## ABSTRACT

Unmodified silica gel exhibits limited adsorption capacity toward anionic pollutants. Congo red is an anionic azo dye found in aquatic environments and has the potential to produce carcinogenic compounds through degradation processes. This study aims to synthesize mesoporous silica based on sodium silicate ($Na_2SiO_3$) modified with Cetyltrimethylammonium Bromide (CTAB) as a pore-templating agent and chitosan as an active amine group enhancer ($–NH_2$) to investigate the effect of chitosan variation on the material characteristics and the adsorption–desorption performance toward congo red dye. Synthesis was carried out using the sol-gel method by mixing sodium silicate and CTAB, followed by calcination to obtain mesoporous silica. Functionalization with 1.5% chitosan was then performed by varying (50; 80; 120; dan 150 mg). Adsorption tests were conducted in congo red solution at concentrations of 10-50 ppm, and desorption tests were performed using 1N NaOH for up to three cycles. Adsorption–desorption measurements were conducted using UV-Vis spectrophotometry at λ 498.5 nm. Material characterization included Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). The FTIR characterization results of silica-CTAB before calcination identified C–H stretching absorption bands at wavenumbers 2855-2961 $cm^{-1}$, confirming the incorporation of CTAB; after calcination, these bands disappeared as evidence of complete CTAB decomposition. Functionalization with chitosan was confirmed by the appearance of methylene C–H stretching bands at 2917-2944 $cm^{-1}$ and N–H stretching bands at 3300-3320 $cm^{-1}$, while the Si–O–Si framework remained dominant at 1071-1074 $cm^{-1}$. SEM analysis revealed that silica-CTAB particles exhibited an amorphous morphology with a rough and aggregated surface texture, whereas after chitosan immobilization the particle surface appeared smoother and more cohesive due to the formation of a polymer layer coating the silica particles. The adsorption test of congo red at concentrations of 10–50 ppm showed that the 8.00 mL silica-CTAB-chitosan adsorbent possessed the highest adsorption capacity, reaching 73.61 mg/g at a concentration of 50 ppm. Desorption tests using 1N NaOH over three regeneration cycles yielded very low desorption percentages, namely 7.58% for silica-CTAB and 10.36% for silica-CTAB-chitosan 3.33 mg.



Keywords: Mesoporous silica, CTAB, Chitosan, Adsorption, Desorption, Congo red.