

PC 36. Textile Dyeing with Natural Dyes: Review and Insights from a Novel Mathematical Model

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Abstract

The growing environmental concerns surrounding synthetic dyes have intensified the search for sustainable alternatives in the textile industry [1]. Conventional dyeing processes consume excessive water and release toxic, non-biodegradable compounds into ecosystems. In this context, natural dyes—derived from renewable sources such as plants—offer a promising, eco-friendly solution. This work presents a concise review of the state-of-the-art in textile dyeing with natural dyes, highlighting current challenges and advancements. Few mathematical models of textile dyeing process have been reported focusing mainly on the use of chemical dyes [2] or the treatment of textile dye effluents [3]. Concerning mass transfer phenomena, the dyeing process is modelled considering the dye molecules diffusion through the textile porous and their sorption/desorption dynamics with the fibers. In this study, we present insights from a novel mathematical model developed to simulate the dyeing process with natural colorants. As a case study, cotton and wool samples were dyed with pigments extracted from purple onion peel. A one-dimensional numerical approach, combined with volume-averaging techniques, was employed to study mass transfer across the sample thickness and predict dye concentration distribution over time. As an advantage, this type of models enables the prediction and optimization of dye-fiber interactions under various conditions, providing guidance for developing efficient, environmentally responsible dyeing workflows.

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References

- [1] H. Ben Slama et al. (2021). Appl. Sci. 11(14), 1–21.
- [2] S. M. A. Selene et al. (2008). Appl. Math. Model. 32(9), 1711–1718.
- [3] S. M. A. G. U. de Souza et al. (2007). Transp. Porous Media. 68(3), 341–363.