Sintesis *Core-Shell* Fe_3O_4@SiO_2 Termodifikasi Alkil Dimetil Benzil Amonium Klorida (ADBAC) dengan Sumber Magnetit dari Pasir Besi dan Sumber Silika dari Abu Vulkanik Untuk Adsorpsi Cr(VI)

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INTISARI

Telah dilakukan sintesis material core–shell Fe_3O_4@SiO_2 menggunakan sumber magnetit dari pasir besi Pantai Glagah dan silika dari abu vulkanik Gunung Semeru. Permukaan material kemudian dimodifikasi menggunakan alkil dimetil benzil amonium klorida (ADBAC) dalam variasi mol tertentu. Keberhasilan sintesis dan struktur material dikonfirmasi melalui karakterisasi XRF, XRD, FTIR, SEM-EDX, TEM, serta TGA-DTA, sementara sifat kemagnetan dikaji menggunakan VSM. Proses adsorpsi logam berat Cr(VI) dilakukan secara batch menggunakan tiga jenis adsorben, yaitu Fe_3O_4 (MPG), Fe_3O_4@SiO_2 (MPG@SiO_2), dan Fe_3O_4@SiO_2-ADBAC (MPG@SiO_2-ADBAC). Tahapan penelitian mencakup optimasi kondisi adsorpsi, pemodelan kinetika dan isoterm, serta desorpsi sekuensial untuk mengetahui jenis interaksi yang terjadi. Evaluasi performa penggunaan ulang adsorben juga dilakukan.

Hasil karakterisasi menunjukkan bahwa sintesis dan modifikasi permukaan berhasil dilakukan. Sifat magnetik menurun seiring pelapisan SiO_2 dan ADBAC. Adsorpsi Cr(VI) optimal terjadi pada pH 2, dengan dosis adsorben terbaik sebesar 250 mg untuk MPG dan MPG@SiO_2-ADBAC, serta 150 mg untuk MPG@SiO_2. Waktu kontak optimum adalah 60 menit, dengan konsentrasi awal terbaik 200 mg/L untuk MPG@SiO_2 dan MPG@SiO_2-ADBAC, serta 100 mg/L untuk MPG. Kinetika adsorpsi mengikuti model orde dua semu, sedangkan isoterm terbaik mengikuti model Langmuir untuk MPG dan MPG@SiO_2-ADBAC, serta Freundlich untuk MPG@SiO_2. Desorpsi sekuensial menunjukkan keterlibatan interaksi elektrostatik, adsorpsi fisik, dan ikatan hidrogen. MPG@SiO_2-ADBAC menunjukkan performa unggul dalam lima siklus adsorpsi dengan tetap dapat dipisahkan secara magnetik

Kata kunci: ADBAC, adsorpsi, abu vulkanik, *core-shell*, ion Cr(VI), pasir besi

Synthesis of Core-Shell Fe_3O_4@SiO_2 Alkyl Modified with Dimethyl Benzyl Ammonium Chloride (ADBAC) using Magnetite Source from Iron Sands and Silica Source from Volcanic Ash for Cr(VI) Adsorption

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ABSTRACT

This study reports the synthesis of core–shell Fe_3O_4@SiO_2 adsorbents utilizing magnetite derived from Glagah Beach iron sand and silica sourced from Mount Semeru volcanic ash. Surface modification was conducted using alkyl dimethyl benzyl ammonium chloride (ADBAC) at varying molar ratios. The successful synthesis and structural integrity of the materials were confirmed through XRF, XRD, FTIR, SEM-EDX, TEM, and TGA-DTA analyses, while their magnetic properties were evaluated using VSM. Adsorption of hexavalent chromium [Cr(VI)] was performed in a batch system employing three different adsorbents: Fe_3O_4 (MPG), Fe_3O_4@SiO_2 (MPG@SiO_2), and Fe_3O_4@SiO_2-ADBAC (MPG@SiO_2-ADBAC). The study included optimization of adsorption conditions for each material, kinetic and isotherm modeling, as well as desorption sequence experiments to determine interaction mechanisms. Reusability performance of the adsorbents was also investigated.

Characterization results confirmed successful synthesis and modification of the materials. A decrease in saturation magnetization was observed with successive coating of SiO_2 and ADBAC layers. Optimal adsorption of Cr(VI) occurred at pH 2, with optimal adsorbent dosages of 250 mg for MPG and MPG@SiO_2-ADBAC, and 150 mg for MPG@SiO_2. All materials reached equilibrium within 60 minutes, with optimum initial Cr(VI) concentrations of 100–200 mg/L. Adsorption kinetics followed a pseudo-second-order model, while isotherm data fitted the Langmuir model for MPG and MPG@SiO_2-ADBAC, and the Freundlich model for MPG@SiO_2. Sequential desorption indicated that adsorption involved electrostatic interactions, physical adsorption, and hydrogen bonding. MPG@SiO_2-ADBAC demonstrated high Cr(VI) removal efficiency over five regeneration cycles and retained magnetic separability.

Keywords: ADBAC, adsorption, volcanic ash, *core-shell*, Cr(VI ions), iron sand