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Adsorption of 4-chlorophenol by inexpensive sewage sludge-based adsorbents

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ABSTRACT

Sewage sludge was used as precursor to develop a potential inexpensive adsorbent by both simple drying and pyrolysis. The resulting materials were evaluated as adsorbents for the removal of 4-chlorophenol (4-CP) from aqueous solution. The dried biosolids showed a BET surface area lower than 3 m^2/g, which yield a maximum adsorption capacity of 0.73 mmol 4-CP/g at pH 5.0 and 15 °C. The carbonization of biosolids under relatively mild conditions allowed obtaining materials with BET surface area up to 45 m^2/g, which led to a significant increase of the maximum adsorption capacity (1.36 mmol 4-CP/g). The high ash content of the starting material (23%, d.b.) limits the development of porosity on a total dry-weight basis. Adsorption data were well fitted to the Redlich–Peterson isotherm equation whereas the most commonly used Langmuir and Freundlich equations were less satisfactory probably because of the occurrence of summative adsorption phenomenon. A thermodynamic study of the adsorption showed the spontaneous and exothermic nature of the process. Thus, simple drying and carbonization provide two ways of valorization of sewage sludge through its conversion into inexpensive low-rank adsorbents potentially useful for the removal of some hazardous water pollutants, like chlorophenols and related compounds.

Keywords: Sewage sludge; Activated carbon; Drying; Pyrolysis; 4-Chlorophenol; Adsorption

1. Introduction

Adsorption is a powerful technique for the removal of water pollutants, being activated carbon (AC) the most commonly used adsorbent due to its large porous surface area, controllable pore structure, high thermo-stability and low acid/base reactivity. ACs have been obtained from different wastes such as coconut shells (Laine and Calafat, 1991; Manju et al., 1998), fruitstones (Gharaibeh et al., 1998; Namasivayam and Periasamy, 1993), fertilizer waste (Gupta et al., 2000; Srivastava and Tyagi, 1995; Srivastava et al., 1997), walnut shell (Zabihi et al., 2010), bagasses (Annadurai et al., 2002; Arami-Niya et al., 2011; Demiral et al., 2011; Gupta and Ali, 2004), peat moss (Chen et al., 2001), coir pith (Namasivayam and Kavitha, 2002; Namasivayam et al., 2001), corncob (Wu et al., 2001), plum kernels (Juang et al., 2002), pinewood (Tseng et al., 2003), fir wood (Wu and Tseng, 2008), husk rice (Han et al., 2008), lignin (Cotoruelo et al., 2011), and industrial wastes (Gupta and Ali, 2006, 2008; Gupta et al., 1998, 2004, 2006, 2007a,b) among others.

Nevertheless, ACs are in general relatively expensive materials and this has impeded so far adsorption to be widely established technique for wastewater treatment. Thus, more cost-effective practical adsorbents are needed (Ali and Gupta, 2007; Gupta et al., 2009). In this sense, the use of sewage sludge as a precursor for adsorbent materials with environmental applications has received increasing attention in the last few years. Substantial quantities of sewage sludge are produced continuously as an unavoidable by-product of wastewater treatment. In addition, the sludge production is still increasing because of the population growth and the stringent standards for the discharge of wastewaters to the aquatic bodies. So far, the main applications of sewage sludge include composting for farmland utilization, landfilling and combustion. However, landfilling will not be sustainable in the long term due to the increasing competition for land, increasing costs

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