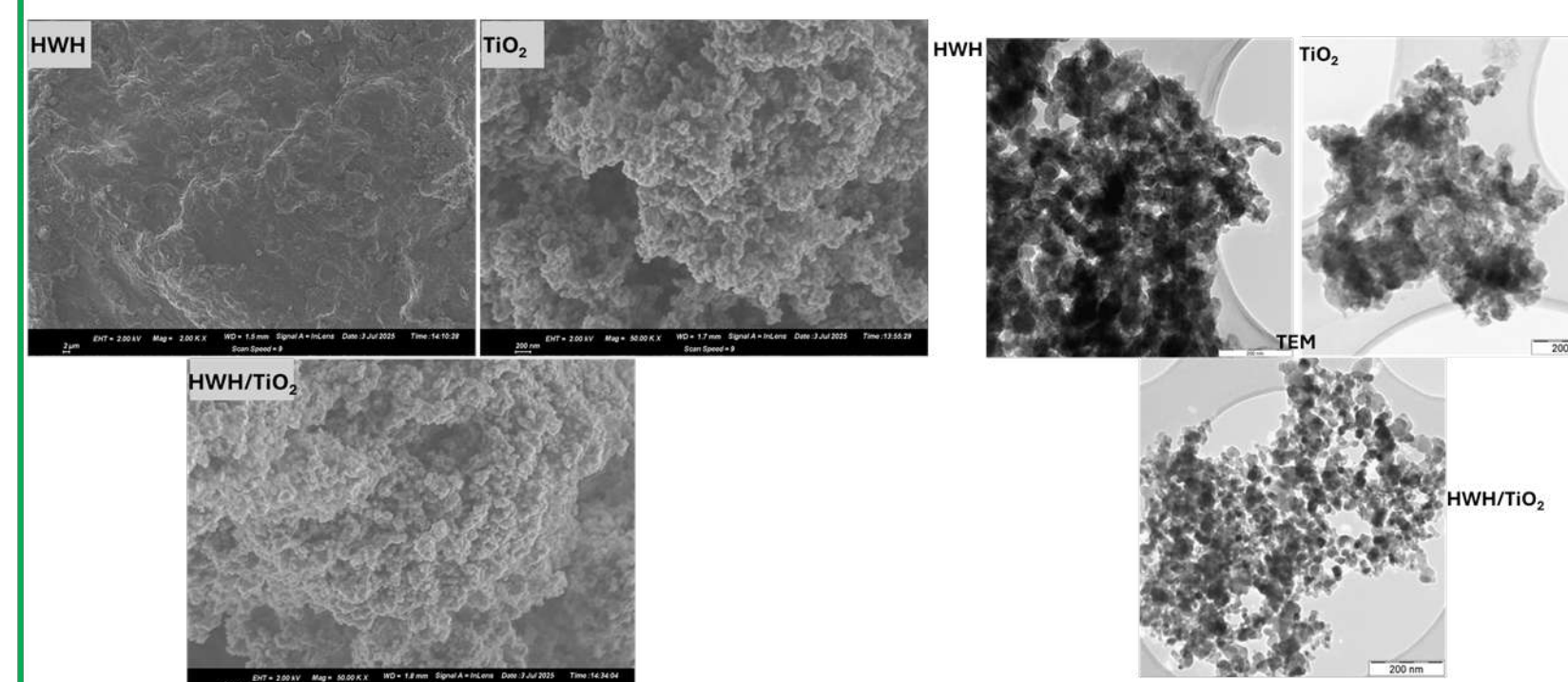


Figure 4: SEM images

Table 2: Textural profile

Material	Surface area (m ² /g)	Pore diameter (nm)	Pore volume (cc/g)
HWH/TiO ₂	302.04	2.19	0.34
HWH	251.20	2.01	0.021
TiO ₂	132.01	1.46	0.053

Figure 5: TEM images

Key findings

- ✓ **EDS analysis** displayed strong C, Ti, and O signals → confirming successful formation of HWH/TiO₂ nanocomposite and incorporation of C and O₂ networks (corroborated by FTIR).
- ✓ **FTIR results** showed essential functional groups (C-O, C=O, -OH, -NH₂, Ti-O/Ti-O-Ti) and confirmed rutile + anatase phases of TiO₂ in the nanocomposite.
- ✓ **SEM images** revealed irregular spheres, multi-layered morphology, and visible pores for HWH/TiO₂ and TiO₂, while hydrochar appeared shapeless with fewer pores.
- ✓ **BET analysis** indicated mesoporous characteristics with superior porosity for HWH/TiO₂, consistent with Jędrzejczak [1] and Sunardi [2].

Potential applications

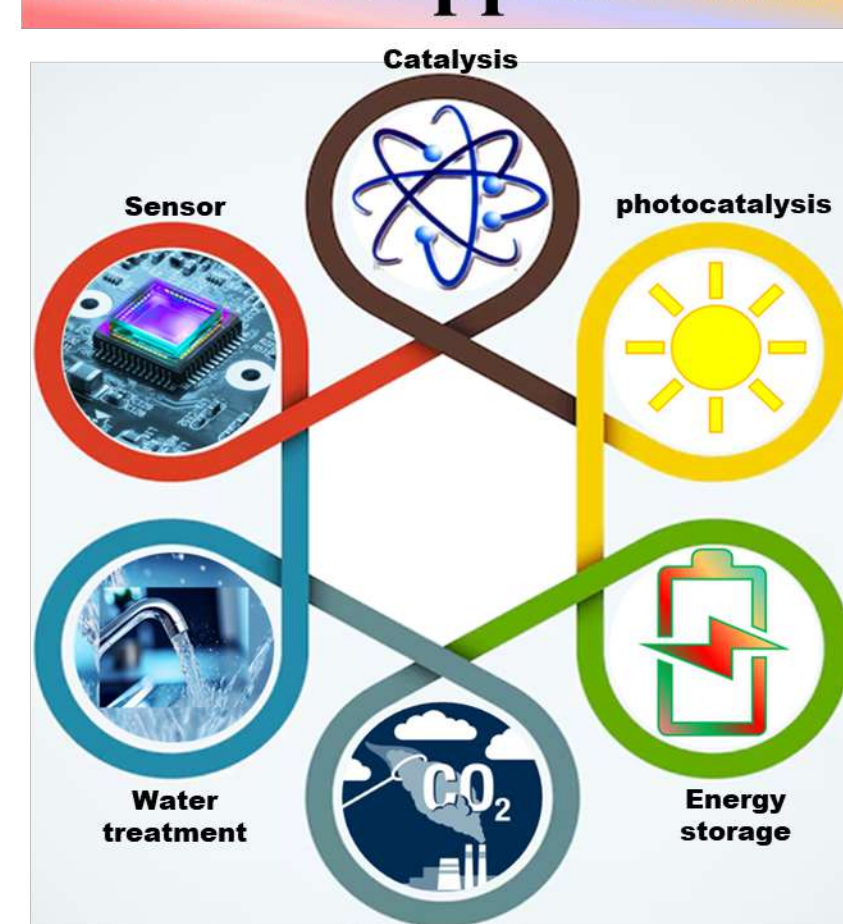


Figure 5: potential applications

Conclusion and relation to SDGs

This study successfully demonstrates that residual hibiscus biomass waste can be effectively valorized into HWH/TiO₂ nanocomposite with enhanced porosity, functional groups, and structural properties while promoting SDGs.



Figure 6: Potential impacts

Acknowledgements

Emmanuel S. S. appreciate Prof. Shepherd M. Tichapondwa, his wife, Ademidun A. Emmanuel, and the UP doctoral scholarship body.

References

- [1] P. Jędrzejczak et al. J. Build. Eng. 78 (2023)
- [2] A.B.T. Sunardi et al Mater. Chem. Phys. 329 (2025) 130049.