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Removal of calcium ions from aqueous solutions by sugar cane bagasse modified with carboxylic acids using microwave-assisted solvent-free synthesis

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ABSTRACT

Removal of Ca(II) from aqueous solutions was potentially achieved using two new naturally benign sorbents. They were obtained via modification of sugar cane bagasse (SCB) with tartaric acid (TA) and citric acid (CA) using microwave-assisted solvent-free synthesis. The highest percentages of surface loading were realized under optimize conditions of mass ratio of SCB and TA or CA, microwave radiation power and time of radiation. Changes in spectral band positions of binding sites of SCB and its modified forms (SCB-TA and SCB-CA) were characterized using FT-IR before and after calcium ions sorption. Also, changes in surface morphology were explored in parallel, using scanning electron microscope (SEM). Moreover, for obtaining maximum Ca(II) removal, batch experiments were carried out at different parameters including hydrogen ion concentration, initial Ca(II) concentrations, mass of the sorbent and finally shaking times. Results of sorption isotherms were better fitted with the Langmuir model ($r^2 = 0.959$ and 0.995 for SCB-TA and SCB-CA, respectively). In addition, the kinetics data were best fitted with the pseudo-second-order type. Applications of the new natural sorbents for lowering hardness and consequently conductivity and total dissolved solids (TDS) in different water samples was superior compared to the cation exchange resin Dowex 50W-X8.

1. Introduction

Calcium is the most abundant mineral in the human body. It is important for intracellular metabolism, bone growth, blood clotting, nerve conduction, muscle contraction and cardiac functions [1,2]. However, there is a significant protective association between drinking-water calcium levels and colorectal [3] gastric [4] and breast cancer [5]. Determination of calcium and other alkali-earth ions in aqueous media is of both scientific and technological relevance. This determination is particularly difficult because of the complex matrix. For solving this problem, there are many methods for detection of calcium [6–9]. Solid phase extraction technique (SPE) has become known as a powerful tool for separation and removal of various inorganic and organic analytes [10–12]. Increasing attention has been focused on removal of metal ions from aqueous solutions using benign natural sorbents such as agricultural wastes to overcome the environmental pollution [13,14]. Sugar cane bagasse (SCB) is a representative example of these sorbents. It is a fibrous residue of cane stalks left over after the crushing and extraction of the juice from the sugarcane. About 54 million dry tonnes of bagasse is produced annually throughout the world [15]. The huge quantities of the remaining sugarcane bagasse are burnt in the fields or on the road, and the pollution caused by burning agricultural residues has been a serious problem. Thus, there is an urgent need to find suitable applications for this waste. Moreover, it was found that, SCB is an abundant, inexpensive, and promising industrial waste with cellulose-lignin polymeric structure. However, direct using of the natural sorbents to act as metal ion sorbent from aqueous solution is limited. So, pre-modification using organic chelating agents are important to increase their metal uptake capacity and selectivity as well [16]. In the last few years, there are several studies of modification of SCB using conventional synthetic methods [17,18]. Microwave heating is today a mature technique which finds wide applications. Recently, microwave energy has been widely used in several fields of applications on both research and industrial processes [19]. This technique did not include the organic solvent, trying to minimize the use of hazardous chemicals and develop environmentally acceptable method to prepare chelating agents from easily available agricultural residues. In particular, microwave heating arises from the direct interaction of matter with electromagnetic energy and it offers a number of potential advantages over conventional heating [20]. The main advantage of using microwave heating is that the treatment time can be considerably reduced, which in many cases represents a reduction in the energy consumption as well. The main goal of this manuscript is performing a benign modification process. This includes the use of SCB as a natural sorbent, TA and CA as benign modifiers – keeping in mind that Ca(II) can strongly bind to carboxylate groups incorporated either aliphatic or aromatic carboxylic acids [21,22]– and an environmentally friendly

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