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REVIEW ON USE OF MEMBRANE PURIFICATION IN RADIOACTIVE WASTE MANAGEMENT

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ABSTRACT

The dangers of radionuclides emitted by nuclear power plants are well recognized. To condense the radionuclides and prevent their diffusion into the environment, separation methods are employed. The current study discusses recent developments in the treatment of radioactive waste utilizing membrane separation technology. The first section covers membrane techniques for collective radionuclide separation, whereas the second section covers membrane techniques for selected radionuclide separation. Reverse osmosis, precipitate followed by ultrafiltration or microfiltration, and membrane distillation are all techniques for separating radionulides. Liquid assisted membranes, polymer inclusion membranes, solid synthetic polymer electrolysis, nanofiltration, electrochemical salt-splitting technique, and other sophisticated separation technologies have been used to isolate individual components.

KEYWORDS: *Membrane purification, Purified radioactive source, radioactive wastes, Electrolysis.*

INTRODUCTION

Nuclear fuel cycle activities (uranium conversion and enrichment, fuel fabrication, and spent fuel reprocessing), procedure of nuclear power stations, disinfecting and decommissioning of nuclear facilities, and organizational uses of radioisotopes (medicine, industry, agriculture, research reactors, and test facilities) are indeed the main sources of radioactive waste. Liquid radioactive waste must meet extremely stringent demands in order of radioactive element and other impurity limits in order to be released into the environment safely (suspended particulates, biofoulants and organic or inorganic chemicals). The waste must be processed to meet the requirements outlined in national laws, which include mass loss as well as the reduction of radioactive substances and other dissolved substances in the effluent. Chemical precipitation, sedimentation, ion exchange, thermal evaporation, biological methods and membrane permeation are some of the methodologies used to treat fluid radioactive waste. In addition to waste disposal, radioactive isolation and purifying for specific uses are also required. Insulation materials have shown good potential from the front end of the nuclear fuel cycle, i.e. mining, to the back end, where irradiated wastes are digested for safe disposal. When subjected to the action of a driving force, a membrane acts as a protective layer between two phases, remaining impermeable to specific particles, molecules, or substances. The membrane allows some elements to pass through into the permeate stream, while others are maintained and accumulate in the retentate stream[1].

Membranes come in a variety of thicknesses and structures, including homogeneous and heterogeneous. Membranes may also be categorized based on the size of their pores. There are three distinct pore diameter (dp) size categories according the International Union of Pure and Applied Chemistry (IUPAC): microporous (dp 2 nm), mesoporous (2 nm dp 50 nm), and pore structure (dp > 50 nm). Particle transport may be active or passive, and membranes can be neutral or charged. Pressure, concentration, chemical, or electrical gradients across the membrane may help with the latter. The various membrane processes. With the advancement of membrane technology, custom-made membranes for specific separations have become commonplace. Group colloid removal (concentration-based separation) and particular element purification are two of the ways in which the technique is used. The former involves removing activity using a mix of radionuclides found in the waste stream[2].

Individual elements such as molybdenum, iodine, cesium, strontium, tritium, lanthanides, and actinides are separated in the latter. The number of reviews on membrane applications in radioactive waste treatment is rather small. The role of reverse osmosis (RO) and membrane distillation (MD) in the disinfection of low-level wastes has indeed been extensively discussed. Other membrane technologies, such as supported films, haven't yet before been investigated. The current review provides information on various recent membrane filtration applications in the diagnosis of radioactive wastes. Membranes' use for both collective and selective radionuclide removal is also discussed[3].

DISCUSSION

1. Collective ion and colloid removal:

RO and MD have been widely used in purification methods for collective radio-colloid elimination. By putting pressure to the solution while it is on one side of a selective membrane, the RO filtering technique eliminates inter - correlated from solutions. As a consequence, the solute is kept on the pressured side of the membrane while the pure solvent (typically water) is permitted to flow through. Figure 1 depicts a schematic of the RO process. This barrier should not allow big particles to pass through the holes in order to be "selective," but smaller components of the solution (such as the solvent) should be allowed to flow freely. The greatest separation is achieved in a thick barrier layer in the polymer matrix of reverse osmosis membranes. The membrane is usually constructed to allow just water to flow through this thick layer, blocking the passage of solutes (such as salt ions). This procedure necessitates a high pressure, typically 2-50 MPa, on the highly concentrated side of the membrane. Elements such as Cs, Sr, and Co are the primary beta-gamma emitters, whereas actinides are the primary alpha emitters. It is feasible to produce activity concentration discharge values of less than 10 kBq/m^3 for beta and gamma emitters, and less than 1 kBq/m^3 for alpha emitters. The variance in discharge levels is mostly due to size differences. Synthetic polymeric Micropores cannot handle acidic or alkaline solutions above the 4-9 pH range, despite their ability to tolerate a significant amount of radiation exposure. MD is based on the relative volatility of different components in the feed solution. The partial pressure differential across the barrier provides the driving force for transit. Separation happens when a convection or diffusive process allows solvent vapor (typically water vapor) to flow through the membrane pores [4].

The vapor pressure differential between the two remedy interfaces owing to a temperature difference is the driving factor for vapor transport in this process. MD has some similarities to pervaporation (PV), another membrane-based separation method, but there are several key distinctions. Direct contact of the membrane with a liquid feed and evaporation of the penetrating components are used in both techniques. PV, on the other hand, utilizes nonporous membranes whereas MD uses porous membranes. Instead of molecule weight or size, the chemical nature and shape of the polymeric membrane, as well as the degree of interaction between the polymer and the permeants, are key variables to consider in nonporous membrane. A solution diffusion process transports across nonporous membranes, and separation is accomplished by variations in solubility and/or diffusivity. As a result, the pore size and average pore diameter of such membranes cannot be used to describe them[5].

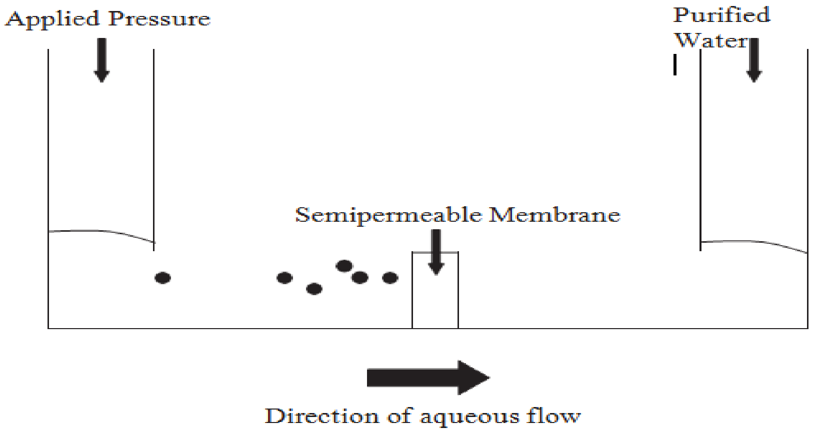

Figure 1Schematic of reverse osmosis In a typical U-tube experiment liquid level is shown by curved lines[5]

1.2 Ceramic membranes:

The usefulness of RO membrane in the pH range has indeed been addressed before. This claim was made in reference to polymer-based membranes, which have been widely utilized in the application. When compared to organic polymer-based membranes, ceramic membranes are thought to be superior in terms of fouling resistance. Because of their excellent thermal, mechanical, and chemical durability, zeolite membranes have gotten a lot of interest in this area. Furthermore, due of their distinctive pore structures, zeolite membranes offer a lot of potential for separating mixtures of molecules through adsorption and molecular sieving. Separation by photovoltaics (PV) and vapor permeation (VP) utilizing ceramic membranes may be a cost-effective and energy-efficient alternative to traditional distillation, especially for azeotrope or close-boiling liquid combinations. On various substrates, several kinds of supporting polycrystalline zeolite membranes with minimal inter-crystal holes were created.

Atomic sieving, competitive adsorption, and diffusion are some of the general processes for separation across ceramic membranes. Supposedly, zeolite membranes are appropriate for ion removal from aqueous solutions by RO, according to a molecular dynamic simulation. The simulation showed that utilizing RO via zeolite membranes, 100 percent Na rejection could be accomplished, MFI being one commercialized kind. The size exclusion of hydrated ions, which have kinetic sizes (0.8-1.0 nm for ($Na(H_2O)x$)) considerably greater than the opening of the MFI zeolite membrane, is the separating mechanism of flawless MFI zeolite membranes (diameter 0.51 nm)[6].

2. Selective radionuclide removal:

Membranes are changed for various treatment methods in order to separate particular components. Ion-selective membranes, fluid membranes, and ion-exchanger-based membranes are the three main types. Supported liquid membrane and polymer inclusion membranes are two types of liquid membranes. Membrane cells are used in electrochemical processes to remediate waste components. The salt is electrochemically divided and allowed to flow across a cation sensitive or anion selective membrane in this technique, resulting in a final solution that really is cation or anion free. Electrochemical systems have the benefit of being able to handle a variety of wastes, or streams containing specific waste components, in a single treatment unit. For industrial electrochemical operations, a variety of ionselective membranes have been created[7].

Supported liquid membranes (SLMs) integrate extraction and strip into a single phase, while traditional methods such as solvent need two distinct steps. Solvent extraction of metal ions just at interface between a feed solution and a membrane, transport of a extracted species to the contrary side of the membrane, and rear at the other side of the barrier between the membrane and an able to receive solution are the three processes involved in metal ion separation using maintain the position membranes. The greatest driving power for the separation of a target species is provided by a one-step liquid membrane method. The organic liquid immersed in the pores of a microporous support, such as microporous polypropylene hollow fibers, is the liquid membrane phase in SLMs. When the biological liquid comes into touch with the microporous support, it quickly wets the team's pores, forming the SLM. The organic-based SLM is located between two aqueous solutions, the feed solution and the strip solution, for the harvesting of a target species from an aqueous feed solution, where the SLM acts as a semipermeable membrane again for transport of the target organisms from the feed water to the strip solution. The SLM's organic component is immiscible in the water feed and strip streams and consists of an extractant, a diluent (usually an inert organic solvent), and a modifier. Facilitated transport is the method by which the target species moves from the feed solution to the strip solution in SLMs[8].

3. *Ceramic membranes:*

The usefulness of Filter medium in the pH range has been addressed before. This claim was made in reference to polymer-based membranes, which have been widely utilized in the application. When compared to organic thermoplastic membranes, ceramic membranes are thought to be superior in terms of fouling resistance. Since of their excellent thermal, mechanical, and chemical durability, zeolite membranes have attracted a lot of interest in this area.

Furthermore, due of their distinctive pore systems, zeolite membranes have a high potential for separating mixtures of molecules through adsorption and molecular sieving. Separation by photovoltaics (PV) and vapor permeation (VP) utilizing ceramic membranes may be a cost-effective and energy-efficient alternative to traditional distillation, especially for azeotrope or close-boiling liquid combinations. Various kinds of supporting polycrystalline zeolite films with minimal inter-crystal holes have been produced on various substrates. Molecular sieving, competitive adsorption, and diffuse are some of the general processes for separation across ceramic membranes. Theoretically, zeolites are appropriate for ion removal from aqueous solutions by RO, according to a molecular dynamic simulation. The simulation showed that utilizing RO via zeolite membranes, 100 percent Na rejection could be accomplished. MFI being one commercial kind. The size restriction of hydrated ions, which have kinetic sizes (0.8e1.0 nm for ($Na(H_2O)x$)) considerably greater than the opening of the MFI zeolite membrane, is the separation mechanism of flawless MFI zeolite films (diameter 0.51 nm). In Table 3, the sizes of hydrated ions are listed. The results of simulations and experiments using mesoporous membranes to completely separate ions and dissolved chemical molecules from aqueous solutions revealed that zeolites may be able to separate ions and disintegrated organic compounds simultaneously from aqueous solutions using RO. Another zeolite-based membrane, Zeolite NaA membranes (NaA is the commercial name), was produced by hydrothermal treatment on a porous a-alumina substrate with subsequent growth crystallization and tested for low-level nuclear solution decontamination using the RO method. More than 99 percent rejection factors were found for ionic solutions of 0.001 M Cs, Sr_2, and MoO_2.The hydroxyl sodalite barrier is another example of this kind of membrane. At high temperatures, the performance of this membrane was shown to be better to that of zeolite membranes. In the temperature range 303-473 K and pressure 22 MPa, sodium salt rejection of w99.99 percent was recorded[9].

4. *Distinguishing particular components:*

The radioactive wastes produced by nuclear fuel cycle operations come in a variety of forms. Depending on the kind and amount of radioactivity, as well as the chemical composition and physical condition of the waste, each form of waste needs a unique treatment.High Level Waste (HLW) is one of the most dangerous wastes generated in the nuclear industry, accounting for approximately 99 percent of the overall radioactivity emitted in various waste streams throughout the nuclear fuel cycle. Remanufacturing may recover valuable nuclear elements such as uranium and plutonium (produced by neutron irradiation of 238U) from spent fuel. The PUREX method, which is built on a solvent extraction approach, is the most popular aqueous cleansing method. As an extractant, it utilizes tri-n-butyl phosphate (TBP) dissolved in a hydrocarbon diluent such n-dodecane. After dissolving the spent fuel in nitric acid, the uranium and plutonium are recovered into TBP and peeled using appropriate strippants. After the recovery of uranium and plutonium, the highly radioactive waste raffinate includes numerous radionuclides as well as large amounts of actinides such as neptunium, americium, and curium, which are poorly recovered in TBP. In addition, this waste solution contains tiny percentages of uranium and plutonium that were not removed throughout the processing. Evaporation concentrates the raffinate, which contains all of these radioactive nuclides, into highly radioactive liquid waste (HLW). This trash contains a wealth of useful radioisotopes that may be separated and purified for specific uses. Membrane technique has been successfully proven for the separation and purification of particular radionuclides, and it has applications in a variety of fields[10].

CONCLUSION

The information presented in this article suggests that capacitors have a broad use in radioactive waste handling. On an industrial scale, communal element removal has been implemented; nevertheless, the bulk of data on individual element separation comes from experimental size studies. This indicates that additional effort is needed to go from a modal to an actual scale. The use of nanoparticle-encrusted screens in water filtration is becoming more popular. The use of nanoparticles in membrane fabrication provides for more control over fouling as well as the capacity to create desired structure and functions. Both sorption and catalytic degrading applications have been used with them. There are no studies on these for the purifying of radioactive waste, thus this is an essential new field to research.

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