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Filtration performance of microporous ceramic supports

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Abstract

The use of inorganic membranes in pollution treatment is actually limited by the cost of such membranes. Advantages of inorganic membranes are their chemical, thermal and pH properties. The purpose of this work was the development of microporous ceramic materials based on clay for liquid waste processing. The supports or ceramic filters having various compositions were prepared and thermally treated at 1100 °C. The results show that, at the temperature studied, porosity varied according to the support composition from 12% for the double-layered (ceramic) support to 47% for the activated carbon- filled support with a mean pore diameter between 0.8 and 1.3 μm, respectively. Volumes of 5 l of distilled water were filtered tangentially for 3 h under an applied pressure of 3.5 and 5.5 bar. The retention of tubular supports prepared was tested with molecules of varying size (Evans blue, NaCl and Sacharose). The study of the liquid filtration and flow through these supports showed that the retention rate depends on support composition and pore diameter, and solute molecular weight. The S1 support (mixture of barbotine and 1% (w/w) activated carbon) gave a flux for distilled water of 68 L/m^2 h while the double-layered support resulted in a flux of 8 L/m^2 h for the same solution at the pressure of 3.5 bar. At a pressure of 5.5 bar an increase in the distilled water flux through the various supports was observed. It was significant for the S1 support (230 L/m h).

Keywords: Support ceramic; Synthesis; Flux; Effluent

1. Introduction

The importance of membrane technologies for waste water treatment has increased in recent years and has emerged as an important separation and purification method in various process industries to prevent water resources pollution by toxic elements (such as Pb, Cd, Hg and dyes) [1–4]. The consequence of the pollution of the water resources is an increase of the concentration of toxics in the drinking water which also increases the cost of water potabilisation [1,3,5]. Membrane processes are now used to obtain effluents without contaminants; they recycle process water, and recover valuable products, which can be reused in the process itself or in other applications [6,7]. Inorganic membranes (oxide-based membranes such as Al_2O_3, ZrO_2, TiO_2 and hyteropolysiloxanes) have attracted more attention due to high mechanical, chemical and thermal resistance, which can be potentially applied in liquid separation, gas separation, pervaporation, membrane reactors, etc. [7–10]. The progress in the development of membranes for the treatment of aqueous solutions has attracted much interest in recent years [10–12]. The aim of this work was to elaborate various membrane supports (ceramic filters) based on a local clay (the product used in this work was an Algerian natural product, a barbotine from Ghazaouet area, western Algeria), and secondly to study filtration flow rates under pressure [13,14]. The supports are used in gas and liquid effluent processing as well as in improving water drinking ability. This kind of technique (membrane and support) was applied in physical and biological decontamination [10]. The supports can be operated at elevated temperatures above 100 °C and can withstand pH values of 0–14. Supports can be regenerated using high flow rate deionised water flowing tangentially. Then can also be regenerated manually through gentle scraping or chemically using hydrochloric acid (pH = 3) or sodium hydroxide solutions (pH = 10) [11].

2. Materials and methods

The support used to deposit the ultrafiltration membrane was made of a natural Algerian clay which is a low cost material. The

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Table 1
Mineralogical composition of barbotine [13]

Raw material	Composition									
	%	WL	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O
Hycast clay (V_c)	21	2.52	11.13	6.51	0.21	0.46	0.04	0.08	0.04	0.44
Kaoline (KR)	07	0.84	3.36	2.53	0.03	0.04	0.01	0.01	0.06	0.06
Kaoline (LPC)	20	2.36	9.60	7.40	0.01	0.02	0.02	0.06	0.02	0.38
Kaoline Tamazirt (F2)	08	0.84	4.01	2.72	0.02	0.13	0.06	0.03	0.01	0.23
Feldspath (incusa)	13	0.06	8.89	2.24	–	0.01	0.06	0.01	0.30	1.43
Feldspath (NM)	07	0.03	4.87	1.29	0.02	0.01	0.01	–	0.72	0.02
Sand (Sig area)	24	0.07	23.59	0.17	0.02	0.04	0.03	0.03	0.02	0.04

* WL: weight loss.

barbotine was prepared by mixing Hycast clay (21% w/w), KR-Kaoline 7%, LPC-Kaoline (20%), Tamazirt Kaoline (8%), Incusa — Feldspath (13%), NM —feldspath (7%) and sand (24%) from the Sig area with water. The whole amount of mixture was fed to in a ball grinder then sieved to obtain a final product having diameter lower than 63 µm and a 75–80 centipoises viscosity. The viscosity of barbotine is often determined using the torsion Gallenkamp viscosimeter. Cylinder metal assembled on the wire which underwent torsion of 360° is immersed in barbotine whose mineralogical composition is reported in Table 1. The damping effect of the barbotine simple on the overswing of the cylinder, when the wheel is rotated through 360° and released, allowed the determination of the viscosity.

The plaster moulds are prepared with a porous plaster soaking well with water. After mixing, the barbotine thus obtained was cast in plaster moulds in order to allow the absorption of the liquid by capillarity causing the solidification of the paste. The mechanism of barbotine setting is due mainly to the capillary forces of the fine texture of the plaster pores. During the casting, the moulds were filled and drained manually and the barbotine excess was recovered. The plaster was then extruded to obtain a tubular support. The length of the support was 20 cm. The inner and outer diameters of the tubular support were 15 mm and 19 mm, respectively.

Thermogravimetric analysis (TGA) is an analytical technique used to determine a material's thermal stability and its fraction of volatile components by monitoring the weight change that occurs as a specimen is heated. The measurement was carried in air and the weight recorded as a function of increasing temperature. Sometimes, the measurement is performed in a lean oxygen atmosphere (1 to 5% O_2 in N_2 or He) to slow down oxidation. In addition to weight changes, some instruments also record the temperature difference between the specimen and one or more reference pans (differential thermal analysis, or DTA) or the heat flow into the specimen pan compared to that of the reference pan (differential scanning calorimetry, or DSC). The latter can be used to monitor the energy released or absorbed via chemical reactions during the heating process.

In the present steady heat treatment was imposed on the samples to determine the removal temperature of temporary and consolidation additives. The results show a steady increase in temperature up to 200 °C followed by a plateau corresponding to the complete elimination of temporary additives, then an increase of the temperature up to 573 °C was obtained where this region corresponds to the quartz α to quartz β transformation.

Heat treatment confers to ceramic product their final shape and size as well as their mechanical resistance and properties required for the end-product. Curing induces transformations linked to volume and /or weight change. Structural water is removed in the temperature range 500–600 °C which results in the destruction of the formation of metakaolinite. At 800 °C, silimanite is formed whereas volatile matter decomposes in the range 410–800 °C. Metakaolinite decomposes from 900 to 950 °C and mullite forms starting from 950 °C.

Finally, the temperature was increased up to 1100 °C and maintained at this level for a few hours followed by a slow cooling to avoid cracks in the support. Drying and sintering were performed at 1100 °C for consolidation. The support is only composed of mullite, crystoballite and glassy phase.

The temperature 1100 °C was selected because earlier studies [14] showed that optimal mechanical properties were attained at this temperature.

We developed four different types of supports [13]: a local barbotine support symbolized by S0, a support made up of a

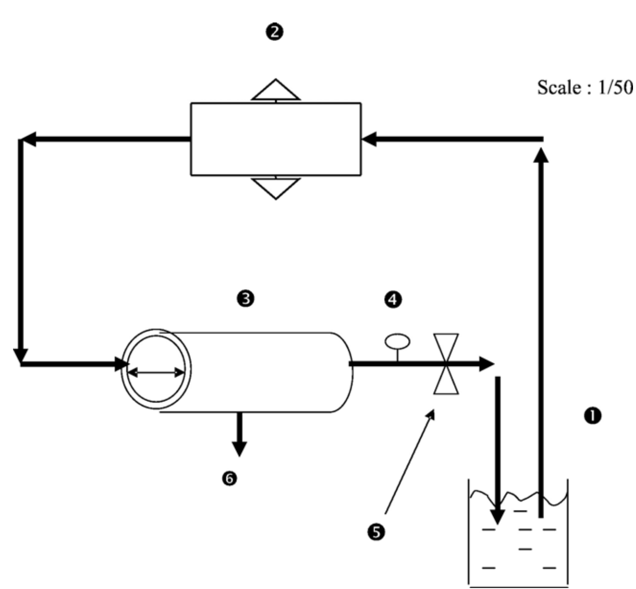

Fig. 1. Filtration flow diagram [13]. ❶ Feed tank; ❷ Feed pump; ❸ Tubular membrane; ❹ Manometer; ❺ Pressure valve; ❻ Filtrate recover.