

ABSTRACT

Congo Red is an anionic dye that is toxic, carcinogenic, and resistant to biological degradation. Wastewater containing Congo Red can reduce water quality, inhibit sunlight penetration into water bodies, disrupt photosynthesis in aquatic ecosystems, and endanger human health. One effective method for removing Congo Red from wastewater is adsorption using silica gel. Conventional silica gel has limitations including restricted pore size and a negatively charged surface, making it ineffective for adsorbing Congo Red. This study aims to synthesize amine-functionalized mesoporous silica using Cetyltrimethylammonium Bromide (CTAB) as a pore-directing agent and 3-Aminopropyltriethoxysilane (APTES) as a surface functionalization agent with varying volumes of 0.15, 0.45, 0.75, and 1.20 mL, and to evaluate its performance in the adsorption-desorption of Congo Red. Synthesis was carried out using the sol-gel method followed by calcination at 700°C for six hours. Characterization was performed using Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). Adsorption tests were conducted at concentrations of 5, 15, 25, 35, and 45 mg/L using a UV-Vis spectrophotometer, while desorption analysis was performed over three cycles using 1 N NaOH as the eluent. FTIR characterization confirmed successful APTES grafting through the emergence of Si-C (1195.71 cm^{-1}) and N-H ($3300\text{--}3350\text{ cm}^{-1}$) bands. SEM images show that the surface texture becomes increasingly granular and homogeneous when APTES is added. The highest adsorption capacity was achieved with the 1.20 mL APTES sample at 81.93 mg/g (45 ppm), far exceeding CTAB-silica at 14.74 mg/g. Desorption tests showed a total desorption of 51.19% for the 1.20 mL APTES sample, compared to 6.69% for CTAB.

Keywords: Congo Red, mesoporous silica, CTAB, APTES, adsorption, desorption

BAB I

PENDAHULUAN

I.1 Latar Belakang

Congo Red merupakan zat warna azo anionik sintetis yang banyak digunakan dalam industri tekstil, kertas, karet, dan plastik. Zat warna ini bersifat toksik, karsinogenik, mutagenik, dan sangat sulit terdegradasi secara biologis karena memiliki struktur aromatik yang stabil (Oladoye dkk., 2022a). Limbah cair industri yang mengandung *Congo Red* apabila dibuang langsung ke badan air akan menyebabkan penurunan kualitas perairan, menghambat penetrasi cahaya matahari ke dalam kolom air, sehingga mengganggu proses fotosintesis ekosistem akuatik dan menurunkan kadar oksigen terlarut (Oladoye dkk., 2022a). Selain itu, keberadaan *Congo Red* di dalam air minum atau rantai makanan dapat menimbulkan efek genotoksik, mutagenik, dan karsinogenik bagi kesehatan manusia (Oladoye dkk., 2022a). Oleh karena itu, penghilangan *Congo Red* dari limbah cair sebelum dibuang ke lingkungan merupakan hal yang sangat penting dan mendesak.

Berbagai metode telah dikembangkan untuk menghilangkan zat warna dari limbah cair, di antaranya koagulasi-flokulasi, membran filtrasi, oksidasi lanjutan, pertukaran ion, dan adsorpsi. Di antara metode tersebut, adsorpsi mendapat perhatian paling luas karena operasinya yang sederhana, efisiensi tinggi, dan biaya yang relatif rendah (Kassa dkk., 2025). Salah satu adsorben yang umum digunakan adalah silika gel, yang memiliki kestabilan termal dan kimia tinggi serta luas permukaan yang besar. Namun demikian, silika gel konvensional umumnya