Ecological Engineering 91 (2016) 317–332

Contents lists available at ScienceDirect

Ecological Engineering

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

Potential of using green adsorbent of heavy metal removal from aqueous solutions: Adsorption kinetics, isotherm, thermodynamic, mechanism and economic analysis

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ARTICLE INFO

Article history:
Received 30 June 2015
Received in revised form 6 March 2016
Accepted 6 March 2016
Available online 12 March 2016

Keywords:
Waste water treatment
Heavy metal
Waste management
Low cost adsorbent
Adsorption isotherm,kinetic studies and thermodynamic parameters
Batch adsorption
Adsorption mechanisms

ABSTRACT

Peanut hull is a local natural abundant agricultural waste in Egypt. The peanut hull was used as an adsorbent without any chemical or physical treatment for copper ions Cu(II) removal from aqueous solutions. Effects of various parameters such as contact time, particle size and dosage of adsorbent, initial pH, solution temperature, and initial concentration of Cu(II) were investigated for a batch adsorption system.The optimum operating conditions were (1 h, 150 rpm shaking speed, 25 °C, pH = 4, 1 g peanut hulls of particle size < 250 μm/50 ml of 150 ppm cupper ions solution concentration). The maximum adsorption capacity was 14.13 mg/g peanut hulls. Several kinetic models have been investigated to recognize the cupper ions adsorption mechanism onto peanut hulls. The results showed that the adsorption process obeyed the pseudo-second-order and intra-particle diffusion kinetic models, pointing that the adsorption mechanism is chemical and physical adsorption process. Langmuir and Freundlich adsorption isotherms have been investigated. The thermodynamic parameters have been studied, and it proved that, adsorption of Cu(II) using peanut hulls is endothermic and nonspontaneous. This study convinced that the naturally peanut hulls proved to be an alternative, attractive, effective, economic, and environmentally friendly adsorbent for Cu(II) removal from aqueous solution.

1. Introduction

Of the total water on earth, only 0.0008% is available and renewable in rivers and lakes in addition to the water that falls as rain or snow or that has been accumulated and stored as groundwater. These water resources are considered as "clean" water resources that used for human and agricultural uses. It is estimated that by the year 2025, there will be 4–5 billion people on the earth that will live in regions already lacking sufficient clean water (Roger, 2006). Heavy metals are elements with an atomic density greater than 6 g/cm^3; such as Cr^{6+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Zn^{2+} are the most persistent pollutants in wastewater as result of overpopulation and expansion of industrial activities. These heavy metals are toxic to human beings and other living species if their concentrations exceed certain limits (Renge et al., 2012). The degree to which a tissue, cell, organ or system is affected by a heavy metal toxin depends on the toxin itself and the individuals degree of exposure to the toxin are commonly encountered by humans (Goldstein et al., 1971). Copper is found naturallyas a component of many different compounds and in elemental form. The most toxic from of copper is the divalent state Cu(II), cupric. Copper is used profusely in the manufacturing of different metallic alloys and electrical equipment. Copper is released into the environment primarily through mining,agricultural processes, solid waste disposal, welding and electroplating processes, sewage treatment plants, plumbing supplies (pipes, faucets, braces, and various forms of tubing), and electrical wiring materials. Drinking water resources that contaminated with excessive copper can be detrimental and cause metallic taste in the mouth, diarrhea, tachycardia, abdominal pain, vomiting, and cause stomach upset and ulcer, mental retardance,brain and liver damage, and so on. (Aksu and Isoglu, 2005). It is therefore important to remove excess copper in industrial effluents before charging it into surface water and ground water, for the protection of human health and the environment (Wang et al., 2012).

There are a number of methods currently in use for removal of waste water including biological methods, combined chemical and biochemical methods (Tocchi et al., 2012), chemical oxidation and photo-catalysis (Wang et al., 2014; Hamad et al., 2015a,b),

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http://dx.doi.org/10.1016/j.ecoleng.2016.03.015
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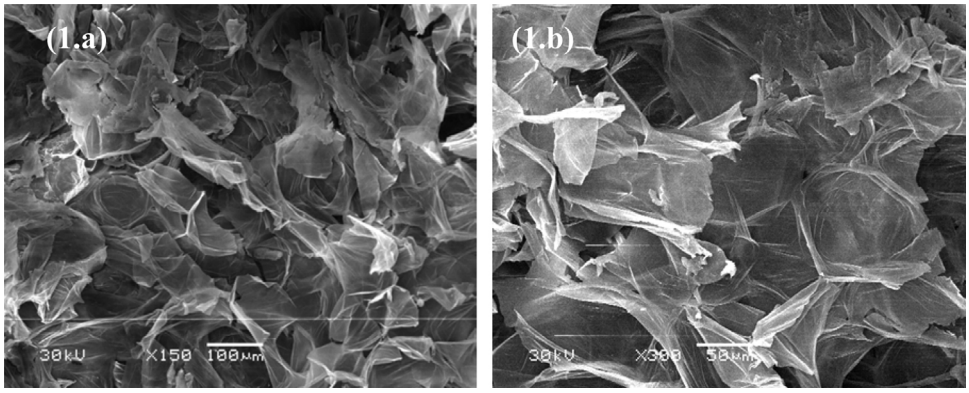

Fig. 1. SEM of peanut hulls surface with magnification factor (a) 150, and (b)300.

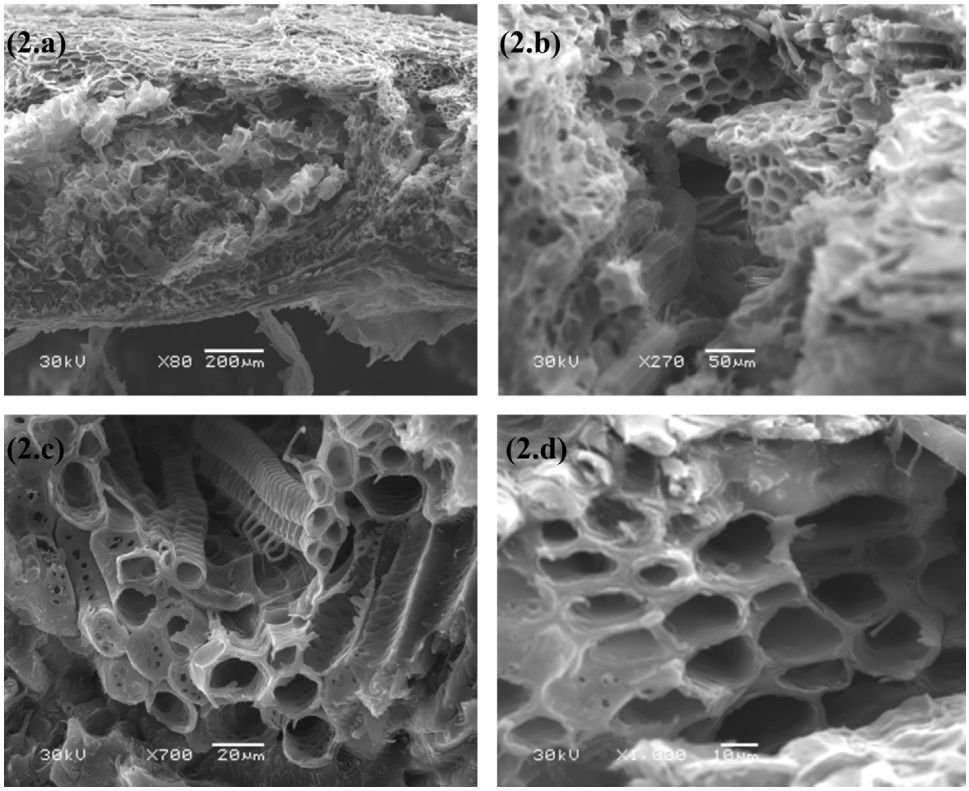

Fig. 2. SEM of peanut hulls cross section with magnification (a) 80, (b) 270, (c) 700 and (d) 1000.

adsorption (Ma et al., 2015), coagulation and membrane treatments (Stajčić et al., 2015); each of these has specific advantages and disadvantages. Hence, there is a crucial need for the development of a method that is highly selective, more efficient, easy to operate and hence cost effective.Adsorption could be a good alternative technology for removal of heavy metal, especially for low concentration. The efficiency of adsorption depends on the adsorbent surface area, surface morphology, pore size distribution, polarity and functional groups attached to the adsorbent surface (Ewecharoena et al., 2009). The principle types of adsorbents include activated carbon (Karnib et al., 2014), synthetic polymers (Pires et al., 2011) and silica-based adsorbents (Wang et al., 2015), however these adsorbents are seldom used for wastewater adsorption because of their high cost.

Agricultural waste is an abundant, availability natural material and one of the rich sources of low-cost adsorbents. Moreover, agricultural wastes offer little economic value and create serious problems due to its incorrect disposal. The annual global production of lingo-cellulosic fibers by products from crops is about 4 billion tonnes, of which 60% comes from agriculture and 40% from forests (Warren et al., 2005). Hence, there are many studies utilized these agricultural by products as adsorbents (Warren et al., 2005). These cellulosic waste materials can be obtained and employed as adsorbents, they can be used raw or activated to remove heavy metal ions from waste water (Ngah and Hanafiah, 2008a). Using of agricultural wastes serves double purposes. One is for environmental purpose; it converts unwanted, surplus agricultural wastes that disposed incorrectly by burning it, to useful value-added adsorbents, and another for economical purpose; using agricultural by products saves the high preparation cost of the prepared adsorbents (Wafwoyo et al., 1999). Many researchers reported the effect of using raw and activated agricultural wastes such as soybean hull and jackfruit (Kurniawan et al., 2006), tree fern (Ho, 2003), sugar beet pulp (Alperİşoğlu., 2005), spent grain, sawdust, fruit