Eco-friendly approach to textile dye remediation using a waste-based LTA zeolite

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Highlights:

- Outstanding adsorption performance of Safranine-T by waste-based LTA zeolite (>96%).
- Best results obtained under moderate conditions (pH 11, room temperature, agitation 150 rpm), favoring scale-up.
- Highly efficient treatment of dye-contaminated wastewater with waste-based zeolites, contributing to the circular economy and sustainability.

Keywords: adsorption; waste-based LTA zeolite; textile dyes.

INTRODUCTION

Dyes are among the most common pollutants in wastewater, as a result of their widespread use by various industrial sectors. In textile production, the total consumption of dyes exceeds 10,000 tons per year, and it is estimated that between 10 and 15% of this amount is released with the effluents[1-2].

The proper treatment of these harmful effluents is a major challenge due to the low biodegradability and structural complexity of most dyes. Conventional treatment methods have several limitations related to their high cost, limited efficiency, generation of secondary pollutants and waste management[3].

Adsorption is one of the most effective methods used to treat dye-containing wastewaters[4], and has attracted growing interest with the use of low-cost alternative adsorbents.

Due to their porous structure and properties, zeolites are excellent candidates for adsorbent materials. In recent years, instead of using commercial chemical reagents, various wastes have been tested in the synthesis of zeolites as a way of minimizing the environmental impacts associated with their production and saving natural resources[5].

Among these wastes, aluminum waste slag can be considered an ideal non-conventional raw material for the zeolite production, considering the high content of aluminum in its composition and the serious environmental problems associated with its management and disposal in the environment[6].

This study reports on the use of an LTA-type zeolite, synthesized from hazardous aluminum waste, in the adsorption of the textile dye Safranine-T (ST) from aqueous solutions.

METHODOLOGY

LTA zeolite, synthesized with fine slag from the tertiary aluminum industry, was used as the adsorbent material in this study. Safranine-T (CI 50240) (Neon Commercial, Brazil) was used as the adsorbate. The aqueous dye solutions were prepared in the required concentrations by diluting the stock solution (1.0 g L^{-1}) in distilled water.

The adsorption tests were carried out on a rotational shaker using flasks containing 50 mL of dye solution (C_0 20 mg L^{-1}). Different temperatures (22, 35, 45 and 55 ºC), pH values (5, 7, 9 and 11) and agitation rates (50, 100, 150 and 200 rpm) were evaluated. The tests were performed in triplicate and the results expressed as the mean values. After treatment, the suspensions were centrifuged (5300 rpm for 5 minutes) and the final concentration determined by colorimetry in a spectrophotometer (HACH DR/3900 VIS) at the wavelength of maximum absorption of the ST (λ 520 nm).

RESULTS AND CONCLUSIONS

The results obtained in this study (**Fig. 1** and **2**) demonstrated the excellent adsorption capacity of the waste-based LTA zeolite, achieving 96.9% ST removal efficiency when using an agitation rate of 150 rpm, at room temperature (22 ºC), pH 11 and with only 10 minutes of contact time, which is very favorable for the treatment of textile effluents. This innovative approach represents an alternative solution to some serious environmental problems all at once; on the one hand, the co-recycling of hazardous aluminum waste avoids disposal in landfills and possible environmental contamination (air,

soil, groundwater and surface water and, consequently, harmful effects on flora, fauna and human health); on the other hand, the recovery of this waste through the synthesis of new value-added materials means saving natural resources that would otherwise be extracted to produce the chemical reagents; and finally, the application of these waste-based zeolites to remediate dye-contaminating wastewaters.

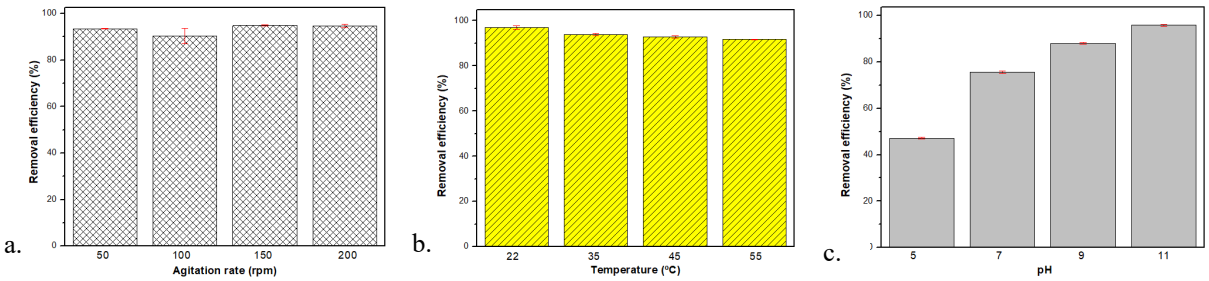

Fig. 1. Comparison of ST removal by waste-based LTA zeolite using different (a) agitation rates, (b) temperatures and (c) pH.

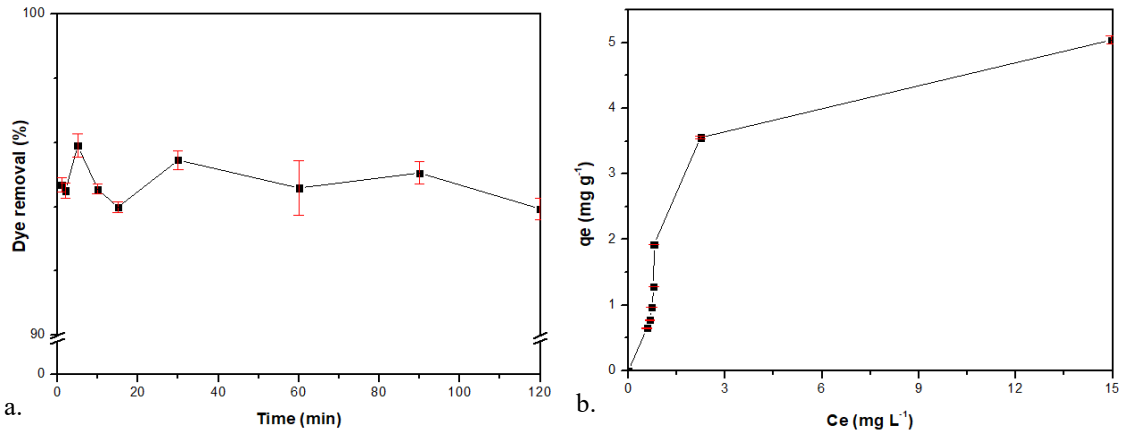

Fig. 2. (a) Kinetic and (b) isothermal experimental data.

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