ELSEVIER

Desalination 183 (2005) 383–394

DESALINATION

www.elsevier.com/locate/desal

Pollutants removal from wastewaters through membrane distillation

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Received 21 February 2005; accepted 10 March 2005

Abstract

The Sweeping Gas Membrane Distillation process is considered for the treatment of wastewaters containing volatile organic compounds such as acetone and ethanol. The separation technique is based on the use of microporous hydrophobic membranes under conditions of non wettability, in which the membrane separates an aqueous phase from a stripping gas.

A wide experimental investigation is performed to study the role of temperature, composition and flow rate of the liquid phase and the influence of the sweeping gas flow rate. Performances of flat PTFE membranes are studied in the case in which dry nitrogen is used as stripping agent. Liquid feed flow rate as well as nitrogen flow rate are identified as the major design quantities since they greatly affect the separation efficiency.

A simplified mathematical model is developed to describe multicomponent mass transfer in the gas phases, in which a pseudo-binary diffusion approach is assumed; molecular diffusion is considered as the prevailing transport mechanism through the membrane. The results obtained are compared with the experiments and the validity range of the model is defined.

Keywords: Membrane distillation; Sweeping gas; Volatile organic compounds; Porous hydrophobic membranes; Removal

1. Introduction

The Sweeping Gas Membrane Distillation (SGMD) is a membrane-based separation process which has been proposed for several purposes such as the production of ultrapure water from salt solutions and the selective removal of volatile organic compounds from aqueous streams [1–6]. A hybrid configuration between SGMD and Air Gap

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Presented at the Conference on Desalination and the Environment, Santa Margherita, Italy, 22–26 May 2005. European Desalination Society.

doi:10.1016/j.desal.2005.03.041

Membrane Distillation was also proposed as Termostatic SGMD in [7,8], in which the separation of azeotropic mixtures was also studied.

The process is one of the various membrane distillation techniques, in which a microporous hydrophobic membrane separates an aqueous solution from a gas phase acting as a stripping agent (Fig. 1c). Under conditions of non wettability, evaporation takes place at the liquid–vapour interface located at the feed/membrane surface and vapours diffuse through a stagnant gas film entrapped within the membrane pores towards the sweeping gas phase downstream the membrane.

Among the various membrane distillation techniques, SGMD and Vacuum Membrane Distillation [9] are certainly the most similar from the operative point of view. In both cases, the driving force of each permeating species is related to the corresponding partial pressure difference existing through the membrane which is sustained by a sweeping gas or by vacuum, respectively. As a consequence, it should be expected that the technological applications as well as the role of the main transport phenomena involved on the process efficiency could be quite similar. Nonetheless, for SGMD the mass transfer resistance in the gas phase can assume a relevant role; in addition, since the process operates at atmospheric pressure, molecular diffusion is the prevailing mass transfer mechanism in the membrane with respect to Knudsen diffusion [3].

The process is here proposed for the purification of dilute wastewaters containing volatile organic compounds, in alternative to conventional separations such as distillation, carbon adsorption, gas stripping, in view of the lower energy demand with respect to conventional techniques. However, the process results economically advantageous only in those cases in which pollutants recovery is not required, since the condensation downstream the membrane unit is the most energy consuming step [10]. As a consequence, SGMD becomes a good alternative to biological abatement for the treatment of end-process streams containing various trace components for which recovery and separation would be remarkably expensive; in this case, the waste gas stream containing volatile organic compounds stripped from the aqueous streams can undergo a simple incineration process.

Previous papers [1,2,5] established the process feasibility for the simple case of pure water, in flat as well as in shell and tube module configurations; the effect of operating variables was also experimentally investigated in [6] in the case of isopropanol-water mixtures. The prevailing role of liquid temperature on process performance, as well as the relevance of liquid and gas flow rates have

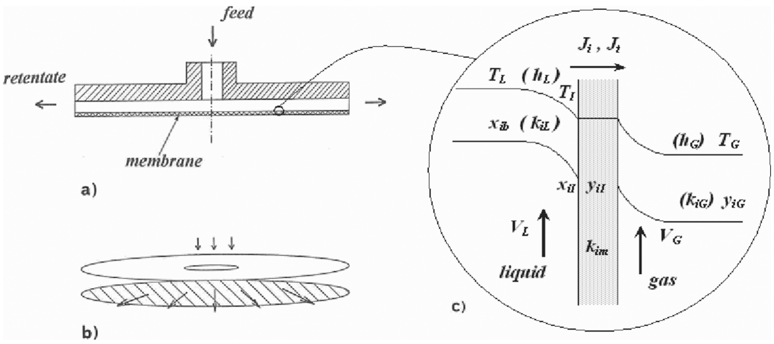

Fig. 1. SGMD process: (a) liquid side semicell; (b) flow pattern in each semicell; (c) detail of the porous membrane showing temperature and composition profiles in the external phases, with reference to the VOC.