Using Different Co-Adjuvant Activating Agents to Improve Activated Carbon Adsorption Capacities

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Introduction

Activated carbon (AC) has proved to be an effective adsorbent for the removal of an assortment of organic and inorganic pollutants from aqueous or gaseous media. However, the pursuit for more effective and cheaper AC is still very active and a diversity of textural and chemical treatments are described as a way to expand their applications. It is well known that the surface area and surface chemistry of AC strongly affect their adsorption capacity [1-3]. In particular, an increase in the nitrogen content has been related to an increase of the basic character and also to the development of the porous structure. In most published work this was achieved through an AC post treatment, including either a reaction with nitrogen containing reagents, such as ammonia, nitric acid, or a diversity of amines. However, the AC prepared directly from a nitrogen rich precursor through a physical or chemical activation is referred to as presenting the best characteristics, namely high nitrogen content, high basic character, low nitrogen leaching and also a good thermal stability [4].

To improve the AC adsorption capacities for acidic pesticide removal from the aqueous phase, we intend to improve the porous structure and introduce nitrogenated groups directly into the AC matrix, using different co-adjuvant activating agents as a nitrogen source, by chemical activation, with potassium hydroxide, of cork or poly(ethyleneterephthalate) (PET) precursors.

Materials and Methods

Highly activated AC have been produced by chemical activation, at 973 K, from PET and cork using a mixture of KOH with a co-adjuvant activating agent. The co-adjuvant agents were substances which contain nitrogen such as urea, 2-chloro-4,6-diamino-,3,5-triazine, (2-hydroxyethyl)urea and polyethylenimine. The precursors were dry mixed with KOH and a co-adjuvant agent, in a fixed mass ratio, and each mixture was submitted to pyrolysis, in a steel container, for 30 min at a final temperature of 973 K achieved using a heating rate of 10 $Kmin^{-1}$, with a flow of dry nitrogen of 85 cm^3min^{-1}.

All AC were chemically and structurally characterized using the most used techniques, such as: determination of the point of zero charge (pzc), elemental analysis, thermogravimetric analysis and by nitrogen adsorption at 77 K. Selected AC were evaluated for the removal of the pesticide 2-methyl-4-chlorophenoxyacetic acid (MCPA) from the liquid phase. In the present work a fixed amount of AC was added to aqueous solutions of known pesticide concentrations in an acidic medium. The equilibrium was attained after one day and the residual pesticide concentration was determined by UV/Vis spectrophotometry, at a wavelength of 228.6 or 279 nm.

Results and Discussion

The experimental procedure used in this work allowed direct introduction of nitrogen into the AC matrix, reducing nitrogen leaching and improving the AC thermal stability, which was confirmed by thermogravimetric analysis. The AC produced from cork with the four co-adjuvant agents presented a basic character, as shown by an increase of the pzc when compared with the cork AC activated without a co-adjuvant. With PET, this feature was not observed and the AC presented mainly a neutral character.

All AC were characterised by nitrogen adsorption at 77 K and gave type I isotherms, characteristic of microporous materials. A really large improvement of the textural properties was observed when any of the four co-adjuvants were used with both cork and PET. The co-adjuvants interact in different ways with the two precursors. Nevertheless, an increase in the apparent surface area and pore volume was also accompanied by a widening of the mean pore size. All AC were tested for the removal of MCPA from the liquid phase and presented an excellent adsorption capacity, reaching values as high as 3.7 $mmolg^{-1}$ with four of the samples. Those which exhibited a higher MCPA adsorption capacity, also presented a highest micropore volume and a broader mean pore size. It should be highlighted that the co-adjuvants tried can be used during the activation step as a way to improve, in an exceptional way, the apparent surface area and the pore volume and to expand the AC application.

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References

1. M.F.R. Pereira, S.F. Soares, J J.M. Órfão, J.L. Figueiredo, Carbon 41 (2003) 811–821.
2. I.P.P. Cansado, P.A.M. Mourão, A.I. Falcão, M.M.L. Ribeiro Carrott, P.J.M. Carrott, Fuel Proc. Technol. 103 (2012) 64-70.
3. A. Bhatnagar, W. Hogland, M. Marques, M. Sillanpaa, Chem. Eng. J. 219 (2013) 499–511.
4. J.M. Valente Nabais, P.J.M. Carrott, M.M.L. Ribeiro Carrott, J.A. Menéndez, Carbon 42 (2004) 1315–1320.