

POLYMERIC INORGANIC COMPOSITE MEMBRANES FOR WATER PURIFICATION

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ABSTRACT- The term "selective barrier" refers to an interface or membrane that is very narrow and hence prevents material from moving between phases. The ability of narrow sheets of solution to penetrate particular materials is determined by their unique physical and chemical properties. These materials can be either natural or manmade. The numerous benefits of polymeric-inorganic composites over traditional membranes have propelled them to the forefront of engineered material advancements. Polystyrene, PVC, tungstate, metal phosphate, and arsenate are among the metal oxides that can be used to create synthetic membranes. For separation applications, the vast majority of synthetic membranes now in use are polymer-polymer composites. Their bulk structure, production method, surface chemistry, and shape are the criteria used to classify them. The chemical and physical properties of synthetic membranes and the fundamentals of membrane separation methods are all part of what are known as differentiators. Metals, ceramics, liquids, polymers, or a combination of the two are some examples of inorganic materials that can be used to create artificial membranes. Heterogeneous solids, such as mixed glasses or polymeric mixtures, can be used to produce composite materials, in addition to liquids and uniform polymer sheets. Linear ion-exchanger gel membranes on a disk and a ribbon are indistinguishable from one another. Membranes with distinct histological properties are created when a colloidal ion-exchanger and an inert binder are combined. The biotech, textile, fuel cell, water purification, food, pharmaceutical, and other multibillion dollar industries might all benefit from membrane-based innovations.

Keywords: *Polymeric-inorganic composite, Membrane characteristics, Membrane classification, Membrane applications, Water purification process.*

1. INTRODUCTION

The ability of a membrane to act as a selective barrier prevents molecules from undergoing phase switches. By obstructing the passage of bulky materials, a membrane divides a space into two distinct portions. The ability of particle species to traverse physicochemical barriers between adjacent phases or compartments is dependent on their properties and composition. Adobe, a massive straw-and-clay mixture, has had a significant influence on global history. Particle size has a direct correlation to the size of the interparticle distance in composite mixes. Microcomposites and nanocomposites rely on these types of materials. Selectivity, shock resistance, chemical and physical strength, and electrical conductivity are all critical properties of composite membranes that enable them to perform well in demanding environments. To fulfill the requirements, it is necessary to select the appropriate inorganic material and polymer binder. Nylon, polyamide, polysulfone, polyvinyl alcohol,

polytetrafluoroethylene, and cellulose acetate are common composite materials utilized in membrane production.

Materials utilized include plastic and polypropylene. Composite membranes are made out of inorganic compounds and can include oxides, tungstates, carbonates, metal phosphates, and arsenates, among others.

The sol-gel technique simplifies the production of screens by combining polymers with inorganic chemicals. Hybrid approaches, in-situ polymerization, molecular self-assembly, co-precipitation, and intercalation are other viable options for achieving this. The development of hybrid anion exchange membranes utilizing liquid or sol-gel silane binding agents has been an area of intense focus. The effectiveness of the coating process is influenced by the membrane's ionic conductivity. This is demonstrated by many strong functional groups, such as sulfonic acids, phosphonic acids, and quaternary ammonium salts. Primary, secondary, and tertiary amines, as well as carboxylic acids and hydroxyls, are examples of weak ionic functional groups that contribute. Based on the results, it is clear that ionic conductivity is insufficient to produce highly ionic conductive membranes with an increased number of holes.

The amount of porosity in a hybrid membrane can be controlled by selecting the appropriate inorganic and organic components and manufacturing techniques. The mixed membrane's conductivity increases with increasing amounts of water. Industrial applications can only benefit from materials with low water content and high ion conductivity. Reduced water volume and increased ionic conductivity are two requirements for commercially viable composite membranes.

2. MEMBRANE SEPARATION TECHNOLOGIES

A polymeric-inorganic hybrid membrane's particle flow can be regulated by adjusting the pore size. With larger capillary diameters, particles are unable to pass the cell membrane. Membrane filtration is relatively insensitive to changes in pore size. The effectiveness of these barriers in preventing mass transport is highly dependent on their thickness and porosity. A thicker barrier should, in principle, make particle passage more difficult. In most cases, the reaction of a membrane begins with surface gradients. When dialysis, ultrafiltration, microfiltration, or nanofiltration are employed in reverse osmosis, concentration gradients perform optimally. Pressure gradients are the most effective for these approaches. At each junction, the size of the membrane holes determines the subsequent step. The ability to conduct electricity is the most common metric employed by researchers, although there are many more attributes that can be considered while designing membranes. When fabricating membranes for use in electrochemical reactions, such as water electrolysis or fuel cell batteries, consideration of species transfer is critical. Improving the functionality of membranes is crucial for electrochemical systems. Membranes play the role of molecular sieves in processes such as ultrafiltration, nanofiltration, and reverse osmosis. The electrochemical membrane separates the fuel and oxidant molecules by use of conductive pathways and molecular sieves. Troubles arise for membranes whenever there is a shift in the electric field. In Figure 1, we can see the membrane-splitting process.

The selectivity, stability, speed, and durability of a membrane determine its mass-separating capabilities, as do its properties under pressure and high temperatures. When using membrane material, it becomes more challenging to distinguish between substances with comparable electrical or chemical properties as well as molecular weights. A hybrid membrane's stability in the face of heat, chemicals, and mechanical stress determines its lifespan. Whenever the feed solution's pH fluctuates, process temperatures are high, or membrane cleaning is required frequently, this becomes critically crucial. When it comes to ultrafiltration and reverse osmosis, the mechanical properties of the membranes are mostly affected by pressure. Membrane characteristics ought to remain constant regardless of feed solution changes or duration of use. Optimal performance from membrane separation systems is possible with enhancements to their transport characteristics, flux rates, and operational lifetimes.

3. CLASSIFICATION OF MEMBRANES

The ability of membrane technology to purify surface, brackish, marine, and well water is well-known. Water can be treated to a drinkable standard using pressure-driven membrane technology. The optimal membrane technology to use is proportional to the size of the water contaminants and additives. Salty sources, such as the ocean or subterranean aquifers, are a common source of potable water for humans. Many previously uninhabitable areas now have access to potable water because to innovations in renewable energy, pretreatment, and reverse osmosis. Due to insufficient supplies of potable water, the situation worsens. Nanofiltration and reverse osmosis (RO) remove pathogens from water, however to a lesser degree. Multiple methods have been developed for the removal of inorganic microcontaminants from water, including electrodialysis, Donnan dialysis, membrane bioreactors, and the removal of heavy metals, arsenic, and fluoride ions. Nanofiltration (NF) and reverse osmosis (RO) are two high-pressure membrane processes that remove dissolved organic contaminants from water. Environmental regulations, water scarcity, and common sense all point to an increase in the use of membrane technology.

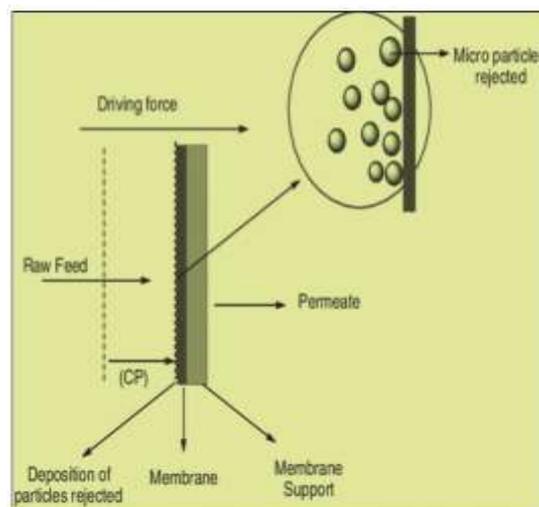


Figure 1: Schematic representation of composite membrane separation processes.

The particles of the colloidal ion-exchanger are held together by an inert glue. Different from cation exchange membranes, anion exchange membranes allow only ions with a negative

charge to flow through. A homogeneous membrane is one in which the charges are uniformly distributed over its surface. Using cross-linked polystyrene and metallic phosphate or tungstate, cation-selective membranes with a homogeneous composite distribution can be made. The components of anion-selective membranes include polystyrene, metal, and quaternary ammonium (NR+4) groups. By combining the chloromethyl group with the benzene ring and producing trimethylamine from quaternary ammonium, an anion exchange product can be obtained by treating polystyrene with monochloromethyl ether and aluminum chloride.

Mixed membranes do not provide a uniform distribution of the minute ion-exchange particles. A long-lasting heterogeneous membrane with finely dispersed ion exchange particles is created by mixing a polymer plastisol mix with an inorganic ion exchanger. There are various types of membranes, including liquid, micro, ultra, nano, reverse osmosis, ion exchange, and a combination of inorganic and polymeric materials. Membranes are classified according to their porosity and their ability to transport substances. Membranes are organized into groups as seen in Figure 2.

The finely ground ion-exchange particles do not disperse uniformly in heterogeneous membranes. A long-lasting heterogeneous membrane with finely and unevenly distributed ion exchange particles can be made by combining an inorganic ion exchanger with a polymer plastisol mixture. Polymeric inorganic composite membranes, ion-exchange, liquid, ultrafiltration, nanofiltration, and reverse osmosis are among the many varieties of membranes. A new kind of membrane is the polymeric inorganic substance. Figure 2 shows that membranes can be categorized in various ways.

4. POLYMERIC-INORGANIC COMPOSITE MEMBRANES

The most effective engineered materials are compounds of polymers and inorganic elements. Composite screens include both organic and inorganic polymers, however the exact proportions vary. Inorganic and polymeric properties coexist in these membranes. At high temperatures, inorganic materials remain stable and permit ion movement between them; in contrast, polymers are both flexible and capable of joining. Membranes are typically made of polystyrene, polyaniline, or polyvinyl chloride due to their stability and flexibility. Composite membranes have medical, chemical, and materials science applications.

The majority of the time, in industrial processes, fluids containing ions are cleaned, separated, and reused using composite membranes composed of solid polymeric and inorganic ion-exchange materials. Common examples of membrane ion exchange materials include humus, montmorillonite, zeolites, clay, and resins.

The wide range of applications for polymeric inorganic composite ion-exchange membranes stems from their exceptional cation exchange capabilities. These membranes find usage in electrochemical separation, electrodeionization, fuel cell storage batteries, electrodialysis, and many more. Scientists seeking ion-selective membranes will find these goods useful. Cation exchange membranes have been the subject of extensive research due to their practical applications in industry. Despite their usefulness in environmental research for separating and identifying potentially dangerous anions in wastewater and potable water, anion exchangers

have received relatively little media attention. A large number of amphoteric converters exhibit simultaneous ion and cation trading capabilities. The production process and chemical composition determine whether an ion exchange is selective or nonselective.

5. APPLICATION OF POLYMERIC-INORGANIC COMPOSITE MEMBRANES

New membrane-based technologies might have far-reaching consequences for multimillion-dollar corporations in a wide range of sectors. They manufacture fuel cells, biotechnology, clothing, pharmaceuticals, foodstuffs, and potable water, among other things. A variety of procedures make use of polymeric-inorganic hybrid membranes, including gas separation, electro dialysis, hemodialysis, microfiltration, and ultrafiltration. Water electrolysis, fuel cells, and batteries all require membranes, which might potentially undergo species transfer. The electrochemical membrane outperforms more traditional forms of filtration in terms of performance. Like molecular sieves, membranes in ultrafiltration, nanofiltration, microfiltration, and reverse osmosis do their jobs. The membrane separates the anode and cathode in electrochemical devices by functioning as a molecular filter. It stops the fuel and oxidant from mixing. Changes in electric fields present a significantly greater obstacle for membranes. Households, labs, businesses, and even the government all make use of it in different ways.

Composite membranes are preferable to other options because they are stable, can only let heavy metal ions pass through, and have the ability to interchange ions. Membranes like these have application in the following sectors:

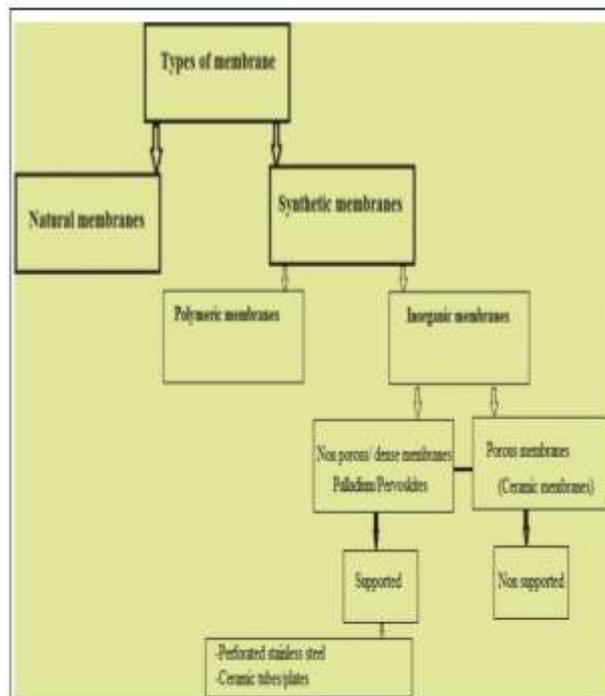


Figure 2: The schematic representation of membrane classification

5.1. For Preparation of Qualitative Water

Brackish, marine, surface, and well water are among the several kinds of water that are created with this method. Water purification is the principal use of pressure-driven membrane technology. What kind of membrane technology is needed depends on how many contaminants and other things are in the water. One common method for purifying saltwater and groundwater into drinkable water is desalination.

Technology, design, alternative energy sources, pretreatment, and application materials have recently advanced to the point that reverse osmosis may produce potable water in resource-poor regions in a sustainable and achievable way. Water is treated using nanofiltration and reverse osmosis (RO) to remove impurities and microorganisms. It is possible to eliminate inorganic micropollutants such as nitrate, fluoride ions, boron, arsenic, chromium, and heavy metals by using techniques like electrodialysis, Donnan dialysis, nanofiltration, membrane bioreactors, and ultrafiltration with polymers and detergents. Reverse osmosis (RO) and nanofiltration (NF) are two high-pressure membrane methods that can be employed to extract DOC from untreated streams. Due to water scarcity, environmental concerns, and the preference for reusing water over discarding it, expanded membrane technology is often necessary.

5.2. Removal of Specific Constituents

Membrane technologies like ultrafiltration, nanofiltration, microfiltration, and reverse osmosis (RO) are finding more and more applications in urban wastewater systems. Before the reverse osmosis treatment, microfiltration and ultrafiltration membranes are submerged to remove various pollutants from the water. Water purification systems that use membrane technology and ultraviolet light oxidation are essential for the elimination of microbes.

5.3. Nuclear Industry

The use of membrane techniques in sustainable technology has the potential to lessen the demands on energy, raw materials, and trash. When it comes to environmental problems, they can handle anything, even those involving nuclear power. Many nuclear power plants across the globe routinely handle liquid radioactive materials. It is critical to have ceramic or composite barriers that can block radiation, chemicals, and heat. Thermal membrane distillation with long-lasting porous membranes was used to quantify the radioactive waste. Ion exchange membranes and liquid membranes are two new electric techniques that could be used in the nuclear sector. Using membranes instead of the present recycling and reuse processes would have been a smart move.

5.4. Pulp and Paper Industry

The pulp and paper sector uses membrane filtering these days. More and more people are turning to membrane filtering as a means to preserve energy, preserve the environment, and recover valuable resources. Water treatment, chemical recovery, and bleaching effluent cleanup are just a few of the many uses for these membranes in the paper and pulp business. Water recycling and the paper and wood sectors' ability to close the loop could both be enhanced by membrane technology. One of the many uses for membranes is in the wastewater treatment, concentration, and separation processes. In an effort to lessen the environmental impact of pulp and paper mills, they are taking steps like reducing water consumption, recycling and recovering valuable materials, and so on.

5.5. Food Industry

The use of membrane technology for food separation and processing is on the rise. Using membrane separations, new materials and meals can be processed. Clean energy includes membrane separation as one of its components. This method concentrates food solutions while avoiding phase changes and high-pressure flow reversal, therefore maintaining the nutrients. The energy that is generated by membranes that use reverse osmosis or ultrafiltration is readily used. By using this method, aromatic chemicals, low-molecular-weight salts, and monosaccharides can be extracted from food. Enzymes, vegetable oils, fermented drinks, and fruit juices can all be concentrated and purified using membrane technology. Membrane technologies that utilize pressure sort particles according to their size. So, in a variety of ways, they are cooking.

5.6. Solvent Purification

Petrochemicals, chemicals, microelectronics, biotechnology, food processing, and medicines are just a few of the many sectors that rely on solvents. putting contaminated solvents back into use, no matter how bad the contamination is. There are many different ways to manufacture or recover liquids using distillation, which is an extremely energy-intensive process. This way of doing things is not workable since it is too expensive, wasteful, and inefficient. Technology that uses screens to separate molecules at room temperature is thus gradually displacing it. An improvement in chemical techniques for solvent recovery and purification should lead to a decrease in commodity costs, energy use, pollution, material consumption, and associated hazards.

5.7. Reagent Purification

Membrane distillation is a way to purify acids like sulfuric, ammonia, hydrochloric, nitric, and perchloric. Membrane distillation involves separating two water solutions of different temperatures using a microporous hydrophobic membrane. Because liquids are unable to pass through the hydrophobic barrier, an interface is formed between the gasses and liquids. Since the original material is difficult to recover using membrane purification, the process is limited to handling a small number of chemical compounds. Concentrating and separating non-volatile substances is possible with membrane distillation. This includes ions, acids, colloids, and macromolecules. Chemical contaminants like benzene and trichloroethylene can also be removed. You can use it to get alcohol out of solutions that are too weak or too watery.

5.8. Pharmaceuticals and Medicine

The medical industry relies heavily on membrane technology. Numerous methods, including as microfiltration, ultrafiltration, and reverse osmosis, can be employed to purify and concentrate molecules of varying sizes. Nowadays, membrane technology is used for a lot of different things, such cleaning, concentration, and chemical separation. Pharmaceutical waste streams can be controlled using evaporation or nanofiltration, thus burning isn't always necessary. There is a vast array of medical device coatings, drug delivery, bioseparations, diagnostics, tissue regeneration, and artificial organ production that utilizes membranes. In the following steps, membrane separation techniques including microfiltration and ultrafiltration are used to clean and separate the biopharmaceuticals. The novel membrane filtration technology allows for the effective separation of monoclonal antibodies.

A variety of methods, including membrane filtration (including nanofiltration and reverse osmosis), bioreactors, and accelerated oxidation, are used to treat wastewater from pharmaceutical companies. Reliable membrane nanofiltration allows for catalyst recovery and solvent changeover. This makes it easier to use organic solvents to make intermediates and medicinal molecules. To enhance the crystallization of therapeutic substances, the pharmaceutical sector utilizes hollow fiber membranes.

5.9. Soil Science and Technology

The restrictions require the removal of organic pollutants and hazardous metals from the property. The contaminants that were present in the solid matrix are still present in the wash distillate, which is produced by washing dirt with water. Concentrating cleansed liquids using screens is not usual practice. Membranes have a wide variety of fascinating uses. Both the concentration and reduction of pollutant quantities are the goals of these methods. Heavy metals were removed from soil via acid dissolution, microfiltration, and nanofiltration. Microfiltration was used to extract soil particles from leachate that included metal. Through the use of nanofiltration, the quantity of acid that was lost in the slurry could be recovered, and the amount of runoff was decreased. Using membranes to filter out debris should efficiently and thoroughly remove metals with less waste, according to the small-scale research.

6. CONCLUSION

The process of membrane separation can be accomplished using electrodialysis, hemodialysis, microfiltration, gas separation, reverse osmosis, or pervaporation. Groundwater in India isn't fit for human consumption and must be treated before it can be utilized. Desalination is a procedure that gets water from salt or seawater and makes it drinkable. Two effective methods for purifying water are reverse osmosis (RO) and membrane distillation (MD), which are briefly discussed on this page. Reverse osmosis (RO) membranes are the best option for desalinating saltwater and groundwater since they can successfully filter out contaminants and provide room for advancement. Membranes for desalination, which are a combination of inorganic and polymeric components, have been employed in the vast majority of newly built plants in the past forty years. The metal used to make this membrane was die cast into a mold. A combination of organic and inorganic molecules in the correct proportions is made. Synthetic membranes are classified into different classes according to their description and their intended purpose.

REFERENCES

1. Gangopadhyay, R., & De, A. (2001). Conducting polymer composites: Novel materials for gas sensing. *Sensors and Actuators B: Chemical*, 77(1), 326–329.
2. Ulbricht, M. (2006). Advanced functional polymer membranes. *Polymer*, 47(7), 2217–2262.
3. Souza, V., & Quadri, M. (2013). Organic–inorganic hybrid membranes in separation processes: A 10-year review. *Brazilian Journal of Chemical Engineering*, 30(4), 683–700.
4. Gohil, G. (2006). Preparation and characterization of monovalent cation selective



- sulfonated poly(ether ether ketone) and poly(ethersulfone) composite membranes. *Journal of Colloid and Interface Science*, 298(2), 845–853.
5. Beg, M., & Matin, M. (2002). Studies with nickel phosphate membranes: Evaluation of charge density and test of recently developed theory of membrane potential. *Journal of Membrane Science*, 196(1), 95–102.
 6. Balster, J. (2005). Preparation and characterisation of monovalent ion selective cation exchange membranes based on sulphonated poly(ether ether ketone). *Journal of Membrane Science*, 263(1–2), 137–145.
 7. Scherer, R. (2001). Preparation and physical characterization of a sulfonated poly(styrene-co-divinylbenzene) and polypyrrole composite membrane. *Materials Chemistry and Physics*, 71(2), 131–136.
 8. Chiang, C. (1978). Electrical conductivity in doped polyacetylene. *Physical Review Letters*, 40(2), 1472–1475.
 9. Gurunathan, K. (1999). Electrochemically synthesised conducting polymeric materials for applications towards technology in electronics, optoelectronics and energy storage devices. *Materials Chemistry and Physics*, 61(3), 173–191.
 10. Nagarale, R. K. (2004). Studies on electrochemical characterization of polycarbonate and polysulfone based heterogeneous cation-exchange membranes. *Reactive and Functional Polymers*, 61(2), 131–138.