

EMERGENCE OF MEMBRANES IN THE TREATMENT OF WASTEWATER AND WATER

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Abstract

The most vital chemical element on earth is water. Although the annual precipitation on the surface of the globe may be adequate, the uneven distribution of rainfall does not satisfy human needs in all parts of the world. Existing water supplies may be saltier than what is considered potable in some desert regions. As a result of rising population and standard of living, careless water use in many large cities, and most importantly, pollution of natural water reserves by sewage and industrial waste, many areas in many cities have reached a critical point where they are unable to meet rising demands. Desalting can be a useful addition in this situation to help with wastewater reclamation. Desalting technology is used in pollution control and includes a broad view of the problem of pollution in general, its technological solutions, applications in the social and economic spheres, and desalting techniques like distillation, deionization by membranes, salt separation by freezing, and chemical deionization methods. In this sense, membrane processes have a significant impact on lowering water scarcity. They can be employed to treat waste waters before they are released into surface water, to recover industrial materials before they end up in waste streams, and, of course, to treat water for human consumption. The effectiveness of membranes in treating water and wastewater has been greatly influenced by their capacities. Desalting has been practised since ancient times. The Bible contains the earliest mention of turning salt water into fresh water, where the bitter water became pleasant after passing through wood. Aristotle (384–322 BC) also described the procedure used by seafarers to draw fresh water from the ocean. In a kettle of boiling seawater, they hung sponges from the ceiling. Squeezing the sponges allowed freshwater to be retrieved

after the vapours had condensed on them. The wax pot experiment by Aristotle is another crucial link. Numerous Arab and Byzantine intellectuals from antiquity wrote about desalination. In the writings of Al-Hirani, Al-Biruni, Nikephoros Blemmides, Gilbertus Angelicus, and others, the citations can be found. Famous scientists who tried to desalt water include Sir Richard Hawkins, Hauton, Samuel Reyer, Thomas Bartholin, and Robert Boyle. Giorgio Nebbia and Gabriella Nebbia Menozzi provided an outstanding overview of the development of various desalting processes throughout history.

Paper Identification



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INTRODUCTION : Humans, ecosystems, the food and water processing industries, as well as other sectors of society are all under serious threat from the fast industrialization and ever-increasing pollution brought on by human activity. Prior to release, harmful industrial effluents needed to be eliminated since they pose a risk to human health. In order to address these environmental challenges, scientists want materials that are environmentally friendly, naturally selective, incredibly repeatable, and effective at removing hazardous metal ions. Solvent extraction, adsorption, pre-concentration, reverse osmosis, and ion exchange are just a few of the techniques that have been developed to remove these metals from aqueous systems. When zirconium aluminophosphate (ZrAIP) is made using the sol-gel method [28–30], an inorganic precursor is hydrolyzed, condensed, aged, and then dried. In specifically, distilled water was used to agitate a mixture of 0.1 M aluminium sulphate (Merck, 99%) and 0.1 M zirconyl chloride (Otto Kemi, 99%). In order to create gel, 0.1 M orthophosphoric acid (Fischer scientific) was continuously added to the mixture. The gel was then allowed to age for 24 hours at room temperature.

TECHNIQUES FOR DESALTING :

Desalting methods can be divided into two broad groups, as shown in Table 1.1: (i) processes that remove salts from solutions, and (ii) processes that isolate pure water from solutions. Both of these categories have the potential to develop into valuable separation procedures.

Separation Processes

| Water from solution | Salt from solution |
|------------------------------|--------------------------|
| 1. Distillation | 1. Ionic processes |
| Vertical tube evaporator | Ion exchange |
| Horizontal tube evaporator | Electrodialysis |
| Multi-stage flash evaporator | Transport depletion |
| Vapor compression | Osmionic |
| Solar evaporation | Piezodialysis |
| 2. Reverse Osmosis | Electrochemical |
| 3. Crystallization | Biological system |
| Freezing | 2. Other processes |
| Hydrate formation | Liquid-liquid extraction |

Table 1.1. Methods for separation are broadly categorised.

The most advanced method for eliminating salts from aqueous solutions is electrodialysis and ion exchange. In terms of the use of chemicals or electrical energy to regenerate the resins, their economic viability is highly dependent on the salinity or raw water content. In order to purify brackish water, they may therefore be used.

THE DEVELOPMENT OF MEMBRANE TECHNOLOGY ACROSS TIME

Building on Zsigmondy's earlier work, Sartorius created the first membranes for use in practical applications in Germany after World War I. Nitrocellulose membranes were used as ultrafilters in Zsigmondy's study to separate macromolecules and tiny particles from an aqueous solution. These dense ultrafiltration membranes manufactured at the same time as the porous cellulose nitrate or cellulose nitrate-cellulose acetate membranes were solely used in the laboratory. Ferry has studied early research on membranes for microfiltration and ultrafiltration. Kolff was the first to show how membranes could be used in haemodialysis in the 1940s, despite the fact that the phenomenon of dialysis has long been understood.

DEFINITIONS OF MEMBRANE AND MEMBRANE FUNCTION

MEMBRANE

H. K. Lonsdale stated in the editorial a comprehensive definition of membranes provided by many researchers working in the field of membrane studies, including: Membranes are described as such in Webster's New Collegiate Dictionary. A piece of parchment that is a portion of a roll and (i) a thin, soft, malleable sheet of animal or plant origin. These definitions are outdated and simplistic in comparison to the modern world. In the second edition of the McGraw-Hill Dictionary, the term "membrane" is given a different, more accurate definition as the "ion exchange medium used in dialysis, diffusion, osmosis, reverse osmosis, and electro dialysis" and "the medium through which the fluid stream is passed for the purpose of filtration." A membrane can be viewed as a phase or group of phases that regulates the transport of matter and energy between two fundamental uniform phases that it separates, according to Patrick Meares, a renowned scientist in the department of chemical engineering at the University of Exeter and a longtime editorial member of the Journal of Membrane Science. A thin sheet that divides two phases and serves as a picky impediment to the transport of materials is another definition of the membrane. While preventing others, it permits the passage of some drugs.

MEMBRANE OPERATION

In a membrane operation, a feed stream is split into two major streams: a permeate that contains materials that have passed through the membrane and a retentate that contains species that are not permeable (Figure 1.1). Membrane operations can be used to fractionate a mixture as well as concentrate or purify a solution, suspension, or combination. The following straightforward expression can be used to represent the transmembrane flux for each element for all transport phenomena:

$$\text{Flux} = \text{Force} \times \text{concentration} \times \text{mobility}$$

The gradients of chemical potential $d\mu_i$ of every component that can be transported serve as local forces in Eq. 1, which is appropriate to treat as a local equation. In the majority of cases, the concentration will vary with distance through the membrane and through the boundary layers at the two interfaces of the membrane fluid.

Component i 's chemical potential can vary as the sum of the following terms:

$$d\mu_i = RT d \ln a_i + V_i dP + Z_i F D\psi \quad -2$$

The pressure P and electric potential can be changed to enhance the separation between mobile components when the activity a_i is not under the arbitrary control of the operators. Eq. 2 can aid in making a qualitative decision regarding the membrane's functionality.

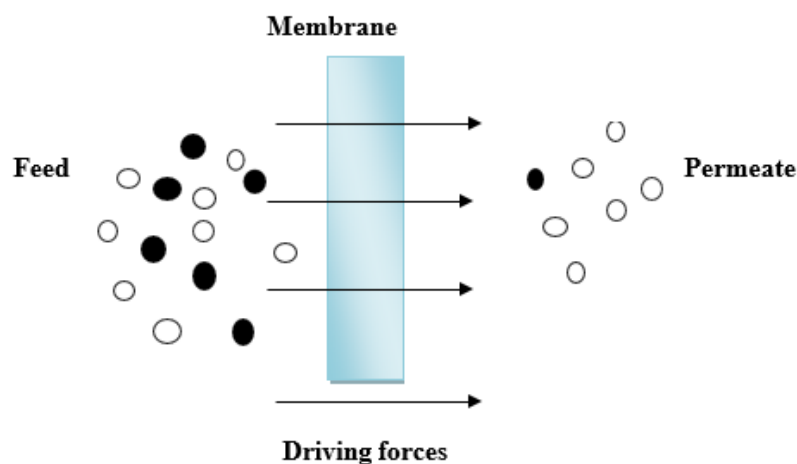


Figure 1.1. Schematic diagram showing membrane operation under the effect of driving forces (ΔT , ΔP , ΔC , ΔE).

Few gradients that are present on each side of the membrane frequently cause membranes to react. Therefore, the gradients to which the membrane operations respond can be broadly categorised, and these gradients are as follows:

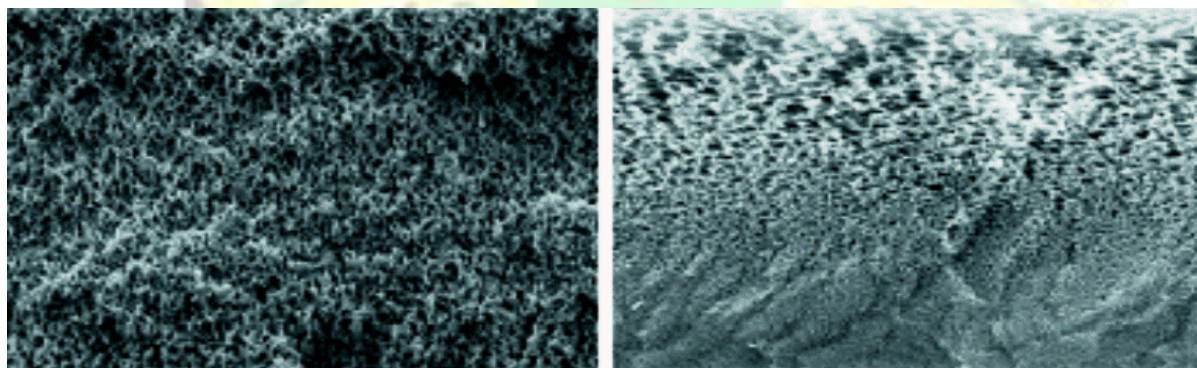
- ❖ Membrane structure
- ❖ Phases in contact
- ❖ Driving force
- ❖ Separation mechanism

MEMBRANES THAT ARE SYMMETRIC OR ISOTROPIC

A symmetric or isotropic membrane, such as a microporous, dense, or electrically charged membrane, is one that has the same physical and chemical structure throughout its thickness in the direction of travel of the penetrating species. Symmetric membranes typically have a thickness between 10 and 200 μm . The entire membrane thickness in this situation determines the resistance to mass transfer. An increase in penetration rate is caused by a reduction in membrane thickness. Symmetric structures were produced as a result of the polyethersulfone-based Kraus patent. The most current products are based on polyethersulfone, while symmetric membranes Durapore (polyvinylidene fluoride) and Ultipore (Nylon66) continue to hold the majority of the market share in 2006. It is possible to think of symmetric membranes as having pores with sizes that are essentially constant throughout their thickness. So each percentage of thickness would contribute equally to flow resistance if it were divided into two equal parts.

ANISOTROPIC OR ASYMMETRIC MEMBRANES

Asymmetric or anisotropic membranes, such as thin film composite membranes, are defined as having varying chemical and physical properties depending on the direction of the thickness of the membrane. These membranes are composed of a very thin, very selective top layer called the skin that is supported by a much thicker, porous substrate that is typically made of the same material but could very well be comprised of different materials. Asymmetrical structures are typically produced in one piece with the thin active layer if the materials are the same. These are made up of a very dense top layer or skin that ranges in thickness from 0.1 to 0.5 μm and is supported by a porous sublayer that is between 50 and 150 μm thick. The sublayer is merely there for mechanical support and provides very little mass transfer resistance. The only factor affecting the overall flow and selectivity is skin structure. Each equally thick fraction of each asymmetric membrane has a unique pore size and flow resistance. High transport rates and excellent separation are also possible with anisotropic membranes, which also solves the issue of mechanical integrity that arises when handling ultrathin membranes. Asymmetric microporous membrane structures were created by Wrasidlo in the middle of the 1980s as a result of the development of a new class of polymers, initially polysulfone and later a more stable polyethersulfone. The asymmetric polyethersulfone-based membrane Sartopore 2 from Sartorius was introduced to the biotech filtration industry in 1997.

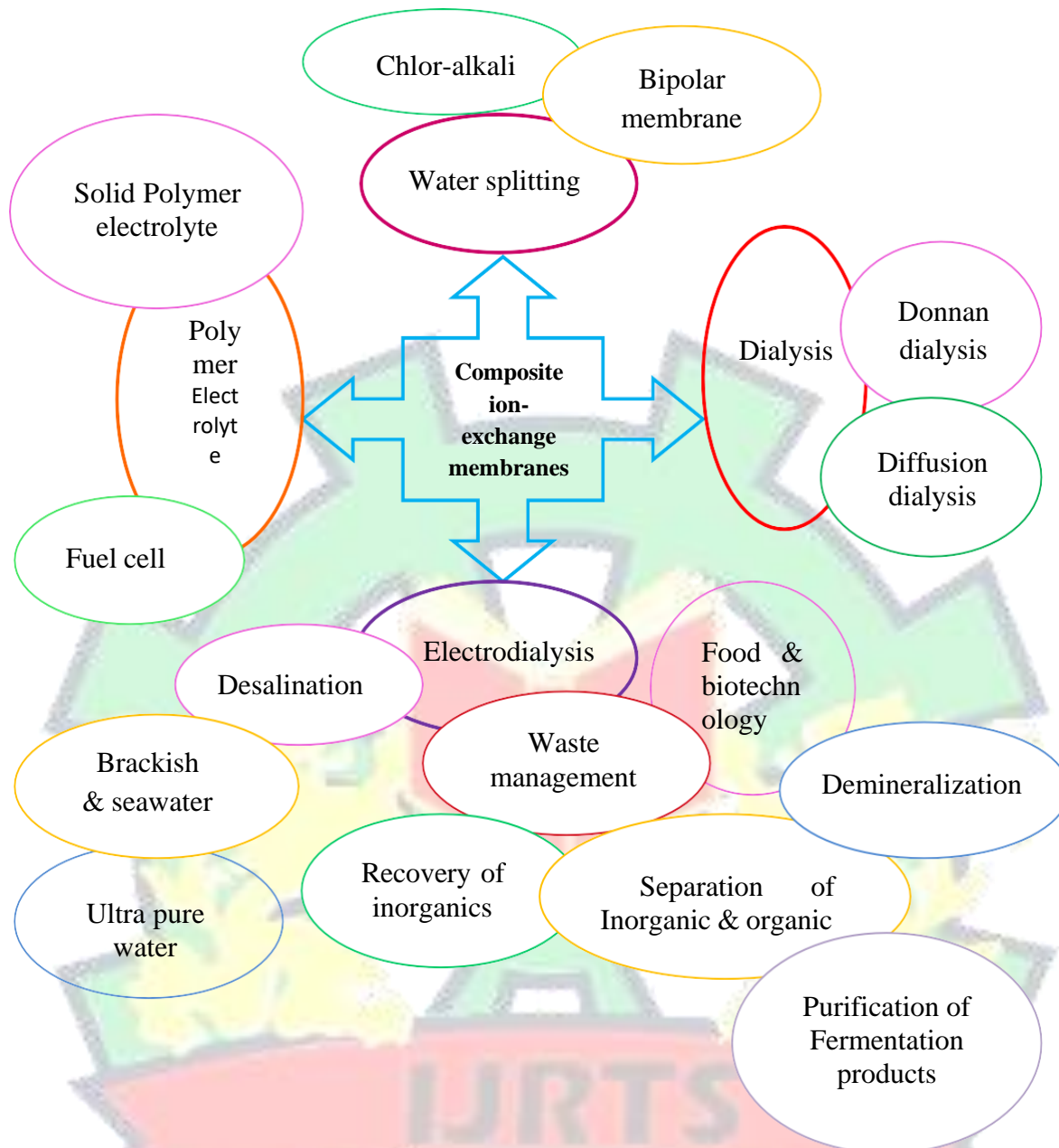


Symmetric and Asymmetric Membrane cross-sections are shown in micrographs, respectively.

BIOTECHNOLOGY MEMBRANE PROCESSES

The use of membrane separation techniques for treating bioactive ingredient solutions is advantageous because they are non-thermal, mild, and don't require any additives. The following list of biotechnology's diverse applications, including how membrane processes contribute, is provided:

- (i) Methods for recovering and using enzymes or entire cells have been improved.
- (ii) Improvements in techniques for immobilising them
- (iii) The creation of enzyme membrane reactors.



Summary of composite ion-exchange membrane applications in various processes

In the field of biotechnology, bioactive hybrids are used to create biosensors and bioreactors. Livage et al. It have recently reviewed these fields. They use the high activity of enzymes, antibodies, or microorganisms to carry out particular reactions that aren't conceivable using the conventional chemical pathways. To be reused and shielded from denaturation, active biospecies are immobilised on or in solid substrates. Enzymes are produced by a variety of microorganisms, including fungus and bacteria, and are used in fermentation processes to make things like medications, drinks, and food. Currently, bio-immobilization through covalent binding or entrapment is accomplished using synthetic polymers such polyacrylamides, polyvinyl alcohol,

and biopolymers like proteins-albumin, collagen, and gelatin [147]. In biosensors for the titration of glucose, optical bio-sensors or amperometric biosensors have been widely utilised.

PEMFC (PROTON-EXCHANGE MEMBRANE FUEL CELLS) USES

The proton exchange membrane is the most crucial component in the fuel cell core for cell efficiency and longevity. Its functions include acting as a gas separating barrier (H_2 , O_2), allowing proton transport from the anode to the cathode, and being an electron nonconductive substance. Typically, organic polymers having acidic properties like carboxylic, sulfonic, or phosphonic groups that dissolve when solvated with water to enable H_3O^+ hydrated proton transfer make up membranes. As a result, the number of ionic groups and the rate of hydration are connected to membrane performance. Aromatic-based polymers, such as polysulfones, poly(benzimidazoles), poly(imides), or poly(aryletherketones), also known as PEEK, are among the potential materials, but they must be functionalized with sulfonic groups to be used. The flow diagram (Figure 1.1) unequivocally demonstrates how composite ion-exchange membranes can be used in a variety of operations and daily life.

CONCLUSION :

Numerous membranes have been created, such as composite membranes made of phosphonated poly(vinyl alcohol) and zirconium iodophosphate, polystyrenebismuth oxyiodide, poly(vinyl chloride)-zirconium aluminophosphate, and polystyrenetin molybdate. Precipitation, precipitation-deposition, and sol-gel processes have all been used to create these membranes. Composite membranes made of inorganic precipitated materials and organic binder are crucial in membrane research to meet separation science requirements. The synthesis to look at the shift in selectivity for different electrolytic ions was successful. It has also been done to phosphonate one of the membrane synthesis routes to clearly demarcate its function in the membrane's water uptake property, which also confirms the existence of pores responsible for the transport capabilities. In order to confirm that the composite membranes were formed, the characterization of the membranes using FT-IR, XRD, TG-DTA, and SEM examination was compared for the pristine and composite membranes. To demonstrate the transport property through the membranes, the various electrochemical properties for various electrolytes in differing concentration ranges have also been extensively examined. One of the most crucial electrochemical parameters to know about is membrane potential, which gives information on the transport number, mobility ratio, fixed charge density, distribution coefficient, and charge effectiveness of the ions moving across the membrane. Numerous monovalent electrolytic solutions with various cations and anions were utilised in a range of concentrations to study these

features. With regard to them, the cation with the smallest size exhibits the greatest selectivity, but for anions, differences are discovered based on size, mobility ratio, and strong interaction with the membrane matrix. To determine the fixed charge density of the membrane, various theoretical models—Nagasawa, Kobatake, and Teorell Meyer and Sievers—have been addressed.

Various counter- and co-ions have been used to study the membranes' permselectivity. In separation sciences, the permselectivity of the membrane, or its propensity to distinguish between counter and co-ions, is crucial. To verify its highest selectivity for any specific ions of the electrolytes used throughout the experiment, permselectivity 175 of the various composite membranes were obtained. The structure of the membrane, the size of the permeating component, the chemical make-up and electrical charge of the membrane material and permeating components, as well as the driving force, such as a concentration or electrical potential gradient across the membrane, all affect how quickly a component can move through a membrane. The membrane with good electrochemical characteristics can be employed in separation technology if it meets these requirements.

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