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Adsorption of Pb (II) and Cu (II) by Attapulgite/(La+Fe)

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Abstract: *With the rapid development of Chinese industry, the discharge of heavy metal-containing wastewater is increasing. Heavy metal-containing wastewater is complex, polluting and difficult to degrade, posing a serious threat to human health. Attapulgite is a kind of silicate mineral rich in Magnesium and Aluminum. It has the nanochannel structure, a very large specific surface area and a certain ion exchange property, therefore, attapulgite has good adsorption capacity. In this paper, attapulgite was modified by acid, La(NO3)2 and FeCl3 6H2O loading and thermal to adsorb simulated heavy metal-containing wastewater. The effects of different attapulgite usage, solution concentration, pH and adsorption time on the adsorption of heavy metals were studied. The results show that 0.4g is the optimum usage of attapulgite; the adsorption is decreases with the increase of the concentration of standard solution; with the increase of pH, the adsorption is increases and then decreases, 4 is the optimum pH for adsorbing Cu(II), 5 is the optimum pH foradsorbing Pb(II); the adsorption also decreases with the increase of concentration, and finally it tends to balance; with the adsorption time increases, the adsorption is increases and then tends to remain unchanged. At the same time, attapulgite and modified attapulgite were characterized by scanning electron microscopy and X-ray diffraction. In addition, the best adsorption model was found to be Freundlich by isothermal adsorption experiments. Through the kinetic experiments, the adsorption kinetics of the attapulgite is described as the most consistent with the quasi-secondary kinetics, so as to understand the adsorption mechanism of the attapulgite.*

Keywords: *Attapulgite Clay, Modification, Adsorption, Cu(II), Pb(II)*

1. Introduction

Since the 21st century, population growth and economic activities caused heavy metal pollutants emitted. Then the pollutants entered the water through atmospheric dust and surface runoff, resulting in increasingly serious pollution of heavy metals. Inside, Pb(II) is the only trace element that is not needed in the human body. The Pb(II) enters the brain tissue through the blood, damages the cerebral cortex and cerebellum, interferes with metabolic activities, causing swelling of the small capillary endothelial cells, and causes diffuse brain damage. Excessive Cu(II) absorption in the body will cause adverse reactions such as diarrhea and vomiting, and even cause organ failure in severe cases. Attapulgite is one kind of abundant mineral resources in China, is the development of low cost in water treatment, significant environmental effects of adsorbent material. Attapulgite has the porous chain-layered crystal structure. Therefore, the attapulgite has a large specific surface area and good adsorption performance. In this paper, the attapulgite was modified by acid, La $(NO_3)_2$ and $FeCl_3$ $6H_2O$ loading and thermal. Based on this, a series of single factor experiments were carried out to obtain the best adsorption conditions. At the same time, the attapulgite was cha- racterized by X-ray and SEM. Two isothermal adsorption models and three adsorption kinetic models were also established to explore the adsorption mechanism. I hope that my research will help improve the adsorption efficiency and the applicability of modified attapulgite.

2. Experiment

2.1 Experimental Instruments

SHZ-B type water bath thermostat oscillator (Changzhou Renhe Instrument Factory); OTL1200

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type tube furnace (Nanjing Nanda InstrumentFactory); UV-1100 type UV-visible spectrophotometer (Shanghai Meipuda Instrument Co. , Ltd.).

2.2 Experimental Drugs

Hydrochloric acid(AR); ammonia(AR); Leadnitrate(AR); Sodium diethyldithio carbamate(AR); Copper nitrate(AR); Lanthanum nitrate(AR); Ferric chloride hexahydrate(AR); Hydroxylamine hydro-chloride(AR); Ammonium citrate (AR); Ethylenediamine(AR); Dithizone(AR); Trichlorome -thane(AR).

2.3 Characterization

Three types of attapulgite were characterized by X-ray and SEM. They are original attapulgite, acid modification attapulgite and 400 ℃ thermal modification attapulgite.

2.4 Standard Curve

Pipette 0.2 mL, 0.5 mL, 1.0 mL, 2.0 mL, 4.0 mL Cu(II) standard solution into five 50 mL volumetric flask, and add 2.0 mL 1% HNO_3 solution and 6.0 mL chromogenic agent solution to each volumetric flask, then add water to dilute to scale line. Blank group solution add 2.0 mL HNO_3 solution and 6.0 mL chromogenic agent solution and then add water to dilute to scale line. Standing for 15 min. The absorbance was measured at 460 nm with a glass cuvette and draw the standard curve.

Pipette 0.5 mL, 1.0 mL, 2.0 mL, 4.0 mL, 5.0 mL Pb(II) standard solution into five 50 mL volumetric flask, then add water to dilute to scale line. The concentration is 0.1 ug/mL, 0.2 ug/mL, 0.4 ug/mL, 0.8 ug/mL, 1.0 ug/mL. Add 5.0 mL of 0.1 ug/mL, 0.2 ug/mL, 0.4 ug/mL, 0.8 ug/mL, 1.0 ug/mL Pb(II) solution to five 125 mL separatory funnel, add 15.0 mL 1% HNO_3, 2.0 mL 10% ammonium citrate, 1.0 mL 20% hydroxylamine hydrochloride, adjust the pH to 8.5, and add 5.0 mL 10% ethylenediamine, 5.0 mL of dithizone-trichloromethane solution, vigorously shake for 1 min, and standing for 15 min. Use chloroform as a blank group. The absorbance was measured at 517 nm with a glass cuvette and draw the standard curve.

2.5 Repetitive Experiment

Add 25 ug/mL Cu(II) standard solution 50 mL and 0.1 g modified attapulgite to 4 conical flasks, take the sample at 30 min, 50 min, 70 min, 90 min. The experiment was done twice.

2.6 Effect of Usage of Modified Attapulgite

Add 50 mL of 25 ug/mL Cu(II) standard solution to 5 conical flasks and add 0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g of modified attapulgite, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis. Add 50 mL of 10 ug/mL Pb(II) standard solution to 5 conical flasks and add 0.1 g, 0.2 g, 0.3 g, 0.4 g, 0.5 g of modified attapulgite, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis.

2.7 Effect of Solution pH

PH is an important factor affects the adsorption of Cu(II) and Pb(II) by modified attapulgite. In alkaline environment, Cu^{2+} form $Cu(OH)_2$, and Pb^{2+} form $Pb(OH)_2$. Therefore, alkaline solutions are not considered in this paper. Under acidic conditions, Cu^{2+} and Pb^{2+} are hydrolyzed to produce $Cu(OH)_2$ and $Pb(OH)_2$ precipitates. The K_{SP} of Cu^{2+} is $K_{SP}[Cu(OH)_2]=2.2\times10^{-20}$. The maximum concentration of Cu(II) used in the experiment is 70 ug/mL, so the pH should be less than 4.67; The K_{SP} of Pb^{2+} is $K_{SP}[Pb(OH)_2]=1.42\times10^{-20}$. The maximum Pb(II) used in the experiment is 45 ug/mL, so the pH should be less than 5.62.

The 70 ug/mL Cu(II) solution was adjusted to pH 1.00, 2.00, 3.00, 4.00. Add 50 mL of the above pH solution into 4 conical flasks, add 0.4 of modified attapulgite, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis. The 45 ug/mL Pb(II) solution was adjusted to pH 1.00, 2.00, 3.00, 4.00, 5.00. Add 50 mL of the above pH solution into 5 conical flasks, add 0.4 of modified attapulgite, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis.

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2.8 Effect of Solution Concentration

Add 50 mL Cu(II) solution of 20 ug/mL, 30 ug/mL, 40 ug/mL, 50 ug/mL, 60 ug/mL, 70 ug/mL, add 0.4 of modified attapulgite in 6 conical flasks, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis. Add 50 mL of Pb(II) solution of 5 ug/mL, 15 ug/mL, 25 ug/mL, 35 ug/mL, 45 ug/mL, add 0.4 of modified attapulgite in 5 conical flasks, put them in the water bath thermostat oscillator at 30 ℃. After shaking for 90 min in the oscillator, sampe and analysis.

2.9 Effect of Adsorption Time

Add 50 mL of 25 ug/mL Cu(II) standard solution and 0.2 g of modified attapulgite into 9 conical flasks and put them in the water bath thermostat oscillator at 30 ℃. After shaking for 5 min, 10 min, 20 min, 30 min, 50 min, 70 min, 90 min, 120 min, 150 min, sampe and analysis. Add 50 mL of 10 ug/mL Pb(II) standard solution and 0.2 g of modified attapulgite into 9 conical flasks and put them in the water bath thermostat oscillator at 30 ℃. After shaking for 5 min, 10 min, 20 min, 30 min, 50 min, 70 min, 90 min, 120 min, 150 min, sampe and analysis.

2.10 Isothermal Adsorption Curve

(1) Langmuir Isotherm Adsorption

The model, also known as the monolayer adsorption model, is based on the ideal surface and the ideal adsorption layer. The Langmuir's linear derivation ex- pression is:

$$C_e / q_e = C_e / q_m + 1 / Kq_m \tag{1}$$

Of this, C_e is the equilibrium concentration of the solution, mg / L; q_e is the maximum adsorption capacity, mg/g; K is the Langmuir constant.

The Langmuir model is based on the assumption of single-layer adsorption. The assumptions of this model cannot be strictly established and can only explain the adsorption of monolayers. However, the Langmuir model has a good description of the adsorption mechanism in the process of pushing, and it has a foundation in the establishment of other models, so it is still a very important adsorption isotherm model.

(2) Freundlich Isotherm Adsorption

It is a widely used empirical formula that mainly describes the adsorption equilibrium of heterogeneous adsorption surfaces, and its nonlinear equation is expressed as:

$$q_e = K_F C_e^{1/n} \tag{2}$$

Of this, K_F is the adsorption coefficient, K_F is relevant to adsorbate properties, temperature and nature of the adsorbent, the usage of attapulgite; and n is Freundlich constants, is relevant to properties of adsorption system, typically $n > 1$.

In order to judge the accuracy of the model and determine the K_F and n values, usually (Formula 2-2) is taken as a logarithm, then its logarithmic expression is:

$$\lg q_e = \lg K_F + 1 / n \lg C_e \tag{3}$$

Freundlich in the case of uneven surface, and is not limited to monolayer adsorption. It is an ideal empirical isotherm adsorption equation. The surface condition is not limited to monolayer adsorption, which is an ideal empirical isotherm adsorption equation. Taking $\lg C_e$ as the abscissa and $\lg q_e$ as the ordinate to perform straight line fitting, determine the expression, and obtain the values of each parameter.

2.11 Adsorption Kinetic Curve

(1) Quasi-first-order Adsorption Rate Equa- tion

This model is the most commonly used kinetic model in the liquid phase adsorption kinetics model and can be expressed as:

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$$dq_t / dt = k_1(q_e - q_t) \tag{4}$$

q_t and q_e is the adsorption amount at time t and adsorption equilibrium, k_1 is the quasi-first-order adsorption rate constant.

Let t=0 be q_t=0, then

$$\ln(q_e - q_t) = \ln q_e - k_1 t \tag{5}$$

Taking $\ln(q_e-q_t)$ as the ordinate and t as the abscissa, the constant k_1 is obtained from the slope of the fitted line.

(2) Quasi-secondary Adsorption Rate Equa- tion

The quasi-secondary adsorption dynamics expression is:

$$dq_t / dt = k_2(q_e - q_t)^2 \tag{6}$$

After the integral of:

$$t / q_t = 1/(k_2 q_t^2) + t / q_e \tag{7}$$

k_2 is the quasi-secondary adsorption rate constant.

No variables are known before the quasi-secondary dynamics model is fitted, and the model can better reveal the adsorption process. Taking t/q_t as the ordinate and t as the abscissa, the constant k_2 is obtained from the slope of the fitted line.

(3) Intragranular Diffusion Model Equation

Based on the intraparticle diffusion model proposed by Weber and Morris theory, the equation can be expressed as:

$$q = K_d t^{1/2} + C \tag{8}$$

K_d is the intraparticle diffusion coefficient, q is the adsorption amount on the surface of the adsorbent at time t.

Taking q as the ordinate and $t^{1/2}$ as the abscissa, the constant K_d is obtained from the slope of the straight line obtained by fitting.

2.12 Calculation of Adsorption Amount and Rate

$$q_e = \frac{V(C_0 - C_e)}{m} \tag{9}$$

q_e is the amount of adsorption of the sample, mg/g; C_0 is Cu (II)/Pb(II) concentration of the solution before adsorption, ug/mL; C_e iS Cu(II)/Pb(II) concentration of the solution after adsorption, ug/mL; V is the volume of the solution, mL; m is the quality of the adsorbent, g.

$$\eta\% = \frac{C_0 - C_e}{C_0} \times 100\% \tag{10}$$

η is the removal rate, %; C_0 is Cu(II) or Pb(II) concentration of the solution before adsorption, ug/mL; C_e is the concentration of Cu(II) or Pb(II) in the solution after adsorption, ug/mL.

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3. Results and Discussion

3.1 Standard Curve

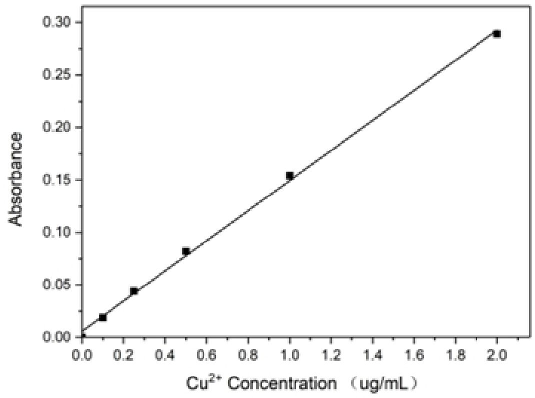

Figure. 1 Cu(II) standard curve

Standard curve equation:c=(A-0.00607)*10/0.14326, R^2=0.99909.

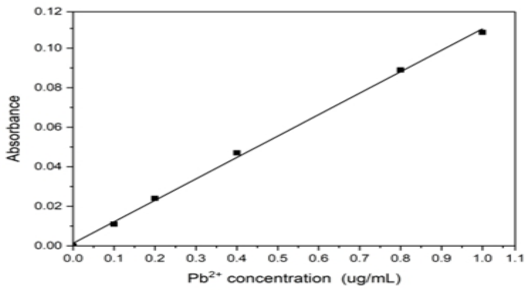

Figure. 2 Pb(II) standard curve

Standard curve equation:c=(A-0.00132)*10/0.10843, R^2=0.99825.

3.2 Repetitive Experiment

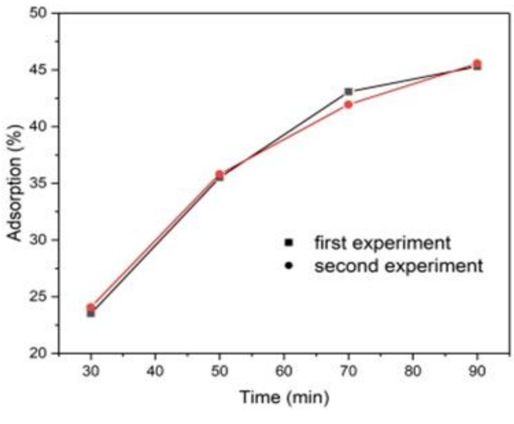

Figure. 3 Repeatability experiment

Repetitive experiments mean that the same experimental results can be obtained for different experiments, different experimental personnel, locations, and time under the same experimental conditions to confirm the con- clusions of the experiments and provide a reliable experimental basis for knowledge. Repeatability experiments require the same results in different laboratories and different operators. Although the location and personnel of the experiment are different, it should be under the same experimental conditions. The same conditions refer to the same standard instrument, the same experimental material, and the same experimental procedure, and the same or similar experimental results are obtained under the same experimental conditions. Repetitive experiments provide conditions for the reliability of scientific knowledge. It can be seen from Figure 3 that the experiment is reproducible.

3.3 Effect of Usage of Modified Attapulgite

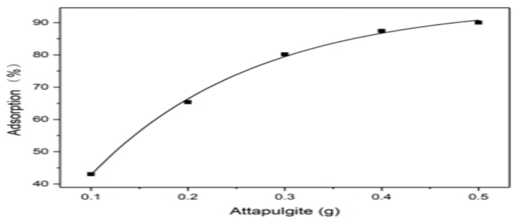

Figure. 4 Effect of attapulgite usage - Cu

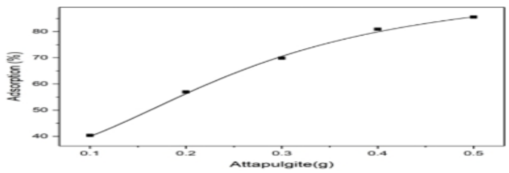

Figure. 5 Effect of attapulgite usage- Pb

It can be seen from Figure 4 and Figure 5 that as the usage of attapulgite increases, the adsorption rate increases, and the adsorption rate can reach 80% or more when the amount of attapulgite is increased to 0.4 g. However, the growth rate of the adsorption rate gradually decreases, and the growth rate has become relatively small at 0.4-0.5 g, and the upward trend is not obvious. The optimum amount of attapulgite for adsorbing copper and lead is 0.4 g.

This may be because when the amount of attapulgite is small, the amount of surface active sites of the adsorbent is less than that of Pb(II) or Cu(II), and the heavy metal ions cannot be completely adsorbed on the surface of the material; when the amount of attapulgite increases, the adsorption activity The number of sites also increased, and the adsorption rate also increased. When the dosage reached a certain value, the adsorption of heavy metal ions by attapulgite was basically balanced, and the increase of adsorbent did not bring about a significant increase in the adsorption rate. It will remain stable and the attapulgite will be sufficient for relatively heavy metal ions.

3.4 Effect of Solution pH

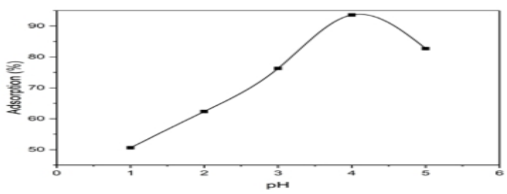

Figure. 6 Effect of Solution pH - Cu

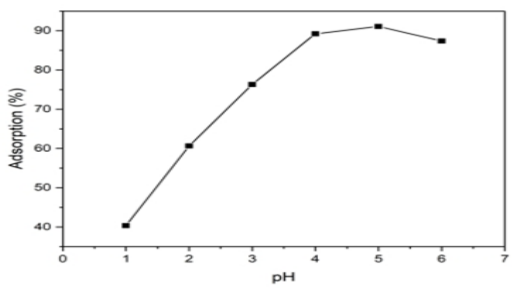

Figure. 7 Effect of Solution pH - Pb

Figure 6 and Figure 7 show the effect of solution pH on the adsorption of attapulgite. The removal rate of heavy metal ions is less than 65% in the low pH range, and the optimum pH for adsorbing Cu(II) is 4, The optimum pH for adsorbing Pb(II) is 5. This may be because when the pH of the solution is

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lower, the solution is more acidic, and there is a high concentration of H^+ in the system. These H^+ can compete with Cu^{2+} and Pb^{2+} in the solution, lead to the amount of adsorption is low. As the pH value of the solution increases, the free H^+ in the system gradually decreases, the negative impact of competitive adsorption on the adsorption of heavy metal ions on the attapulgite decreases, and the adsorption rate increases, but when the pH is reached 5 (adsorbed Cu(II)) and 6 (adsorbed Pb(II)), the adsorption decreases. The main reason is that heavy metal ions and OH^- form hydroxide precipitates, which have an effect on the adsorption effect.

3.5 Effect of Solution Concentration

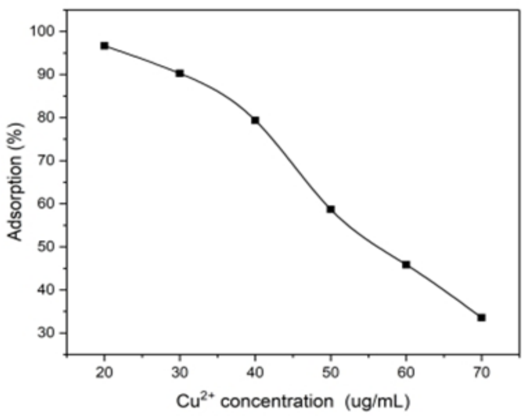

Figure. 8 Effect of Solution Concentration – Cu

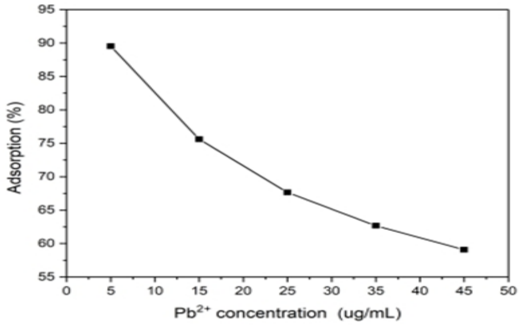

Figure. 9 Effect of solution concentration - Pb

Figure 8 and Figure 9 show the effect of solution concentration on adsorption. It can be seen from the figure that the adsorption decreases with the increase of initial concentration, and the optimum solubility when adsorbing Cu(II) is 20 ug/mL, the optimum solubility when adsorbing Pb(II) is 5 ug/mL.This may be because the theoretical maximum adsorption capacity of attapulgite is constant. When the available capacity is occupied, as the initial concentration increases, the adsorption active sites are competitive and the adsorption capacity is reduced.

3.6 Effect of Adsorption Time

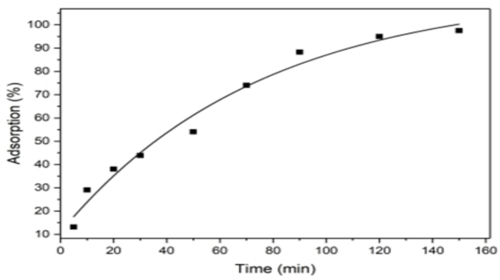

Figure. 10 Effect of adsorption time – Cu

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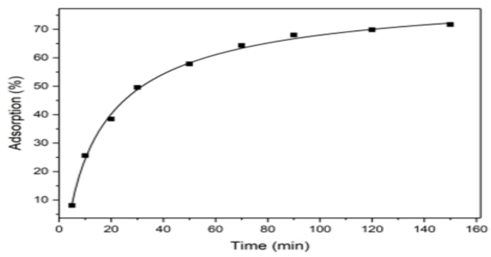

Figure. 11 Effect of adsorption time - Pb

Figure 10 and Figure 11 show the effect of adsorption time on the adsorption rate. As the adsorption time increases, the adsorption rate increases, but the rate of increase decreases continuously until the change in adsorption rate tends to balance. This may be because at the beginning of the adsorption of attapulgite, the concentration of heavy metals in the solution is large, the driving force of adsorption and mass transfer is also large, and the adsorption rate increases rapidly. However, as the reaction progressed, the concentration gradually decreased, and the adsorption of the adsorbate from the macropores to the micropores was slow, which slowed the growth rate, indicating that the adsorption process gradually reached equilibrium with the extension of the oscillation time. At about 90 min, the adsorption rate of attapulgite grows slowly. The optimal reaction time is 90 min.

3.7 Isothermal Adsorption Model

(1) Langmuir Isotherm Adsorption

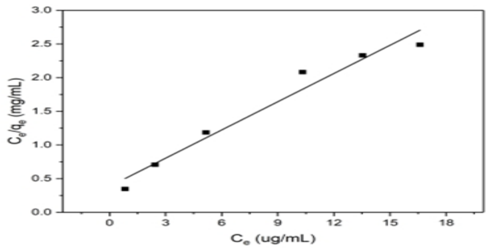

Figure. 12 Langmuir isotherm adsorption curve – Cu

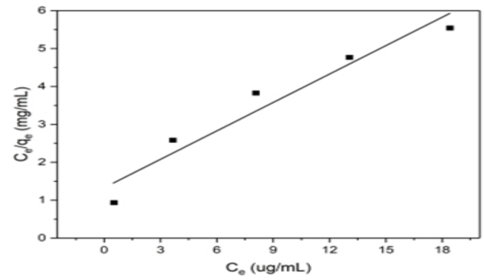

Figure. 13 Langmuir isotherm adsorption curve - Pb

The Langmuir isotherm adsorption curve fitting data is shown in Table 1.

Table 1 Langmuir isotherm adsorption curve fitting data

Langmuir	equation	q_m	R^2	K
Cu(II)	y=0.1397x+0.3847	7.1561	0.9643	6.7563
Pb(II)	y=0.2498x+1.3290	4.0027	0.9367	3.0119

K is the equilibrium constant of adsorption, and its value. It is related to the properties and temperature of adsorbents. The larger the K value, the stronger the adsorption capacity. From Table 1, it can be seen that the K value is 6.7563 and 3.0119. indicating that the attapulgite has strong adsorption capacity for Cu(II) and Pb(II).

(2) Freundlich Isotherm Adsorption

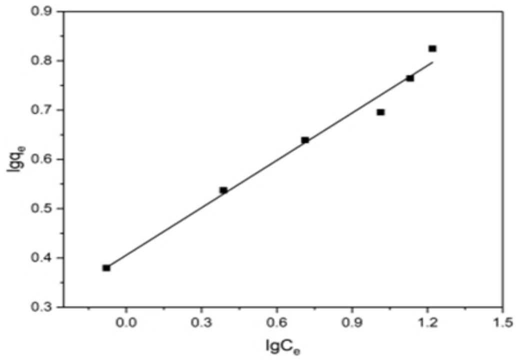

Figure. 14 Freundlich isotherm adsorption curve – Cu

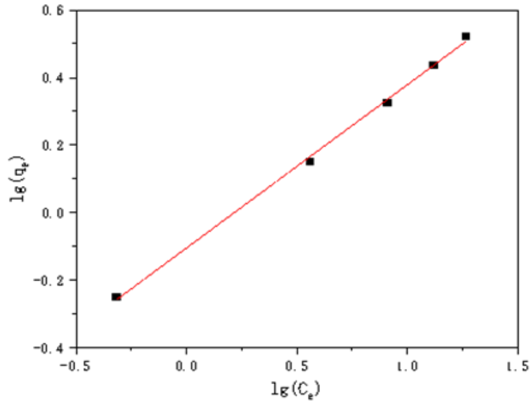

Figure. 15 Freundlich isotherm adsorption curve – Pb

The Freundlich isotherm adsorption curve fitting data is shown in Table 2.

Table 2 Freundlich isotherm adsorption curve fitting data

Freundlich	equation	1/n	R^2	K_F
Cu(II)	y=0.3203x+0.4058	0.3203	0.9840	2.5455
Pb(II)	y=0.4831x-0.1038	0.4831	0.9984	0.7874

It is generally believed that the value of 1/n is generally between 0 and 1, and the size of the value indicates the influence of the concentration on the amount of adsorption. The smaller the 1/n, the better the adsorption performance. When 1/n is 0.1 to 0.5, it is easy to adsorb; when 1/n>2, it is difficult to adsorb. In Table 3, 1/n=0.3203 and 0.4831 can be obtained, indicating that the attapulgite has strong adsorption capacity for Cu(II) and Pb(II). Comparing the fitting data of Langmuir and Freundlich isotherm model curves, the correlation co- efficient R^2 of Freundlich's fitting results to attapulgite is higher than that of Langmuir model, and the data points basically fall on the fitting curve, which can better reflect the adsorption behavior of attapulgite. It can be seen that the adsorption process of Cu(II) and Pb(II) by attapulgite is more in line with the Freundlich isotherm adsorption model. This is mainly because the Langmuir isotherm adsorption model is based on assumptions such as homogeneous monolayer adsorption. However, the attapulgite is a porous layer chain structure. Therefore, the isothermal adsorption process of Cu(II) and Pb(II) by attapulgite does not fit the assumptions of the Langmuir adsorption isotherm model. The Freundlich isotherm adsorption model is often used to describe the multi-layer adsorption of hetero- geneous multi-adsorption sites consistent.

3.8 Adsorption Kinetics

(1) Quasi-first-order Adsorption Rate Equation

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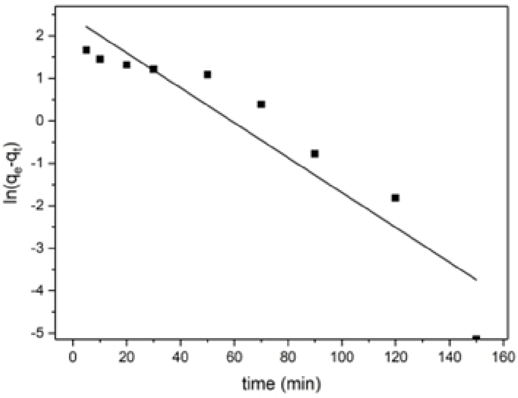

Figure. 16 Quasi-first adsorption rate curve – Cu

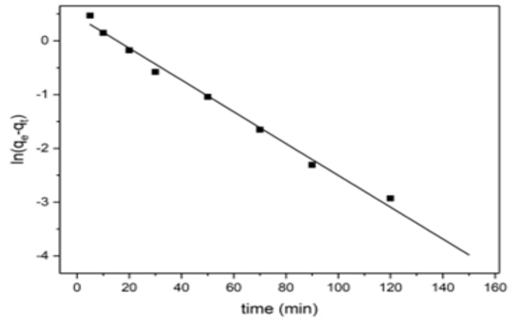

Figure. 17 Quasi-first adsorption rate curve - Pb

The fitting data of the quasi-first-order adsorption rate equation is shown in Table 3.

Table 3 Fitting data of quasi-first-order adsorption rate equation

Quasi-first	equation	q_e	R^2	k_1
Cu(II)	y=-0.04106x+2.4177	11.2201	0.8836	0.04106
Pb(II)	y=-0.02956x+0.4538	1.5742	0.9972	0.02956

(2) Quasi-secondary Adsorption Rate Equation

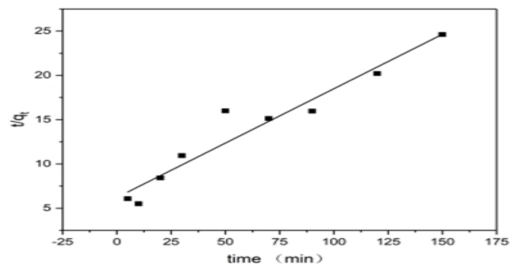

Figure. 18 Quasi-secondary adsorption rate curve - Cu

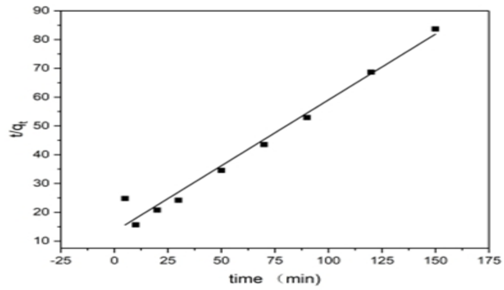

Figure. 19 Quasi-secondary adsorption rate curve – Pb

The fitting data of the quasi-secondary-order adsorption rate equation is shown in Table 4.

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Table 4 Fitting data of quasi- secondary -order adsorption rate equation

Quasi-secondary	equation	q_e	R^2	k_2
Cu(II)	y=0.1228x+6.2102	8.1446	0.9371	0.004327
Pb(II)	y=0.4571x+13.3027	2.1878	0.9785	0.02320

(3) Intragranular diffusion equation

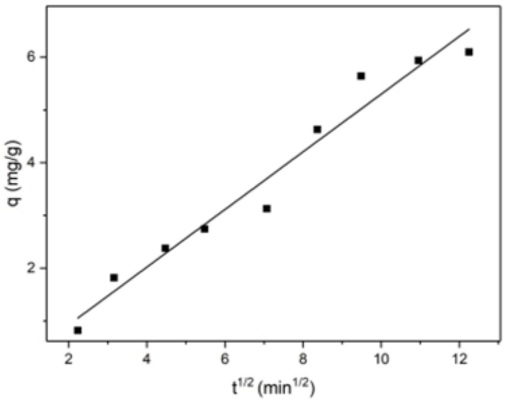

Figure. 20 Intragranular diffusion - Cu

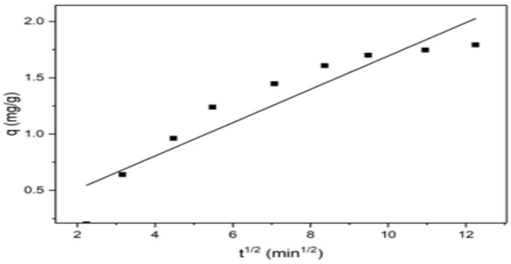

Figure. 21 Intragranular diffusion - Pb

The fitting data of the Intragranular diffusion equation is shown in Table 5.

Table 5 Intragranular diffusion equation fitting

Intragranular diffusion	equation	C	R^2	K_d
Cu(II)	y=0.5465x-0.1661	-0.1661	0.9636	0.5464
Pb(II)	y=0.1480x+0.2136	0.2136	0.8796	0.1480

It can be seen from the table that the quasi-first-order adsorption rate of Pb(II) has the best fitting effect. The quasi-secondary adsorption rate of Cu(II) has the best fitting effect. It can be seen from the intragranular diffusion model that the adsorption of Cu(II) and Pb(II) by attapulgite is mainly on the outer surface.

3.9 SEM Analysis

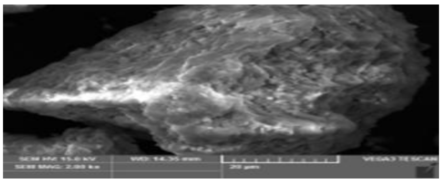

Figure. 22 Original attapulgite

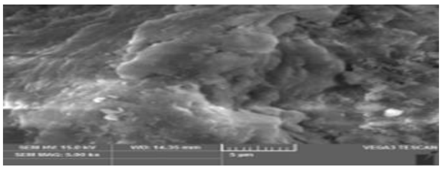

Figure. 23 Original attapulgite

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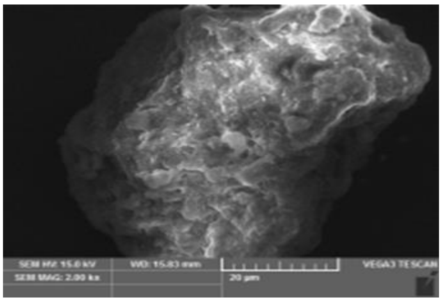

Figure. 24 Acid modification

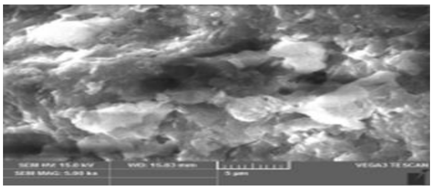

Figure. 25Acid modification

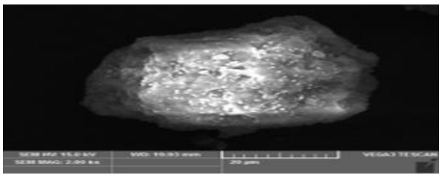

Figure. 26 Compound modification

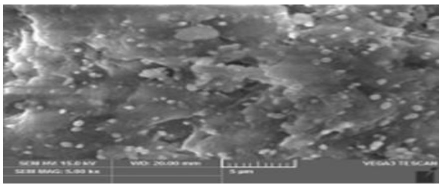

Figure. 27 Compound modification

Figure 22 is an SEM image of two thousand times of original attapulgite magnification, Figure 23 is an SEM image of five thousand times of original attapulgite magnification. Figure 24 is an SEM image of two thousand times magnification after acid modification, Figure 25 is an SEM image magnified of five thousand times after acid modification. Figure 26 is an SEM image of acid modification, metal salt loading, and thermal modification of two thousand times. Figure 27 shows acid modification and metal salt loading and thermal modification of two five housand times.

It can be seen from the figure that after acid modification, the surface of the attapulgite becomes smoother, many impurities disappear, and the number of holes increases. At the same time, it can be clearly seen that the metal salt is successfully loaded onto the surface of the attapulgite. After thermal modification at 400 °C, the number of pores of the attapulgite increases and the specific surface area increases. This is because after the attapulgite is fired at a high temperature in a tube furnace, different states water in the crystal structure can be removed, the internal structure becomes loose and porous, the specific surface area is increased, and the adsorption capacity is enhanced.

3.10 XRD Analysis

Figure 28 is an XRD pattern of attapulgite. Among them, A is the XRD pattern of the original attapulgite, B is the XRD pattern after the acid modification, C is the XRD pattern after the acid modification and the metal ion loading and then the thermal modification. The charac- teristic peak of attapulgite, iron and strontium is marked in the figure. As can be seen from the analysis, the attapulgite has a broad and gentle diffraction peak in the vicinity of $2\theta=8.544°$, $2\theta=19.846°$, $2\theta=28.126°$. The diffraction peak of ferric oxide appeared in the vicinity of $2\theta=33.125°$, and the characteristic peak of antimony trioxide appeared in the vicinity of $2\theta=29.96°$. It can be seen from the figure that acid modification, metal salt and thermal modification have little effect on the characteristic peaks of attapulgite.

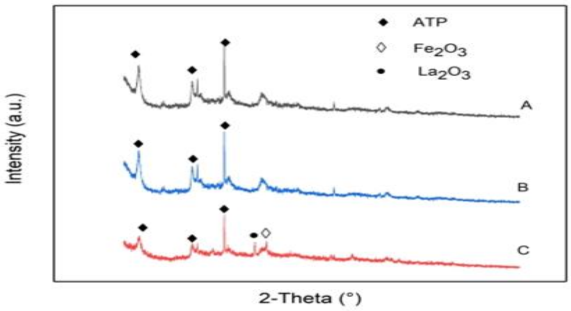

Figure. 28 XRD

4. Conclusion

By comparing the characterization of the attapulgite before and after modification, it is found that the number of modified attapulgite pores increases, the specific surface area increases, and the adsorption capacity can be enhanced. Through the single factor study of the usage of attapulgite, pH, solution concentration and adsorption time, it was found that the adsorption of Cu(II) and Pb(II) by attapulgite increased first and then tend to unchanged with the increase of the usage of attapulgite, 0.4g was optimum usage; when Cu(II) is adsorbed, in the range of pH 1-4, the adsorption increases with the increase of pH, the adsorption begins to decrease at 4-5, 4 is the optimum pH for adsorbing Cu(II); In the range of pH 1-5, the adsorption rate increases with the increase of pH, the adsorption begins to decrease at 5-6, and 5 is the optimum pH for adsorption of Pb(II); the adsorption also decreases with the increase of concentration. And the adsorption increases slowly after 90 min.The quasi-first-order adsorption rate of Pb(II) has the best fitting effect. The quasi-secondary adsorption rate of Cu(II) has the best fitting effect. It can be seen from the intragranular diffusion model that the adsorption of Cu(II) and Pb(II) by attapulgite is mainly on the outer surface.

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