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Review

Use of cork powder and granules for the adsorption of pollutants: A review

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ABSTRACT

Cork powder and granules are the major subproducts of the cork industry, one of the leading economic activities in Portugal and other Mediterranean countries. Many applications have been envisaged for this product, from cork stoppers passing through the incorporation in agglomerates and briquettes to the use as an adsorbent in the treatment of gaseous emissions, waters and wastewaters. This paper aims at reviewing the state of the art on the properties of cork and cork powder and their application in adsorption technologies. Cork biomass has been used on its original form as biosorbent for heavy metals and oils, and is also a precursor of activated carbons for the removal of emerging organic pollutants in water and VOCs in the gas phase. Through this literature review, different potential lines of research not yet explored can be more easily identified.

Contents

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1. Introduction

Cork consists in the outer bark of the cork oak tree, known botanically as *Quercus suber* L. (Silva et al., 2005). Cork harvest and subsequent transformation supports one of the most important industries in the Portuguese economy and in the Mediterranean region. The traditional use of cork has been on stoppers for wine bottling, which covered around 58% of sales in 2010 of the largest cork company in Portugal and in the world (Corticeira Amorim, 2011). However, there are many other applications for cork and its related products: agglomerates, flooring and walls coverings, insulation cork board, cork/rubber composites, ecoceramics exploring the thermal and acoustic insulation and vibrating insulation (Gil, 2007). More recently, due to its unique properties and renewable character, cork is being used as an original material in innovative ecodesign – being incorporated in furniture, kitchen utensils, accessories and toys (SusDesign, 2008). The use of cork for environmental problems, namely oil spills is the first commercial application of the cork sorbent potential.

The variety of resources which can be produced or extracted from cork has drawn the attention of many researchers. The chemical composition of cork has been studied since the 18th century (Conde et al., 1998), however, the total knowledge of cork's chemical characteristics is not yet complete, and much less of all its potential applications and transformations. Therefore, publications about cork on indexed journals have been growing steadily, indicating a growing interest of the scientific community on cork research (Fig. 1). Moreover, since the beginning of the 21st century, the Portuguese cork industry has been investing on R&D: only between 2000 and 2002, 35 patents were registered, while only 19 had been registered in the previous decade (APCOR).

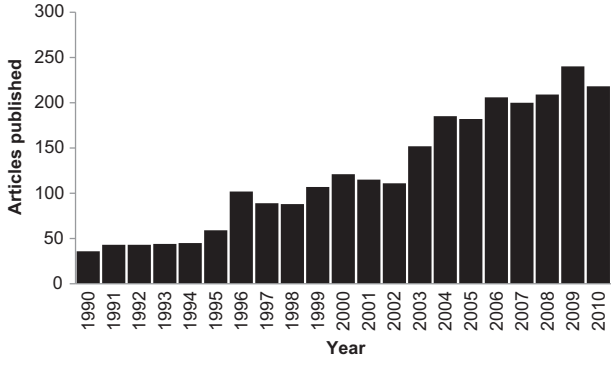

Fig. 1 – Evolution of the number of publications on indexed journals containing the keyword "cork" between 1990 and 2010.

After producing cork stoppers and disks, granulated cork with different granulometries and densities is produced for numerous applications. This process also produces a cork powder with high heating value that is used for energy production and quite often on co-generation processes. The lowest granulometries of cork granules produced are currently designated cork powder. Therefore, new applications are being searched for this byproduct, such as incorporation in agglomerates and briquettes, use as agricultural substrate, filling agent, source of chemicals or in the linoleum production (Gil, 1997), removal of pollutants by biosorption, and production of activated carbons (Silva et al., 2005). Recently, a new patent (Portuguese patent n° 103,286) was issued for the bioremoval of Pb(II) from waters using cork powder.

Being a renewable resource and an agricultural and industrial waste, cork powder is therefore a promising resource for environmental technology if applied in the purification of waters and treatment of wastewaters and gaseous emissions. This paper aims to summarize the developments of recent research on the use of cork powder and its derived materials on adsorption technologies for removal of pollutants.

2. Cork and cork powder

2.1. *Properties of cork*

The bark of *Q. suber* L., the cork oak (Fig. 2), grows as a continuous and thick circular layer produced by the phellogen (Pereira, 1988) and is periodically harvested from the tree, usually every 9–12 years (Silva et al., 2005). Cork oak presents the advantage of being the only tree whose bark can regenerate after harvest, making cork a true environmentally friendly material, as it is a renewable resource (Fernandes et al., 2010). The cork oak grows mostly in the Mediterranean region, where the ideal climatic conditions occur: dry summers and mild winters (Barberis et al., 2003; Jové et al., 2011).

Due to the nature of the cork oak tree, in its life cycle it produces three qualities of cork: virgin cork (first extraction); reproduction cork from the second stripping; and reproduction cork from subsequent strips. Virgin cork is produced by the original phellogen of the tree (Pereira, 1988) and is stripped from the cork oak when it is 20–30 years old (Lopes et al., 2001). It is irregular in structure, thickness and density and can only be used for cork board, insulation, and similar applications (Cumbre et al., 2000). The following layers are stripped out at intervals of 9–10 years (Fialho et al., 2001; Lopes et al., 2001). The lifespan of the cork oak tree is of 170–200 years, therefore it is stripped around 15–18 times (Jové et al., 2011). Although first reproduction cork is more regular than virgin one, only