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Equilibrium, kinetic and thermodynamic studies on aluminum biosorption by a mycelial biomass (*Streptomyces rimosus*)

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abstract

This work focused on kinetic, equilibrium and thermodynamic studies on aluminum biosorption by *Streptomyces rimosus* biomass. Infrared spectroscopy analysis shows that *S. rimosus* present some groups: hydroxyl, methyl, carboxyl, amine, thiol and phosphate. The maximum biosorption capacity of *S. rimosus* biomass was found to be 11.76 mg g^{-1} for the following optimum conditions: particle size,]250–560] μm, pH 4–4.25, biomass content of 25 g L^{-1}, agitation of 250 rpm and temperature of 25 °C. Langmuir, Freundlich and Dubinin–Radushkevich (D–R) models were applied to describe the biosorption isotherms at free pH (pH_i 4) and fixed pH (pH_f 4). Langmuir model is the most adequate. With fixed pH, the maximum biosorption capacity is enhanced from 6.62 mg g^{-1} to 11.76 mg g^{-1}. The thermodynamic parameters ($\Delta G°$, $\Delta H°$ and $\Delta S°$) showed the feasibility, endothermic and spontaneous nature of the biosorption at 10–80 °C. The activation energy (Ea) was determined as 52.18 kJ mol^{-1} using the Arrhenius equation and the rate constant of pseudo-second-order model (the most adequate kinetic model). The mean free energy was calculated as 12.91 kJ mol^{-1} using the D–R isotherm model. The mechanism of Al(III) biosorption on *S. rimosus* could be a chemical ion exchange and carboxyl groups are mainly involved in this mechanism.

1. Introduction

Aluminum is widely used in many industries; it is therefore massively rejected in the environment. It is used in the transformation industry (manufacturing of light alloy for aeronautic, automobile, domestic utensils, boats, packing, . . .) [1,2]. Aluminum is also used in the chemical industry as a catalyst, pigment, agent of skin tanning and tissue mordanting. It is involved in the composition of abrasives, ink, cement and explosives [1,3]. It is also used in the pharmaceutical industry, in anti diarrheic and antacid preparations [3].

Aluminum is a very reactive element. Its bonds are strong and difficult to displace [4]. It can accumulate in the cell leading to the formation of voluminous deposits incompatible with the good working process and the cellular life [5]. Therefore, aluminum is involved in the apparition of Alzheimer's disease among aged subjects exposed to a concentration greater than 110 μg L^{-1} in drinking water and also the cause of two severe neuro-degenerative diseases: amyotrophic lateral sclerosis and Parkinson [6,7].

In soft water, aluminum has a toxic action after a week of contact with a concentration of 0.1 mg L^{-1}. At higher dose of 88 mg L^{-1} of $AlCl_3$, it may cause death to some fish within a long action time. At 132 mg L^{-1} of $AlCl_3$, most of fish perish in a few hours. In plants, the toxic action of aluminum on germs of squash, corn, beans, rice and wheat was noticed in acid soils provoking a decrease of phosphoric acid absorption. In barley and millet, bad effects (as an intoxication of the roots) appear at a concentration of 1 mg L^{-1}. In aquatic plants, the presence of 0.005–0.01% of aluminum salt provokes a weakening and some assimilation troubles. Corn cultivated in an aqueous medium with increasing doses of aluminum from 10^{-10} mg L^{-1} to 100 mg L^{-1} was affected both in its growth and fruitfulness. The utmost of toxicity for *Scenedesmus* algae is about 1.5 mg L^{-1} and 136 mg L^{-1} for *Daphnia magna* [8].

The biosorption is currently considered as an alternative process for metallic pollutant elimination. It is simple, efficient and economic. In the case of aluminum, different types of adsorbents were used: starch, clay, activated charcoal, wood charcoal [9], date-pit and BDH activated carbon [10], plants [11], algae [12,13], mushrooms [14,15] and bacteria [16]. The present study proposes a new biosorbent for the treatment of waters charged with aluminum: *Streptomyces rimosus*, mycelial bacteria, Gram+, belonging to actinomycetes. This biomass constitutes a solid waste of

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