Production of a paper mill sludge-based activated carbon and application in the removal of pharmaceuticals from water

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The application of wastes as new resources is gaining increasing attention by the scientific and industrial community since it is completely in line with the new paradigm of a circular and sustainable economy. The use of industrial residues for the production of alternative adsorbents has been object of several studies. In this context, the use of primary sludge (PS) from the pulp and paper industry (which consists mainly of cellulose) as precursor for the production of carbon adsorbents has already shown to constitute a promising solution (Jaria et al., 2017), namely concerning its use for the removal of pharmaceuticals from water (Calisto et al., 2014; Calisto et al., 2015; Jaria et al., 2015; Ferreira et al., 2016). The use of paper mill sludge to produce alternative adsorbents can, therefore, address two great challenges: the remediation of contaminated waters and the management of an industrial waste in a sustainable way.

In this work, a full factorial design (FFD) was applied to the production of a chemically activated carbon using PS as precursor in order to determine the best production conditions. Four factors at two levels were studied, namely: a) temperature of pyrolysis (under N₂ atmosphere) (650 °C and 800 °C); b) residence time (60 minutes and 150 minutes); c) type of activating agent (KOH and K₂CO₃); and d) precursor-activating agent ratio (1:1 and 10:1). These factors are known to influence the properties and the adsorbent performance of the final material. The best experimental conditions were then determined by the application of a desirability function where multiple responses were analysed, specifically, the production yield, the adsorption capacity towards different pharmaceuticals (sulfamethoxazole (SMX), carbamazepine (CBZ) and paroxetine (PAR)), the organic carbon content and the specific surface area (SBET). Physical and chemical characterization of the materials with the best responses were performed by means of Fourier Transform Infrared spectroscopy, determination of the zero point charge, determination of the carbons’ surface functional groups by Boehm’s titrations, proximate and ultimate analysis, and scanning electron microscopy. Very little differences between the two chemical activating agents used and the two residence times tested were observed. The higher temperature (800 °C) and the 1:1 precursor-activating agent ratio showed the best adsorption performance, resulting, however, in the worst yields. Four production conditions of the FFD analysis presented very good results for the adsorption of the considered pharmaceuticals, indicating that the produced adsorbents are able to compete with commercial activated carbons (Table 1).

Table 1. Comparison between the results for the adsorption percentage (%) of SMX, PAR, and CBZ obtained for one of the produced adsorbents and for one commercial activated carbon.

<table>
<thead>
<tr>
<th>Carbon adsorbent</th>
<th>SMX Adsorption (%)</th>
<th>PAR Adsorption (%)</th>
<th>CBZ Adsorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced AC</td>
<td>74.7</td>
<td>83.6</td>
<td>84.7</td>
</tr>
<tr>
<td>Commercial AC</td>
<td>25.8</td>
<td>28.6</td>
<td>13.5</td>
</tr>
</tbody>
</table>

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