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To cite this article: Shan Zhong and Bolin Li 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **252** 042068

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Study on preparation of magnetic Nano-adsorbent and its heavy metal enrichment performance

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Abstract. In order to avoid the secondary pollution of adsorbent, the magnetic nanomaterials were modified by special groups to realize the rapid and efficient removal of heavy metal ions in wastewater and the recovery and reuse of adsorbent. On the carrier of Fe₃O₄ magnetic nanomaterials preparation of adsorbent Fe₃O₄@SiO₂, carboxymethyl- β -cyclodextrins, and carries on the related research tests due to the conclusion: (1) the maximum adsorption capacity of Pb²⁺ and Cd²⁺ 67.75 mg/g and 27.56 mg/g, removal rate of 86.8% and 83.6%; (2) the optimal pH of the adsorbent is 5.5, the acid and alkali resistance is better and its resistance to alkali is better than the acid resistance; (3) the increase of ionic strength in solution reduces the equilibrium adsorption of adsorbent.

1. Introduction

In recent years, the problem of non-compliance of surface water quality has become more frequent. In addition, groundwater pollution in most areas of the country is relatively serious and poses a major threat to the safety of domestic production and water use [1]. Through the statistical analysis of the total national wastewater discharge in recent years, it has been found that the total discharge of sewage shows an increasing trend. Among the many problems of water pollution, the problem of heavy metal pollution is particularly prominent, and groundwater quality and safety are not optimistic [2]. For the treatment of wastewater containing heavy metals, a variety of treatment methods have been derived, such as adsorption and electrolysis. However, traditional adsorbents have many disadvantages, such as poor adsorption effect, high use cost, and difficulty in achieving separation between solid and liquid [3]. Therefore, it is urgent to prepare a new type of adsorbent with high efficiency and low cost. In this study, special groups of magnetic nanomaterials were modified to achieve rapid and efficient removal of heavy metal ions in wastewater and the reuse and recycling of adsorbents.

2. Preparation of magnetic nano-adsorbent

2.1. Application of magnetic nanomaterials in heavy metal processing

Compared with traditional nanomaterials, magnetic nanomaterials not only possess many excellent properties (such as small particle size, large surface area, etc.), but also have some unique properties such as superparamagnetic and single domain properties. And Curie temperature [4-9], these properties make it possible to use as an adsorbent in the treatment of waste water containing heavy metals, and it



is easily separated from the aqueous solution under an external magnetic field, making it easy to recover and regenerate the adsorbent material. Compared with traditional processing materials, magnetic nanomaterials have lower prices, better selectivity for heavy metals, and no repetitive pollution after use. They have obvious advantages when applied to the treatment of heavy metal-containing wastewater, and can contain heavy metals. Wastewater treatment provides a broader space.

2.2. Preparation of magnetic nano-adsorbent

In this study, magnetic nanomaterial Fe_3O_4 was used as a carrier, and a layer of SiO_2 was coated on the surface to obtain $\text{Fe}_3\text{O}_4@\text{SiO}_2$ core-shell composite nanomaterials, followed by a mesoporous SiO_2 film to obtain $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{SiO}_2$. The carboxymethyl- β -cyclodextrin was grafted to obtain magnetic nano-adsorbent $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{SiO}_2$ -carboxymethyl- β -cyclodextrin. The specific preparation process is shown in Figure 1.

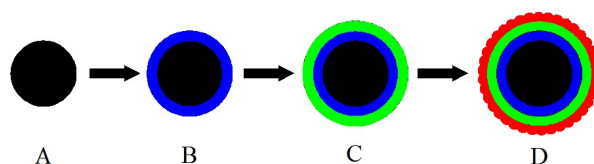


Figure 1. Schematic diagram of preparation process of magnetic nano-adsorbent

3. Experiment procedure

3.1. Material preparation method

(1) Preparation of magnetic nanomaterial Fe_3O_4

At present, several common nanoparticle synthesis methods include coprecipitation synthesis, hydrothermal synthesis, solvothermal synthesis, and oxidative synthesis. Among them, the coprecipitation method is relatively simple to implement and the conditions for the synthesis experiments are relatively mild, and it is easy to prepare a large number of materials. The product particles synthesized by this method have smaller particle size, more uniform distribution, and a better appearance of the product, so this study adopts a traditional method. The chemical co-precipitation method prepares the magnetic nano-material Fe_3O_4 , the preparation method of magnetic nano-material Fe_3O_4 refers to the method of Xiaoping Shao et al. [10].

(2) Preparation of carboxymethyl- β -cyclodextrin

By modifying the cyclodextrin and introducing a carboxyl group through a substitution reaction, not only can the original hydrogen bond network of the cyclodextrin molecule be effectively destroyed, but also the introduced carboxyl group contains a large number of oxygen atoms and can form hydrogen with hydrogen in the water molecule. The bond, which greatly improves the solubility of the modified cyclodextrin; at the same time, a large amount of carboxyl groups is attached to the edge of the cavity of the cyclodextrin, which can dissociate to $-\text{COO}-$ at a pH of the solution > 4 , thus containing the solution. The heavy metal ions react to form complexes. Therefore, the grafting of carboxymethyl- β -cyclodextrin onto $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{SiO}_2$ can increase the active sites on the surface of the material, thereby improving its adsorption performance. The preparation of carboxymethyl- β -cyclodextrin was prepared according to the method of Chen Longran et al. [11].

(3) Preparation of $\text{Fe}_3\text{O}_4@\text{SiO}_2$

As exposed Fe_3O_4 particles are easily oxidized and corroded in air and acidic media [12], the material will lose its nano-effects, which will reduce the adsorption and selectivity of the adsorbent. The commonly used inorganic materials for coating and modifying Fe_3O_4 mainly include SiO_2 , certain metals and some common inorganic compounds, and the coated products have various structures such as core-shell structure, surface mosaic structure and layered structure. In many cladding materials, SiO_2 can effectively reduce the contact between Fe_3O_4 surface and the external environment, so as to achieve

effective protection of the magnetic core. In this study, a layer of SiO₂ film was introduced on the outer surface of Fe₃O₄ through a modified Stober method to stabilize and protect the internal Fe₃O₄ particles, and the product was stably and uniformly dispersed in the solution.

(4) Preparation of Fe₃O₄@SiO₂@SiO₂

In order to further increase the surface area of Fe₃O₄@SiO₂ and increase the adsorption capacity of heavy metal ions, a layer of hollow mesoporous SiO₂ film can be introduced on the basis of the original material to prepare mesoporous SiO₂ coated Fe₃O₄@SiO₂@SiO₂ magnetic composite micro The ball, the dense structure of the internal SiO₂ layer plays a role in stabilizing and protecting the Fe₃O₄ nanoparticles; the mesoporous structure of the external SiO₂ layer can bring rich porosity and larger specific surface area, facilitating the grafting of more CM-β-CD to give the composite material good adsorption properties.

(5) Preparation of Fe₃O₄@SiO₂@SiO₂- Carboxymethyl-β-Cyclodextrin

Although the prepared Fe₃O₄@SiO₂@SiO₂ magnetic nanocomposite microspheres have a large surface area and rich pore structure distributed on the outer surface, the pore size distribution is relatively uniform, but its adsorption effect on heavy metal ions in water is not satisfactory, and it needs to be Modified treatment to improve its adsorption properties. In this study, the complexation of heavy metal ions with -COOH in CM-β-CD was used to synthesize Fe₃O₄@SiO₂@SiO₂-carboxymethyl-β-cyclodextrin magnetic nano-adsorbent, removal of heavy metal ions.

3.2. Material characterization method

The Fourier transform infrared spectroscopic analysis was performed on the synthesized Fe₃O₄, Fe₃O₄@SiO₂ and Fe₃O₄@SiO₂@SiO₂-CM-β-CD, respectively. Infrared spectroscopy analysis showed that the surface of the magnetic nanomaterial Fe₃O₄ was successfully coated with silica and the grafting of carboxymethyl-β-cyclodextrin was achieved. X-ray diffraction analysis was performed on the synthesized Fe₃O₄ and magnetic nano-adsorbent Fe₃O₄@SiO₂@SiO₂-CM-β-CD, respectively. XRD pattern analysis showed that the synthesized magnetic nanomaterials Fe₃O₄ and magnetic nano-adsorbent all had a stable reverse spinel structure. The crystal structure of triiron tetraoxide was very stable in the synthesis process, and no phase change occurred. The synthesized magnetic nanostructures were synthesized. The adsorbent has the same crystalline form as the magnetic nanomaterial Fe₃O₄.

4. Study on the enrichment of heavy metals from magnetic nano-adsorbent

Using the magnetic nanomaterial Fe₃O₄ as a carrier, a batch experiment was performed on the synthesized magnetic nano-adsorbent Fe₃O₄@SiO₂@SiO₂-CM-β-CD using a single-factor experiment method to study the initial pH of the solution, solution ionic strength, adsorption time, The influence of heavy metal ion concentration and other factors on the sorbent-enriched heavy metals, determined the best adsorption conditions in this experiment, and studied the stability of magnetic nano-sorbents in different pH solutions. In addition, when the adsorption reaction time and the initial concentration of heavy metal solution were tested, the maximum adsorption capacity and related adsorption mechanism of the adsorbent were explored by simulating the adsorption kinetics model and studying the adsorption isotherm model.

4.1. Material testing methods and related calculations

4.1.1. Material testing method. In this study, batch experiments were performed to test the material's adsorption performance. Except where otherwise specified, all batch experiments were performed at 25°C. 50 mL of a certain concentration of heavy metal solution was weighed in a centrifuge tube at 200 r/min for 24 h. All experiments were performed. Both 0.05 mol/L nitric acid solution and 0.05 mol/L ammonia water were used to adjust the pH. Stability experiments were performed in solutions of different pH. The concentration of heavy metal ions in the solution was determined by atomic absorption spectrometry.

4.1.2. Adsorption capacity and heavy metal removal rate calculation method

(1) Unit adsorption capacity is calculated using the following formula:

$$q_e = \frac{(C_0V_0 - C_eV_e)}{M} \quad (1)$$

q_e : equilibrium adsorption capacity ($\text{mg} \cdot \text{g}^{-1}$);

C_e : heavy metal ion equilibrium concentration ($\text{mg} \cdot \text{L}^{-1}$);

C_0 : initial concentration of heavy metal ions ($\text{mg} \cdot \text{L}^{-1}$);

V_0 : Initial volume of solution (L);

V_e : Volume of diluted solution (L);

M : Adsorbent dosage (g).

(2) Removal efficiency is calculated using the following formula:

$$\eta = \frac{C_0V_0 - C_eV_e}{C_0V_0} \times 100\% \quad (2)$$

H : removal rate(%);

C_e : heavy metal ion equilibrium concentration ($\text{mg} \cdot \text{L}^{-1}$);

C_0 : initial concentration of heavy metal ions ($\text{mg} \cdot \text{L}^{-1}$);

V_0 : Initial volume of solution (L);

V_e : Volume of diluted solution (L).

4.2. Related research content

4.2.1. Study of different pH conditions. Weigh 0.05g of adsorbent and add 50mL of a certain initial concentration of heavy metal ion solution (initial concentration of cadmium ions is 40mg/L, lead ions is 60mg/L), adjust the pH of the solution to 2, 3, 4, 5, 5.5, 6 by nitric acid solution and ammonia water respectively. The frequency of 200r/min was continuously shaken at 25°C for 24h, and the supernatant was diluted to measure the concentration of heavy metal ions.

4.2.2. Coexistence ion strength study. Weigh 0.05g of adsorbent, add 50mL of a certain initial concentration of heavy metal ions solution (initial concentration of cadmium ions 40mg/L, lead ions 60mg/L), respectively, appropriate amount of NaNO_3 , to maintain the concentration of NaNO_3 solution for 0, 0.05, 0.1, and 0.2 mol/L, the initial pH of the solution was adjusted to 5.5 with a solution of nitric acid and ammonia, and the sample was continuously shaken at 25°C for 24 hours at a frequency of 200 r/min. The supernatant was diluted to measure the concentration of heavy metal ions.

4.2.3. Adsorption kinetics study. Weigh 0.05g of adsorbent, add 50mL, a certain initial concentration of heavy metal ions solution (initial ion concentration of 40mg/L, lead ions of 60mg/L), the initial pH of the solution is adjusted by nitric acid solution and ammonia to 5.5, using 200r/min The frequency of /min is shaken at 25°C for 2 min, 5 min, 10 min, 20 min, 30 min, 60 min, 90 min, 120 min, and 150 min, respectively. The supernatant is diluted to determine the concentration of heavy metal ions.

4.2.4. Adsorption isotherms study. Weigh 0.05g of adsorbent, add 50mL, a certain concentration gradient of heavy metal ions solution, the initial pH of the solution is adjusted to 5.5 by nitric acid solution and ammonia water, using a frequency of 200r/min continuous shaking at 25 °C 24h, take the supernatant Determine the concentration of heavy metal ions after proper dilution.

4.2.5. Adsorbent stability study. Weigh 0.05g of adsorbent, respectively, was added to 15mL solution, using hydrochloric acid and ammonia to adjust the initial pH of the solution is 2,4,6,8,10, at 200r/min oscillation frequency, 25 °C shaking for 24h, take The supernatant was diluted appropriately and the heavy metal ion concentration was determined.

4.3. Drawing of working curve

4.3.1. Cadmium ion operating curve. To draw a standard curve, cadmium ion standard solutions with concentrations of 0.2, 0.4, 0.6, 0.8, and 1.0 mg/L were prepared, and the concentration of residual cadmium ions in the solution was determined by atomic absorption spectrophotometry. The resulting absorbances are shown in Table 1. Show. The standard curve for the determination of cadmium ion concentration by atomic absorption spectrometry is shown in Figure 2.

Table1. Absorbance of cadmium ions at different concentrations

Sample No.	Concentration(mg/L)	Absorbance
blank	0.0	0.00203
1	0.2	0.12739
2	0.4	0.25905
3	0.6	0.38945
4	0.8	0.49751
5	1.0	0.60488

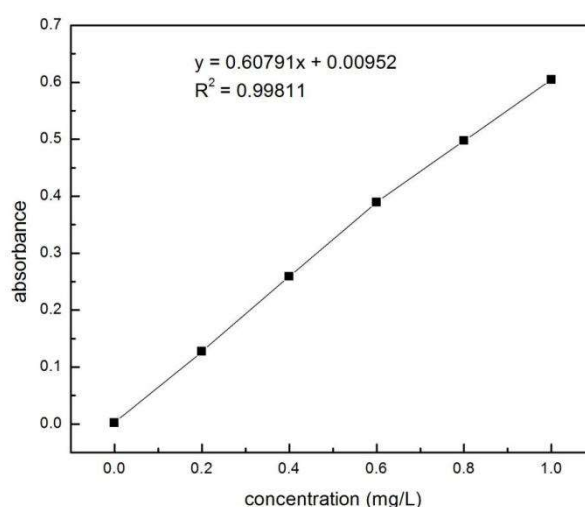
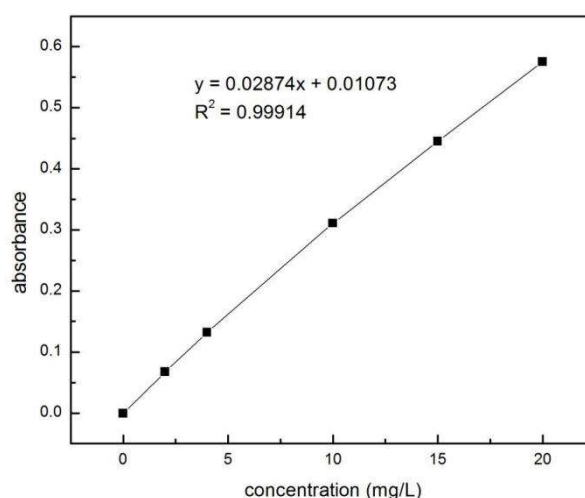


Figure 2. Standard curve of cadmium ion

4.3.2. Drawing of lead ion working curve. To prepare a standard curve, lead ion solutions with concentrations of 2, 4, 10, 15, and 20 mg/L were prepared, and the concentration of residual lead ions in the solution was determined by atomic absorption spectrophotometry. The resulting absorbances are shown in Table 2. The standard curve for the determination of lead ion concentration by atomic absorption spectrometry is shown in Figure 3.

Table2. Absorbance of lead ions for each concentration gradient

Sample No.	Concentration(mg/L)	Absorbance
blank	0	-0.00083
1	2	0.06769
2	4	0.13172
3	10	0.31098
4	15	0.44491
5	20	0.57563

**Figure 3.** Lead ion standard curve

5. Experimental results and discussion

5.1. The initial pH of the solution

The initial pH of the solution plays an important role in the adsorption process. H^+ and OH^- can affect the adsorption efficiency of heavy metal ions greatly by affecting the surface charge and protonation degree of the adsorbent. In this study, hydrochloric acid and sodium hydroxide solution were used to control the solution to maintain different initial pH. The effect of the initial pH of the solution on the adsorption performance was studied. The relationship between the amount of adsorption and the initial pH of the solution was shown in Figure 4, and between the removal efficiency and the initial pH of the solution was shown in Figure 5.

The initial pH of the different solutions showed that the optimal pH for the adsorption of Pb^{2+} and Cd^{2+} was 5.5. In the pH range of 2-5.5, the enrichment performance of magnetic nano-sorbents for Pb^{2+} and Cd^{2+} is greatly affected by the initial pH of the solution. Whether it is Pb^{2+} or Cd^{2+} , the equilibrium adsorption capacity of adsorbent increases with the pH. When $pH = 5.5$, the equilibrium adsorption capacity of the adsorbent and its removal rate of heavy metal ions in the solution reached a maximum value. At this time, the adsorption capacity of magnetic nano-adsorbent for Pb^{2+} was 52.1 mg/g, the removal rate for Pb^{2+} was 86.8%, the adsorption capacity for adsorbent for Cd^{2+} was 20.9 mg/g, and the removal rate for Cd^{2+} was 83.6%.

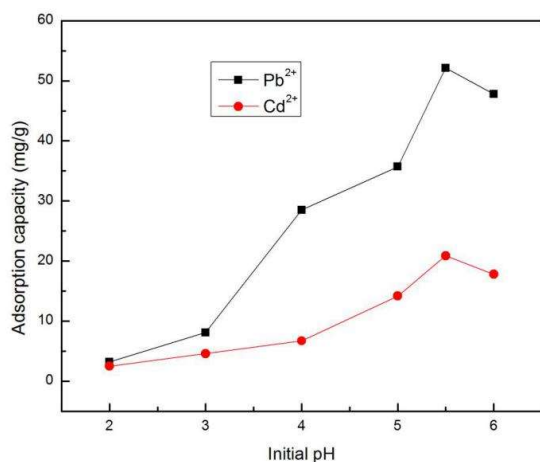


Figure 4. Adsorption amount and the initial pH of the solution

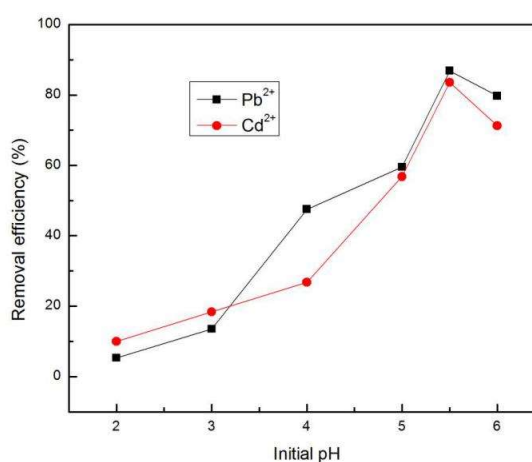


Figure 5. The removal rate and the initial pH of the solution

5.2. The effect of coexisting ionic strength

In this study, Na⁺ was used as a coexistent ion to study the adsorption performance of adsorbents at different concentrations by setting gradient experiments. The equilibrium adsorption capacity of magnetic nano-adsorbent at different ionic strengths is shown in Figure 6.

As shown in Figure 6, as the Na⁺ concentration in the solution increases, the equilibrium adsorption capacity of the adsorbent gradually decreases. Liu et al. [13], as showed that the presence of inorganic salts in solution may have two opposite effects. On the one hand, due to the electrostatic interaction between the inorganic salt and the opposite charge on the surface of the adsorbent, the adsorption capacity of the adsorbent decreases as the concentration of the inorganic salt increases; on the other hand, the inorganic salt ions can also promote the carboxylation on the adsorbent. The dissociation of the functional groups is such that the amount of adsorption increases. In addition, when the concentration of NaNO₃ in the solution is low, the former dominates the adsorption process. At higher concentrations of NaNO₃, the two effects are comparable, so the effect of NaNO₃ concentration on adsorption is not significant. In this study, the highest concentration of NaNO₃ was only 0.2 mol/L, which was still a low concentration condition. In this case, the inhibitory effect of Na⁺ on the adsorbent dominated, and the inhibitory effect became more pronounced with the increase of inorganic salt ion concentration. Obviously, the equilibrium adsorption capacity of the adsorbent gradually decreases.

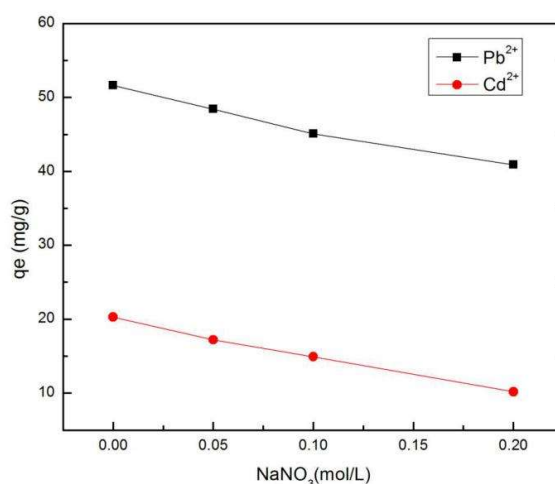


Figure 6. Diagram of different ionic strength and equilibrium adsorption capacity

5.3. Adsorption kinetics

In order to explore the adsorption rate and related adsorption mechanism, the effect of different adsorption time on the removal effect of heavy metal ions was studied in this experiment. By controlling different reaction times, the adsorption effect of the adsorbent was tested, and the effect of the adsorption time on the unit adsorption amount was shown in Figure 7. The effect of the obtained adsorption time on the removal efficiency is shown in Figure 8. It can be seen that the magnetic nano-adsorbent The adsorption kinetics of Pb^{2+} or Cd^{2+} are basically the same, and the adsorption rate of heavy metal ions by the adsorbent is very fast. After 10 minutes of adsorption, 80% of the total adsorption has been completed. When the adsorption was carried out to 20min, the adsorption reaction reached equilibrium. The adsorption capacity of adsorbent for Pb^{2+} was about 51.9mg/g and the removal efficiency was about 86.5%. The unit adsorption capacity for Cd^{2+} was about 20.5mg/g. About 82.1%. Regardless of Pb^{2+} or Cd^{2+} , the removal efficiency curve and the adsorption amount curve are basically consistent. After that, the adsorption rate of the adsorbent gradually decreases, and finally approaches zero, and the adsorption and removal rate of heavy metal ions basically do not change. When the reaction was carried out to 90min, the removal rate of the heavy metal ions in the solution caused by the sorbent significantly fluctuates, which may be due to improper experiment operation or instrument measurement error.

At the beginning of adsorption, the adsorption capacity and removal efficiency of adsorbent for Pb^{2+} and Cd^{2+} are very high, and the adsorption rate has reached about 80% after 10 min of adsorption. With the progress of the adsorption process, the removal rate of heavy metals decreased significantly, and the adsorption equilibrium was achieved about 20 min after the start of adsorption. Excluding the problems caused by improper experiment operation and instrument measurement error, after the adsorption reached equilibrium, the unit adsorption amount and removal rate of the adsorbent changed little with time, indicating that the adsorbent was in saturation at this time.

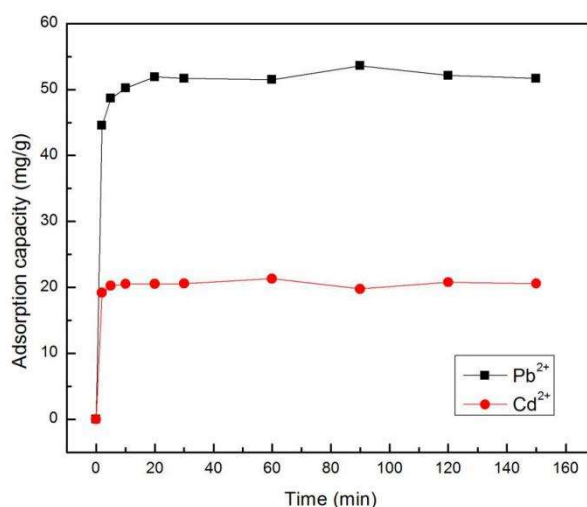


Figure 7. Adsorption amount vs. reaction time

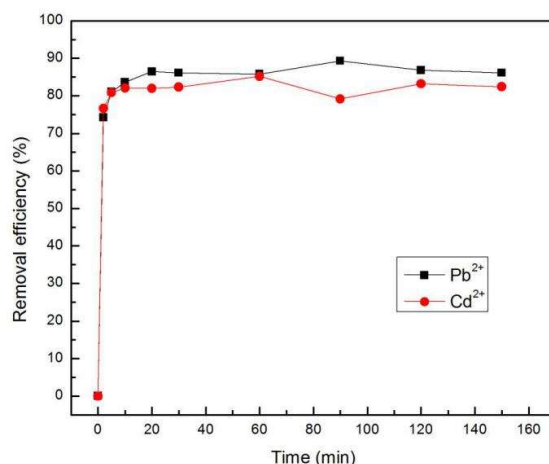


Figure 8. Diagram of removal efficiency vs. reaction time

Different contact time experiments show that the adsorption kinetics of magnetic nano-adsorbents is similar to Pb^{2+} and Cd^{2+} , and the adsorption reaction speed is very fast. The equilibrium can be achieved after about 20 minutes after the start of the reaction. Different kinetic models were used to simulate the adsorption process. It was found that the pseudo-second-order kinetic model can simulate the actual adsorption process. And from the pseudo-second-order kinetic model fitting curves, it can be seen that when the adsorption equilibrium is reached, the adsorption capacity of adsorbent for Pb^{2+} is 52.16 mg/g and that for Cd^{2+} is 20.58 mg/g. This is close to the experimental results, and it also shows that the pseudo-second-order reaction kinetics model can well fit the process.

5.4. Adsorption isotherms

In this study, adsorption experiments were carried out with adsorbents at different initial concentrations of heavy metal ions to determine relevant parameters and to perform adsorption isotherms. The adsorption isotherm diagram of the magnetic nanoparticles adsorbed on two heavy metal ions is shown in Figure 9.

From Figure 9, we can see that the adsorption of Pb^{2+} and Cd^{2+} by the magnetic nano-adsorbent first increases with the increase of the heavy metal ion concentration after the adsorption experiment starts, and the adsorbent increases when the concentration increases to 100mg/L and 40mg/L, respectively. The unit adsorption increase gradually decreases and there is no longer a tendency to increase, and thus it can be considered that the adsorption process has reached the equilibrium trend.

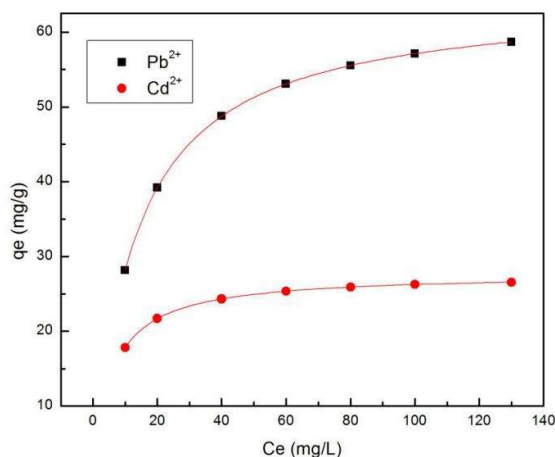


Figure 9. Adsorption isotherms for two heavy metal ions

Adsorption of heavy metal ions by the adsorbent is mainly accomplished by the active groups on the surface of the adsorbent. Therefore, when the concentration of the solution is low, the content of heavy metal ions is insufficient to react with all active groups, and there is an excess of adsorption sites on the surface of the adsorbent, so when the concentration of heavy metal ions continues to increase, the amount of adsorption gradually increases. When the concentration of heavy metal ions continues to rise and eventually reach saturation, all active groups present on the surface undergo complex reaction with heavy metal ions. At this time, there are no extra adsorption sites, and the adsorption capacity reaches saturation and no longer changes. This is the reason why the adsorption isotherm rises quickly after the adsorption isotherm starts, then tends to be flattened and finally remains unchanged.

5.5. Stability

The iron leaching rate of magnetic nano-sorbents measured after shaking in a solution with different pH for 24 h was lower because the two-layer silica and carboxymethyl- β -cyclodextrin coated on the surface of ferric oxide. Silica has good chemical stability and does not react with acid and alkali solutions. When coated on the surface of ferric oxide, it reduces the contact area between the inner iron core and the external solution and avoids the corrosion of the inner iron core, and thus reduce the leaching rate. In addition, by successfully grafting carboxymethyl- β -cyclodextrin, the adsorbent's resistance to alkaline solutions is greatly enhanced and alkali resistance is also improved.

6. Conclusion

In this study, magnetic nanomaterial Fe_3O_4 was used as a carrier, and a novel magnetic nanoparticle adsorbent $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{SiO}_2$ -carboxymethyl-beta-cyclodextrin was prepared by a variety of synthetic methods. The characterization was tested by different methods, and the adsorption was analyzed. The enrichment effect of heavy metal on the heavy metal and its corresponding mechanism provide a reliable and reliable basis for the rapid and effective treatment of heavy metal pollution. The conclusions are as follows:

(1) The magnetic nanomaterial Fe_3O_4 was prepared by the traditional co-precipitation method. The Stober method and the templating agent method were used successfully to coat the double-layer SiO_2 on the surface. Finally, the carboxymethyl- β -ring was grafted on the surface of the composite nanocomposite microspheres. Dextrin (CM- β -CD) successfully synthesized magnetic nano-adsorbent $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{SiO}_2$ -CM- β -CD. By Fourier-infrared spectroscopy analysis and X-ray diffraction analysis of the synthesized material, it was found that the surface of magnetic nanomaterial Fe_3O_4 was successfully coated with two layers of silica, and the successful grafting of carboxymethyl- β -cyclodextrin was realized. It was demonstrated that the magnetic nano-sorbent was successfully prepared, and the synthesized magnetic nano-sorbent had the same crystal shape as the magnetic nanomaterial Fe_3O_4 .

(2) The optimal pH for the adsorption of Pb^{2+} and Cd^{2+} by magnetic nano-adsorbent is 5.5. In the pH range of 2-5.5, the adsorption capacity of adsorbent to Pb^{2+} and Cd^{2+} increased with the increase of pH; when pH=5.5, the adsorption capacity of the magnetic nano-sorbent and the removal rate of heavy metal ions reached the maximum value. The adsorption capacity of magnetic nano-adsorbent was 52.1 mg/g for Pb^{2+} , 86.8% for Pb^{2+} , 20.9 mg/g for Cd^{2+} , and 83.6% for Cd^{2+} . By detecting the iron leaching rate of the magnetic nano-adsorbent under different pH conditions, it was found that the adsorbent has better acid and alkalinity, and can keep low iron leaching rate in solutions with different pH, and its alkali resistance is excellent. In acid resistance.

(3) Low concentrations of inorganic salt ions have a strong inhibitory effect on the adsorbent. Different ionic strength experiments show that under low concentration conditions, inorganic salt ions interact electrostatically with the opposite charge on the surface of the adsorbent, causing adsorption. The adsorption capacity of the agent is reduced.

(4) The adsorption speed of the magnetic nano-adsorbent is very fast, and the equilibrium can be achieved when the adsorption is about 20 minutes. The pseudo-second-order kinetic model can fit the adsorption process well, and the equilibrium adsorption of Pb^{2+} by the adsorbent is 52.16 mg/g from the

pseudo-second-order kinetic model fitting curve. The equilibrium adsorption amount of Cd^{2+} is 20.58 mg/g.

(5) The adsorption processes of two heavy metal ions were simulated by different models. It was found that the Langmuir model can better simulate the adsorption process, indicating that the process belongs to monolayer adsorption, and the adsorption of the adsorbent pairs is known from the Langmuir adsorption model. The maximum adsorption of Pb^{2+} is 67.75 mg/g, and the maximum adsorption of Cd^{2+} is 27.56 mg/g. The freundlich adsorption model fitting curve shows that the $1/n$ of the two heavy metal ions adsorbent is less than 1, indicating that the adsorption process is easier to occur.

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