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Insight into the binding of copper(II) by non-toxic biodegradable material (*Oryza sativa*): effect of modification and interfering ions

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Abstract The present studies are focused on the use of non-toxic biodegradable straw from *Oryza sativa* in its simple and modified forms for the binding of copper(II) ions. A relatively new "green" method was adopted for modification with urea under microwaves. The studies have been performed by using the aqueous solution of Cu(II) ions with and without the presence of Cd(II) and Pb(II) as interfering ions. FTIR analysis showed the presence of oxygen- and nitrogen-containing functional groups in simple and modified materials. The emergence of new bands and shifts in the peaks confirmed the modification. The kinetics of the process was studied using the commonly employed mathematical models. Although Elovich model seemed to fit yet coefficient of determination did not reinforce it. Pseudo-second-order model was found to explain the kinetics of the binding of metal ions by simple and modified straw. The equilibrium was studied using the non-linear approach. Based on root mean square error values, it was found that Langmuir model was the most suitable model, followed by Temkin model. Surface areas were compared for single and multi-metal systems. The effect of pH was also studied. Under the studied set of conditions, the modification of straw caused a decrease in the equilibrium time of contact and increase in the biosorption capacities. The presence of other ions decreased the capacities drastically due the competition to bind with the materials.

Keywords *Oryza sativa* · Urea · Non-linear · Langmuir · Intraparticle diffusion

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Introduction

Almost all crustal copper is contained within igneous rocks. Copper usually occurs in nature as oxides and sulfides. Free Cu^{2+} dominates in acidic environments (Bodek et al. 1998). The major concern over contamination due to copper uses is introduction of the metal to bodies of freshwater and saltwater where aquatic life may be adversely affected. As copper is an essential element, the adverse effects only appear at copper intake levels higher than those required for metabolism. Many industrial activities including petroleum refining, paints and pigments, steel-works, foundries, electroplating and metal bearing industrial effluents are the major anthropogenic sources responsible for the incorporation of copper in aquatic environments (Mohan et al. 2006; Kannambda et al. 2010). The maximum permissible contaminant level for Cu(II) ions in industrial effluents, as suggested by USEPA, is 1.3 mg/L (USEPA 2002). However, the maximum tolerable limits of Cu(II) in potable water as set by WHO and EU are 1.0 and 2.0 mg/L, respectively (Kumar and Puri 2012).

Biosorption is the accumulation and concentration of pollutants from aqueous solutions by the use of biological materials. It attempts to overcome the disadvantages of the conventional adsorption process. A number of materials including chitin, chitosan, yeasts, fungi, bacteria, algae, and higher plants have been utilized in an attempt to search for materials with better biosorption capacities and/or having an insight into the mechanism of binding of the pollutants with the materials. These materials are known to contain a number of polar functional groups including alcohol, aldehyde, ketone, carboxylic, phenolic, ether, amide, sulfhydryl, phosphate, etc. These groups have the ability, to some extent, to bind heavy metals [Cu(II) for

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