IOP Publishing Advances in Natural Sciences: Nanoscience and Nanotechnology
Adv. Nat. Sci.: Nanosci. Nanotechnol. **16** (2025) 025014 (8pp) https://doi.org/10.1088/2043-6262/adc977

Use of nano-magnetic materials for removal of Congo red dye from aqueous solutions

Ahmed Yousif Hammood[1], Muayad H M Albehadili[2], Muhand K AL-Tememi[1], Ahmed A Majed[3,4] and Wejdan Ali Radhi[5]

[1] Marine Science Center, University of Basrah, Basrah, Iraq
[2] College of Marine Science, University of Basrah, Basrah, Iraq
[3] College of Education for Pure Science, University of Basrah, Iraq
[4] Scientific Research Center, Al-Ayen University, Thi-Qar, Iraq
[5] Basra Education Directorate, Ministry of Education, Basrah, Iraq

E-mail: eduppg.ahmed.majed@uobasrah.edu.iq

Received 3 December 2024
Accepted for publication 2 April 2025
Published 24 April 2025

Abstract

Sol–gel auto-combustion was used to create ferrite nanoparticles with the structure $Co_{0.5}Cr_{0.5}Fe_2O_4$ using lemon juice as a fuel agent and surfactant. It was investigated whether the generated nanomaterials could absorb Congo red dye. Different techniques were used to characterize the prepared nanocomposite x-ray diffraction (XRD), FE-SEM, EDX, FT-IR and Zeta Potential. The XRD characterization proved the phase purity of the prepared material, the particle size was 28.34 nm. The study dealt with the use of the prepared compound as an adsorbent surface for Congo red dye from its aqueous solutions. Freundlich and Langmuir equations were applied to the adsorption process data for different temperatures. The results showed that the Langmuir equation is more linear than the Freundlich equation. In addition, the thermodynamic results showed that the adsorption of Congo red dye was spontaneous, as the value of (ΔG) was negative at low concentrations before turning to a positive value with increasing concentrations. Also, the adsorption process was endothermic and increased in randomness through the positive value of (ΔS). The adsorption results showed that equilibrium was reached in 300 min and that the removal of Congo red dye constituted 84.24% of the total. The possibility of reusing the prepared compound several times was studied, and the results showed the possibility of activating the surface while maintaining its properties as a good adsorbent surface.

Keywords: adsorption, Congo red dye, ferrite nanoparticles, Langmuir and Frendlich, thermodynamic
Classification numbers: 2.03, 5.02

1. Introduction

The aquatic environment suffers from various types of pollutants, such as heavy metals, dyes, petroleum products, and the products of various industrial activities that are mainly untreated and make their way into the aquatic environment. Thousands of chemicals may be used in industrial processes that include a large number of organic and inorganic compounds that are released into the environment. Watercolor [1], Exposure of the aquatic environment to this huge amount of pollutants of various types and forms leads to pollution and destruction of life forms in it as a result of the transformation of these pollutants into more complex forms, causing short or long-term toxic effects that may in turn lead to a negative impact on living organisms, including humans, and makes water Not suitable for required uses [2, 3].

Organic dyes are one of the most important water pollutants and are currently estimated at more than one hundred thousand commercially available dyes, amounting to more than (7×10^5) tons of dyes produced annually [4]. The amount of dyes that are consumed in the textile industry and around the world is estimated at more than (10 000 tons) annually, and about (1%) of these dyes are discharged into water channels annually, and accurate data on the amount of