

# Removal of cadmium(II) from aqueous solutions by steam-activated sulphurised carbon prepared from sugar-cane bagasse pith: Kinetics and equilibrium studies

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## Abstract

Removal of cadmium(II) from aqueous solutions was studied using steam activated sulphurised carbon (SA-S-C) prepared from bagasse pith (a sugar-cane industry waste). Batch adsorption experiments were performed as a function of solute concentration, contact time, adsorbent dose, pH, temperature and ionic strength. The maximum removal took place in the pH range of 5.0 to 9.0. The maximum adsorption of 98.8 % (24.70 mg/g) took place by SA-S-C with 8.9 % sulphur content at pH 6.0 from an initial Cd(II) concentration of 50 mg/dm<sup>3</sup>. The sorption process follows pseudo-second-order kinetics. Kinetic parameters as a function of initial concentration and temperature were determined to predict the adsorption behaviour of Cd(II) onto SA-S-C. Decrease in ionic strength of the solution was found to improve the adsorption capacity of the adsorbent. The equilibrium data could be best fitted by the Langmuir adsorption isotherm equation over the entire concentration range (50 to 1 000 mg/dm<sup>3</sup>). The effectiveness of the SA-S-C for Cd(II) removal was examined and compared with other adsorbents reported in the literature. At solution pH of 6.0, the maximum adsorption capacity of SA-S-C calculated by the Langmuir isotherm is 149.93 mg/g at 30°C. Acid regeneration was tried for several cycles with a view to recover the sorbed metal ions and also to restore the sorbent to its original state.

**Keywords:** Adsorption dynamics, Langmuir equation, Cd(II) removal, Sulphurised carbon, Desorption

## Introduction

Cadmium (Cd), which is widely used and extremely toxic in relatively low dosages, is one of the principle heavy metals responsible for causing kidney damage, renal disorder, high blood pressure, bone fraction and destruction of red blood cells (Drash, 1993). Because of the toxicity and bioaccumulation, Cd(II) is considered as a priority pollutant by the U S Environmental Protection Agency. The permissible limit for Cd(II) as described by WHO is 0.01 mg/dm<sup>3</sup>. The main anthropogenic pathway through which Cd(II) enters the water bodies is via wastes from industrial processes such as electroplating, plastic manufacturing, metallurgical processes and industries of pigments and Cd/Ni batteries (Cheremisinoff, 1995). Adsorption of heavy metal ions onto activated carbon has been applied widely as a unit operation in the treatment of industrial wastewater. The use of commercial activated carbon is not suitable for developing countries because of its high cost. Therefore, there is a need to produce activated carbon from cheaper and readily available materials, which can be used economically on a large scale. Activated carbons prepared from rice husk, groundnut husk, fertiliser waste slurry, peanut hull, jute stick, *Moringa oleifera* seed husk, coconut husk and sawdust (Manju and Anirudhan, 1997; Raji et al., 1997; Warhurst et al., 1997) have been used for wastewater treatment and the potential of their ultimate usage may be determined by their adsorption capacity, regeneration characteristics and physical properties of the subsequent product.

In recent years considerable attention has been devoted to develop surface modified carbons from locally available materials for the treatment of heavy metal-bearing wastes. Removal of heavy metals from wastewater by adsorption on copper and lanthanum impregnated activated carbons from sawdust and coconut husk has been reported (Manju et al., 1998; Raji and Anirudhan, 1999). Recent studies speculated that the reaction between heavy metal ions and sulphur groups present in the adsorbent materials accounted for high adsorption efficiency. In this direction, Gomez-Serrano et al. (1998) reported the ability of commercial activated carbon loaded with sulphur groups for the removal of Hg(II), Pb(II) and Cd(II). Sreedhar et al. (1999) studied the sorption of Hg(II) by polysulphide-treated coconut husk. Bagasse pith is a sugar industry waste by-product, which is available in large quantities at no cost and can form a good basis for the development of adsorbent materials. Only a limited number of studies, however, have so far been focused on the use of bagasse pith for the removal of heavy metal ions from wastewater (Gupta et al., 1998; Peternele et al., 1999). Earlier workers have successfully used a single-step steam pyrolysis activation to make high-quality carbon from a variety of materials (Warhurst et al., 1997). The purpose of this work is to study the possibility of the utilisation of single-step steam pyrolysis in the presence of H<sub>2</sub>S and SO<sub>2</sub> for the production of sulphurised carbon for the reduction of cadmium concentration in the solution, since this material has not been considered previously for this purpose. This study examines the effects of the initial concentration of Cd(II), adsorbent dose, initial pH, contact time, temperature, etc. in metal adsorption with bagasse pith-based sulphurised activated carbon prepared by single-step steam pyrolysis in the presence of H<sub>2</sub>S and SO<sub>2</sub> and the results are presented in this paper. Desorption and regeneration studies have also been carried out.

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