Adsorption Sulfate from Wastewater by Using New Material

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Abstract. Using physical activation, a new composite adsorbent was prepared by modifying low-cost local adsorbent. This low-cost local adsorbent was also prepared from activating sludge, bentonite, and limestone (SBL). In comparison to the low-cost LCL, the adsorption capacity of the new composite adsorbent was improved. This was measured in terms of its ability to remove sulfate from wastewater. The behavior of the sulfate adsorption processes by using (SBL) as an adsorbent was investigated in batch experiments by examining different values of solution pH, contact time, adsorbent dose, and initial SO_4 concentration. The high removal efficiency was exhibited by (SBL) = 96%. These results reveal the great potential of the new composite adsorbent (SBL) if applied to the absorption of sulfate ions.

Keywords: Adsorption; sulfate; sludge; physical activation.

1. INTRODUCTION

Freshwater is the primary component of the planet and is necessary for the survival of all living things. Due to the increasing rise of industrial, agricultural, and commercial activities and urbanization, these activities produce noticeably more wastewater [1]. Many wastewaters will have a certain level of various contaminants, including heavy metals, sulfate, organics, etc. Sulfate must be removed from wastewater to comply with environmental rules and protect public safety and health [2]. Due to its toxicity to the environment, sulfate is one of the main industrial pollutants that has drawn a lot of attention in water research [3]. High levels of sulfur in the water bodies cause several environmental issues, including the mineralization of water, disruption of the natural sulfur cycle and food chain, and atmospheric emission of hydrogen sulfide [4]. Sulfate removal has traditionally been accomplished using conventional wastewater treatment methods. Still, these methods have some disadvantages, including high operational and maintenance expenses and the need for chemical treatment of the wastewater. Because some of the chemicals used in the process are harmful to the ecology, this threatens the ecosystem [5]. Here are several water treatment methods and their benefits and drawbacks [6].

However, absorption is the main concern here. A fluid (in this instance, water) and a solid phase are involved in the unit operation of adsorption. (The adsorbent) One or more dissolved contaminants are found in the fluid phase (The adsorbate). Water is purified as the dissolved pollutants are moved from the liquid phase to the adsorbent surface [7]. Adsorption is presently used to treat water because it has several benefits, including low cost, high efficiency, simplicity in use, ability to use a variety of solids as adsorbent materials, and ability to recover both the adsorbent and the adsorbate [8]. The competitive and effective nature of adsorption as a polishing process must be emphasized when pollutants are present in water at concentrations between ng L-1 and mg L-1 [9]. The municipality and affected businesses were under tremendous strain due to the large amounts of sludge produced during wastewater treatment operations. 25–65% of the total running cost of secondary wastewater treatment is spent on treating and disposing of the sludge. [10]. Generic adsorbent main types, including polymeric adsorbents, molecular sieves of (zeolites and carbon), activated alumina, silica gel, and activated carbon, have dominated the commercial use of adsorption. Some adsorbents, such as zeolites, occur naturally, but the majority are manufactured. The characteristics of each adsorbent are the type of the adsorbing surface, the pore structure, and the porosity [11].

Using clay material sludge, waste limestone, and bentonite as adsorbent (SBL) for the removal of sulfate ions is a good choice because of its low cost and high efficiency. According to our knowledge, few researchers are concerned about investigating the removal of sulfate ions by clay minerals. This study aims to remove the sulfate from wastewater by using wasted and low-cost material as an adsorbent.

2. MATERIAL AND METHODS

2.1 Materials

Dewatered sludge was obtained from the wastewater treatment plant of Karbala City. The bentonite and limestone samples were collected from commercial markets. The chemical materials include potassium sulfate, Sodium hydroxide, Barium chloride, and Filter paper (Whatman 7.0 cm). to filter the sample solution and distilled water from commercial markets with high purity.

2.2 Preparation of Adsorbent

The synthesized Adsorbent composites were prepared via physical activation. The materials used are dried in a drying oven for 12 hours at a temperature of (105) °C, then the materials are grinding, sludge bentonite and limestone (SBL) composite prepared as bentonite is gradually added to the water, then sludge is added with the addition of water and gradually limestone add with water [12]. The solution is mixed in the magnetic stirrer for 30 minutes. After that, the solution is filtered. Using filter papers, the filter is burned in the oven for 2 hours at a temperature of (800) °C. The result is grinding by the grinder. The mixture of sludge, bentonite, and limestone at mass ratios of 4:1:1, 3:1:1, 2:1:1, 1:4:1, 1:3:1, 1:2:1, 1:1:4, 1:1:3, 1:1:2, and 1:1:1.

2.3 Batch Experiments

Batch adsorption experiments were carried out to investigate the adsorption performance of SBL for sulfate. The process was done under initial conditions: the initial concentration = 900 mg/l, PH =7.5, contact time =60 min, agitation speed =200 rpm, and adsorbent dosage =100 mg/50ml at room temperature 25 C to ensure homogenous mixing [13]. Then, the solution was filtered using 0.45 μm membrane filters. The sulfate concentration was measured by barium chromate spectrophotometry. The effect of initial concentration: 100 mg of adsorbent was added into 50 mL of wastewater and mixed by magnetic stirrers. The required concentration of the sulfate was achieved by using Equation 1 as assuming complete dissolution [14]:

$$\mathbf{W=C_i\times V\frac{M.wt}{At.wt}} \tag{1}$$

Where: W= the weight of the salt (mg), V= volume of the solution (L), Ci= the required sulfate concentration (mg/L), M.wt= the salt molecular weight (g/mole), At.wt= the SO_4 atomic weight (g/mole). Diluted according to Equation 2 to prepare the required concentration; also, the pH of every solution was adjusted by using 0.1 mole HCl or 0.1 mole NaOH as needed [15].

$$\mathbf{C_1} \times \mathbf{V_1} = \mathbf{C_2} \times \mathbf{V_2} \tag{2}$$

Where: $\mathbf{C_1}$= solution concentration=1000 mg/L, $\mathbf{V}_1$= required volume of the solution (L), $\mathbf{C_2}$= dilute concentration of the solution (mg/L) and V_2= dilute solution volume (L). The efficiency of the adsorption process can be calculated from the change in % removal value with time; the change in % removal with time was decided from this equation.

$$\mathrm{R\% = (Co - Ce)/Co * 100} \tag{3}$$

3. RESULTS AND DISCUSSION

3.1 Preparation Results

The results of batch experiments. It was carried out to examine the efficiency of the adsorbent to remove sulfate from wastewater. In the initial condition, the best mass ratio of SBL is 1:1:2 with a percent of efficiency of 88%, as shown in Table 1 below.

Table 1: Removal efficiency of SBL composite.

Composite	No.	Mass ratio (B+L+S)	Efficiency (%)
Bentonite, limestone, sludge composites	1	1:1:4	67
	2	1:1:3	71
	3	1:1:2	88
	4	1:4:1	55
	5	1:3:1	45
	6	1:2:1	77
	7	4:1:1	65
	8	3:1:1	72
	9	2:1:1	45
	10	1:1:1	76

The optimum condition is tested on a 1:1:2 mass ratio of SBL composite, which is used to prepare the adsorbent for the following experiments.

3.2 Adsorption Results

This section of the experiment aimed to evaluate how well the adsorbent removed sulfate from simulated contaminated wastewater. This section shows the experiments that are conducted in various (contact time, pH solution, initial concentration, agitation speed, and adsorbent dosage).

3.2.1 Impact of Dosage on Sulfate Adsorption

The effects of dosage on the removal of sulfate are shown in Figure 1; with an increase in the dosage of SBL from 0.05 mg/50 mL to 0.1 mg/50 mL, the removal of sulfate increased from 55% to 79% and still increase with dose increase where chive 88% with 0.2 mg/50 ml. However, sulfate removal increased slightly as the dosage of SBL increased from 0.2 mg/50 mL to 0.6 mg/50 mL. With an adsorbent dose of 0.5 g, the highest rate of sulfate removal was achieved. After that, despite an increase in adsorbent dosage, the amount of sulfate in the solution and its binding to the adsorbent remained constant [16].

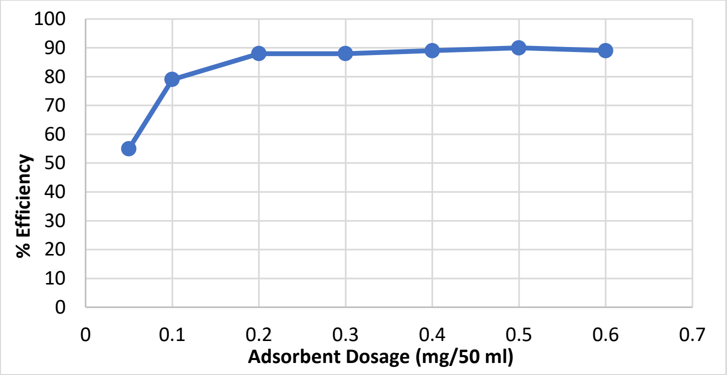

Figure 1: Effect of dosage on removal efficiency.

3.2.2 Impact of Adsorption Time on Sulfate Adsorption

The effects of adsorption time on the sulfate adsorption using SBL are illustrated in Figure 2. It was evident that the adsorption rate was fast from zero to 60 min, and then it stabilized with an increase in time. So, the optimum contact time was found to be 60 min.

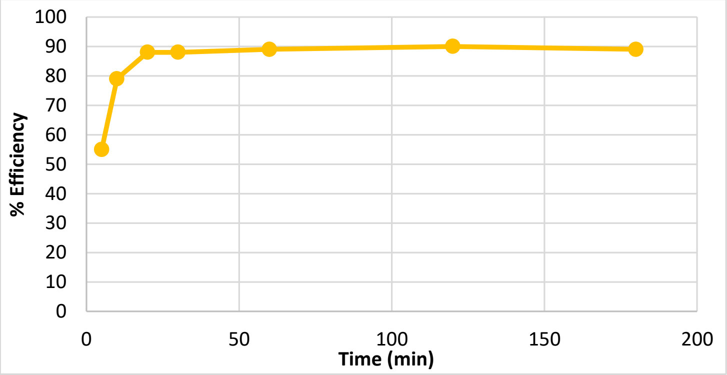

Figure 2: Time effect on removal of sulfate.

3.2.3 Impact of pH Values on Sulfate Adsorption

The answer: Because it impacts the adsorbent's surface charge, pH is a crucial factor in the adsorption process. A pH range of 2 to 11 was used in this work to investigate the impact of pH on adsorption capacity. The outcome, displayed in Figure 3, demonstrated that the initial pH value significantly impacted the adsorption capacity. Efficiency increases as pH rises from 2 to 6. However, the efficiency decreases as the PH increases from 6 to 11. So, the optimum pH value was found to be 6.

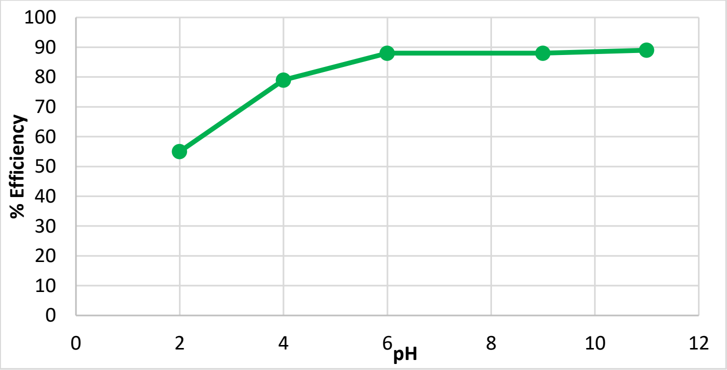

Figure 3: pH effect on sulfate removal.

3.2.4 Impact of the Initial Concentration on Adsorption

The impact of the initial sulfate concentration on removal efficiency is shown in Figure 4. The result showed that efficiency was significantly affected by initial sulfate concentration. The efficiency stabilized with increasing concentration from 100 mg /l to 500 mg/l, then decreased with an increase in concentration.

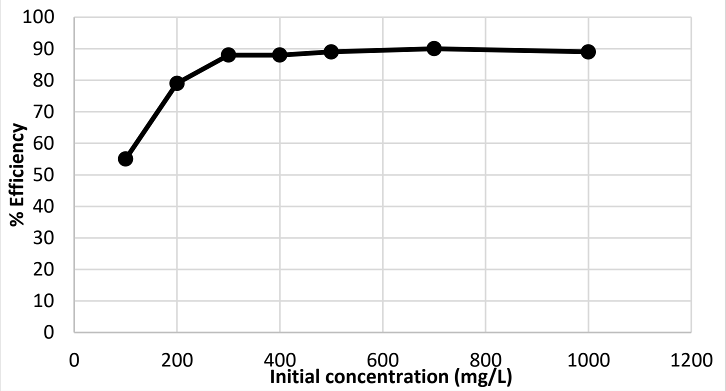

Figure 4: Effect of initial concentration on removal efficiency.

3.2.5 Agitation Speed

In order to study the effect of agitation speed on sulfate removal efficiency from contaminated wastewater, several experiments were carried out at different agitation speeds, raining from 0 (without agitation) to 250 rpm with contact time=60 min; C_o=900 mg/L; dose= 0.1 g/50 mL; pH=6; T= 25^{o}C. The removal efficiency of sulfate before agitation, as shown in Figure 5, was 10 %. This efficiency was increased gradually as agitation speed increased from zero to 250 rpm, becoming 96% for sulfate. This increase is related to the fact that the sulfate ions diffusion on the adsorbent surface is improved as the agitation speed increases.

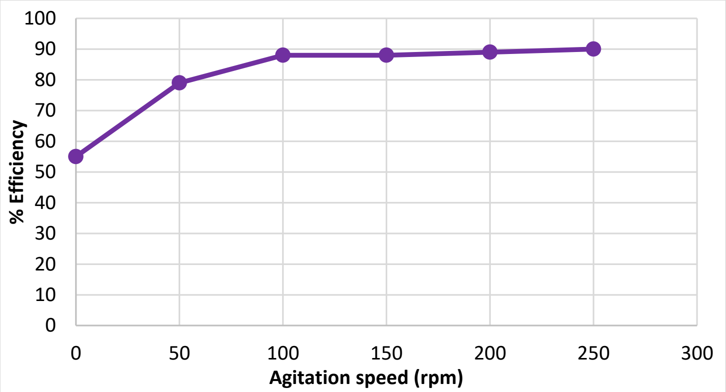

Figure 5: Effect of agitation speed on removal of efficiency.

4. CONCLUSIONS

The new composite adsorbent prepared for adsorption sulfate showed a high capacity compared to adsorption using different adsorbents, such as low-cost local adsorbents. This study synthesized a sludge, bentonite and limestone composite (SBL) by physical activation. The SBL composite (mass ratio of 1:1:2). The composite adsorbent exhibited excellent ability to remove sulfate from aqueous solution. The significant findings are summarized as the % removal of sulfate ions affected with main parameters: speed of rotation, PH value, initial concentration, contact time, and amount of dosage with a constant of temperature in (25C^o). The maximum % Removal of sulfate ions reached a maximum value at pH = 6 for a solution, the adsorbent dose=0.5, contact time = 60 min, and agitation speed =250 rpm. The integrated treatment showed a higher performance for sulfate removal, achieving an overall removal efficiency of 96%.

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