Bioresource Technology 114 (2012) 20–25

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Biosorption of aquatic cadmium(II) by unmodified rice straw

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ARTICLE INFO

Article history:
Received 13 September 2011
Received in revised form 17 January 2012
Accepted 19 January 2012
Available online 16 February 2012

Keywords:
Rice straw
Cadmium biosorption
Pseudo-second order kinetic model
Isothermal model
Biosorption mechanism

ABSTRACT

Cadmium is the most common toxic metal threatening safe rice supply. Rice straw has the potential to remove Cd from large-scale effluent contaminated by heavy metals since it exhibited a short biosorption equilibrium time of 5 min, high biosorption capacity (13.9 mg g^{-1}) and high removal efficiency at a pH range of 2.0–6.0. The main Cd biosorption mechanism was Cd^{2+} ion exchange with K^+, Na^+, Mg^{2+} and Ca^{2+}, together with chelation with functional groups such as C═C, C—O, O—H and carboxylic acids. When 0.5% (w/v) rice straw was exposed to 50 mg mL^{-1} $CdSO_4$ solution with shaking at 150 r min^{-1} for 3 h, about 80% of the aquatic Cd was absorbed and the Cd content in rice straw reached 8–10 mg g^{-1}, suggesting that the metal-enriched rice straw could become high quality bio-ore by virtue of the industrial mining grade of its metal content and easy metal recovery.

1. Introduction

As clean freshwater is increasingly more difficult to obtain in parts of the world, recycling of wastewater is seen as a means to increase water supply. However, some wastewater contains high concentrations of metals, which will pose a risk to all forms of life along food chain. For example, consumption of the rice irrigated with river water containing cadmium (Cd) led to the well known Itaï–Itaï disease in Japan in 1955 (Rocha et al., 2009). Cd is listed as one of the top toxic metals, since it causes carcinogenic and renal disturbances, lung insufficiency, bone lesions, cancer, anemia, hypertension, Itaï–Itaï disease and weight loss (Qi and Aldrich, 2008; Rocha et al., 2009; Farooq et al., 2010).

Cd is also one of the most common metal pollutants in wastewater discharged from industrial activities such as electroplating, smelting, alloy, pigment, and plastic manufacturing, mining, metallurgy, and refining (Farooq et al., 2010). Many methods have been developed to treat wastewater polluted by heavy metals, including chemical precipitation, ion exchange, electrolysis, coagulation and membrane separation (Kim et al., 2005), but these methods have disadvantages such as secondary pollution, high cost, high energy input, large quantities of chemical reagents or poor treatment efficiency at low metal concentration (Ahluwalia and Goyal, 2007; Gao et al., 2008). A promising alternative is biosorption since it has high efficiency and low cost, wide adaptability and selectivity in removing different kinds of heavy metals, and stable performance in purifying wastewater of low metal concentrations (1–100 mg L^{-1}) (Sud et al., 2008). Although various types of biomass, such as fungi, bacteria, yeast and algae, have been investigated under laboratory conditions, natural agricultural byproducts have the most potential as natural sorbents for heavy metal detoxification of large-scale effluent, due to their low cost, abundance, reliability and availability. Many kinds of plant materials have been adopted to sorb Cd^{2+}, such as wheat straw (Dang et al., 2009), tobacco powder (Qi and Aldrich, 2008), *Pinus sylvestris* sawdust (Taty-Costodes et al., 2003), rice husk (Kumar and Bandyopadhyay, 2006), beans and almond shell (Mehrasbi et al., 2009).

Rice straw contains large amounts of cellulose, hemi-cellulose, lignin and silica. Those compounds provide binding sites for metals (Gao et al., 2008). Therefore, rice straw should be a good candidate for the scale-up treatment of wastewater containing Cd pollutant (Hameed and El-Khaiary, 2008; Bishay, 2010). In the present study, the biosorption of Cd^{2+} by unmodified rice straw was systematically studied, using a combination of mathematical modeling, ion exchange experiments and infrared (IR) spectroscopy.

2. Methods

2.1. Materials

Rice straw was collected from Xiangyang City, Hubei Province, China, washed with distilled water, crushed with grinder (FW 100, Tianjin Theis brand), sieved with a standard sieve to obtain powder with a particle diameter of less than 0.5 mm. The powder was dried in an electrically heated blast dry box (DL-101-1,

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doi:10.1016/j.biortech.2012.01.110