Treatment of Synthetic Wastewater Containing Fe^{2+} Using Adsorption Method with *Mulberry* Leaves

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ABSTRACT

Besides the toxic effects of heavy metals on the environment, their harmful impact on water resources is becoming increasingly significant. Among these, Fe^{2+}, due to its high levels in the body, negatively affects various organs such as the heart, liver, and pancreas. Several methods, including chemical precipitation, bioremediation, ion exchange, membrane filtration, electrochemical treatment, and adsorption, are well-documented in the literature for removing toxic substances. This study focused on removing Fe^{2+} cations from water using adsorption. For this purpose, an adsorbent made from mulberry leaves—commonly recognized in the literature for its health benefits—was utilized. During the experiment, optimal conditions for mulberry leaves were identified as: 0.3 g of adsorbent, 30 mg/L Fe^{2+} concentration, 30 °C temperature, 150 rpm agitation speed, pH 10, and 180 minutes of contact time. Under these conditions, Fe^{2+} removal was achieved with an efficiency of 86.20%. This research aims to contribute to the literature on Fe^{2+} removal by using mulberry leaves, a natural and sustainable adsorbent material.

Keywords: *Mulberry* leaves, Fe^{2+}, Heavy metal, Wastewater, Adsorption

1. INTRODUCTION

Water is the most fundamental and essential building block of human and other living life. However, several factors pose serious threats to clean water resources, including rapid population growth and increased industrialization caused by dense urban living. Heavy metals found in industrial wastes are among the most dangerous and harmful substances due to their high toxicity [1-4].

Various industrial sources, such as battery production, pigment and dye industries, metalworking processes, and the mining sector, cause heavy metal toxic effects that lead to bioaccumulation in living organisms. Once heavy metals enter the ecosystem, they persist in soil, water, and air for long periods, infiltrating the food chain and posing a threat to life [5-8]. Fe^{2+} is the metal with the widest range of applications among all heavy metals. Fe^{2+}, which is found in high concentrations in wastewater, has harmful effects on human health and the environment. Its impact on the environment can cause soil and water pollution through factory waste or agricultural practices. Therefore, removing Fe^{2+} from wastewater is extremely important. Heavy metal removal from wastewater can be achieved through various methods to reduce environmental pollution and improve water quality. The most common methods include chemical precipitation, bioremediation, ion exchange (9), electrochemical treatment (10), and adsorption [11]. Among these and similar methods, the advantages of the adsorption technique include ease of application and the ability to eliminate even low concentrations [12].

Using sustainable food materials as adsorbents provides environmentally friendly and cost-effective solutions, offering major benefits in areas like wastewater treatment and heavy metal removal. These materials are affordable and biologically compatible because they come from natural sources, and they do not harm the environment [13,14].

When examining the literature data, the mulberry leaves included in this study are actually a plant known as the iron fan or the herb of immortality and are generally evaluated for their health benefits [15]. The alkaloids, flavonoids, steroids, amino acids, polyphenols, and polysaccharides found in their structures show that mulberry leaves help balance blood sugar, regulate fat levels, and possess antiviral and anti-tumor properties [16].

The reason mulberry leaves were chosen as the adsorbent in this study is their high surface area, abundance of organic compounds, and their expected ability to adsorb toxic metals. The mulberry leaves used were collected from black mulberry trees and prepared by drying them using appropriate methods.

This study investigated how parameters such as adsorbent amount, initial concentration, agitation speed, ambient temperature, pH level, and contact time affect the adsorption process for removing Fe^{2+} heavy metal ions from wastewater using mulberry leaves. The evaluation was based on the percentage removal values.

2. MATERIAL AND METHODS

2.1. Materials and Reagents

Mulberry leaves, shown in Figure 1 and used as the adsorbent material, were collected in Istanbul. The stock solution was prepared using $FeCl_2$ (supplied by Sigma-Aldrich), a solid containing 1000 mg/L Fe^{2+}. The working solutions were prepared from this stock using appropriate dilution ratios. The Mikrotest MSD-08 purification system supplied the water used during the experiments. Mixing was performed with a Julabo SW22 shaking water bath. An Agilent 8453 spectrophotometer was used for UV-VIS measurements. To examine the effects of different pH values, buffer solutions of pH 4 (citrate), 7 (phosphate), and 10 (carbonate) were supplied by Merck. 1,10-Phenanthroline, used to monitor Fe^{2+} concentration, was provided by Merck.



Figure 1. Mulberry leaves

2.2. The Adsorption of Fe^{2+}

Adsorption experiments were conducted using the batch method. The collected mulberry leaves, used as an adsorbent material, were first washed with tap water and then with distilled water. They were then dried in an oven at 80°C for 24 hours, ground into a fine powder, and sieved through a 60-80 mesh sieve.

For this purpose, a stock solution containing 100 mg/L Fe^{2+} was prepared. A working solution of 30 mg/L was then made from the stock solution in an appropriate ratio. The solution was transferred into beakers, where mulberry leaves, chosen as the adsorbent, were added in specific amounts. The solutions were then shaken for a set period. After shaking, the samples were filtered through filter paper, and their absorbance was measured at 510 nm using a UV-VIS spectrophotometer [17]. The percentage removal was calculated as shown in Equation 1.

$$\%\text{Removal} = [(C_0 - C) / C_0] \times 100 \quad (1)$$

C_0 is the initial concentration of dyestuff, and C is the concentration of dyestuff in solution at any given time.

3. Results

3.1. Investigation of the Effect of Adsorbent Amount on Fe^{+2} Adsorption Process

To examine the effect of adsorbent amount on Fe^{2+} removal, samples were weighed from *mulberry* leaf-based adsorbent in ranges from 0.1 to 1.5 g. Then, 50 mL of a 30 mg/L Fe^{2+} solution was added. The adsorption process was performed at 180 rpm, 30 minutes, and 25 ºC using the batch method. After the process, filtration was done with filter paper (Whatman Cat Number 1001-150). 1,10-Phenanthroline was added to the Fe^{2+} sample [17]. The sample was measured at 510 nm on a UV-VIS spectrophotometer. The results are presented in Figure 2.

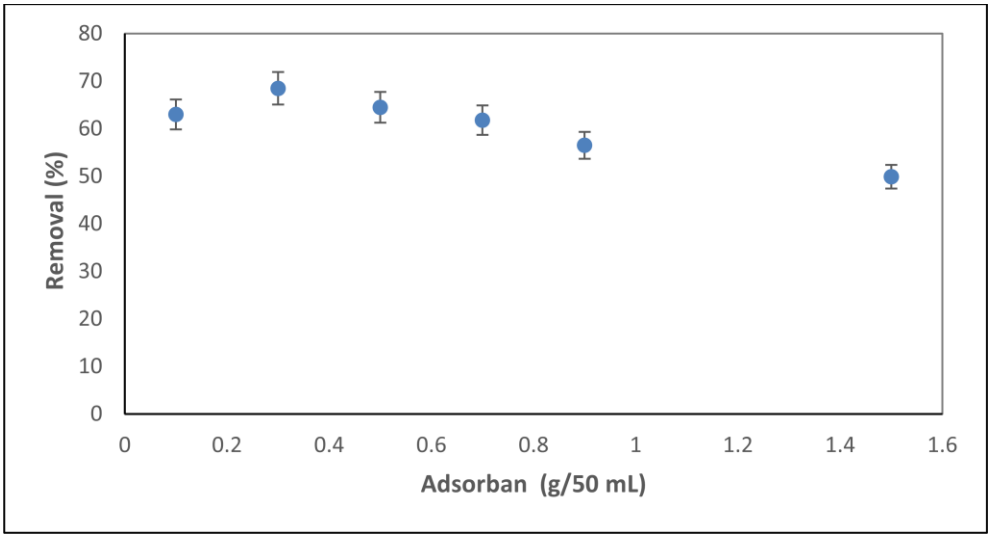


Figure 2. The removal efficiency of Fe^{2+} using different amounts of adsorbent

According to the results, the optimal adsorbent amount was 0.3 g, achieving 68.5% removal. It is believed that at higher adsorbent levels, the surface density increases, and the forces causing adhesion may lead to repulsive interactions, which can slightly decrease the removal percentage.

3.2. Investigation of the Effect of Initial Concentration on Fe^{+2} Adsorption Process

To examine the effects of the initial Fe^{2+} concentration on the percentage removal, solutions were prepared at different concentrations ranging from 10 to 50 mg/L. Then, 0.3 g of mulberry leaf adsorbent was added. The adsorption process was carried out at 180 rpm for 30 minutes at 25 °C. The percentage removal values are shown in Figure 3.

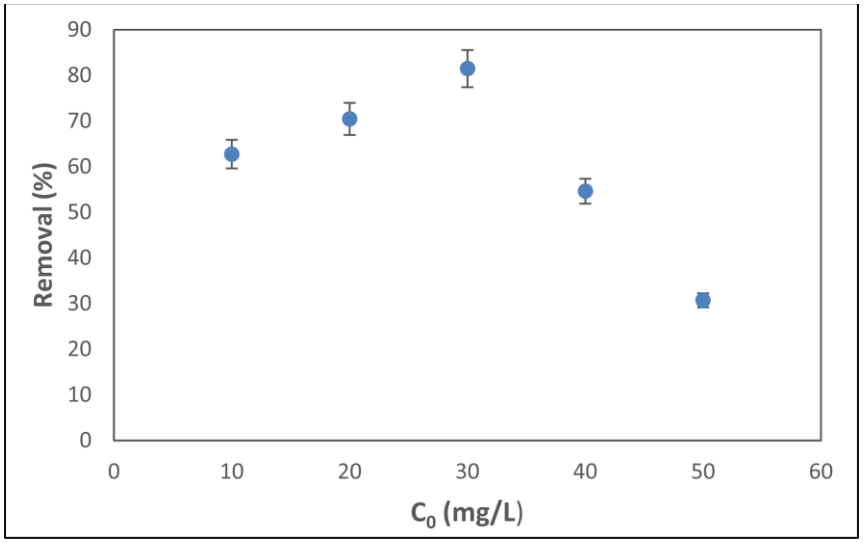


Figure 3. Removal efficiency values of Fe^{2+} for different initial dye concentrations.

At this stage, the optimal initial concentration shifts to 30 mg/L Fe^{2+} and 81.49%. Beyond a certain saturation point, the tendency for desorption to occur becomes clear, with a decrease in % removal after the optimal value of 30 mg/L.

3.3. Investigation of the Effect of Ambient Temperature on Fe^{+2} Adsorption Process

To evaluate how temperature affects Fe^{2+} adsorption, experiments were conducted at temperatures ranging from 25 to 50 °C. Other operating conditions included 0.3 g of adsorbent, 50 mL solution, 30 mg/L Fe^{2+}, 180 rpm, and a 30-minute duration. The percentage removal results are presented in Figure 4.

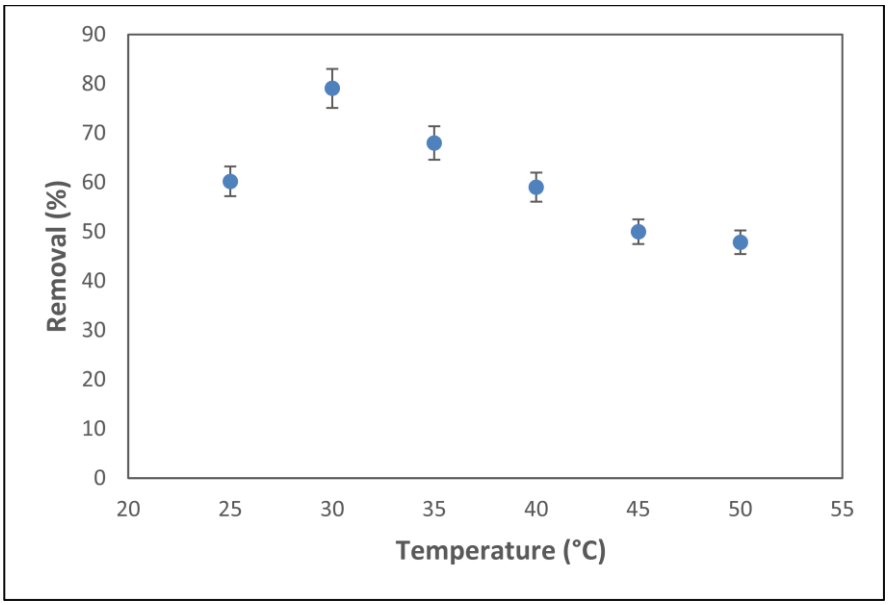


Figure 4. The effect of temperature on the removal efficiency of Fe^{2+}.

The optimal temperature effect was found to be 79.07% at 30 °C. Above this temperature, the increasing kinetic energy of the solution promotes desorption, leading to lower % removal values, as shown in Figure 4.

3.4. Investigation of the Effect of Agitation Rate on Fe^{+2} Adsorption Process

To examine the effect of stirring speed on the adsorption process, stirring was carried out at various speeds ranging from 100 to 180 rpm. Other parameters included 0.3 g of adsorbent, 50 mL of a 30 mg/L Fe^{2+} working solution, and the process was conducted at 30 ºC for 30 minutes.

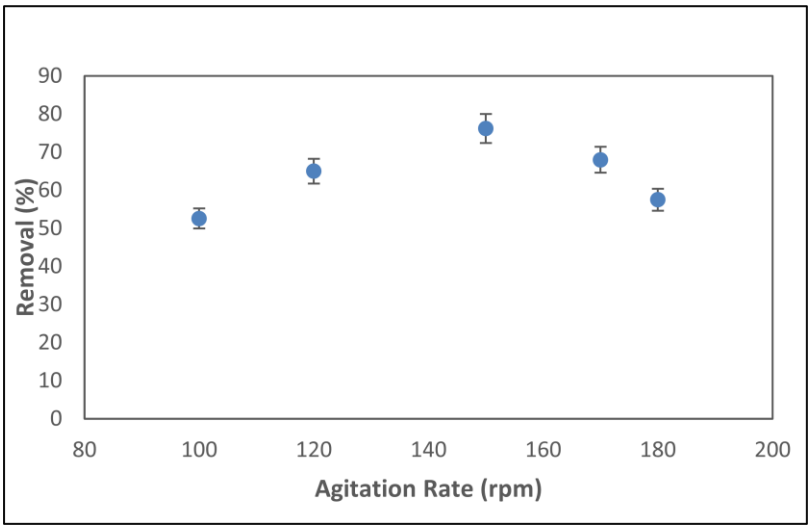


Figure 5. The removal efficiency results at different stirring values.

As shown in Figure 5, the optimal value was determined to be 76.20% at 150 rpm. Below this level, it is assumed that the adsorptive surfaces in the solution are not fully occupied. At higher agitation speeds, adsorption processes such as surface adhesion are believed to detach from the adsorbent surfaces, leading to lower % removal values.

3.5. Investigation of the Effect of pH on the Fe^{+2} Adsorption Process

To determine the effect of pH on removal efficiency, pH levels of 4, 7, and 8 were used. Other parameters included 0.3 g of adsorbent, 50 mL of a 30 mg/L Fe^{2+} working solution, 150 rpm, and the process was performed at 30 ºC for 30 minutes. The results are shown in Figure 6.

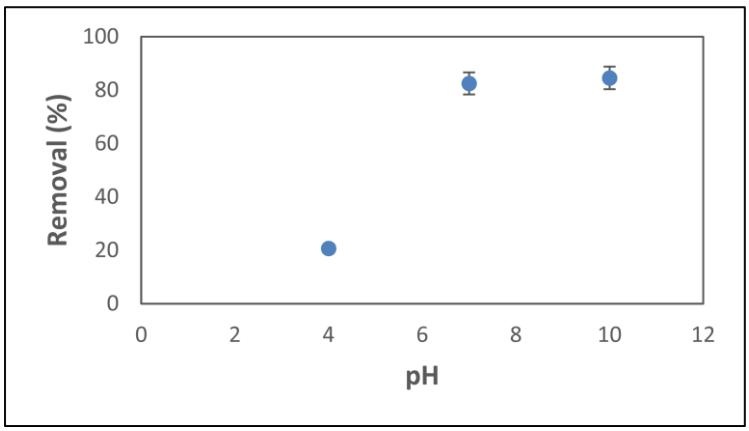


Figure 6. Effect of different pH levels

The optimal pH value was determined to be 10, achieving a removal rate of 84.56%. It is understood that the concentration of OH^- ions at higher pH levels positively influences adsorption, thereby increasing the removal efficiency.

3.6. Investigation of the Effect of Contact Time on the Fe^{+2} Adsorption Process

To investigate the effect of contact time on the % removal, the studies were repeated for durations ranging from 5 to 180 minutes. Other parameters used were 0.3 g of adsorbent, 50 mL of 30 mg/L Fe^{+2}, 30 °C, and 150 rpm. The % removal results are shown in Figure 7.

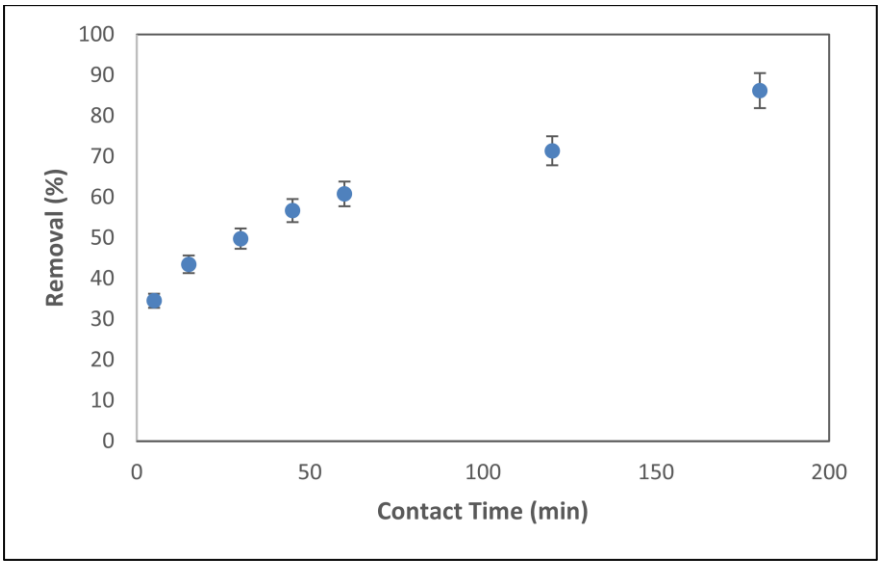


Figure 7. The effect of time on Fe^{2+} removal efficiency.

When adsorption time is considered as a continuous variable, it is observed that the highest removal rate of 86.20% occurs after 180 minutes. It is believed that when the contact time is shorter, the adsorbent surfaces may not yet be fully occupied, and therefore the percentage removal doesn't reach its maximum.

4. Discussion and Conclusion

This study, utilizing mulberry leaves as an environmentally friendly and natural adsorbent, investigated the removal of Fe^{2+}, a toxic heavy metal, from aqueous solutions. The optimal conditions were 0.3 g of adsorbent, a 50 mL volume, an initial Fe^{2+} concentration of 30 mg/L, 30°C temperature, 150 rpm agitation speed, pH 10, and 180 minutes of contact time. Under these conditions, the maximum Fe^{2+} removal rate of 86.20% was achieved. Therefore, it can be concluded that *mulberry* leaves can effectively be used to remove the heavy metal Fe^{2+}.

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