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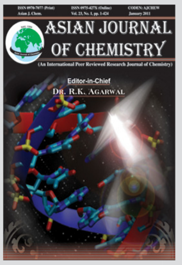

Adsorption Characteristics of Activated Red Mud for Lead Removal

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Red mud is the waste of alumina industry and has high Fe_2O_3 and SiO_2 content which are active components for the adsorption of heavy metal anion pollutants. In this study, the uptake of lead by red mud activated by heat treatment was investigated. The factors influencing the adsorption were also investigated. The result showed that the red mud sample treated using heat reatment at 700 ºC for 2 h achieved the highest lead removal. Lead removal by the activated red mud was significantly pH dependent. The adsorption fits Langmuir isotherm model well and the maximum adsorption capacities of the heat activated red mud was 38.2 mg/g.

Key Words: Activated red mud, Adsorbent, Lead removal by adsorption.

INTRODUCTION

Red mud is the main residue of the Bayer process in which alumina is extracted from its ore, the mineral bauxite. Alumina is obtained after bauxite digestion in caustic soda where aluminium oxides dissolve as sodium aluminates. About 50×10^9 kg of red mud are produced every year in China[1] and their high pH caustic level represents an important environmental problem in areas where this industry is implanted.

Lead is toxic to human life and is the common species in ground water and difficult to remove. For this reason it is necessary to eliminate lead from water. Studies using red mud as unconventional adsorbents for water and wastewater treatment purposes are motivated by the fact that red mud is a fine-grained mixture of oxides and hydroxides, capable of removing several contaminants, as well as being widely available. Thus, several studies have reported that red mud or activated red mud can be utilized for adsorbing heavy metals and anionic pollutants from water, including phosphate[2], cadmium, copper[3], arsenic[4] and phenol[5]. In the present paper, the utilization of the activated red mud as an adsorbent for removal of lead from water was studied.

EXPERIMENTAL

The red mud was provided by Xinfa Group (Shandong China). The grain size of red mud was mostly (> 90 %) less than 10 μm and had the following average composition (by wt %): Al_2O_3: 18.0, Fe_2O_3: 26.1, SiO_2: 17.0, TiO_2: 4.9, Na_2O: 6.3, CaO: 3.5, H_2O: 24.2. All the other chemicals *viz*., HCl, NaOH and NaCl used in the experiment are of analytical grade.

Activation methods: The details of preparing activated red mud with heat treatment method are as follows. The initial red mud is filtered and washed with deionized water three times to remove the soluble compounds. The residue is then dried at 110 ºC overnight and calcined in air for 2 h at 700 ºC. Finally, the sample is again sieved through a 0.2 mm screen and stored in a vacuum desiccator until used for the batch sorption experiments.

Adsorption experiments: The adsorption experiments were carried out with batch method. Herein, all chemicals used for this study are analytical grade. All experiments were carried out at a constant ionic strength of 0.01 M maintained with NaCl. A known amount of red mud (2.0 g/L) and lead solution were taken in a 100 mL stoppered conical flask. Sodium chloride was added to maintain ionic strength and pH was adjusted to the desired level (pH = 7.0) with 0.1 M NaOH or 0.1 M HCl solutions. The final volume was adjusted to 50 mL with deionized water and agitated at constant speed (600 rpm) with magnetic stirrer at 25 ºC for 3 h and then centrifuged for 5 min at 3000 rpm. The supernatant solution was analyzed for residual concentration of lead using flame atomic absorption spectrometer (Australia GBC Corporation) method. The amount of lead adsorbed was calculated from the following eqn. 1.

$$q = (C_0 - C_e) \times \frac{V}{m} \qquad (1)$$

where q = lead adsorbed (mg/g); C_0 = initial concentration of lead (mg/L); C_e = concentration of lead in solution at equilibrium time (mg/L); V = solution volume (L); m = red mud dosage (g). The experimental parameters studied are contact pH (2-9), time (0.5-6 h), initial lead concentration (0-1000 mg/L) and temperature (20-80 ºC).

RESULTS AND DISCUSSION

Effect of pH: The effect of pH on the adsorption of lead by achieved red mud is presented in Fig. 1. It is evident that the amount of lead adsorbed increases with pH. The steady state is attained when pH exceeds 7.0.

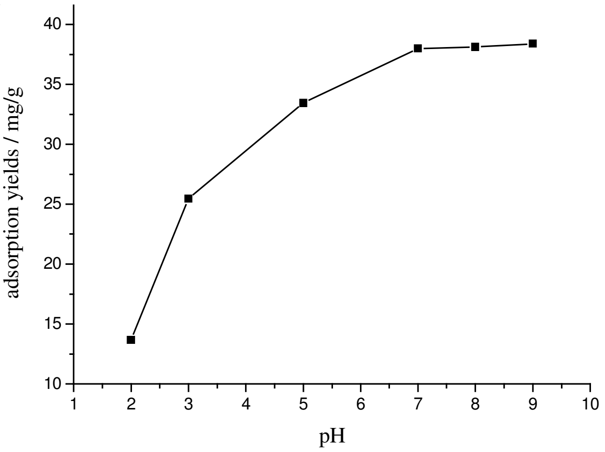

Fig. 1. Effect of initial pH on lead removal

Effect of the contact time: The concentration variation of lead with time is determined by taking subsamples at different time steps for 6 h and the amount of lead adsorbed over time is depicted in Fig. 2. Here, it can clearly be seen that the removal of lead starts shortly after the shaking is started and increases over time. The steady state is attained after roughly 3 h and the results indicate that there is no significant change in the equilibrium concentration after this time up to 6 h.

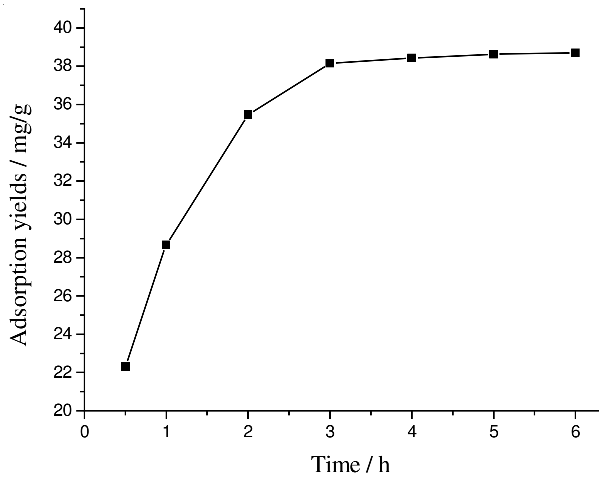

Fig. 2. Removal of lead as a function of equilibrium time

Effect of initial lead concentration: Solutions of different initial lead concentrations, ranging from 50-1000 mg/L, were used to investigate the effect of concentration on the removal of lead by activated red mud. Effect of initial lead concentration on lead adsorption was given in Fig. 3. The adsorption yields (mg/g) were increased by increasing of initial lead concentration.

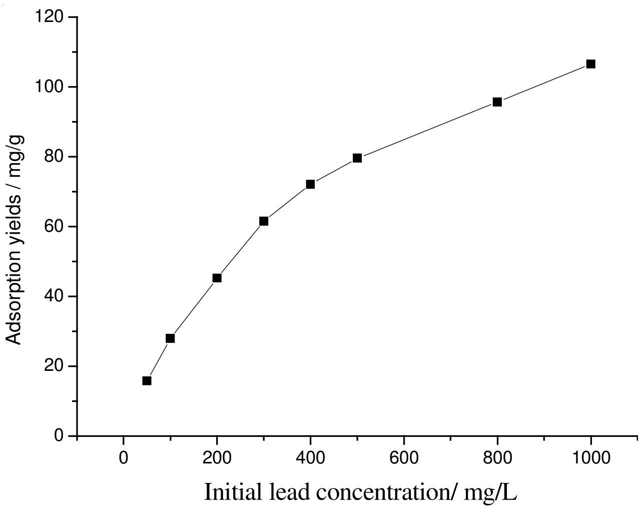

Fig. 3. Effect of initial lead concentration on the removal of lead

Effect of temperature: As shown in Fig. 4, the amount of lead adsorbed increases with contact temperature. The steady state is attained at 50 ºC and the results indicate that there is no significant change at this temperature up to 80 ºC. It is believed that the absorption reaction is endothermal chemisorption process, thus, raising temperature could fasten adsorptivity velocity and enhance adsorbability of red mud. The chemisorption rate of red mud for lead was slow. This is supported by the fact that the adsorption balance time is as long as 3 h. The adsorptive capacity won't drop with the rising of time, this illustrates the absorption reaction is hard for desorption.

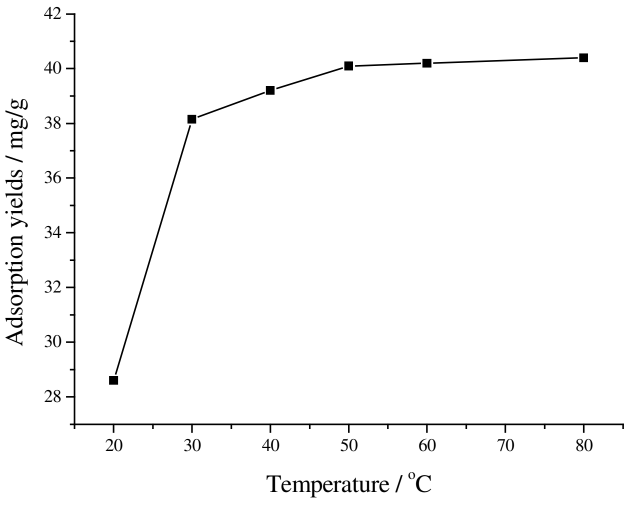

Fig. 4. Effect of temperature on the removal of lead

Adsorption isotherms: The relationship between the amount of lead adsorbed and the lead concentration remaining in solution is described by an isotherm. The most important model of monolayer adsorption came from the work of Langmuir. This isotherm is given as eqn. 2.

$$q_e = \frac{Q_0 b C_e}{(1 + bC_e)} \tag{2}$$

The constants Q_0 and b are characteristics of the Langmuir equation and can be determined from a linearized form of eqn. 3.

$$\frac{C_e}{q_e} = \frac{1}{(Q_0 b)} + \frac{C_0}{Q_0} \tag{3}$$

where C_e = concentration of lead (mg/L) at equilibrium, Q_0 = monolayer capacity of the adsorbent (mg/g) and b = Langmuir adsorption constant (L/mg).

The experiment shows that the adsorption behaviour of lead by the achieved red mud accords with Langmuir isotherm mode. The related correlation coefficients (R^2 values) are over 0.99. The Langmuir isotherm model assumes uniform energies of sorption on the surface with no transmigration of adsorbate on the adsorption surface. The Langmuir isotherm plot is shown in Fig. 5.

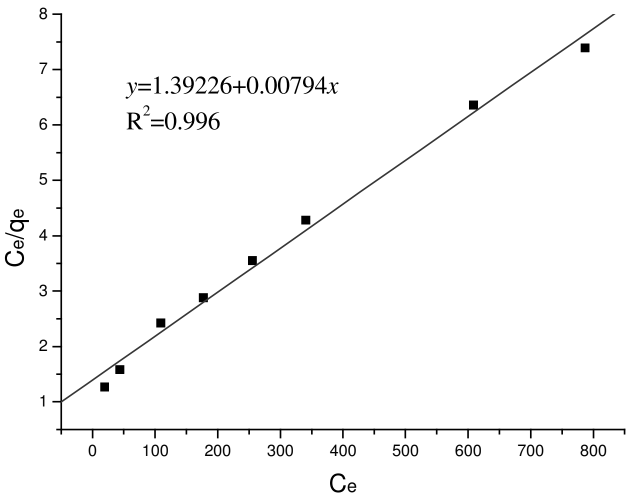

Fig. 5. Langmuir isotherm plot for lead adsorption achieved on red mud

Conclusion

This study investigates the possibility of increasing the lead adsorption capacity of red mud through heat treatment. It is found that the achieved red mud is an effective adsorbent for the removal of lead from aqueous solutions. Achieved red mud can be used as an adsorbent for lead removal in the pH best range of 7-9. The time for the adsorption balance is 3 h. The influence of temperature to the adsorption is obvious. The adsorption ratio will increase with the rising of temperature, indicating a chemi adsorption and the adsorption behaviour of lead by the achieved red mud accords with Langmuir isotherm mode.

ACKNOWLEDGEMENTS

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