

Water-Absorption Behavior of Hybrid Biocomposites Based on *Syagrus romanzoffiana* Palm Waste and Short Sisal Fibers: Application of ANN, RSM Optimization, and Fick's Diffusion Model

Djamel Ghernaout^a, Messaouda Boumaaza^{id}^b, Ahmed Belaadi^c, Nouredine Elboughdiri^a, Mhamed Benaissa^a, Mostefa Bourchak^d, Herbert Mukalazi^e, and Alsamani Ahmed Salih^a

^aChemical Engineering Department, College of Engineering, University of Ha'il, Ha'il, Saudi Arabia; ^bLaboratory of Civil Engineering and Hydraulics (LGCH), University 8 Mai 1945 Guelma, Guelma, Algeria; ^cDepartment of Mechanical Engineering, Faculty of Technology, University 20 Août 1955-Skikda, El Hadaiek, Skikda, Algeria; ^dAerospace Engineering Department, King Abdulaziz University, Jeddah, Saudi Arabia; ^eDepartment of Mathematics and Statistics, Kyambogo University, Kampala, Uganda

ABSTRACT

This research advances sustainable production methods by focusing on the reuse of agricultural waste. The absorption behavior of hybrid biocomposites reinforced with biochar derived from *Syagrus romanzoffiana* palm waste (SrPW) and *Agave sisalana* fiber (AsF) in an epoxy matrix was examined. The primary objective was to assess how varying AsF content (10, 15, 20, and 30%) affects the dynamic behavior of hybrid biocomposites incorporating a fixed 2% of biochar. Response surface methodology (RSM) and artificial neural networks (ANN), optimized using a genetic algorithm, were employed to evaluate and simulate absorption characteristics. The ANN approach demonstrated superior accuracy and robustness compared to RSM, as indicated by high correlation coefficients (0.9999 in training, 0.9702 in testing, and 0.9970 in validation) between model predictions and experimental results. This predictive method minimizes the need for extensive experimental trials, thereby saving time and resources. The resulting green composite, based on epoxy, palm waste, and sisal, presents an environmentally friendly alternative for potential sustainable applications.

HIGHLIGHTS

- Development of innovative hybrid biocomposites using *Syagrus romanzoffiana* (Sr) palm-waste biochar and short sisal fibers in an epoxy matrix;
- Pure Fickian diffusion traits were witnessed across all laminate configurations throughout extended water immersion testing;
- Artificial Neural Network (ANN) modeling demonstrated higher predictive accuracy as well as generalization than Response Surface Methodology;
- The integrated ANN-Genetic Algorithm approach identified optimal parameters with slight deviation from experimental results;
- Valorization of Sr waste supports a circular economy by converting agricultural residue into high-value biocomposites.

摘要

本研究著重於農業廢棄物的再利用，藉此推動永續生產方法。研究探討了以環氧樹脂基體為基礎、並以源自 *Syagrus romanzoffiana* 棕櫚廢棄物 (SrPW) 的生物炭及龍舌蘭纖維 (AsF) 作為增強材料的混合生物複合材料之吸附行為。主要目標是評估不同 AsF 含量 (10%、15%、20% 及 30%) 如何影響含有固定 2% 生物炭的混合生物複合材料的動態行為。研究採用響應面法 (RSM) 及經遺傳演算法優化的人工神經網路 (ANN)，用以評估與模擬吸收特性。與 RS 法相比，人工神經網路法展現出更優異的準確性與穩健性，這從模型預測值與實驗結果之間的高相關係數 (訓練階段為 0.9999、測試階段為 0.9702、驗證階段為 0.9970) 即可看出。此預測方法可最大限度地減少大量實驗測試的需求，從而節省時間與資源。最終製成的綠色複合材料，以環氧樹脂、棕櫚廢料及劍麻為基材，為潛在的永續應用提供了環保的替代方案。

KEYWORDS

Agave sisalana, *Syagrus romanzoffiana* palm waste; hybrid biocomposite; water absorption; ANN/RSM; desirability function/genetic algorithm

關鍵詞

龍舌蘭 (*Agave sisalana*)、羅曼佐夫棕櫚 (*Syagrus romanzoffiana*) 廢料; 混合生物複合材料; 吸水率; 人工神經網路 / 響應面法; 可取性函數 / 遺傳演算法