ABSTRAK

Industri di Indonesia mengalami peningkatan produksi limbah seiring perkembangan zaman, salah satunya yaitu limbah cair dari proses pewarnaan. Malachite green (MG) adalah salah satu zat warna yang sering digunakan, namun memiliki kandungan senyawa yang bersifat toksik, sehingga dapat berdampak terhadap kesehatan. Salah satu metode yang telah dikembangkan untuk pengolahan limbah cair yaitu metode adsorpsi. Penelitian ini dilakukan untuk mengetahui karakteristik SiO_2 dan Fe_3O_4@SiO_2-CS, studi termodinamika, studi adsorpsi, energi aktivasi, serta pengujian pemakaian berulang Fe_3O_4@SiO_2-CS. Senyawa SiO_2 dihasilkan dari abu layang dengan metode sol gel yang berupa padatan kasar berwarna putih dan hasil sintesis Fe_3O_4@SiO_2-CS berupa padatan berwarna hitam yang dapat ditarik menggunakan batang magnet. Hasil karakterisasi FTIR, XRD, SEM-EDX, BET, VSM menunjukkan adanya serapan –NH, Fe–O, dan Si–O–Si, struktur kubik Fe_3O_4, perubahan morfologi dan ukuran partikel, serta sifat kemagnetan dari Fe_3O_4@SiO_2-CS. Analisis pH PZC diperoleh pada pH 5. Studi termodinamika menunjukkan proses adsorpsi berlangsung secara endotermik dan spontan. Adsorpsi MG mengikuti kinetika PSO dan Isoterm Freundlich dengan energi aktivasi sebesar 28,248 kJ/mol. Uji *reusability* menunjukkan efisiensi adsorben Fe_3O_4@SiO_2-CS setelah lima kali pemakaian ulang. Hasil ini menunjukkan bahwa Fe_3O_4@SiO_2-CS merupakan adsorben potensial dan ramah lingkungan dalam mengatasi pencemaran zat warna MG di limbah industri.

Kata Kunci: termodinamika, adsorpsi, kitosan, Fe_3O_4, SiO_2, *malachite green*

ABSTRACT

The industry in Indonesia is experiencing an increase in waste production along with the times, one of which is liquid waste from the dyeing process. Malachite green (MG) is one of the dyes that is often used, but it contains toxic compounds that can impact health. One method that has been developed for the treatment of liquid waste is the adsorption method. This research was conducted to understand the characteristics of SiO_2 and Fe_3O_4@SiO_2-CS, thermodynamic studies, adsorption studies, activation energy, and testing the repeated use of Fe_3O_4@SiO_2-CS. The SiO_2 compound was produced from fly ash using the sol-gel method, resulting in a coarse white solid, while the synthesis of Fe_3O_4@SiO_2-CS produces a black solid that can be attracted by a magnet. The characterization resultsed from FTIR, XRD, SEM-EDX, BET, and VSM show the presence of –NH, Fe–O, and Si–O–Si absorption, the cubic structure of Fe_3O_4, changes in morphology and particle size, as well as the magnetic properties of Fe_3O_4@SiO_2-CS. The PZC pH analysis obtained at pH 5. Thermodynamic studies indicated that the adsorption process occurs endothermically and spontaneously. Adsorption of MG follows PSO kinetics and Freundlich isotherm with an activation energy of 28.248 kJ/mol. Reusability tests demonstrated the efficiency of the Fe_3O_4@SiO_2-CS adsorbent after five reuse cycles. These results showed that Fe_3O_4@SiO_2-CS is a potential and environmentally friendly adsorbent in addressing the pollution of the dye MG in industrial waste.

Keywords: thermodynamic, adsorption, chitosan, Fe_3O_4, SiO_2, malachite green