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Review Article

A Review on Studies and Research on Use of Pervaporation as Separation Method

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ABSTRACT

Pervaporation is one of the most efficient membrane separation processes. It finds wide application for the separation of aqueous-organic and closely boiling mixtures. Pervaporation is permselective evaporation. The liquid droplets which diffuse through membrane undergo phase change during diffusion, causing the separation. Many investigators have carried out research on this separation methods to study and compare the use of different membranes. Also studies on the affecting parameters are reported. The modeling and simulation studies have also been reported. The current review summarizes research and studies carried out pervaporation.

Key words: Membrane, separation, permeate, performance parameters, cost.

INTRODUCTION

Chemical processes involve various unit operation and unit processes carried out for conversion or separation of raw materials to get the products. The separation method is the most important aspect of chemical engineering. Separation methods which are commonly used include distillation, leaching, extraction, absorption and drying. [1-5] These unit operations are nowadays being modified in order to economize the process. Combined methods such as molecular distillation, reactive distillation, solar distillation, reactive adsorption are being explored for various products. [6-11] The membrane separation is one of the important separation method used in chemical and biochemical industries. [12-15] Membrane separation involves reverse osmosis, ultrafiltration, microfiltration pervaporation, and nanofiltration. Also membrane bioreactors are being used for specific applications. Pervaporation involves permeation coupled with vaporization. Current review summarizes research and studies on pervaporation.

RESEARCH AND STUDIES ON PERVAPORATION

Vane et.al. used vibrant membrane module in their studies. [16] They carried out the separation of volatile organic compounds (VOCs) from aqueous solutions by pervaporation. They investigated two primary variables, vibrational amplitude and liquid flow rate. They observed that vibrations were able to reduce concentration polarization in the system as inferred from an order of magnitude increase in the overall mass transport coefficient. The vibrating membrane application can be applied for microfiltration, ultrafiltration, nanofiltration, or reverse osmosis.

Kujawski studied application of pervaporation in environmental applications. [17] He described examples of polymers for membrane preparation as well as performance parameters of pervaporation and vapor permeation membranes. His study also included applications of pervaporation and vapor permeation in environmental protection. Pervaporation has advantages such as simple operation and control, reliable performance, high flexibility, unproblematic part-load operation, high product purity (no contamination by entrainment), no environmental pollution, Also energy and space requirements are less. They concluded that the most successful processes require integration with existing conventional separation unit operations.

Aouinti and Roizard carried out investigation on pervaporation of toluene-n-heptane mixtures with hybrid PVC membranes. [18] They studied the design and preparation of hybrid mixed matrix membranes based on PVC (polyvinylchloride). They considered separation of toluene-n-heptane mixtures by pervaporation. They found that the permeation properties of PVC can be strongly modified by the incorporation of fillers, leading to the reinforcement of its barrier properties. They concluded that a simple and economical polymer, such as PVC, can be used with an appropriate filler to obtain high separation properties for aromatic-alkane mixtures by pervaporation. The intrinsic PVC affinity for aromatics induced by the polar chlorine atoms of the polymer backbone favours such application.

Rao et. al. prepared Sodium alginate (SA) and Hydroxy propyl cellulose (HPC) blend membranes(SA/HPC) by solution casting method and cross linking with glutaraldehyde (GA). [19] They carried out sorption studies to evaluate the extent of interaction and degree of swelling of the membranes. They carried out experiments in pure liquids as well as in mixtures of water and isopropanol. They concluded that the present blend membranes are promising candidates for pervaporation dehydration of isopropanol. Jeon et.al. investigated pervaporation of butanol/water mixtures using siloxane polymer/ceramic composite membranes. [20] In their investigation they coated siloxane polymers on a prepared alumina ceramic support layer (γ-Al_2O_3/α-Al_2O_3). Membrane hydrophobicity was enhanced by depositing a layer of rubbery polydimethylsiloxane (PDMS) on the γ-Al_2O_3 surface and a secondary coating of phenyltrimethoxysilane (PHTMS). They studied effects of the secondary PHTMS coating with respect to butanol concentration, temperature, and flow rate of feed solution. They observed that the PhTMS/PDMS/ceramic composite membrane showed promising potential to improve butanol recovery from the fermentation broth but the trade-off is total flux reduction.

Yang et. al. carried out investigation on desorption and pervaporation properties of zeolite- filled PDMS, poly (dimethylsiloxane) membranes. [21] They studied role played by zeolite fillers in PDMS membranes in desorption and pervaporation. Their study indicated that the hydrophobic zeolites enhance significantly the organic flux, leading to an improvement of both the flux and the selectivity. Sudhakar et.al. carried out studies on pervaporation dehydration of isopropanol. [22] They developed sodium alginate-13x zeolite-filled mixed matrix membranes. They observed that flux and selectivity increased systematically with increasing amount of zeolite in the SA matrix. Pervaporation was used for separation of ethanol and water by Mulder et.al. [23] They found that it was possible to remove ethanol preferentially and continuously from a fermentation reactor by pervaporation in combination with ultrafiltration. Inadequate homogeneity and/or thickness of the selective top layer are problems associated with the composite membranes prepared by dip-coating. Acharya carried out an investigation on separation of isopropyl alcohol-water by hybrid distillation pervaporation system. [24] He carried out the comparative study of pervaporation over a conventional azeotropic distillation for the separation of IPA/water mixture. He found that hybrid distillation of pervaporation method was better. Also he found that in new method, that capital cost and operating cost can be reduced compared to conventional methods.

Lone et.al. carried out studies on modeling and simulation of a hybrid process (pervaporation+distillation)using MATLAB. [25] They reported the modeling and simulation of a hybrid process, based on the combination of distillation and pervaporation for the separation of azeotropic mixture of alcohol and ether. According to them pervaporation is most suitable for the separation of azeotropic or constant boiling mixtures which otherwise are difficult to separate by ordinary distillation. In their work, Methyl-tertiary butyl ether, MTBE purity of more than 99% for different thermal conditions of feed was obtained. Hybrid method needs less area than pervaporation or distillation alone. Uragami et.al. studied the effects of the PSt content of polystyrene (PSt)-poly (dimethylsiloxane) (PDMS) interpenetrating network (IPN) polymer membranes on the pervaporation (PV) characteristics during the removal of benzene from an aqueous solution of dilute benzene. [26] They observed that both the permeability and the benzene/water selectivity of the membranes enhanced with increasing PSt content in the PSt-PDMS IPN membrane.

Chang et.al. carried out investigation on pervaporation of emulsion droplets for the templated assembly of spherical particles. [27] They presented a population balance to describe this transport of solvent from nanocrystal- or polymerladen droplets in an emulsion that flows through a pervaporation unit. Their simulation studies indicated that the particle-size distributions are generally bimodal, and are broader for low dispersed-phase volume fractions and very low-solvent solubilities.

CONCLUSION

Studies carried out by various investigators indicates that pervaporation has advantages such as simple operation and control, reliable performance, high flexibility, unproblematic part-load operation, high product purity (no contamination by entrainment), no environmental pollution. Also it was found that, simple and economical polymer, such as PVC, can be used with an appropriate filler to obtain high separation properties for aromatic-alkane mixtures by pervaporation. Pervaporation has many advantages over a conventional azeotropic distillation for the separation of IPA/water mixture such as capital cost and operating cost.

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