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Adsorption of Mercury(II) by Beer Yeast Immobilized in Chitosan/Silicone Leg

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Highly toxic Hg(II) can harm human health seriously and there are many studies on adsorbents to adsorb Hg(II) in water phase. In this test, chitosan, silica gel and beer yeast were used to prepare a new adsorbent to adsorb a small quantity of Hg(II) from water and then the effects of solution pH, contact time, adsorbent dosage and temperature on the adsorption effect of Hg(II) were analyzed. The results showed that when adsorbent dosage was 0.4 g/L, contact time was 40 min and the initial concentration of Hg(II) was 5 mg/L, the removal rate of Hg(II) reached 99.34 %. However, temperature has no obvious effects on Hg(II) adsorption.

Key Words: Chitosan, Yeast biomass, Silicon gel, Mercury ions, Adsorption.

INTRODUCTION

Mercury is one of the most toxic heavy metals in global environment. Inorganic mercury can be transformed into methyl mercury by microorganisms in natural waters and the latter accumulating in living organisms largely can enter the human body through food chains to harm human health seriously[1], resulting in hydrargyrism. According to the national drinking water standard of China, the concentration of poisonous Hg^{2+} should be below 1 μg/L. At present, most wastewater containing mercury is treated by using chemical precipitation, membrane filtration, ion exchange, liquid extraction and electrodialysis[2-6]. However, most of them have disadvantages such as high cost, large inputs of chemicals, incomplete removal and poor applicability, so they have not been applied widely. Adsorption method[7-10] is one of the most popular methods in current research due to its high efficiency and low cost.

Presently, natural materials adsorbing Hg^{2+} in water phase include chitosan[11], minerals[12], microorganisms[13] and so forth, but their adsorption capacities are limited. Therefore, the natural materials have been modified to improve their adsorption properties in many studies, such as chitosan[14] and yeast[15,16]. Nevertheless, there are few studies on the synthesis of new adsorbents using diverse materials. In this paper, chitosan, silica gel and beer yeast were used to prepare an environment-friendly new adsorbent and then the adsorption characteristics of the adsorbent to Hg(II) in water were analyzed.

EXPERIMENTAL

Beer yeast was collected from discarded yeast of a beer plant in Pinggu District. Chitosan (molecular mass 3.0×10^6 Da, 85-95 % degree of deacetylation) and silica gel (100-200 mesh) were from Sinopharm Chemical Reagent Co., Ltd. Hg(II) reserving solution was composed of $HgCl_2$ and deionized water. In addition, chemicals also included acetic acid (A.R), NaOH (A.R), alcohol (A.R) and glutaraldehyde (AR) and water used in the test was deionized water.

Main apparatus were 78-1 magnetic stirring apparatus, HZQ-X100 incubator shaker, GZX-GFC*101-1-S electro-thermostatic blast oven, TGL-16 table-top & high-speed refrigerated centrifuge, electric balance, Delta320·s pH meter produced by Mettler Toledo Instrument (Shanghai) Co., Ltd. and AFS-930 atomic fluorescence spectrophotometer.

Preparation of beer yeast: After the discarded beer yeast immersing in 1 mol/L nitric acid was shaked for 24 h. It was washed by deionized water 5 times and centrifuged for 15 min in a centrifuge at a rotational speed of 1 400 rpm. Afterwards, it was dried at 50 ºC and ground to pass through a 50-mesh sieve.

Preparation of chitosan solution: 25 g of chitosan was dissolved in 1000 mL of 1 % (w/v) acetic acid solution and the mixture was stirred by a magnetic shaker at room temperature overnight.

Immobilization of beer yeast in chitosan/silicone leg matrix: Chitosan slurry (500 mL), yeast biomass (1 g) and silicon gel (50 g) were mixed and stirred for 4 h to get a

uniform mixture. The slurry put in a sterile syringe was dropped into 1000 mL of 1 M sodium hydroxide and ethanol solution to be solidified for 4 h, forming small balls with a diameter of 3 mm. Hereafter, they were washed by deionized water until pH = 7. These small balls were put in 100 mL of deionized water to which 1.2 mL of 25 % glutaraldehyde solution was added afterwards. After 2 h of reaction, these small beads were washed by sterile deionized water to remove excess glutaraldehyde and then they were preserved in normal saline in a refrigerator.

Preparation of Hg(II) solution: 0.1354 g of $HgCl_2$ was put dissolved in 1000 mL of deionized water to prepare 1000 mg/L Hg(II) solution and then it could be diluted to various concentrations of Hg(II) solutions according to experimental demands. Meanwhile, pH of the solutions was adjusted using 0.1 N HCl or NaOH.

Biosorption experiments: 100 mL of Hg(II) solution with a mass concentration of 5 mg/L was poured into each conical flask with a volume of 250 mL and a certain amount of prepared adsorbent was added to the flasks. Afterwards, these flasks were shaked at a rotational speed of 180 rpm in the thermostatic blast oven. The simulated wastewater containing Hg(II) was treated under different pH, adsorbent amounts, contact times and temperatures. Hg(II) concentration in supernatant was measured by using atomic fluorescence spectrometry to calculate its adsorption rate according to the follow-up formula:

$$\eta = (C_0 - C)/C_0 \times 100\ \%$$

where η is adsorption rate (%); C_0 is the initial concentration of Hg(II) (mg/L); C is the equilibrium concentration of Hg(II) (mg/L).

RESULTS AND DISCUSSION

Effects of contact time on Hg(II) adsorption: When temperature was 25 ºC, pH = 5, Hg(II) concentration was 5 mg/L and adsorbent amount was 0.4 g/L, the effects of contact time on Hg(II) adsorption were studied. As shown in Fig. 1, Hg(II) was adsorbed by the adsorbent very fast within 40 min and and the adsorption rate of Hg(II) increased to 99.42 % at the 40th min. However, the increase in the adsorption rate was increasingly small with the contact time, showing that Hg(II) adsorption reached balance gradually. After 40 min, the adsorption rate of Hg(II) reduced slightly and tended to a certain value. The results above indicated that Hg(II) was adsorbed by the adsorbent rapidly and desorption occurred with the time, so that the removal rate of Hg(II) decreased.

Effects of solution pH on Hg(II) adsorption: As temperature was 25 ºC, Hg(II) concentration was 5 mg/L, adsorbent amount was 0.4 g/L and contact time was 40 min, the influences of solution pH on Hg(II) adsorption were analyzed. According to Fig. 2, when pH < 4, large quantities of hydronium in the solutions may compete with Hg(II) for adsorption sites on adsorbent surface, so that the adsorption rate of Hg(II) was low. As solution pH exceeded isoelectric point, negative charges on adsorbent surface increased gradually, so that the adsorption rate of Hg(II) reached the maximum value when pH = 5 and decreased to 94.78 % while pH = 7. As pH increased to 8, the adsorption rate raised to 96.22 %, but now $Hg(OH)_2$ was deposited in the solutions, so the increase in the adsorption rate of Hg(II) was related to $Hg(OH)_2$.

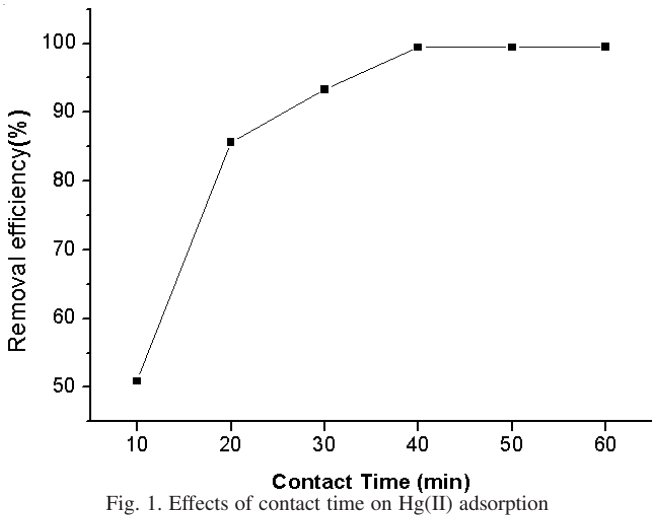

Fig. 1. Effects of contact time on Hg(II) adsorption

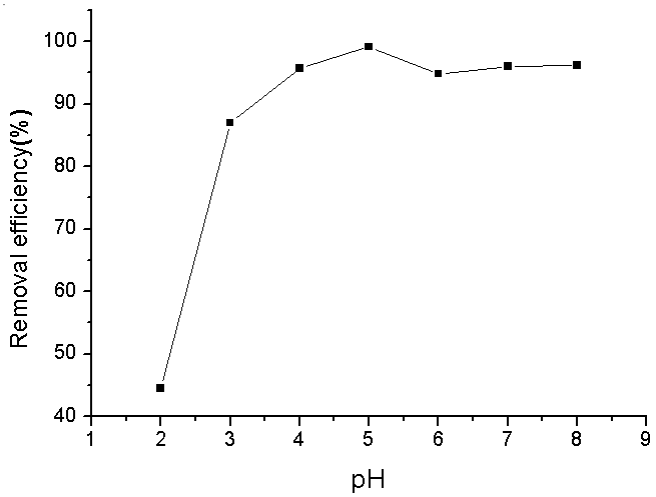

Fig. 2. Effects of solution pH on Hg(II) adsorption

Influences of adsorbent dosage on Hg(II) adsorption: At 25 ºC, pH = 4, Hg(II) concentration was 5 mg/L and contact time was 40 min, the impacts of contact time on Hg(II) adsorption were studied. Fig. 3 showed that the removal rate of Hg(II) increased with the increase of adsorbent dosage. As adsorbent dosage increased from 0.2 to 0.3 g/L, the removal rate of Hg(II) increase fast and it was up to the maximum when adsorbent dosage increased to 0.4 g/L.

Effects of temperature on Hg(II) adsorption: As contact time was 40 min, pH = 5 and Hg(II) concentration was 5 mg/L, the influences of temperature on Hg(II) adsorption were discussed. As shown in Fig. 4, there were no obvious changes in the removal rate of Hg(II) when temperature varied from 20 to 45 ºC, showing that temperature had no significant effects on the adsorption rate of Hg(II).

Conclusion

Microspheres of beer yeast immobilized in chitosan/silicone leg were obtained. Analysis indicated the microspheres can absorb Hg(II) in water solution. Under this condition, adsorbent dosage was 0.4 g/L, contact time was 40 min and the initial concentration of Hg(II)was 5 mg/L, the removal rate of Hg(II) reached 99.34 %. However, temperature has no obvious effects on Hg(II) adsorption.

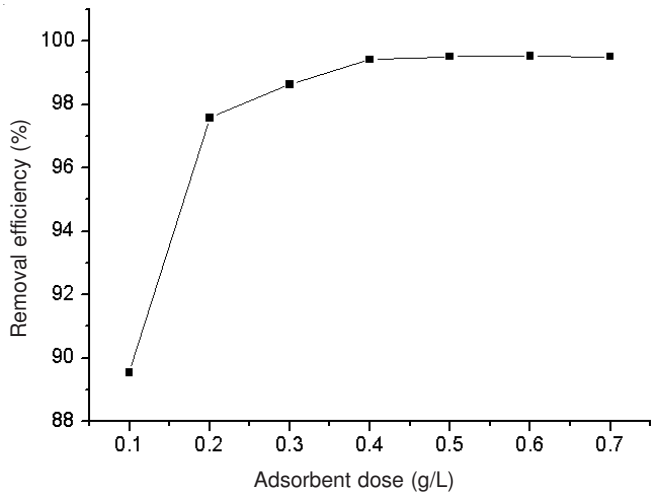

Fig. 3. Influences of adsorbent dosage on Hg(II) adsorption

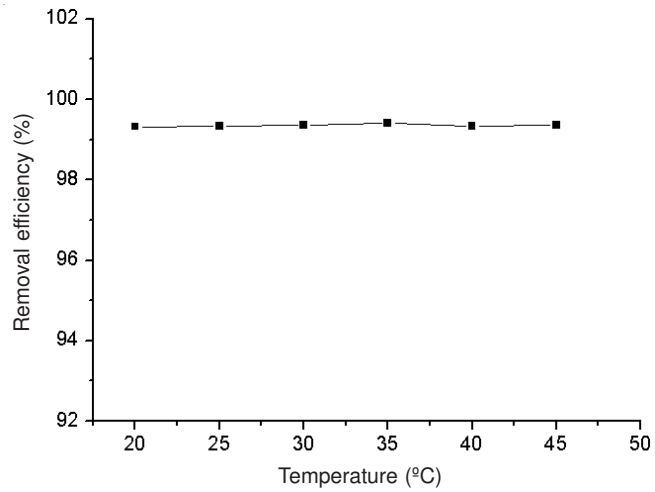

Fig. 4. Effects of temperature on Hg(II) adsorption

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