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Novel Fe loaded activated carbons with tailored properties for As(V) removal: Adsorption study correlated with carbon surface chemistry

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HIGHLIGHTS

▶ The characterization of four novel activated carbons for As(V) adsorption is proposed.

► Oxidation and iron impregnation are used to modify the surface chemical properties.

► The adsorption study includes experimental isotherms and a modelling.

► The best adsorption capacity obtained is close to 17 mg of As(V) per g of adsorbent.

▶ Novel correlations are found between surface properties and adsorption capacities.

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ABSTRACT

Novel Fe loaded activated carbons have been prepared from sugar beet pulp (BP) agricultural residues by direct steam activation followed by iron impregnation with or without previous oxidation. The corresponding activated carbons were: BP-H₂O, BP-H₂O-Fe, BP-H₂O-H₂O₂-Fe and BP-H₂O-MnO₂-Fe. The textural characterization of these tailored activated carbons was based on nitrogen adsorption/desorption isotherms leading to BET surface area values between 741 and 821 m^2/g and total porous volumes between 0.58 and 0.79 cm³/g. Elemental analysis and ash content showed that carbon content reached 78% for BP-H₂O with 13.6% of ash and decreased to 50% in iron-based materials. BP-H₂O and BP-H₂O-Fe revealed a basic nature with pH_{PZC} values of 9.8 and 9 respectively while BP-H₂O-Fe and BP-H₂O-MnO₂-Fe had acid pH_{PZC} (5.1 and 3.6). Their surface chemistry has been investigated by XPS analysis and by the quantification of the surface chemical moieties based on Boehm's approach. A clear relationship was found between the surface iron content and the strong acidic groups. Arsenic (As(V)) adsorption isotherms were performed and Langmuir, Freundlich, Redlich-Peterson models were used to describe the experimental data by non-linear regression. It was found that Redlich-Peterson isotherm provided the best fit and the Langmuir adsorption capacities confirmed that the iron-based activated carbons were highly attractive for As(V) removal with capacities up to 17 mg g⁻¹. Finally, it has been shown that the surface iron content determined by XPS analysis is very well correlated with Langmuir a_m values ($r^2 = 0.982$) and with the strong acidic moieties deduced from the Boehm's method.

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1. Introduction

Most environmental arsenic problems are the result of mobilization under natural conditions. However, mining activities, combustion of fossil fuels, the use of arsenic pesticides, herbicides or crop desiccants and the use of arsenic additives to livestock feed

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create additional impacts. Two predominant species found in natural waters are inorganic forms of arsenic namely, arsenate As(V) and arsenite As(III). Their presence depends on the pH and redox conditions of the medium. As(V) which is the thermodynamically stable form, is found in oxic surface waters, rivers and lakes [1]. Furthermore, arsenate possesses three pK_a values (2.3, 6.8 and 11.6): therefore in most of natural waters, As(V) exists mainly in the H₂AsO₄⁻ or HAsO₄²⁻ forms. Arsenic in natural waters is a serious worldwide problem, especially in Bangladesh and China [2–4].

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