DEHYDRATION BY PERVAPORATION MEMBRANE PROCESS
(Sustainable Energy Saving Technology)

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ABSTRACT
Pervaporation, in its simplest form, is an energy efficient combination of membrane permeation and evaporation. It's considered an attractive alternative to other separation methods for a variety of processes. For example, with the low temperatures and pressures involved in pervaporation, it often has cost and performance advantages for the separation of constant-boiling azeotropes. Pervaporation is also used for the dehydration of organic solvents and the removal of organics from aqueous streams. Additionally, pervaporation has emerged as a good choice for separation heat sensitive products.

Keywords: ***Fundamentals of pervaporation, Characteristics of the pervaporation process Pervaporation Membranes, Experimental working model, Advantages & Applications***

INTRODUCTION
Research work on pervaporation dates back to the early part of the 20th century. The term pervaporation was coined by kober in 1917. The first major research effort in commercializing pervaporation was undertaken by Binning in the late 1950s. Binning reported the utilization of membrane pervaporation for dehydration of a ternary azeotrope of isopropanol-ethanol-water from the overhead of a distillation column. This work was followed by several others presenting the separation of n-heptane and iso-octane, the separation of benzene-methanol azeotrope or separation of pyridine-water azeotrope.

Most industrial scale separation processes are based on energy intensive methods such as distillation, evaporation, and freeze crystallization. Membrane separations offer significant advantages over existing separation processes. Current membrane separation technologies can offer energy savings, low-cost modular construction, high selectivity of separated materials, and processing of temperature-sensitive products. Membrane separate mixtures by discriminating the components on the basis of physical or chemical attributes, such as molecular size, charge, or solubility .By passing water and retaining salts, membranes are used to produce over half of the world's desalinized potable water. Membranes can also separate oxygen and nitrogen from air as well as hazardous organics from contaminated water in applications such as groundwater remediation.

The need for membrane separation technology increases as environmental requirements tighten, water circuits close, the recycling of wastes increases and the purity requirements for foodstuff and pharmaceuticals increase. Six major membrane processes (microfiltration,ultrafiltration, reverse osmosis, electrodialysis, gas separation and pervaporation) have found use in such application areas as water purification, chemical and food processing, drug delivery, bioseparations, and medical treatment .

At the present, liquid product mixtures must fulfill high purity requirements as well as effluents; therefore, they have to be concentrated or reconditioned. In the process of product-integrated environmental protection, liquid substances should be separated specifically from the mainstream, either to save raw materials, to prevent or to minimize the disposal of effluents, or to recycle by-products. Such completely or partly soluble fluid mixtures can be separated with membrane methods. Pervaporation is the most well-known membrane processes for the separation of liquid and vapor mixtures.

FUNDAMENTALS OF PERVAPORATION

Definition of Pervaporation Process: Pervaporation is recognized as a separation process in which a binary or multicomponent liquid mixture is separated by partial vaporization through a dense non-porous membrane. During pervaporation, the feed mixture is in direct contact with one side of the liophilic membrane whereas the permeate is removed in a vapor state from the opposite side into a vacuum or sweeping gas and then condense. Pervaporation is unique among membrane separations, involving the liquid-vapor phase change to achieve the separation .The driving force for the mass transfer of permeants from the feed side to the permeate side of the membrane is a gradient in chemical potential, which is established by applying a difference in partial pressures of the permeants across the membrane. The difference in partial pressures can be created either by reducing the total pressure on the permeate side of the membrane by using a vacuum pump system or by sweeping an inert gas on the permeate side of the membrane.

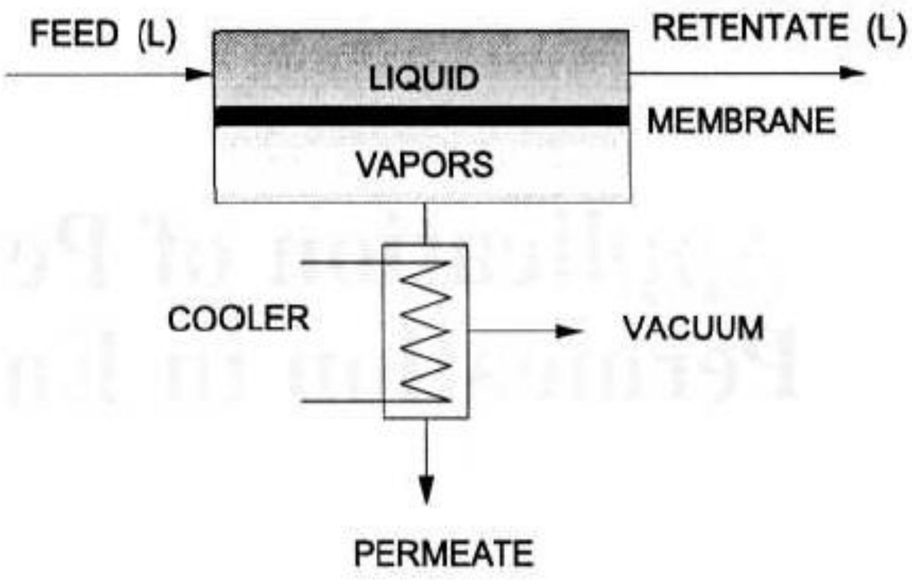


Fig: Schema of pervaporation

Pervaporation Steps

- Selective sorption into the membrane on the feed side
- Selective diffusion through the membrane
- Desorption into a vapour phase on the permeate side

Conventional Separation Challenges

- Mixtures with close boiling points
- Azeotropic mixtures
- Removal or recovery of trace materials from liquid streams
- Concentration of heat sensitive materials
- Concentration of solutions containing traceamounts of volatiles

Characteristics of the pervaporation process include

1. Low energy consumption
2. No entrainer required, no contamination
3. Permeate must be volatile at operating conditions
4. Functions independent of vapor/liquid equilibrium

Characteristics of Membrane

Membrane Process	Feed Phase / Permeate Phase	Driving Force	Membrane	Main Application
Pevaporation	Liquid / Vapour	Chemical Potential Gradient	Hydrophobic	Separation of Liquid Mixtures

PERVAPORATION MEMBRANES

The membranes used in pervaporation processes are classified according to the nature of the separation being performed. *Hydrophilic membranes* are used to remove water from organic solutions. These types of membranes are typical made of polymers with glass transition temperatures above room temperatures. Polyvinyl alcohol is an example of a hydrophilic membrane material. *Organophilic membranes* are used to recover organics from solutions. These membranes are typically made up of elastomer materials (polymers with glass transition temperatures below room temperature). The flexible natures of these polymers make them ideal for allowing organic to pass through. Examples include nitrile, butadiene rubber, and styrene butadiene rubber.

The composition and morphology of the membranes is a key to effective use of membrane technology. The choice of the membrane strongly depends on the type of application. It is important which of the component should be separated from the mixture and whether this component is water or an organic liquid. Generally, the component with the smallest weight fraction in the mixture should preferentially be transported across the membrane.Looking at the mixtures to be separated and their

compositions, the following different kinds of pervaporation processes can be distinguished :

- Dehydration of organic liquids.

For the removal of water from water/organic liquid or vapor mixtures hydrophilic polymers have to be chosen. The hydrophilicity is caused by groups present in the polymer chain that are able to interact with water molecules. Examples of hydrophilic polymers are: ionic polymers, polyvinylalcohol (PVA), polyacrylonitryle (PAN), polyvinylpyrrolidone (PVPD).

- Removal of organics from water or air streams.

For the removal of an organic liquid from water/organic or organic/air mixture hydrophobic polymers are the most suitable polymers as membrane materials.

These polymers possess no groups that show affinity for water. Examples of such polymers are: polydimethylsiloxane (PDMS), polyethylene (PE), polypropylene (PP), polyvinylidenefluoride (PVFD), polytetrafluoroethylene (PTFE).

- Separation of two organic solvents.

For the mixture of two organic liquids or vapors, again three kinds of mixtures can be distinguished: polar/apolar, polar/polar and apolar/apolar mixtures. For the removal of the polar component from polar/apolar mixture polymers with polar groups should be chosen and for the removal of the apolar component completely apolar polymers are favorable. The polar/polar and apolar/apolar mixtures are very difficult to separate, especially when the two components have similar molecular sizes. In principle all kinds of polymers can be used for these systems, the separation has to take place on the basis of differences in molecular size and shape, since no specific interaction of one of the two components can take place.

Selective & Transport Properties of Different Types of Pervaporation Membranes

Membrane Material	Binary Mixture A/B	Contents of A components in Feed (	Temperatu re
Hydrophilic Polymeric Membrane			
Polyvinyl	Water/Ethanol	0.1-8	90-100
Polyamide-6	Water/Ethanol	30	80
Polyamide-6	Water/dioxane	50	35
Polyamide-6	Water/acetic	8.7	15
Hydrophobic Polymeric Membrane			
Polypropylene	Acetone/water	45	116
SiliconeRubber	Isopropanol/W ater	9-100	25
SiliconeRubber	Butanol/Water	0.8	30

EXPERIMENTAL WORKING MODEL

Fig: Experimental Working Model of Pervaporation Membrane Process

Experimental Setup: The system consists of the following parts

i) Three neck round bottom flask.

ii) Bend glass tube.

iii) Vacuum pump

iv) Conical flask surrounded by ice in pan.

v) Membrane cup.

vi) Heating mental.

Experimental Procedure

1) Take 500 ml feed contains 400 ml Ethanol & 100 ml Water in round bottom flask.
2) Warm the mixture up to 85-90 **ºc** by using Heating mental.
3) Vapours of mixture formed & passed through glass tube into the Membrane Cup
4) When Vapours of mixture comes in contact with membrane which is Hydrophilic. Due to hydrophilic membrane selective sorption & diffusion of water vapours into the membrane takes place.
5) Finally Desorption of water vapors on the permeate side takes place by applying vacuum & alcohol vapors retained on membrane.
6) When vapors comes in conical flask were immediately condensed (cool) by ice surrounded it.
7) In this way we separate water from ethanol-water mixture & we get 100 % pure ethanol.

ADVANTAGES & APPLICATIONS

Advantages

- Simple operation and control
- Reliable performance
- High flexibility
- unproblematic part-load operation
- High product purity (no contamination by entrainer)
- No environmental pollution.
- High product yield.
- Low energy consumption.
- Compact design(low space requirements)

Applications

- Removal of water from organic solvents
- Alcohols from fermentation broths (ethanol, etc..)
- Volatile organic contaminants from waste water (aromatics)
- Removal of flavor and aroma compounds.
- C-8 isomers (o-xylene, m-xylene, p-xylene, styrene)
- Alcohols/aromatics (methanol/toluene)
- Alcohols/aliphatics (ethanol/hexane)

Established industrial applications of pervaporation

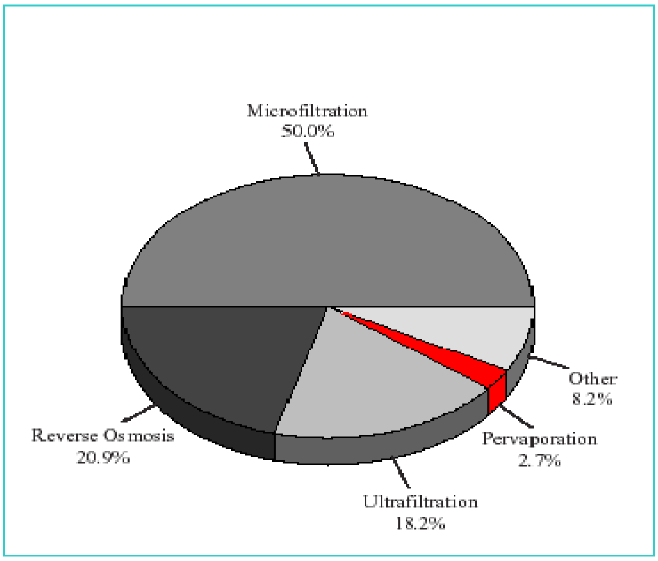
- The treatment of wastewater contaminated with organics
- Pollution control applications

- Recovery of valuable organic compounds from process side streams
- Separation of 96% ethanol-water solutions
- Harvesting of organic substances from fermented broth.

Comparison of the Dehydration Costs of Ethanol

Utilities	Pervaporation	Entrainer Distillation	Molecular Sieves
Vapor	6.40	60.00	40.00
Electricity	8.80	4.00	2.60
Cooling Water	2.00	7.50	5.00
Replacement of Membrane	15.30	---	---
Entrainer	---	4.80	---
Replacement of Molecular			
Total cost	32.50	76.30	72.60

Existing Scenario of Membrane Used



CONCLUSION

Pervaporation over techno-economic solution to separation problem in chemical process industry. It has seen protecting environment thus contributing sustainable development. It offers new areas of separation in high value products. It opens up challenging areas for research and development like development of new polymeric membrane material in engineering design of pervaporation operation, modeling for performance prediction, etc.

In general, pervaporation will especially be used in those cases where a small quantity has to be removed from a large quantity. In all the above applications, the most successful processes require integration with existing conventional separation unit operations. Nevertheless, pervaporation have been identified as areas of vast potential for future research and commercial development.

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