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# Ecofriendly Synthesis and Multiscale Characterization of *Abies marocana* Needle-Derived Biosorbent for Wastewater Remediation

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## INTRODUCTION & AIM

The increasing demand for environmentally sustainable technologies in wastewater treatment has promoted the exploration of biosorbents derived from renewable plant-based materials. Such biosorbents are particularly attractive due to their low cost, availability, and minimal environmental impact [1].

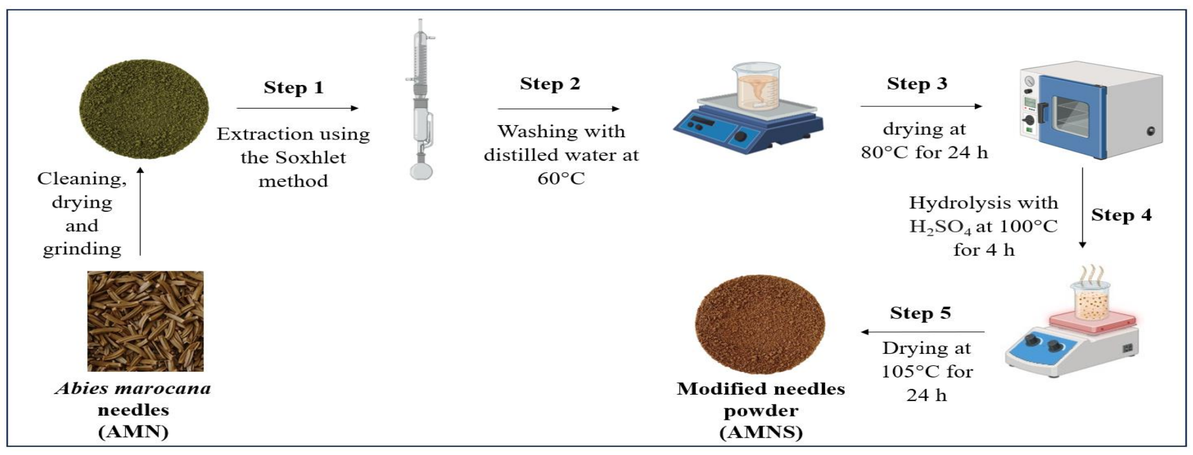
*Abies marocana*, an endemic conifer of northern Morocco, offers significant potential as a precursor for biosorbent development. Its lignocellulosic composition provides a diversity of functional groups capable of interacting with organic pollutants. Chemical activation of *A. marocana* needles is expected to enhance their surface area, porosity, and surface chemistry, thereby improving adsorption efficiency [1].

This study aims to synthesize and characterize a chemically activated *A. marocana* biosorbent and to evaluate its preliminary performance for the removal of methylene blue from aqueous solutions.

## METHOD

### Biosorbent preparation

Raw *Abies marocana* needles were collected, washed, dried, and ground. The biomass was chemically activated using concentrated sulfuric acid ($H_2SO_4$) to improve surface properties and create additional adsorption sites. The treated material was thoroughly rinsed, neutralized, and oven-dried prior to analysis [1].



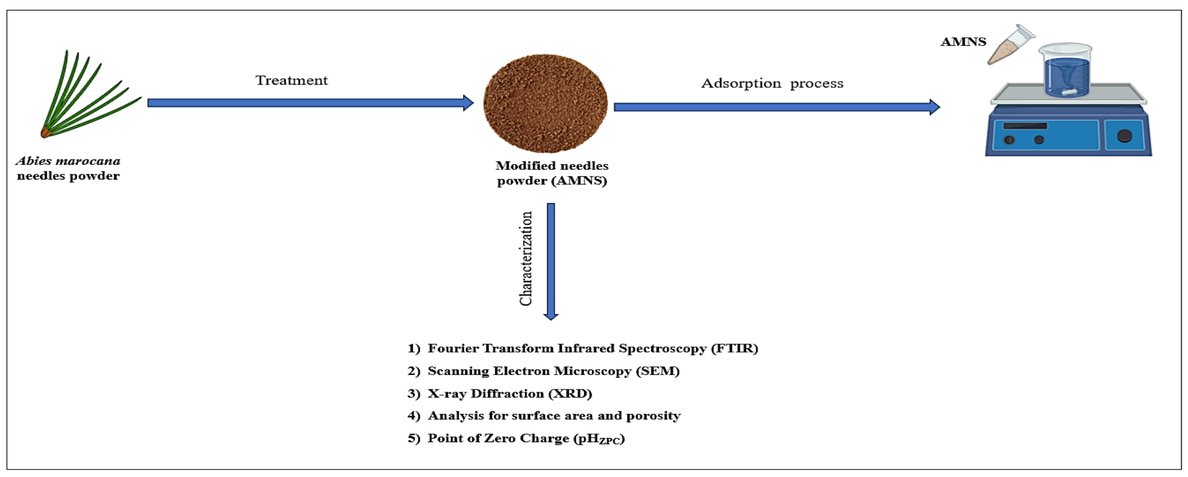

### Characterization techniques

To evaluate the structural, chemical, and morphological properties of the prepared biosorbent, several characterization techniques were employed [1] .

- **FTIR spectroscopy**: identification of surface functional groups.
- **SEM**: observation of surface morphology.
- **Surface area and porosity analysis**: determination of textural properties.
- **XRD**: evaluation of crystallinity.
- **pHpzc**: determination of the point of zero charge.

### Adsorption studies

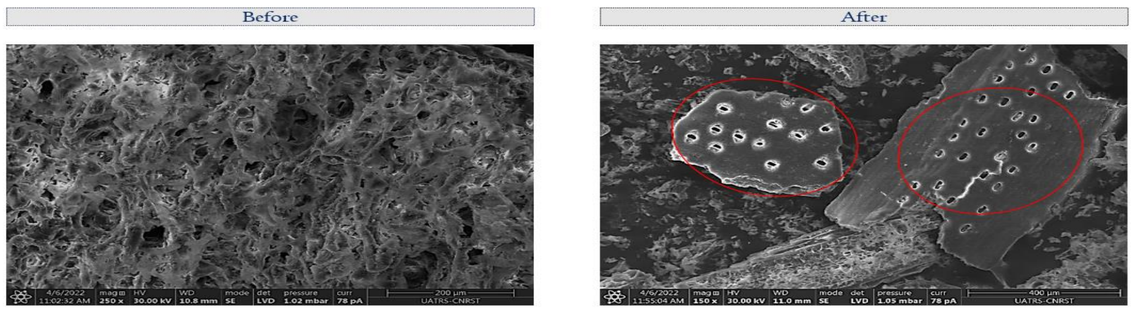
Batch adsorption experiments were performed using methylene blue solutions to assess preliminary adsorption capacity and evaluate biosorbent–dye interactions [1] .



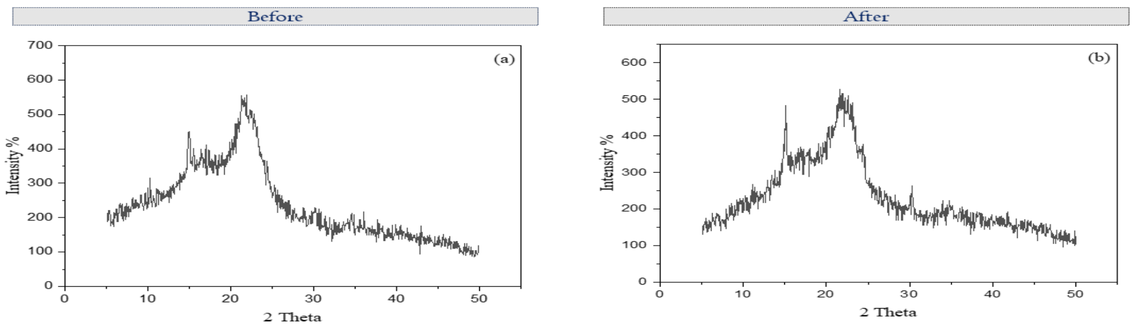

## RESULTS & DISCUSSION

### Characterization

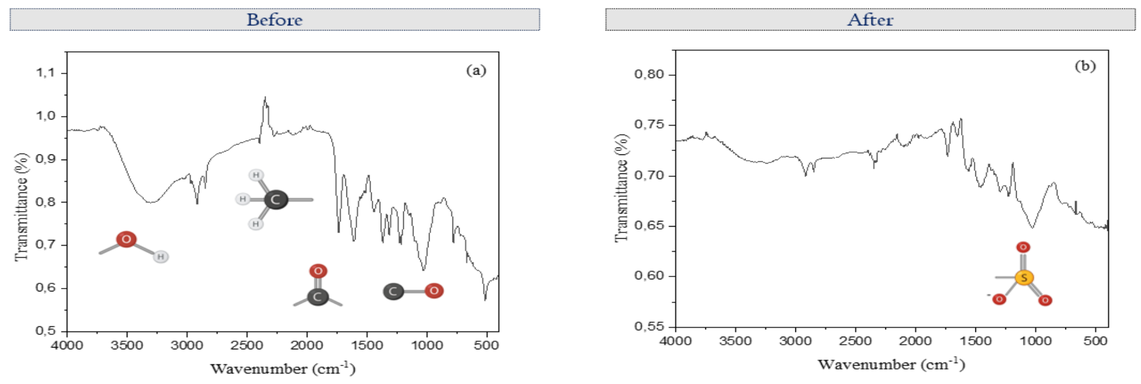
**SEM** showed a porous, heterogeneous surface after chemical activation, enhancing adsorption capacity.




**XRD** revealed an amorphous carbonaceous structure favorable for adsorption



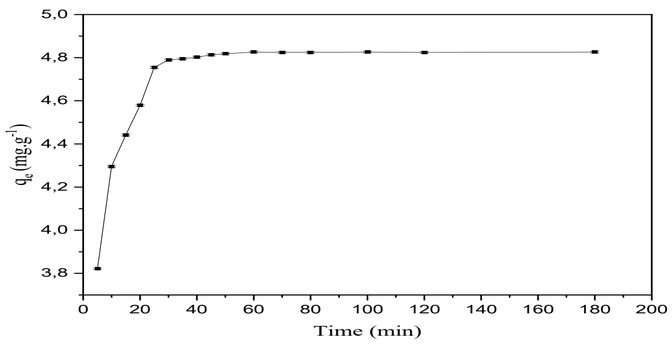

**FTIR analysis** of the raw biomass showed hydroxyl, carbonyl, C–O, and C–H groups from cellulose, hemicellulose, and lignin. Acid treatment partially degraded hemicellulose and introduced sulfonic groups (–O–$SO_3$–), enhancing adsorption.




Chemical treatment improved *A. marocana* biosorbent properties: **iodine index** increased to 933.45 $mg{\cdot}g^{-1}$, **surface area** to 509.74 $m^2{\cdot}g^{-1}$, and **pHpzc** was 7.857, enhancing adsorption capacity.

### Adsorption studies

**Preliminary tests** showed that the treated *A. marocana* biosorbent efficiently adsorbed methylene blue, reaching equilibrium rapidly.




## CONCLUSION

The chemically treated *Abies marocana* biosorbent demonstrated enhanced surface chemistry, porosity, and adsorption capacity. Preliminary tests confirmed its effectiveness in removing methylene blue, highlighting its potential as a low-cost, sustainable material for wastewater treatment.

## REFERENCES

[1] Zirari M., Aouji M., Hmouni D., El Mejdoub N. (2025) Adsorption behavior and mechanism of modified *Abies marocana* needles for methylene blue removal. *Water Practice & Technology* 19(9):3808–3817.