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Removal of Monovalent and Divalent Cations from Brine Water by Electrodialysis Using Modified Polyethersulfone Membranes

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Toxic Metal Ions; Wastewater; Polymeric; Ion Exchange; Cation-Exchange Membranes.

Highlights:

- Treatment brine water by electrodialysis.
- Removal toxic metal ions from brine water.
- Modified polymeric membrane to process wastewater.

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Abstract: In electrodialysis, an ion exchange membrane removes unwanted ions from wastewater and toxic metal ions from effluents. Montmorillonite-based modified "polyethersulfone membranes" have been studied as a potential small-scale electrodialysis approach for removing ions from wastewater. The study featured several steps, including solid polymerization, electrolyte balance, and removal of each component from the water. The study used three distinct "cation-exchange membranes (CEM)" types. The selected water body was diluted 100 times before being added to the electrodialysis cell in amounts of the center, cathodic, and anodic chambers, each containing 55, 30, and 40 mL. The initial pH for the real solutions of the water body was 7.16 at 25°C. Compared to "Sulfonated poly arylene ether sulfone (S-PESOS)" (23.23%) and Nafion® (35.34%), "hexamethylenediamine (HEXCl)" stands out as the only cross-linked material with significantly high-water content. When the membrane water content is too high, the membrane may lose its mechanical strength and cannot provide enough ionic conductivity. The semi-empirical model's parameters were estimated to simulate the elimination of Na⁺, K⁺, Ca²⁺, and Mg²⁺ by three membranes. HEXCl and S-PESOS were electrodialyzed and used to treat the serial dilution from the water with cationics. The removal rate gradually rose after the electrodialysis started.

إزالة الكاتيونات أحادية التكافؤ وثنائية التكافؤ من المياه المالحة عن طريق التحليل الكهربائي باستخدام أغشية بولي إيثرسولفون المطورة

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الخلاصة

في الغسيل الكهربائي يتم استخدام غشاء التبادل الأيوني لإزالة الأيونات غير المرغوب فيها من مياه الصرف وإزالة أيونات المعادن السامة من النفايات السائلة. تمت دراسة "أغشية البولي إيثرسولفون" المعدلة القائمة على المونتوريلونيت كنهج محتمل على نطاق صغير للذيلزة الكهربائية لإزالة الأيونات من مياه الصرف. تضمنت الدراسة عدة خطوات بما في ذلك توازن إلكتروليت البلمرة الصلبة، وإزالة كل مكون من الماء. استخدمت الدراسة 3 أنواع متميزة من "أغشية التبادل الكاتيوني". (CEM) تم تخفيف الجسم المائي المختار 100 مرة قبل إضافته إلى خلية التحليل الكهربائي بكميات من الغرف المركزية والكاثودية والأنودية تحتوي كل منها على 55 و 30 و 40 مل. كان الرقم الهيدروجيني الأولي للحلول الحقيقية للجسم المائي 7.16 عند 25 درجة مئوية. عند مقارنتها بـ "بولي أربيلين إيثرسولفون المسلفون (S-PESOS) (23.23) % (و 35.34) % Nafion®)، يبرز "hexamethylenediamine (HEXCI)" باعتباره المادة الوحيدة المترابطة التي تحتوي على محتوى مائي أعلى بشكل ملحوظ. عندما يكون محتوى الماء في الغشاء مرتفعاً جداً، فقد يفقد الغشاء قوته الميكانيكية ويكون غير قادر على توفير ما يكفي من الموصلية الأيونية. تم تقدير المعلمات المقدره للنموذج شبه التجريبي لمحاكاة التخلص من Na^+ و K^+ و Ca^{2+} و Mg^{2+} إما عن طريق ثلاثة أغشية. تم تحليل HEXCI و SS-PESOS كهربائياً واستخدمت لمعالجة التخفيف التسلسلي من الماء باستخدام الكاتيونات. ارتفع معدل الإزالة تدريجياً بعد بدء الغسيل الكهربائي. تشير هذه النتيجة إلى أن عملية الإزالة قد تم تسريعها قليلاً قبل الانتشار الداخلي.

الكلمات الدالة: أيونات المعادن السامة، مياه الصرف الصحي، البوليمرية، التبادل الأيوني، أغشية تبادل الكاتيونات.

1. INTRODUCTION

A membrane is a key part of electrochemical sensors. The electrical current in an ion exchange membrane decreased, implying that the toxic metal ions solution's electrolyte properties are reduced and removed from wastewater [1]. According to Alakhras et al. [2], electro dialysis is a viable technique for selective ion separation in wastewater and a powerful method for desalinating brackish water. Numerous studies have been conducted on electro-membrane techniques to retrieve, separate, neutralize, and concentrate either minerals or acids. Polymeric materials, presumably perfluorinated or not, can be used to create membranes. Perfluorinated membranes, like Nafion®, have higher electron electrical properties of about 0.1 S/cm and excellent oxidative and resistance to chemical attack. However, because of their steep cost, they only have a restricted number of applications [3]. Nano-, micro-, ultra-, electro dialysis, and fuel cell technologies are various non-fluorinated membrane types created to desalinate seawater. Comparable membranes include those made of Nafion® [4]. "Poly (ether ether ketone)-block-sulfonated polybutadiene," "poly (ether ether ketone)-block-sulfonated polyvinylidene fluoride (PVDF)" copolymers, and "sulfonated-fluorinated poly (arylene ether)s" with exceptional Proton conductivity and membrane ion exchange properties are only a few examples, which exhibits notable mechanical improvements and thermal constancy. Sulfated poly-aromatic membranes are often inexpensive, environmentally benign, and adequately impervious to chemical attacks [5].

According to Caprarescu et al. [6], "styrene-acrylonitrile copolymer" combinations have also been used to electro dialyze Cu (II) ion removal from effluents, "with such an extraction efficiency of 70% under potentiostatic conditions. Montmorillonite-based modified polyethersulfone membranes have been studied as a potential small-scale electro dialysis" approach for removing the zinc ions from wastewater. The modified montmorillonite enhanced the separation efficiency of the final membranes. Caprarescu et al. [7] investigated crystal violet for removal from the solution using a membrane infused with real fruit extracts. At a constant voltage of 15 V, the treatment procedure was conducted in electro dialysis cells. At 90 minutes, approximately 96% of the dye was removed, and the utilized membranes remained stable at 330°C. Monovalent and divalent ion separation from untreated wastewater is a recurrent problem in industry, especially in areas with high salinity [8]. Making water supply is a different situation. Magnesium and calcium cations must be largely eliminated to create adequate soft water. The lowest level for human health in drinking water is 500 mg/L of overall dissolved salts [9]. Due to the need to keep the lowest level of salinity, monovalent ions and cations responsible for water hardness, including magnesium and calcium, must be removed to produce drinking water [10]. Concentrate, commonly referred to as brine, is a desalination byproduct that has a detrimental impact on its ecosystem due to its high salinity. Brine management methods must be practical and economical to lessen environmental

damage [11]. Various disposal techniques have been recently used, such as surface flowing water, sewage disposal, deep-well injection, evaporating ponds, and land application. These thermal desalination techniques, however, are not viable due to their high capital expenses and limited applicability. Treatment reduces environmental contamination and waste volume and produces freshwater with a high recovery rate, currently considered one of the most reasonable options for brine disposal [12]. An efficient potable water additional treatment technology for removing natural organic matter (NOM) from water samples is anion exchange (AIX), which uses anion exchange resins. Due to its simple operation, changeable structure, and on-site regeneration, it has been widely employed in drinking water [1-3]. However, one of the main disadvantages of the AIX method is the production of anion exchange wasted brine. Due to the high concentration of desorbed NOM made primarily of humic substances (HSs) and excess inorganic salts, primarily NaCl, and the high conductivity of this wasted brine, it is not biodegradable [4,5]. As a result, full-scale use of AIX in the water supply is constrained by the difficulty and expense of anion exchange wasted brine disposal [6]. The standard techniques for disposing of spent anion exchange brine are underground storage, landfills, sewage or ocean discharge, deep well injection, and evaporative ponds [5- 8]. However, deep well injection, ground storage, and landfills seriously contaminate groundwater and degrade the soil [5, 6]. Dumping into the ocean also pollutes and upsets its ecological equilibrium [5]. To create NaCl, evaporation ponds require a lot of land and energy [6,8]. As a result, it is essential to develop and implement a sustainable and cost-effective strategy for treating wasted brine from ionic interaction. Secondary plant products may be recovered to solve the issue. The anion exchange wasted brine contains NaCl and HSs that can be segregated to produce highly concentrated NaCl for on-site developers to reuse while reusing the HSs in agriculture and cattle breeding [13,14]. Electrodialysis (ED) has been suggested as a viable electro-membrane technique to distinguish between inorganic and organic chemicals [15]. It is frequently utilized in industrial effluent and brackish water treatments. From saltwater reverse osmosis brines, significant concentrations of NaCl might be obtained using electrodialysis [11]. The leachate of commercial household waste could also be concentrated or desalinated by electrodialysis [16]. Recently, anion exchange wasted brine treatment has begun to use electrodialysis. Three methods—NF, UF, and ED— were quickly detailed to extract NOM from a simulated humic acid solution (produced by Aldrich) [17]. The findings of the

NaCl and NOM separating using ED were incomparable to the actual anion exchange wasted brine since the ED phase separation did not compare its energy usage. Another study proposed a two-stage prototype ED to cleanse the spent brine and recover its NOM [23]. However, no information was provided regarding ED's energy requirements since the concentration of the retrieved NaCl solution was low. Some new NaCl solution was required to be blended in for resin regeneration. On the other hand, a combined impact of the applied electric field and ion exchange membranes perm selectivity just on the desalination efficiency of ED for wasted ion exchange brine was examined [18]. However, neither the efficiency of the pilot-scale electrodialysis nor the passage of the NOM components using the "ion exchange membranes (IEMs)" was examined. The ion exchange membrane type significantly impacts the desalination/concentrate effectiveness in the ED system [19,20]. Operating parameters, i.e., concentrate volume and flow rate, also affect ionic movement over ion exchange membranes [21,22]. The present study investigates the possibility of using a "solid polymer electrolyte (SPE)" or an anionic membrane in such an alkaline fuel cell. The ionic conductance and transportation numbers were first assessed using the potentiometric method and electrochemical impedance to determine the membrane's electrochemical characteristics.

2. EXPERIMENTAL PROGRAM

2.1. Apparatus and Procedures

For such a study, three distinct types of cation-exchange membranes (CEM) were used, as shown in Fig.1. The 10% cross-linked sulfonated polyether sulfone hexamethylene diamine (HEXCl) and octylamine-grafted sulfonated polyether sulfone (S-PESOS) were purchased. The Nafion membrane is offered for purchase. Excellent chemical and mechanical stability, low electrical resistance, and perm-selectivity are the S-PESOS and HEXCl membrane characteristics. An anionic exchanging membrane was also employed using the Polymeric Anion-Exchange Membrane (PAEM). Due to the development of the fuel cell with a proton exchange membrane technology, "sulfonated poly arylene ether sulfone (SPES)" has attracted much attention in the field of membrane synthesis. However, handling these materials can be challenging, and weakening and solubilization have been noted during heating. Novel materials are being studied using SPES implanted with varied octylamine ratios. Their water solubility was decreased using octylamine grafting, improving their manageability and suppleness. The ionic conductivity depends on the graft rate.

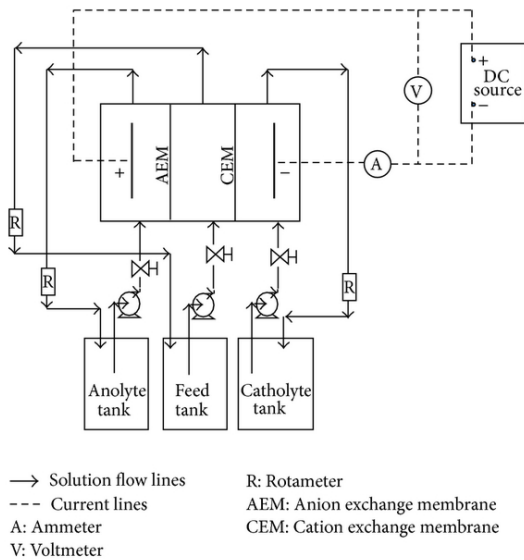


Fig. 1 Sketch of the Desalination Experiment Using Electrodialysis.

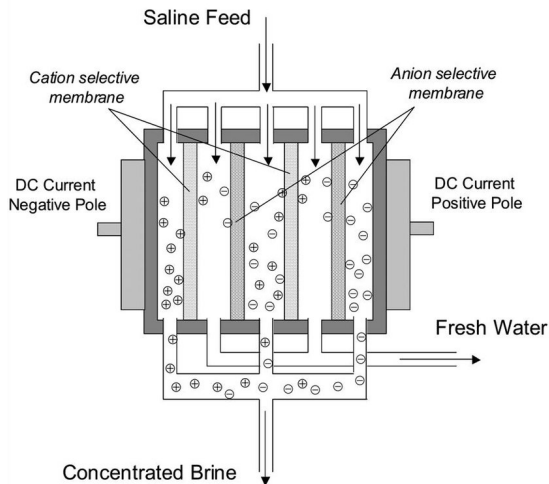


Fig. 2 Unit of Electrodialysis Desalination.

The polymer created the membrane with a sulfonated group and 0.3 grafted octyl sulfonamide groups, each made from a monomeric unit. This membrane had a proton conductivity of around 1 mS/cm when tested with 1.0 mol/L H₂SO₄. It was discovered that proton transport numbers were close to one, as shown in Fig.2. The novel membrane, made with hexamethylenediamine and polyether sulfonesulfochloride, is sulfonated polyether sulfone cross-linked with 10% HEXCl. Utilizing a novel technique and 1,6-hexamethylenediamine at low temperatures, it was cross-linked. The rate of sulfonation was over 1.10 mmol/g. The Hittorf approach yielded a value for the ionic protonic transport number of 1.0. The polymeric substance is identical to S-PESOS in having one free sulfonated group for every monomeric unit. Due to its cross-linking, the membrane cannot be dissolved in polar or water-based solvents. It has an ionic conductivity like S-PESOS. "Cross-linking occurs more quickly; this tends to increase

hardening and lessen the flow of ions. Nafion comprises perfluoro-sulfonic acid, a hydrophobic fluorocarbon spine, and hydrophilic sulfonic acid pendant side chains. This Nafion-based film primarily used in chlor-alkali electrolysis, acting as a perm-selective barrier." Nafion® membranes in polymer electrolyte membrane fuel cells were frequently used due to their excellent proton conductivity and less water distention. This membrane's equivalent weight and thickness were 1100 g/mol and 178 μm, respectively. High sulfonation levels in Nafion® membranes improve the elimination of monovalent ions like Na and K. Effective proton conduction can be produced by placing hydrophilic/hydrophobic sequence structures in Nafion®. Recently created by Mabrouk et al. [13], PAEM is simple to set up and has good capabilities that may be used in sizable electro dialysis plants. Considering this, PAEM has recently been used to remove nitrate anions from aquatic media. Compared to removing acetate anions, the anion-exchange film demonstrated great selectivity. The PAEM ionic conductivity was examined using potentiometric and electrochemical impedance techniques. The Hittorf and Henderson procedures were used to estimate the transport rates. The water content and "ion exchange capacity (IEC)" were also measured. More than 0.95 was found for the Henderson transport number values. The Hittorf approach, in contrast, produced better results, with values in the 0.99–1.00 range. 13.3%–18.4% water was found to be exhibited.

2.2. Experimental Procedure

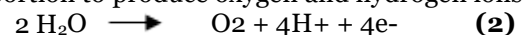
Figure 3 describes the process in detail and the subsequent steps.

2.3. Experimental Sets

The selected water body was diluted 100 times before being added to the electro dialysis cell in amounts of the center, cathodic, and anodic chambers, each containing 55, 30, and 40 mL. The initial pH for the real solutions of the water body was 7.16 at 25°C, and the initial ion concentrations of sodium, potassium, calcium, and magnesium were 336.12, 1086.98, 279.09, and 204.01, respectively. The experiment had a current intensity of 50mA, and the ions migrated around the electro dialysis cell from the cathode. On the creation of the electric field, chloride ions were found to have migrated to the anode. As shown in Eq. (1), hydrogen was created because of the electrolytic reduction of the water particles in the cathodic region.



In contrast, soda was produced because the generated hydroxide ions neutralized the incoming sodium ions. According to Eq. (2), water molecules were oxidized in the anodic portion to produce oxygen and hydrogen ions.



This process created hydrochloric acid when chloride ions were moved from the main compartment across all the anion exchange screens. Table 1 exhibits the properties of the four membranes employed in this analysis. The three membranes' differences in structure and characteristics are noteworthy. Only HEXCL was cross-linked, and it had a substantially larger water content (52.78%) than S-PESOS (23.23%) and Nafion® (35.34%). A membrane with high water content may lose its mechanical strength and be unable to offer enough ionic conductivity. The maximum rate of demineralization was produced by the Nafion® membrane, which also had the highest IEC and conductivity, as shown in Fig.4.

3.RESULTS AND DISCUSSION

Table 2 shows the typical ionic makeup of the various solutions. The high concentration of sodium ions (1086.98 mg/L) in the solution substantially impeded the mobility of potassium ions (336.12 mg/L), which explains why Na⁺ initially moved more freely inside the membranes. Table 3 shows sodium, potassium, calcium, and magnesium levels decreased after

125 minutes of electro dialysis. In terms of their rates of demineralization, the examined cations for S-PESOS and Nafion® were rated in the order listed below: Na⁺ > Ca²⁺ > Mg²⁺ > K⁺, etc. The huge ion concentration difference (Na⁺ > K⁺) significantly impacted the monovalent ions; however, the low molar hydrated volume greatly influenced divalent ions (Ca²⁺ > Mg²⁺). The membrane was more selective to divalent ions in the K⁺, Ca²⁺, and Mg²⁺ systems than potassium ions. Due to the high ion valence, the membrane's affinity grew with the ion charge and the electrostatic attraction. The semi-empirical model's estimated parameters were estimated for simulating the elimination of Na⁺, K⁺, Ca²⁺, and Mg²⁺ by three membranes, as shown in Table 4. τ and R_{max} data pair displayed an intriguing dualism, which should be a crucial consideration when selecting the best and most affordable membranes to utilize and the ions to be removed by electro dialysis. The growth of "Sulfonated polymer membranes" for proton exchange membrane fuel cells (arylene ether sulfone) (SPES) has drawn much attention (PEMFC) (refer to Fig. 2 for schematic representation).

Table 1 Various Characteristics of Four Membranes.

Membrane	IEC (mmol/g)	Conductivity (S/cm)	Water Content (%)	Thickness (μ m)
S-PESOS	1.09-1.16	0.013-0.019	21.86-23.23	161-166
NAFION	1.22-1.78	0.102-0.107	31.78-35.34	170-181
HEXCL	1.13-1.54	0.054-0.073	48.98-52.78	95-100
PAEM	0.42-0.59	0.012-0.017	13.23-18.12	81-8

Table 2 Average Characteristics of Diluted Solution with the Water Obtained.

Ion	Concentration (mg/L)
Lithium	0.97
Potassium	336.12
Sodium	1086.98
Bicarbonate	1.25
Magnesium	204.01
Calcium	279.09

Table 3 Na⁺, K⁺, Ca²⁺, and Mg²⁺ Demineralization Rates After 125 Minutes of Electro dialysis Using Three Membranes.

Membrane	Velocity of Average demineralization (%)			
	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
HEXCL	40.09	24.04	41.67	37.86
Nafion	62.78	41.34	45.98	42.02
S-PESOS	55.12	37.89	43.21	40.82

Table 4 Parameter Estimation for Na⁺, K⁺, Ca²⁺, and Mg²⁺ Removal Simulated Using a Semi-Empirical Model.

Cation	Membrane	a (min ⁻³)	t ₀ (min)	t ₁ (min)	C ₀ (mg/L)	C _e (mg/L)	R _{max} (%)	t (min)	ϕ
Na ⁺	HEXCL	1 051 322.0	19.198	133.89	1086.8	658	39.34	101.71	0.006 233
	S-PESOS	692 322.7	25.94	124.23	1086.8	488	54.78	88.43	0.016 968
	Nafion®	952 059.5	50.812	135.45	1086.8	412	62.98	98.35	0.012 989
K ⁺	HEXCL	2 127 655.0	34.634	132.38	334.2	263	24.02	128.68	0.005 895
	S-PESOS	1 097 250.0	31.465	125.67	334.2	219	38.01	103.21	0.011 086
	Nafion®	903 365.2	34.112	120.78	334.2	201	40.98	96.68	0.019 898
Ca ²⁺	HEXCL	1 415 546.0	65.145	127.88	279	169	41.56	112.29	0.011 374
	S-PESOS	931 927.3	30.498	119.81	279	165	42.9	97.68	0.019 467
	Nafion®	2 165 644.0	130.45	134.70	279	158	45.65	129.21	0.005 234
Mg ²⁺	HEXCL	885 172.3	36.898	118.74	208	131	37.37	95.87	0.013 758
	S-PESOS	2 967 742.0	137.89	209.23	208	129	40.56	143.56	0.012 037
	Nafion®	885 096.1	44.989	117.92	208	114	41.93	95.99	0.022 657

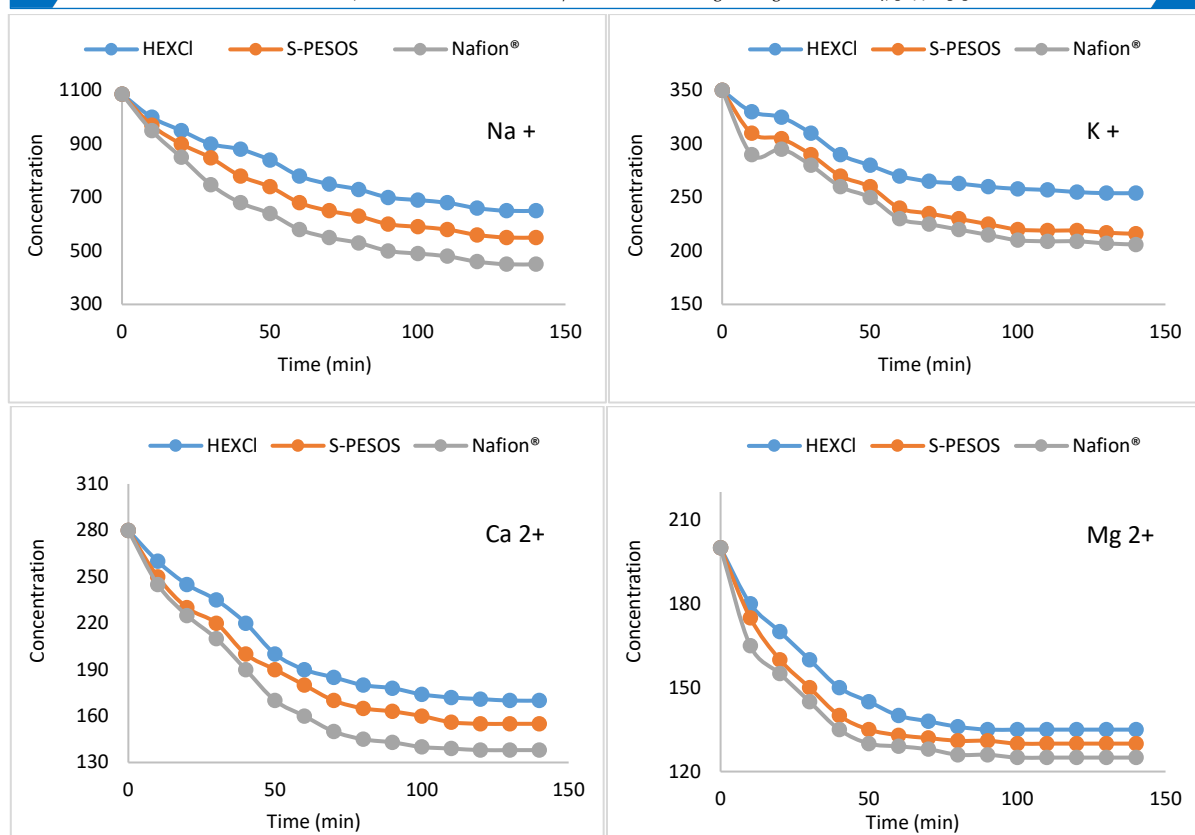


Fig. 5 The Concentrations of Mono Ions (Na^+ and K^+) and Divalent Ions (Ca^{2+} and Mg^{2+}) at $\text{pH} = 7.16$ and $T = 25^\circ$.

However, such membranes are fragile and challenging to work with. The study looked at novel membranes made of SPES grafted with various amounts of octylamine. Five novel materials made with "sulfonated polyethersulfone sulfonamide (SPESOS)" were produced using different amounts of grafting. Their original IEC values were 2.4 meq.g^{-1} (1.3 H^+ per monomer unit) and were constructed utilizing SPES. Whereas the conductivity of Nafionproton® was around 0.1 S cm^{-1} in aqueous H_2SO_4 (1 M) at ambient temperature, virgin SPES with just that IEC was water swelling and then became soluble at 80°C . The material became water-insoluble after being grafted with varied concentrations of octylamine; membranes became less brittle and exhibited adequate ionic conductivity. In the present study, the ion conductivity of SPES was 0.019 S/cm , and IEC was 1.16 mmol/g , which states that it had low conductivity and IEC compared to Nafion [24]. To generate a new proton exchange membrane that can be used in fuel cells with "proton-exchange membranes (PEMFC)," "sulfonated polyether sulfone (S-PES)" and "sulfonated polyether sulfone octyl sulfonamide" were mixed (S-PESOS). S-PESOS was used in five mixes with variable sulfonamide compound grafting ratios developed, described, and tested in a PEMFC. Their comparable chemical structures facilitated these two polymers' compatibility. In the same conditions, the created membranes

showed a sizable capacity for water swelling and an ionic conductivity similar to Nafion® (0.1 S cm^{-1}). The present study showed that Nafion had the highest ion conductivity and IEC, causing the highest demineralization compared to HEXCl and S-PESOS, as it had low water content. In contrast, the HEXCl had the highest water content, disturbing the membrane's mechanical properties and reducing ion conductivity [25]. The ion exchange equilibrium at room temperature (283, 298, and 313 K) is analyzed for three systems, including monovalent and divalent ions, using a CMX cationic exchange membrane. The concentration used for all experiments was 0.1 mol/L . At temperatures ranging from 283 to 313 K, isotherms for ion exchange between Na^+ and K^+ , Na^+ and Ca^{2+} , and K^+ and Ca^{2+} were created for ternary systems. $\text{K}^+ > \text{Ca}^{2+} > \text{Na}^+$ was the resulting affinity order, as shown in Fig.5. It was determined that as the temperature was raised, the selection coefficients for $\text{KK}^{2+}\text{Na}^+$, $\text{K}_2\text{Na}^+\text{Ca}^{2+}$, and $\text{K}_2\text{Ca}^{2+}\text{K}^+$ increased. According to the present study, the high ion valence grew the membrane's affinity as the ion charge did, which enhanced the electrostatic attraction [26]. It was studied whether electro dialysis might remove the traces of fluoride, nitrate, and boron released into artificial aqueous systems, including organic molecules. The hydrated ionic radius and the contaminant's transportation through the ion exchange

membrane were positively correlated without biological matter. Compared to F, which had a large hydrated atomic bond and a strong hydration shell, NO_3^- was effectively eliminated. NO_3^- had a weak hydration shell and a small hydrated ionic radius—the elimination of F and NO_3^- insignificantly affected by solution pH because of their pH-independent speciation. However, raising the pH of the solution and the level of demineralization was required for the boron removal. Membrane deposits of organic material and inorganic trace contaminants impacted the system performance by increasing stack resistance, reducing flow, and eliminating total dissolved solids [27]. Additionally, the membrane's excess water and ion exchange capability were assessed. After that, the SPE was used to assemble an alkaline lab fuel cell, proving the system's feasibility. Finally, the performances were significantly enhanced using an interface liquid between the electrodes and the membrane. In the present study, regarding their demineralization rates, the examined cations for S-PESOS and Nafion® were rated in the following order: $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$, etc [28,30]. To create a composite membrane using Nafion for use in "polymer electrolyte fuel cell (PEFC)" applications at low "relative humidity (RH)," "sulfonic acid-functionalized graphene (S-graphene)" was used as a potential filler material and solid acid proton conduction substrate. Adding "sulfonic acid-containing aryl radicals" to graphene can boost the sulfonate members numbers' per domain volume. By incorporating S-graphene into Nafion, a Nafion-S-graphene composite was created. This membrane efficiently absorbed water at low RH values and rapidly transported protons across the electrolyte membrane. Compared to a pure recast Nafion membrane, the Nafion-S-graphene (1%) composite coating had a proton conductivity of 17 mS cm^{-1} at 20% relative humidity. In their optimal operating conditions (70 degrees Celsius, 20% relative humidity, and room temperature), PEFCs with a polymeric composite membrane provided an energy efficiency of 300 mW cm^{-2} at a loading current density of 760 mA cm^{-2} . The energy capacity of the cleaned casting Nafion membrane, operating under the same conditions, was 220 mW cm^{-2} . The Nafion-S-graphene added sequentially could be used in fuel cell applications to address several significant shortcomings in commercial Nafion membranes. The present study states that a membrane with high water content may lose its mechanical strength and be unable to offer enough ionic conductivity. The maximum rate of demineralization was produced by the Nafion® membrane, which also had the highest IEC and conductivity [29,31].

4.CONCLUSIONS

The study concluded that "hexamethylenediamine" and "Sulfonated Poly Arylene Ether Sulfone" were the two cation-exchange membranes that can be used to treat serial dilution with cationic from water. In terms of removal capacities, they were contrasted with the commercial membrane Nafion® [25]. Dialysis was performed for 125 minutes at a pH of 7.16, temperature of 25, and electrical intensity of 50 mA. The examined cations were graded using the S-PESOS membrane according to their rates of demineralization: $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$ [26-28]. The HEXCl membrane, on the other hand, provided superior treatment for the divalent cations. The degree of modeling of ion removal rate was examined by this study using a developed semi-empirical model. The kinetic modeling increased the removal rate after the electro dialysis.

Abbreviation

IEMs	Ion Exchange Membranes
NOM	Network Operations Management
CEM	Cation-exchange membranes
HEXCl	Hexamethylenediamine
S-PESOS	Sulfonated poly arylene ether sulfone
PVDF	Poly Vinylidene Fluoride
NOM	Natural organic matter -
AIX	Anion exchange
NF	Nanofiltration
UF	Ultrafiltration
FD	Electrodialysis
S-graphen	Sulfonic acid-functionalized graphene

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