Study on the adsorption of crystal violet on red mud modified by sodium dodecylbenzene sulfonate (SDBS)

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Abstract. In this paper, different modifiers were used to modify red mud and adsorb crystal violet. The results showed that the red mud modified by sodium dodecylbenzene sulfonate had a better adsorption effect on crystal violet. The effects of adsorption time, pH value, initial concentration of crystal violet and salt ion on the adsorption of crystal violet on modified red mud were studied, respectively. 120 min was selected as the adsorption shock time. The results showed that the basic condition was more favourable to crystal violet adsorption, and the addition of salt ions was not conducive to crystal violet adsorption.

1. Introduction

Red mud is the solid waste discharged in the production process of alumina. It is characterized by strong oxidation and trace radioactivity, belonging to strong alkaline solid waste[1]. The chemical composition of red mud varies greatly due to the grade of bauxite producing area and the production method of alumina[2]. China is a large alumina production country, alumina production is increasing because of the industrial development of our country[3]. The content of bauxite is decreasing year by year, and the output of red mud is on the rise. Because the high alkali content can’t guarantee the quality of building materials, it is necessary to reduce the proportion of red mud in materials to ensure the quality, so a large number of red mud can’t be effectively used[4]. As for the recycling of red mud, it has been concerned in recent years[5-6]. In the paper, SDBS modified red mud was used as an adsorbent for crystal violet adsorption.

2. Materials and methods

2.1. Adsorbent and adsorbate

Red mud modified by sodium dodecylbenzene sulfonate (SDBS): 2.5 g red mud and 150mL of 0.5% sodium dodecylbenzene sulfonate were solution was mixed in a 250mL conical flask and vibrated on an air bath oscillator at 25 °C for 24h. Then the adsorbent was washed with water to neutral and dried in a drying oven at 105 °C for 24 hours.

Red mud modified by cetyltrimethylammonium bromide (CTAB): the modified method was the same as that of the SDBS modified red mud above.

Red mud modified by sulphuric acid: 2.5 g red mud and 150mL of 1mol/L sulphuric acid solution was mixed in a 250mL conical flask and vibrated on an air bath oscillator at 25 °C for 24h. Then the adsorbent was washed with water to neutral and dried in a drying oven at 105 °C for 24 hours.
Red mud modified by iron salt: 10g/L red mud of 500mL was added with 0.5mol/L FeCl₃ solution slowly to pH 5. The solution was precipitated and aged for 24h. The centrifuged sediment was dried in a drying oven at 105 °C for 24h.

Crystal violet (CV) was purchased from Tianjin Zhiyuan chemical reagent Co., Ltd.. The crystal violet solid powder of 0.5000g was accurately weighed, and dissolved in the distilled water into a volumetric flask of 500mL. The diluted crystal violet solutions were diluted with distilled water by the stock solution.

2.2. Experiments of adsorption

50mg/L crystal violet solution of 50mL was mixed with a certain amount of SDBS modified red mud in a 250ml conical flask. The effect of adsorption time, pH value, crystal violet concentration and salt on crystal violet adsorption by SDBS modified red mud has been studied, respectively.

The following equations (1) and (2) were used to calculate E% (the percentage of crystal violet adsorption) and qₑ (the amount of crystal violet adsorbed at equilibrium, mg/g), respectively.

\[
E(\%) = \frac{(C_0 - C_e)}{C_0} \times 100\% \quad (1)
\]

\[
q_e = \frac{(C_0 - C_e) \times V}{M} \quad (2)
\]

Where C₀ and Cₑ (mg/L) were the initial and equilibrium concentration of crystal violet solution; M (g) were the mass of SDBS modified red mud; V (L) was the volume of the solution.

3. Results and Discussion

3.1. Effect of modified reagent on crystal violet adsorption

Table 1 Adsorption of crystal violet by modified red mud of different modified reagent

| Modified reagent | SDBS | SDBS | CTAB | H₂SO₄ | H₂SO₄ | FeCl₃ | Unmodified | Unmodified |
|------------------|------|------|------|-------|-------|-------|------------|------------|
| Adsorbent dosage(g/L) | 6    | 4    | 6    | 6     | 4     | 6     | 6          | 4          |
| E(%)             | 97.3 | 81.9 | 28.5 | 57.7  | 43.0  | 24.3  | 54.7       | 23.8       |

The adsorption of crystal violet by unmodified and modified red mud of different modified reagent such as SDBS, CTAB, H₂SO₄ and FeCl₃ was shown in Table 1. It could be seen that the crystal violet adsorption rate on red mud modified by SDBS was obviously raised. Adsorption effect of sulfuric acid modified red mud on crystal violet improved a little, and that of CTAB and FeCl₃ modified red mud became worse instead. Therefore SDBS modified red mud was used as an adsorbent in subsequent experiments.

3.2. Effect of adsorption time

The adsorption effect of SDBS modified red mud on crystal violet adsorption was shown in Figure 1. 5g/L of adsorbent was mixed with 50mg/L and 80mg/L of crystal violet solution, respectively. It could be seen that the adsorption rate was generally getting better with time increasing. At the primary stage of adsorption (before 60 min), the adsorption rate of crystal violet on SDBS modified red mud increased rapidly. After 60 min, however, the adsorption rate changed slightly with time. In this experiment, the oscillation time of crystal violet adsorption by SDBS modified red mud was 120 min.
3.3. **Effect of pH**

The effect of pH on crystal violet adsorption is shown in Figure 2. SDBS modified red mud of 3g/L was mixed with 50mg/L of crystal violet solution of different pH, respectively. The pH value has a certain influence on the adsorption of crystal violet by SDBS modified red mud. The adsorption effect was better at pH value of 1, however, it decreased rapidly at pH value of 2. Alkaline conditions were conducive to the crystal violet adsorption. The adsorption effect of crystal violet solution was also good without adding acid or base solution, so the pH value of the crystal violet solution was unregulated.

3.4. **Effect of initial crystal violet concentration on its adsorption at different temperature**

The SDBS modified red mud (3g/L) was mixed with crystal violet (initial concentration range of 40~140mg/L) at several temperatures. With the increase of initial concentration of crystal violet, the adsorption rate of SDBS modified red mud on crystal violet gradually decreased and the adsorption amount $q_e$ gradually increased. In the temperature range of 298K-313K, the influence of temperature was not significant when the initial concentration of crystal violet was low. When the concentration of crystal violet was high, the influence of temperature on $q_e$ and adsorption rate was more obvious. Lower temperature was benefit for the crystal violet adsorption.
3.5. Effect of salt ion concentration

The SDBS modified red mud (4g/L) mixed with 50mg/L of crystal violet adding NaCl and CaCl$_2$ to change ions strength. It could be seen in Figure 4 that NaCl had a little effect on crystal violet adsorption, however, CaCl$_2$ significantly inhibited the adsorption effect of crystal violet. Compared with adding NaCl, the addition of CaCl$_2$ at the same concentration made the adsorption rate and $q_e$ of crystal violet lower on SDBS modified red mud. So the addition of salt ion of Na$^+$ and Ca$^{2+}$ was not conducive to the crystal violet adsorption.

4. Conclusion

SDBS, CTAB, $\text{H}_2\text{SO}_4$ and FeCl$_3$ were used to modify the red mud in the paper, respectively, and the adsorption effect of modified red mud and original red mud on crystal violet was compared. The results showed that the adsorption effect of crystal violet by SDBS modified red mud was much better than others. The adsorption time of crystal violet adsorption by SDBS modified red mud was determined to be 120 min by the time experiment. The pH experiment of adsorption of crystal violet on modified red mud showed that the adsorption effect was the worst when pH was 2, and the alkaline
condition was more favourable for crystal violet adsorption. With the increase of the initial concentration of crystal violet, the adsorption rate of crystal violet by SDBS modified red mud decreased gradually, and the adsorption amount increased gradually. Low temperature was more favourable for crystal violet adsorption. The addition of salt ions was not conducive to crystal violet adsorption, and the inhibition of CaCl₂ was more obvious.

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