Study on the Biosorption Performance of *Penicillium chrysogenum* for the Removal of Arsenic (III)

Xiong-ying HUANG¹, Meng TANG² and Gen-lin ZHANG³,*

¹Institute of International Rivers and Eco-Security, Yunnan University, Kunming, Yunnan Province, China.
²School of Architecture and Urban Planning, Yunnan University, Kunming, Yunnan Province, China.
³School of Materials Science and Engineering, Yunnan University, Kunming, Yunnan Province, China.

*Corresponding author

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Abstract. To explore the adsorption characteristics of arsenic (III) by *Penicillium chrysogenum*, the effects of initial pH value, adsorption time, and fungus cell dosage on the adsorption of As³⁺ by *Penicillium chrysogenum* were studied, and the kinetic models were used to explore the mechanism of the adsorption of arsenic(III) by *Penicillium chrysogenum*. The results showed that the adsorption rate reached the maximum when the pH value was 6. The time for adsorption reached equilibrium was 90 min, and the most suitable amount of fungus was 2 g/L. The kinetic experimental data is in good agreement with the pseudo-second-order kinetics model. The adsorption of arsenic by *Penicillium chrysogenum* includes chemical adsorption.

Introduction

Arsenic is widely found in nature and is a trace element contained in almost all geological bodies. Natural activities such as volcanic eruptions and mineral weathering and human activities such as mineral development, smelting, use of arsenic-containing pesticides, and glass manufacturing are important sources of arsenic contamination[1]. Arsenic is the earliest recognized carcinogen in the world. The accumulation of arsenic in crops and arsenic contamination in water are the main causes of arsenic poisoning and carcinogenesis[2,3]. According to the survey, the arsenic concentration in drinking water is positively correlated with the incidence of lung cancer and bladder cancer[4,5].

Microbioremediation technology has the advantages of low cost, high efficiency, no secondary pollution, and has great potential in the restoration of natural water bodies. A large number of scholars have studied the use of microorganisms to repair Cr, Cu, Zn, Pb and other heavy metal pollution, and also found many microorganisms that are highly resistant to heavy metals and removal capacity[6,7].

The arsenic concentration, in Datun Lake, Yunnan province of China, is 0.96 mg/L[8]. In the previous experiments, we screened *Penicillium chrysogenum* from the sediment in Datun Lake and found that it has ability to remove arsenic. The influencing factors and adsorption mechanism of the adsorption of arsenic (III) by this strain were investigated.

Materials and Methods

The adsorption experiments were carried out in a thermostatic shaker at 30°C and 180r/min. The initial concentration of arsenic (III) was 1 mg/L; parallel and contrast were set for each experiment. After the adsorption was completed, the arsenic concentration of the solution was measured with an atomic fluorescence spectrophotometer after 3 times filtration. The removal ratio of As³⁺ is calculated using the equation:

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

\( C_0 \) indicates the arsenic concentration in the blank comparison, and \( C \) indicates the arsenic concentration after the adsorption.
Results Analysis and Discussion

Effect of Initial pH on the Adsorption of Arsenic (III) by Penicillium chrysogenum

The pH of solution was adjusted to 2, 3, 4, 5, 6, 7 and 8 (50ml, 90min, 2g/l) for adsorption experiments. The experimental results are shown in Figure 1.

![Figure 1. Effect of pH on As$^{3+}$ Adsorption by Penicillium chrysogenum.](image)

It can be seen from the figure that the pH value has a great influence on the As$^{3+}$ absorption by Penicillium chrysogenum. The results showed the maximum adsorption rate is reached at pH 5. The effect of adsorption was closely related to the composition of cell wall of the strain. When pH value is low, H+ and H3O+ compete with As$^{3+}$ in the solution to compete for the active sites on the cell surface, and make the cell wall protonated and increase the electrostatic repulsion force on the cell surface, resulting in low adsorption rate of As$^{3+}$. With the increase of pH value, OH- in the solution gradually increases, and OH- competes with the arsenate anions, thereby reducing the amount of arsenic adsorbed. From the figure, it can be seen that the optimum pH value for the adsorption of As$^{3+}$ by Penicillium chrysogenum is 5 or so.

Effect of Adsorption time on the Adsorption of As$^{3+}$ by Penicillium Chrysogenum

The adsorption experiments of As$^{3+}$ by Penicillium chrysogenum (50 ml, pH 6, 2 g/l) with adsorption time of 10 min, 30 min, 60 min, 90 min, 120 min, and 150 min is shown in Figure 2.

![Figure 2. Effect of time on the adsorption of As$^{3+}$ by Penicillium chrysogenum.](image)

In the first 60min, the removal rate increased rapidly. At this time, what happens is the reversible and rapid adsorption of heavy metal ions by adsorption sites and functional groups on the surface of the fungus. The adsorption rate reached the maximum value of 30.18% at 90min. When the time exceeded 90 min, the adsorption rate began to decrease, probably due to the toxic effect of heavy metals, resulting in the release of some arsenic from cells.

Effect of the Amount of Fungus on the Adsorption of As$^{3+}$ by Penicillium chrysogenum

The adsorption experiments were carried out in the arsenic (III) solution (50ml, pH 6, 90min) of
0.5g/L, 1g/L, 2g/L, 3g/L and 4g/L. The adsorption of As$^{3+}$ by *Penicillium chrysogenum* is shown in Figure 3.

Figure 3. Effect of the cell dosage on the adsorption of As$^{3+}$ by *Penicillium chrysogenum*.

The results show that the adsorption rate increased at first and then decreased with the increase of cell mass. When the added cell mass concentration reached 2 g/L, the fungus cell adsorption rate reached a maximum of 32.35%. With the increase of the amount of mycelia, the number of adsorbed active sites increases and the adsorption rate increases. When the amount of fungus cells is too much, the mycelia will aggregate with each other and the effective adsorption sites for exposure will decrease, and the adsorption rate of As$^{3+}$ will naturally decrease.

**Adsorption Kinetics Analysis on the Adsorption of As$^{3+}$ by *Penicillium chrysogenum***

The funguses (2g/L) were put into 50 ml and pH 6 arsenic (III) solution. Measuring the concentration of As$^{3+}$ after adsorbing for 10 min, 20 min, 30 min, 40 min, 50 min, 60 min, 90 min, 120 min, and 180 min. Quasi-first-order kinetic equations are as follows$^{[9]}$:

$$\log(Q_e - Q_t) = \log Q_e - \frac{K_1 t}{2.303}$$

(2)

$Q_e$ is biosorption capacity at the adsorption equilibrium, mg/g (dry weight). $Q_t$ is biosorption capacity at any time, mg/g (dry weight). $K_1$ is the relevant rate constant for first-order adsorption, l/min.

Quasi-second-order kinetic equation:

$$\frac{t}{Q_t} = \frac{1}{Q_e} + \frac{1}{k_2 Q_e}$$

(3)

$Q_e$ indicates the biosorption capacity when the adsorption equilibrium is reached, mg/g (dry weight). $Q_t$ represents biosorption capacity at any time, mg/g (dry weight). $K_2$ is the relevant rate constant for secondary adsorption, mg/g/min.

We can see from Figure 5 that the correlation coefficient R2 obtained from the quasi-first-order kinetics model is 0.9248. It is shown that the quasi first order kinetic model can well describe the adsorption behavior of *Penicillium yellicum* on As$^{3+}$. The adsorption rate constant $K_1$ was calculated to be 0.04 l/min. As can be seen from Figure 6, the correlation coefficient R2 obtained from the pseudo-bistatic model is 0.9902, and the adsorption rate constant $K_2$ is calculated to be 0.02 mg/g/min. The pseudo-second-order kinetic equation can also simulate the adsorption of As$^{3+}$ by *Penicillium chrysogenum*. However, by the comprehensive comparison of R2 value, and the theoretical maximum removal rate and the maximum removal rate that obtained from the experiment, the pseudo-second-order kinetic model can better simulate the adsorption process of As$^{3+}$ by *Penicillium chrysogenum*.
Conclusion

(1) pH has a great influence on the adsorption of arsenic(III) by *Penicillium chrysogenum*. The suitable pH of the strain is 4-6. When the pH is 5, the adsorption effect is the best. Adsorption of arsenic (III) by *P. chrysogenum* reached equilibrium after 90 min, and the adsorption rate was 30.18%. The optimal amount of fungus was 2 g/L.

(2) The removal rate of arsenic is 34.3% under optimal experimental conditions.

(3) The pseudo-secondary reaction kinetics model can better simulate the process of As$^{3+}$ adsorption by *Penicillium chrysogenum* strains. The adsorption of arsenic(III) by *Penicillium chrysogenum* includes diffusion-adsorption and chemical adsorption, and chemical adsorption is the main rate-limiting step.

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References


