PRODUCTION OF ACTIVATED CARBON FROM CELLULOSIC FIBERS FOR ENVIRONMENT PROTECTION

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Activated carbon fibers (ACF) have received an increasing attention in recent years as an adsorbent for purifying polluted gaseous and aqueous streams. Their preparation, characterization and application have been reported in many studies [1], which show that the porosity of ACF is dependent on activation conditions, as temperature, time or gas. ACF provide adsorption rates 2 to 50 times higher than Granlular Activated Carbon [2], because of their low diameter (~ 10 m) providing a larger external surface area in contact with the fluid compared with that of granules. Furthermore, their potential for the removal of various pollutants from water was demonstrated towards micro-organics like phenols [3], pesticides or dyes [4]. Generally, fibrous activated carbons are produced from natural or synthetic precursors by carbonization at 600 – 1,000 ºC followed by an activation step by CO_2 or steam at higher temperature [2]. Another way to produce the fibrous activated carbons is chemical activation with H_3PO_4, HNO_3, KOH…[5]. Different types of synthetic or natural fibers have been used as precursors of fibrous activated carbons since 1970: polyacrylonitril (PAN), polyphenol, rayon, cellulose phosphate, pitch, etc. Each of them has its own applications and limitations. The synthetic fibers being generally expensive, it would be interesting to find out low–cost precursors from local material resources.

This work is a part of a research exchange program between the Vietnamese National Center of Natural Sciences and Technology (Vietnam) and the Ecole des Mines de Nantes (Gepea, France), with the aim to find some economical solutions for water treatment. Fibrous activated carbons are produced from natural cellulose fibers, namely jute and coconut fibers, which are abundant in Vietnam as well as in other tropical countries, have a low ash content and a low cost in comparison with synthetic fibers. Two methods are compared to produce activated carbons: 1) a physical activation with CO_2 at 950 °C after a pyrolysis step using N_2 at 950 °C ; 2) a chemical activation where the precursors are impregnated with 30 % wt. and then activated in N_2 at 900 ºC. The efficiency of both activation ways are compared in terms of process mass yield, pore development (determined by N_2 adsorption at 77 K, mercury porosimetry and SEM observations) and chemical surface (elemental analysis, ash content, surface groups, pH point of zero charge).

Carbonized fibers obtained by pyrolysis of jute and coconut fibers at 950 °C develop a quite high porosity (BET specific surface area about 500 - 650 $m^2\ g^{-1}$) due to an oxidation process by oxygen contained in the precursors (45.7 and 42.8 wt. % for jute and coconut fibers respectively). Concerning the activation step, because of different compositions in terms of cellulose – hemicellulose and lignin, the activated coconut fibers present higher specific surface area (> 1 000 $m^2\ g^{-1}$) that activated jute fibers, with a higher microporosity development (about 80 % vol. against 50 %). Furthermore, for both precursors, the chemical activation by phosphoric acid seems to be "the best" method in terms of pore development as well as acidic surface functional groups generation, due to a different activation mechanism than CO_2. Some macropores are formed by the effect of oxidation gas CO_2 (Fig. 1 for jute fibers). Furthermore, these macropores are mainly located inside the fiber, their axis being parallel with that of the latter.

The high specific surface areas, pore volumes and acidic surface groups contents developed by our fibrous activated carbons enable them to be good adsorbents for water treatment. Adsorption tests carried out in batch reactor for different industrial pollutants (phenol, a dye and a metal ion) show the importance of surface functional groups for the adsorption of all pollutants. In the case of phenol, the specific surface area has also a major effect while it has only an appreciated effect in the adsorption of the dye and the Cu^{2+} ion. For metal ion removal, the great influence of surface acidic oxygen groups of the fibers is put into evidence by assessing a linear regression between adsorption capacities and the concentration in acidic surface groups as demonstrated in Fig. 2.

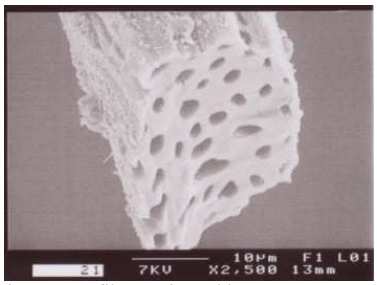

Fig. 1. Jute fiber activated by CO_2 at 950 °C.

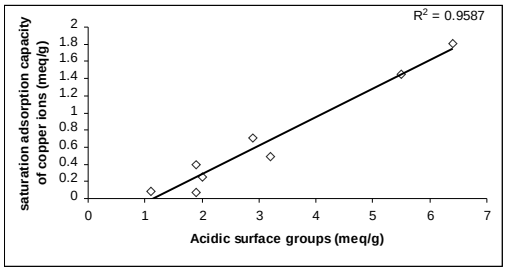

Fig. 2. Adsorption capacities of Cu^{2+} vs. acidic surface groups of raw, carbonized and activated fibers.

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