Converting wastes into resources: the repeatability of carbon adsorbents production from paper mill sludge

C.P. Silva[1], G. Jaria[1], C.I.A. Ferreira[1], M. Otero[2], V.I. Esteves[1] and V. Calisto[1]

[1]Department of Chemistry and Centre for Environmental and Marine Studies (CESAM), University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal
[2]Department of Applied Chemistry and Physics, IMARENABIO, University of Léon, Campus de Vegazana, Léon, Spain
Keywords: Waste management; Circular Economy; Alternative adsorbents; Environment.
Presenting author email: patricia.silva@ua.pt

Pulp and paper industry has massive water requirements that result in the generation of a huge volume of wastewater which, in turn, create enormous amounts of sludge. The disposal of such sludge constitutes an important environmental challenge. The most common solution - landfilling - is being discouraged considering that it poses problems related with leaching and greenhouse gas emissions, which have led to increasingly restrictive legislation. On the other hand, in the past few years, economy has been engaged in the change from a linear economy paradigm (that implies the production, utilization and elimination of materials) to a circular economy concept (based on a zero-waste approach, which involves the recycling of materials and their return to the industry and/or market). Therefore, sustainable practices aiming the valorization of wastes must be developed. In the specific case of sludge from pulp and paper industry, an option is its conversion into carbon-based adsorbents to be applied in water remediation. These adsorbent materials have potential to combine both efficiency and cost-effectiveness, their production meaning a new management solution and a sustainable way for the valorization of sludge. However, from a practical point of view, it is important to investigate if sludge is a consistent raw material and if reproducible final adsorbents may be produced from such sludge (either over time or from different manufacturing processes).

In this work, several primary (PS) and biological sludge (BS) batches from two paper factories with different operation modes were sampled in order to evaluate the consistency of both the raw materials and the carbon adsorbents produced, considering (i) the variability between different sludge batches, and (ii) the variability between factories operating with different production processes. Both PS and BS were dried (at room temperature, followed by a 12 h period at 105 ºC in an oven), grinded, sieved and, afterwards, subjected to pyrolysis (at 800 ºC and under controlled N_2 atmosphere; P materials). Then, a part of P materials was subsequently subjected to an acid washing (PW materials). All the materials were fully characterized by proximate analysis, total organic carbon (TOC) and inorganic carbon (IC), Fourier transform infrared spectroscopy (FTIR) and specific surface area (S_{BET}).

Figure 1. Schematic representation of the use of paper mill sludge as new resource (adapted from http://dx.doi.org/10.1016/j.jenvman.2016.12.004)

Production steps (pyrolysis and washing) did not cause variability in the final carbon materials, however different physico-chemical properties were found between raw materials from different factories, mainly regarding IC. The washing step, performed after pyrolysis, was found to be essential to reduce IC and to considerably increase S_{BET}, yet with high impact in the final production yield. Among the materials produced, PW materials from PS were those having the highest S_{BET} values (387-488 m^2 g^{-1}), which were considered very promising especially considering that

materials were not subjected to any type of activation. Still, considering S_{BET}, P and PW materials produced from BS presented relative high variability between batches, while S_{BET} of materials from different batches of PS did not differ by more than 16%. Overall, it was concluded that precursors from different factories might originate final materials with distinct characteristics. It is, therefore, crucial to take into account this source of variability when considering paper mill sludge as a raw material for carbon adsorbents production. On the other hand, low variability was found between adsorbent materials produced from different batches of sludge within each factory, which is a good indicator of the reliability of such wastes as new resources for the production of adsorbent materials.

Acknowledgments

This work was funded by FEDER through COMPETE 2020 and by national funds through FCT (Fundação para a Ciência e Tecnologia) by the research project PTDC/AAG-TEC/1762/2014. V. Calisto and C.I.A. Ferreira also thank FCT for postdoctoral and PhD grants (SFRH/BPD/78645/2011 and SFRH/BD/88965/2012, respectively). M. Otero acknowledges financial support from the Spanish Ministry of Economy and Competitiveness (RYC-2010-05634). Authors also thank L'Oréal Foundation, FCT and UNESCO (for funding through the L'Oréal Honour Medal for Women in Science 2014, awarded to V. Calisto), the financial support to CESAM (UID/AMB/50017/2013) and to FCT/MEC through national funds, the co-funding by FEDER (within the PT2020 Partnership Agreement and Compete 2020), and RAIZ - Instituto de Investigação da Floresta e do Papel, for kind collaboration.