

# Adsorptive Removal of Synthetic Textile Dyes Using Raw Almond Shells: A Sustainable Approach to Wastewater Treatment

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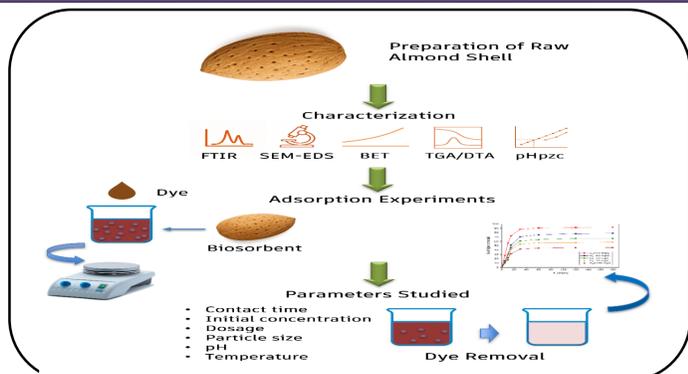
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## INTRODUCTION & AIM

Textile industries generate large volumes of wastewater containing synthetic dyes that are persistent and harmful to aquatic ecosystems. Adsorption using agricultural by-products has emerged as a sustainable and low-cost method for dye removal. In this study, raw almond shells (RAS) were investigated as a biosorbent for removing Bemacron Blue RS 01 (BB-RS01) and Bemacid Marine N-5R (BM-N5R) from aqueous solutions. Characterization of RAS (FTIR, SEM-EDX, BET, TGA/DTA, pH<sub>pzc</sub>) confirmed the presence of functional groups and porous structures favorable for adsorption. Rapid dye uptake occurred within the first 30 min, reaching equilibrium after 2 h. Maximum removal efficiencies of 90% for BB-RS01 and 80% for BM-N5R were obtained, with adsorption capacities of 208.33 mg·g<sup>-1</sup> and 243.90 mg·g<sup>-1</sup>, respectively.

These results highlight the potential of almond shell waste as an efficient and sustainable biosorbent for textile wastewater treatment.

## METHOD



## RESULTS & DISCUSSION

### Characterization of Raw Almond Shells

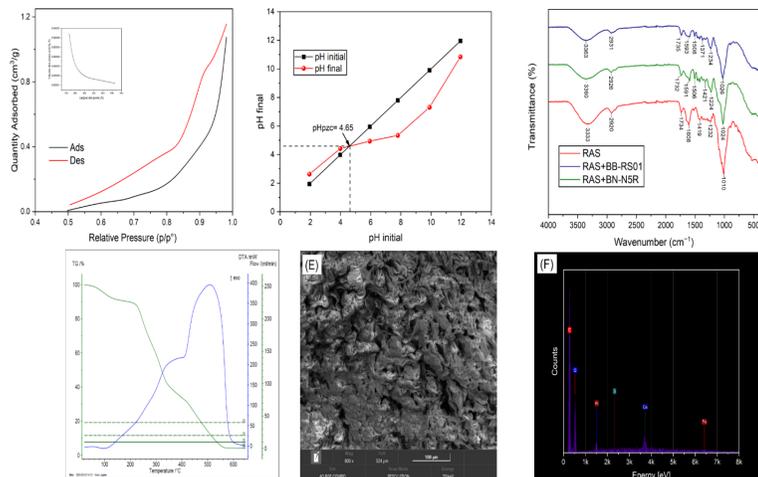


Figure 1: Comprehensive physicochemical characterization of raw almond shells (RAS) including surface morphology (SEM-EDX), functional groups (FTIR), surface area and porosity (BET), thermal stability (TGA/DTA), and surface charge properties (pH<sub>pzc</sub>).

## REFERENCES

- [1] Ait Ahsaine H, Zbair M, Anfar Z, Naciri Y, El Haouti R, El Alem N, et al. Mater Today Chem 2018;8:121–32.
- [2] Inyinbor AA, Adekola FA, Olatunji GA. Water Resour Ind 2016;15:14–27
- [3] Melhaoui R, Miyah Y, Kodad S, Houmy N, Addi M, Abid M, et al. Sci World J 2021;2021:1–13.
- [4] Stavrinou A, Aggelopoulos CA, Tsakiroglou CD. J Environ Chem Eng 2018;6:6958–70.

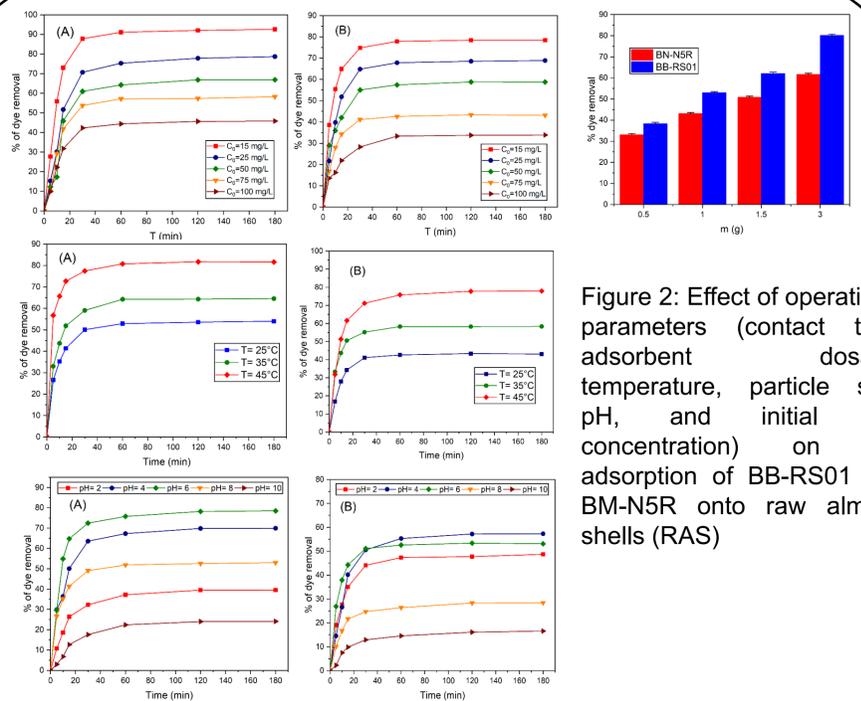


Figure 2: Effect of operational parameters (contact time, adsorbent dosage, temperature, particle size, pH, and initial dye concentration) on the adsorption of BB-RS01 and BM-N5R onto raw almond shells (RAS)

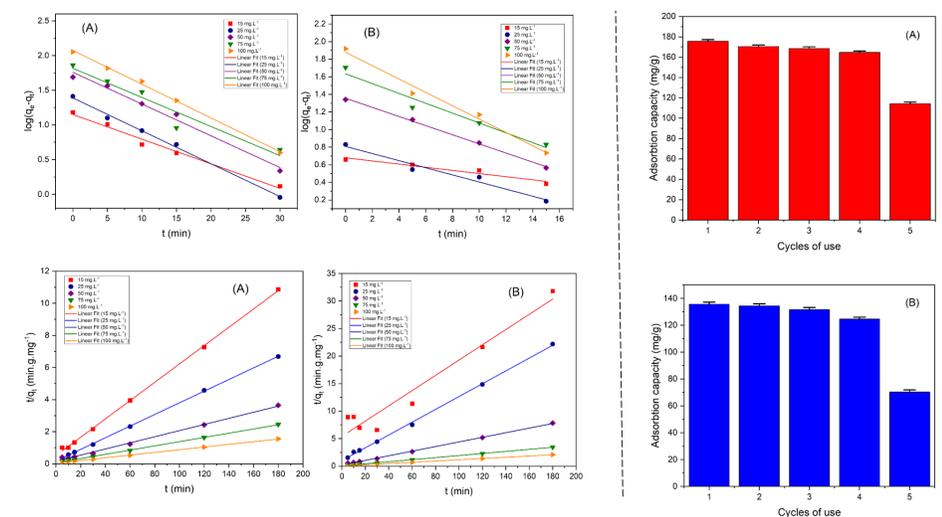


Figure 3: Adsorption kinetic modeling for BB-RS01 and BM-N5R onto raw almond shells (RAS): pseudo-first-order and pseudo-second-order models.

Figure 4: Regeneration and reuse performance of raw almond shells (RAS) for the adsorption of BB-RS01 and BM-N5R over multiple adsorption cycles.

## CONCLUSION

- Raw almond shells (RAS) proved to be an effective, low-cost biosorbent for removing synthetic textile dyes due to their porous structure and functional groups.
- Adsorption was influenced by pH, contact time, adsorbent dosage, and dye concentration, and followed pseudo-second-order kinetics with Langmuir/Freundlich isotherm behavior.
- Future work: test RAS with real textile wastewater, enhance adsorption via activation to produce activated carbon, and optimize regeneration for large-scale applications.

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