RESEARCH ARTICLE

New Approach for Sulfadiazine Toxicity Management using Carboxymethyl Cellulose Grafted Acrylamide Hydrogel

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ABSTRACT

Sulfadiazine (SZ), a small molecule sulfonamide that also named a 2-sulfanilamido-pyrimidine. SZ is an artificial bacteriostatic antibiotic through a widespread spectrum counter to numerous gram-negative and gram-positive bacteria. Sulfonamide antibiotics frequently identified in the earthly and water environment, but little acknowledgment about abiotic deprivation of these antibiotics. The SZ adsorption from aqueous solution studied in the present experiment utilizing carboxymethyl cellulose (CMC) grafted acrylamide (AM) hydrogel as an adsorbent. Effect of time-related to equilibrium, salts, temperature, and pH value was accomplished using kinetics and thermodynamic studies. Fourier-transform infrared spectroscopy (FTIR) and field emission scanning electron microscopy (FESEM) analysis accomplished for CMC-g-AM hydrogel before and after SZ adsorption. The study showed higher adsorption of the SZ on these hydrogels, and the degrees of SZ adsorption on the hydrogels decreased with increasing temperature (exothermic process). Adsorbed quantity of SZ on the surface was declined as the pH augmented. KCl's influence on adsorption is more than that of NaCl, and the $CaCO_3$ is more than of KCl. Spontaneous and feasible adsorption takes place, and adsorption of SZ on hydrogel fits well with the Freundlich model.

Keywords: Adsorption isotherm, Kinetics, Sulfadiazine, Toxicity.

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INTRODUCTION

The SZ, a small molecule sulfonamide antibiotic that also named a 2-sulfanilamidopyrimidine. SZ is an artificial bacteriostatic antibiotic through a widespread spectrum counter to numerous gram-negative and most gram-positive bacteria.[1] Furthermost, sulfonamides are freely absorption orally.[2] Though parenteral management is problematic, then the soluble salts of sulfonamide are basic and frustrating to the tissues. The sulfonamides broadly circulated during all tissues.[3] SZ is a competitively inhibit the enzyme of bacteria called dihydropteroate synthetase. This enzyme is desired for the correct meting out of para-aminobenzoic acid (PABA), which is necessary for the synthesis of folic acid. Oral LD_{50} of SZ is 1,500 mg/kg in mouse.[2] SZ indicated for the management of diverse types of infection, like infections of the urinary tract, toxoplasmosis, meningitis, ear infections, malaria, and others.[4] SZ induces many adverse reaction and diseases in humans, where reported to induce nephrolithiasis in children,[5] induce acute nephrotoxicity, especially in toxoplasmosis of HIV-positive patients,[6] cause intense renal deficiency produced in a patient and cerebral toxoplasmosis and acquired immunodeficiency syndrome (AIDS),[7] induce crystalluria,[8] and also can induce methemoglobinemia in a boy with thalassemia.[9] Sulfonamide antibiotics frequently identified in the earthly and water environment, but tiny acknowledgment about abiotic deprivation of these antibiotics.[9] So from these reported findings, new methods for the urgent treatment of accidental toxicity of humans and removal of earthy and water contamination with SZ are required.[10] CMC hydrogels in the early years developed rapidly and showing a capability function to treat wastewater polluted with heavy metal ions. Numerous types of drug overdose and accidentally ingested drugs.[11] CMC built hydrogels quickly advanced.[12] CMC is a natural biocompatible anionic polysaccharide broadly in the functional hydrogel materials synthesis.[13,14] Its OH and COOH groups are able to absorption of heavy metal ions.[15] Investigators have made excessive energies for joining CMC hydrogels in order to the higher adsorption of heavy metal ions and some drugs by the CMC hydrogels.[15] This study used polyacrylamide (PAM) in the hydrogel. Initially, PAM can simply be cross-linking

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by N, N'-methylene bis acrylamide to form a robust hydrogel with organized cross-linking mass. Then position sites for the metal ions and investigated drug completed by the NH_2 and CO functional groups. PAM has broadly employed as a functional group for the research of numerous adsorbents.[16] In the present study, we use free-radical polymerization for preparing the CMC/ PAM hydrogel. The Freundlich, Langmuir, and Temkin adsorption isotherms, adsorption kinetics, FTIR, and FESEM analysis used in the experiment for the assessment of adsorption.

MATERIALS AND METHODS

Chemicals and Materials

SZ obtaining from Sigma-Aldrich, Germany, sodium CMC (CMC), acrylamide ≥99% (AM), potassium persulfate (KPS) 99% as initiator, N,N,N',N'-tetramethylethylenediamine (TEMED) as activated purchased from HiMedia, India. N,N'-methylene bis (acrylamide) (NMBA), sodium hydroxide, sodium chloride, and hydrochloric acid purchased from Fluka, Germany. Structure of SZ in Figure 1.

Preparation of CMC Grafted Acrylamide Hydrogel

Preparing CMC grafted acrylamide (CMC-g-AM) hydrogel polymer done by adding 0.25 gram of sodium CMC powder to 50 mL distilled water, stirring vigorously at 60°C after that it well-ventilated at room temperature to form the sodium CMC solution. AM (0.0556 mol) added to the 20 grams of CMC solution with continuous stirring for 20 minutes. Five hours under the nitrogen gas stream needed after adding cross-link TEMED and the initiator KPS. Co-polymer submits to numerous times of washing by deionized water and then dried in an oven at 60°C. For gaining particle size of 150 µm, bulky co-polymer undergo grinding and sieving. The hydrogels surface of the CMC was utilized as deprived of additional treatment. The maximum absorbance wavelength (λ_{max}) of SZ was elected at 550 nm. These values were employed for assessment of the SZ that adsorbed.

Adsorption Isotherm

At pH 1.2 (10 mL) of SZ (1–50 ppm), solutions added to 0.05 grams of CMC hydrogel put in locked bottles. Shake solution in a thermostatically well-ordered water bath until equilibrium time reached (90 minutes). After that, the separation of the solution achieved using a centrifuge [Hettich Universal (D-7200)] at 3,000 rpm for 15 minutes. Double beam

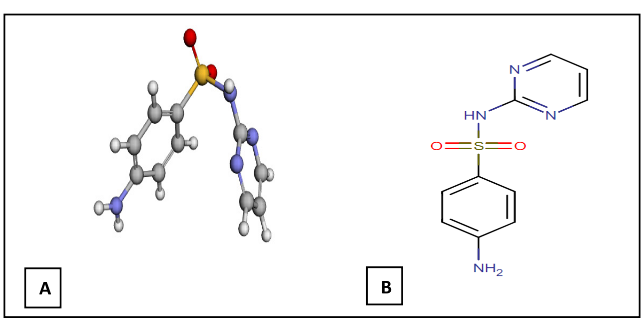

Figure 1: (A) SZ 3D structure; **(B)** chemical structure [4-amino-N-(pyrimidine-2-yl) benzene-1-sulfonamide]

UV-visible spectrophotometer (1650 Japan, Shimadzu. PC) used for measuring the absorbance of a supernatant solution after adsorption of SZ. Drug adsorbed quantity q_t and drug removal percent was calculated by these equations:

$$q_t = (C_0 - C_t)V/W \qquad (1)$$

Where C_0 is initial and C_t is equilibrium drug concentrations in the solution (mg/L), mass of hydrogel in mg represented by m and V is the solution volume in L.

The equilibrium adsorption, q_e (mg/g), was designed using the formula:

$$q_e = (C_0 - C_e)V/W \qquad (2)$$

The drug removal percentage can be calculated:

$$(\%) \text{ of drug removal} = (C_0 - C_e) / C_0) * 100 \qquad (3)$$

Influence of Temperature

For estimation of fundamental thermodynamic functions, the adsorption experiment repeated in the same manner at temperatures of 10, 20, and 30°C.

Influence of pH

Influence of the pH values was measured in adsorption; 0.05 grams of CMC hydrogel was added to an unchanging concentration of the drug at different pH values (1–10) simultaneously an adjustment of temperature and time parameters.

Influence of Ionic Strength

Effect of NaCl, KCl, and $CaCO_3$ was studied through different salt weights (100–500 mg), also drug solution of constant concentration containing 50 mg of the ready hydrogel was used, water bath was adjusted at 25°C for 90 minutes to get equilibrium time, simultaneously the pH, concentration, temperature, and time are adjusted.

RESULTS AND DISCUSSION

Characterization

Infrared spectra of the hydrogel before the adsorption process is begun, as shown in Figure 2, revealed a broad absorption band at the range 3,197 to 3,500 cm^{-1}, demonstrating there is overlap between the NH band and the OH band. Bands at the 2,800 to 2,950 cm^{-1} denotes the CH2-CH3 group's mass vibration owing to the existence of CH bonds in the aliphatic compounds. Additionally, the existence of bands at the wave of 1,600 to 1,750 cm^{-1} range that revealed carbonyl bonds (C=O) for carboxyl groups, finally bands appearance at wave 1,000 to 1,400 cm^{-1} range revealed C-N, C-O, and C-C bonds

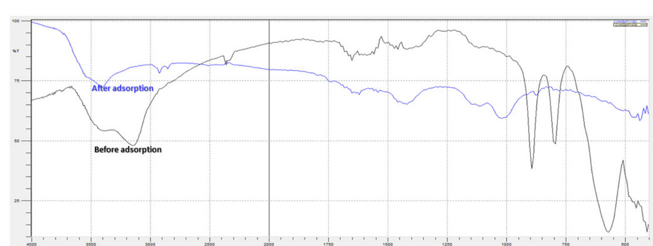

Figure 2: FTIR analysis of CMC-g-AM hydrogel before and after SZ adsorption

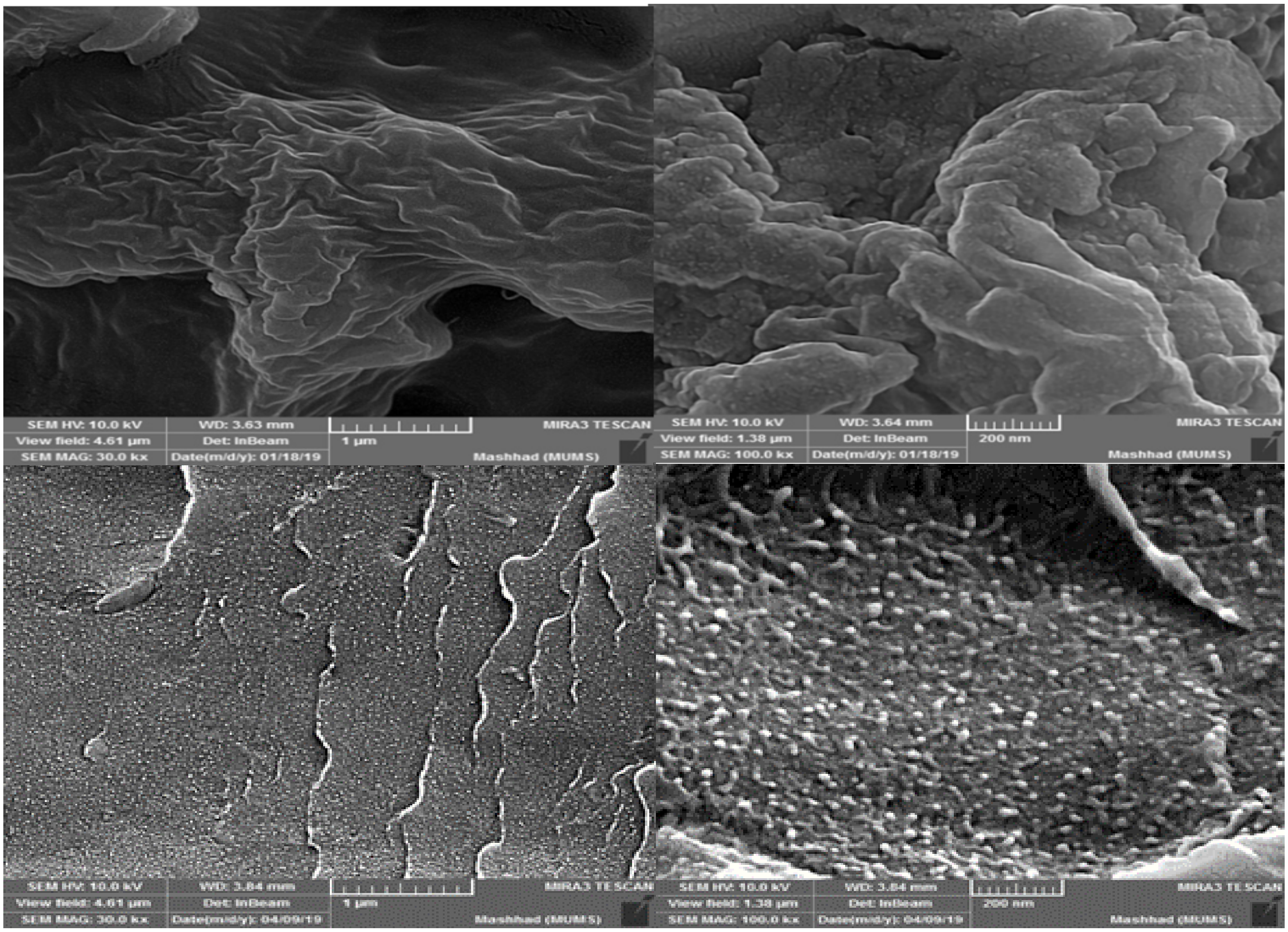

Figure 3: FE-SEM analysis of CMC-g-AM hydrogel: **A-** after SZ adsorption; **B-** before SZ adsorption

vibration. Later adsorption FTIR spectra in Figure 2 displays novel peaks with losing other peaks representing an obvious association between the polymer and SZ. FESEM technique used to determine the surface morphology of poly CMC-g-AM hydrogel was shown in Figure 3.

Adsorption Experiments

Effect of Adsorbent Weight

The results for the SZ uptake via different amounts (0.01–0.2 grams) of the hydrogel in Figure 4. The equilibrium of SZ uptake capacity (q_e) rise as the quantity of the adsorbent rise because of the increased surface area of hydrogel that gives more active sites for SZ adsorption. In the present experiment, the 0.05 grams of hydrogel chosen as the best adsorbent dosage because, at this quantity, the equilibrium (saturation) achieved. 0.05 grams of CMC-g-AM hydrogel selected for subsequent experiments.[17]

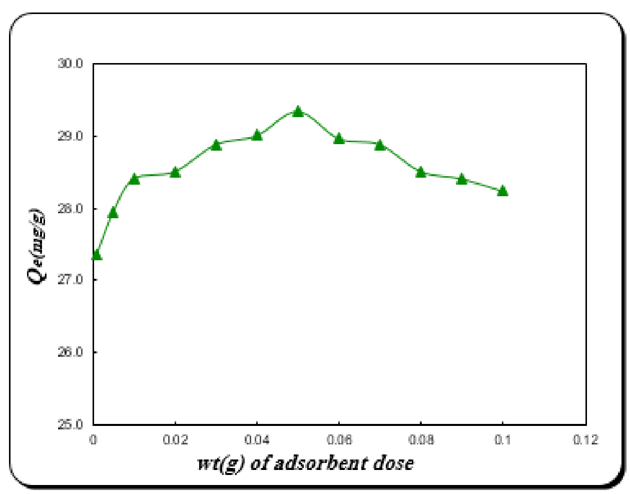

Figure 4: Influence of adsorbent dose on SZ removal percentage

Influence of Temperature and Thermodynamic Function Calculations

The outcomes in Figure 5 displayed the process of adsorption was exothermic because SZ removal percentage decreases with increasing temperature. The highest removal percentage happened at 10ºC after 90 minutes of equilibrium period. But more rise in temperature leads to more sorption because of weak physical bonds between the active site of the CMC-g-AM hydrogels and SZ molecules.[18]

The principles of thermodynamic functions are vital because they clarify numerous interactions, particularly during adsorption processes. Thermodynamic factors of SZ, like change in free energy (ΔG), change in enthalpy (ΔH), and change in entropy (ΔS) assessed from the variation of the thermodynamic equilibrium constant (K) with temperature are presented in Table 1. ΔH amount for an absorption process utilize to distinguish between physical and chemical absorption.[19] The low value of enthalpy (ΔH) provides strong evidence of weak interaction between SZ and hydrogel, and this will give proof there is a physical adsorption process between SZ and the surface of the hydrogel. Results show negative (ΔG) and (ΔS) for adsorption; this means there is spontaneous and feasible adsorption takes place with increased orderliness at the adsorption of SZ onto CMC-g-AM hydrogel. The exothermic natural of SZ adsorption by hydrogel reinforced by the negative values of ΔH.

Adsorption isotherms: Numerous isotherm equations are existing for investigating sorption equilibrium parameters, the most public being is the Freundlich, Langmuir, and Temkin isotherms. The model of Langmuir isotherm (Figure 6A) built on the theory that there is a fixed quantity of active sites, which regularly dispersed over the surface of adsorbent, these sites have identical desirability for adsorption of a monomolecular layer and no interaction between adsorbed molecules.[20] The Freundlich isotherm (Figure 6B) applicable for heterogeneous surface adsorption. This model supposes a positive relationship between adsorbate concentration adsorbent quantities on the surface. Similarly, the energy sorption proportionally declines at the end of the sorption centers of the adsorbent.[21] Timken isotherm (Figure 6C) comprises an element that taking into the account of interactions of adsorbent-adsorbate. By disregarded the meager and significant value of concentrations, the model supposes the adsorption heat of all molecules in the layer would linearly decrease rather than logarithmic with coverage.[21] Calculation of correlation coefficients done by fitting the experimental equilibrium data for the SZ- CMC-g-AM hydrogel system using Langmuir, Freundlich, and Timken isotherms. Figure 6 shows the highest correlation coefficients (R^2 = 0.9444) related to the Freundlich model; these findings demonstrate the SZ adsorption on hydrogel competent well with this model, so these results suggest physical adsorption besides active sites on the hydrogel surface heterogeneously distributed.

Adsorption Kinetics Study and Equilibrium Time Effect

After the steadiness of all other parameters, the SZ adsorption was studied at different times 1 to 180 minutes. In Figure 7, the adsorption capacity of SZ was augmented as the time elongated until reaching maximum value (saturation state); after that, the adsorption capacity decreases with increasing time due to a desorption process. The models of kinetics of the adsorption process, which define the experimental data, elected for adsorption of SZ on the CMC-g-AM hydrogel presented in Figure 7. Experimental data investigation was done using the pseudo-first model and the pseudo-second-order.

Table 2 results display adsorption of SZ by the hydrogel is achievable process because the value of correlation coefficient (R^2) is high for the pseudo-second-order model compared to the pseudo-first-order.[22]

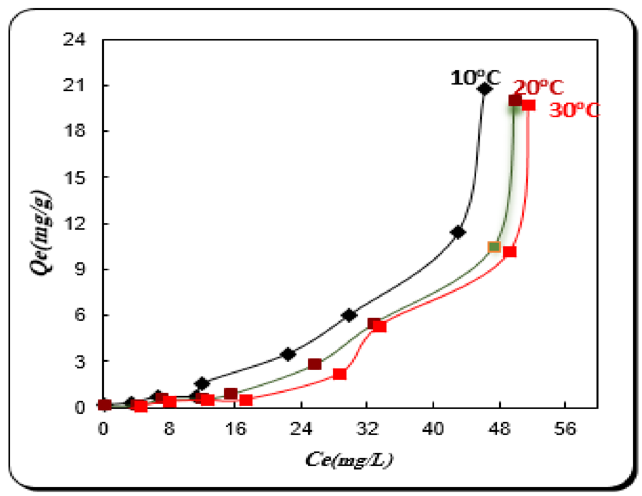

Figure 5: Influence of temperature on SZ removal percent

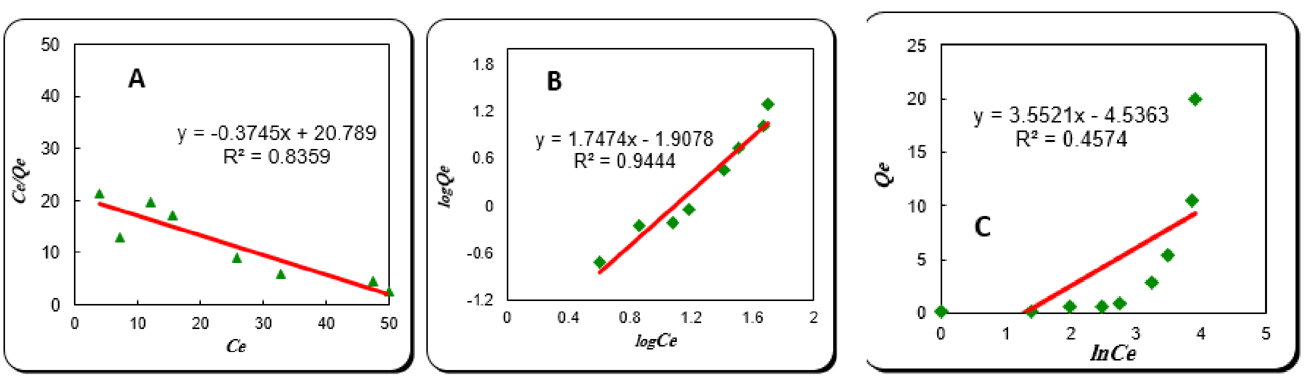

Figure 6: Langmuir **(A)**, Freundlich **(B)**, and Temkin **(C)** isotherms of SZ adsorption on CMC-g-AM hydrogel

Table 1: Thermodynamic parameters of SZ adsorption on the surface CMC-g-AM

Drug	*ΔH*	*ΔG*	*ΔS*	*Equilibrium Constant (K)*
Sulfadiazine	-38.933	-0.783	-125.908	0.776

Table 2: Adsorption kinetics parameters of SZ adsorption

First-order					
Slope	Intercept	k_1 (min)$^{-1}$	q_e (mg/g)	R^2	
–0.0285	0.3426	0.0285	1.408605	0.7392	
Second-order					
Slope	Intercept	q_e (min)$^{-1}$	k_2 (g.mg.min^{-1})	H	R^2
–0.0007	0.5987	–1428.57	8.18E-07	1.670286	0.9122

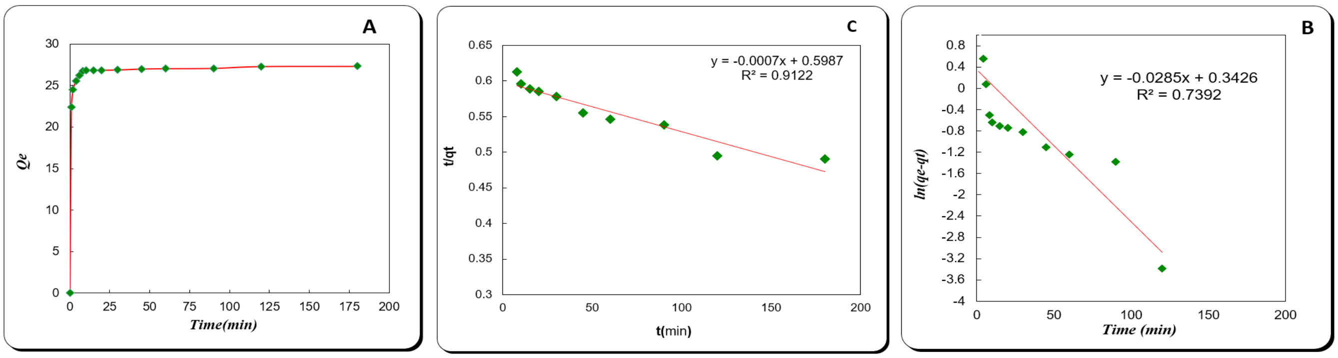

Figure 7: Effect of reaction time **(A)**, pseudo first-order **(B)**, and the pseudo-second-order **(C)** on SZ adsorption

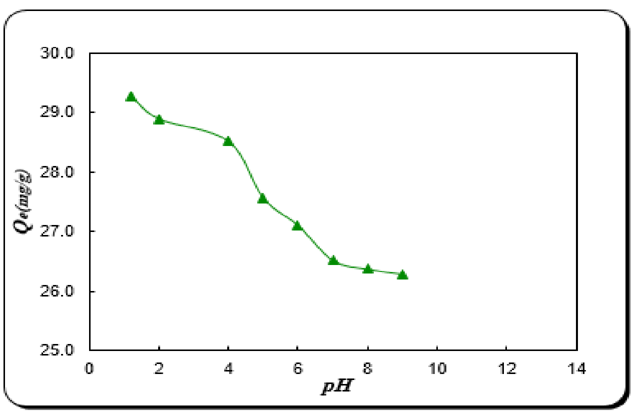

Figure 8: Effect of pH on the adsorption capacity of CMC-g-AM hydrogel for SZ

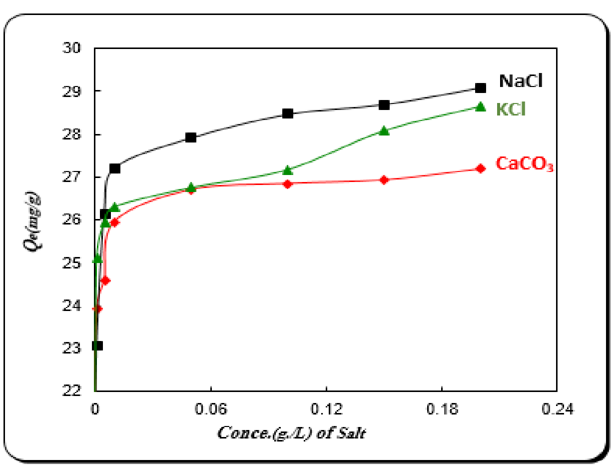

Figure 9: Effect of ionic strength of NaCl, KCl, and $CaCO_3$ on the SZ adsorption on CMC-g-AM hydrogel

Influence of pH

The SZ adsorption quantity on the surface of CMC-g-AM hydrogel is rise as the pH value decline as shown in Figure 8; this is due to the increment in the positive charge of NH_2 of SZ that lead to increase in the adoption of SZ to the negative charge of the polymer. But basic pH media help to remove H from the NH group of the SZ (negatively charged) that lead to repulsion between hydrogel surface active sites and SZ layer.[23]

Ionic Strength Effect

Ionic strength effect of varying weights (0.1 to 0.5 grams) of NaCl, KCl, and $CaCO_3$ solutions for SZ adsorption by hydrogel presents in Figure 9. Results show the adsorption capacities of SZ decline as the salt amount rises due to the electrostatic repulsion effect produced by these salts on the SZ adsorption process. The influence of KCl is more than that of NaCl, and the influence of $CaCO_3$ is more than of KCl; this gives a conclusion there is less electrostatic repulsion effect of NaCl than that produced by KCl and $CaCO_3$ on SZ adsorption. Besides, that $CaCO_3$ has a more repulsion effect on SZ adsorption than that produced by KCl and NaCl due to their two positive charge that binds to the polymer and takes place the active site of SZ adsorption.[24,25]

CONCLUSION

In this experiment, studied the SZ adsorption onto CMC-g-AM hydrogel as a function of adsorbent dose, SZ concentration, pH, temperature, and ionic strength we conclude that: (1) adsorption equilibrium practically well linked with the Freundlich isotherm, (2) thermodynamic outcomes of SZ adsorption on the CMC-g-AM hydrogel is spontaneous and physical, and (3) a negative value for the adsorption entropy, which specifies that molecules of adsorbed SZ ordered on the CMC-g-AM hydrogel surface. Finally, by evaluating the values of ΔHads, ΔSads, and

ΔGads, we concluded that CMC-g-AM hydrogel has a great probability as an adsorbent for SZ removal.

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