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Reverse Electrodialysis Process in Heat Transfer with Energy

Aziz Mohsin Oudah[1,2]
[1]Department of Refrigeration and Air Conditioning Engineering, Azad University, Isfahan, Iran
[2]Iraqi Atomic Energy Authority, Quality Management Division, Directorate of Scientific Policies and Programs
Email address: azizali1234568aziz@gmail.com

Abstract— *In recent years, reverse electrodialysis technologies have become a special separation technology in the water and wastewater treatment industry. The main reason for the development of this technology is the absence of the use of chemicals, the simplicity and at the same time the high efficiency of the process compared to the electrodialysis process. In this research, the reverse electrodialysis process in heat or energy transfer is investigated. The purpose of this thesis was to perform reverse electrodialysis process in heat or energy transfer and it will be examined more closely as a suitable option for progress in the field of energy and heat transfer. The method of this study is library. First, data and information are collected through the study of various articles, and then the work is continued using the laboratory method, and the results of the laboratory method are analyzed and evaluated. In this study, using the results of the laboratory pilot test and the Taguchi method, the optimal conditions for performing the reverse electrodialysis process to produce electrical energy were determined according to the main effective parameters, including the difference in concentration, temperature, and flow rate of two solutions with different concentrations. It was found that the factors selected under the analysis affect the production of electric power with 95% confidence, and the concentration parameter is the most effective factor in the studied system. Also, the electric power produced at different temperatures and concentrations varies with the increase in flow rate, but this increase has a slower trend after certain limits. The results show the ability of the studied system to produce electrical energy from the difference in salinity concentration of two solutions and the possibility of using it in systems such as water desalination plants.*

Keywords— *Reverse electrodialysis, heat transfer, energy transfer, Taguchi method, salt.*

I. INTRODUCTION

While the planet's finite fresh water supplies are slowly being depleted by pollution and climate change, the demand for fresh water on a worldwide scale is rising quickly as human density rises. One of the biggest problems of our day, global water shortage now affects two-thirds of the world's population and is growing alarmingly quickly. Although better water management and conservation are critical responses, more action is required to successfully tackle water shortage, particularly by using unconventional water sources to supplement declining freshwater resources. Alternative water sources, on the other hand, are typically characterized by excessive salinity and need the removal of salt from the water prior to use.

Desalination, the process of separating water from salt, always uses energy, hence reducing energy consumption has long been a priority in the development of desalination technology. Targeting lower salinity waters is a straightforward yet efficient strategy for lowering the minimal amount of energy needed for desalination. As a result, brackish waters (salinity range of around 1 g/L to 10 g/L) are increasingly employed as feed water, in contrast to the abundance, but Much More, as desalination dependence has lately risen. Sodium, Ocean Water So it's essential to find and use the best desalination technology for brackish waters if we want to assure sustainable water production in the future.

More than 80% of desalinated brackish water is produced using reverse osmosis (RO), which currently has the largest desalination capacity worldwide. Contrarily, despite claims that its energy usage is equivalent to or even better than the second-most popular method for desalinating brackish water, electrodialysis (ED), only makes up 8% of the market. Is. RO for unique saltwater circumstances. The circumstances under which each technique is energetically favorable are difficult to differentiate because to the highly different methods of water-salt separation in RO and ED.

A semi-permeable membrane is used in the pressure-based process of reverse osmosis, which enables water molecules to flow through but not solutes. Consequently, a freshwater permeate stream and a concentrated brine stream are produced while the saline pressured feedwater travels over a membrane module. Feedwater pressure controls how much energy a RO system uses since the process requires greater hydraulic pressures than the exit brine's osmotic pressure. The development of the polyamide thin-film composite (TFC) membrane in the late 1970s led to the widespread use of RO, despite the fact that the first live cellulose acetate RO membranes were demonstrated in the 1960s. Current TFC RO membranes enable seawater RO operation with double the lowest thermodynamic energy needs, along with sophisticated energy recovery devices and pumps, making RO an unsurpassed technique for seawater desalination. However, RO energy efficiency is on par with other technologies at lower input salinities, such as in the brackish water regime. Additionally, it has been demonstrated that attempts to decrease the energy consumption of saltwater RO by improving the material characteristics of the membrane (i.e., water permeability) are rather minimal, giving competing technologies a chance to compete for saltwater desalination capacity.

Another relatively established membrane-based desalination method is electrodialysis, which uses electrical technology to desalinate water by transporting ions through a membrane as opposed to water itself. To force ions toward an electrode with an opposing charge, an electric field is provided in ED specifically over a stack of ion exchange membranes. Cations and anions alternately cross the cation and anion exchange membranes as the feed water travels through the flow channels, creating concentrated, ion-depleted solution streams on each side of the membrane. Multi-chamber electrodialysis (ED) has advanced significantly since its initial demonstration in 1940, with applications ranging from the biological, pharmaceutical, and food sectors to the desalination of salt water. As demonstrated in our earlier work, ED is an energy-efficient method for desalinating brackish water due to the creation of highly selective and conductive ion exchange membranes. The market penetration of ED for brackish water desalination is, however, far lower than that of RO and requires additional analysis.

II. REFINED WATER

Any procedure that enhances water quality to make it appropriate for a certain end use is referred to as water treatment. The final purpose might be for drinking, irrigation, maintaining river flow, water enjoyment, or a safe return to the environment, among many other things. Water treatment eliminates impurities and unwanted elements or lowers their concentration so that the water is fit for the application for which it is ultimately intended. Humans may now benefit from irrigation and drinking thanks to this development, which is crucial for their health.

The most essential component for life on Earth is water, and access to drinkable water is a major global challenge in the twenty-first century. All living creatures have a basic requirement for clean, unpolluted water. More than 71% of the surface of the world is covered with water, yet owing to numerous pollution, only around 1% of it is fit for human use. Water contamination is mainly caused by industrial wastewater discharge, agricultural runoff, urban sewage, and environmental and global changes. Heavy metals, dyes, and microorganisms can be harmful to aquatic ecosystems, human health, and the environment at even trace quantities. The United Nations Sustainable Development Group estimates that 733 million people and 2.3 billion people, respectively, would live in water-stressed nations by 2021.

Recovering water from current wastewater or creating alternative water sources for human use are two solutions that must be found to the problem of water shortage.

Wastewater comes in two varieties: domestic and industrial. Domestic sewage is made up of solid and liquid waste products from non-productive activities as well as sewage, bacteria, viruses, poisonous and harmful organisms, and sanitary effluents.

The discharge of untreated sewage from businesses is the main source of water contamination. Distinct businesses release their effluents into rivers or other bodies of water, each with a different amount of pollution. Organic and inorganic contaminants may make up a sizable component of the primary outflow of wastewater. Industries generate wastewater as a byproduct of production procedures, procedures involving paper and pulp, textiles, and chemicals, as well as from a variety of streams such cooling towers, boilers, and production lines.

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A. *Water purification technologies*

- *Processes*

Fig. 1. Empty aeration tank for iron deposition

Hazardous compounds have been removed from water using a variety of treatment techniques. The choice of wastewater treatment systems is influenced by a number of variables, including (1) the degree to which a technique is needed to improve wastewater quality to acceptable levels, and (2) the control method's flexibility. (3) Process cost; (4) Process compatibility with the surroundings.

Physical procedures like settling and filtering, chemical processes like coagulation and disinfection, and biological processes like gradual sand filtration are all used in the removal of contaminants.

Municipal drinking water is treated using a chosen mix of the following procedures (depending on the season and the pollutants and chemicals present in the raw water).

- Chemicals

Fig. 2. Tanks with sand filters to remove sedimented iron (not working at that time)

Chemical techniques are utilized to lessen the discharge of contaminants and sewage into water bodies in addition to physical and biological controls. To transform pollutants into finished goods or to remove pollutants for safe disposal, several chemical processes are utilized.

Pre-chlorination to inhibit biological development and manage algae. If relatively minor levels of manganese are present, aeration with pre-chlorination to eliminate dissolved iron is necessary.

Using chlorine, ozone, and UV radiation, disinfection may eradicate bacteria, viruses, and other diseases.

III. Physical

Physical phenomena rather than biological or chemical changes are used to finish the removal process in physical water and wastewater treatment methods.

The most popular physical exercises include:

One of the most crucial steps in the treatment of wastewater is sedimentation. The process of gravitational sedimentation is used to remove particles from a fluid. Due to the reduction in water velocity throughout the water purification process, the particle in suspension stays stable under static circumstances, and the particles eventually settle by gravity. separating solids is the process of releasing suspended materials that have been enmeshed in a clot.

The method of eliminating contaminants depending on their particle size is called filtering. Water may be reused for a variety of applications once wastewater has been cleaned of impurities. Depending on the contaminants in the water, several filter types are utilized in this procedure. The two primary methods of wastewater filtering are membrane filtration and particle filtration.

The method of extracting dissolved gases from a solution is known as dissolved air flotation (degassing). According to Henry's Law, the partial pressure of the gas and the quantity of dissolved gas in the liquid are inversely related. Degassing, a low-cost technique, raises the pH of the water by eliminating carbon dioxide gas from wastewater.

- *Physicochemical*

Sometimes referred to as "conventional" development. Flocculation-related coagulation Coagulants are added to colloidal suspensions to destabilize them by neutralizing their charges, which causes smaller particles to aggregate during the coagulation process.

Coagulant aids, commonly referred to as polyelectrolytes, are used to strengthen clots and promote coagulation.

Polyelectrolytes, commonly referred to as polymers in this context, are typically made up of either a positive charge or a negative charge. The properties of the source water at the treatment plant alone determine the kind of polyelectrolyte that is utilized.

These are often used with a main coagulant like alum, ferric chloride, or ferric sulfate.

- *Chemical deposition*

The procedure of chemical precipitation is often used to lower the level of heavy metals in wastewater. When dissolved metal ions interact chemically with a precipitating agent like lime, they become insoluble phase. Stronger alkalis may be utilized in industrial settings to induce total precipitation. The common ion effect is often used in drinking water treatment to assist in lowering water hardness. [16]

- *Floating*

To remove particles or dispersed liquids from the liquid phase, flotation exploits bubble attachment.

- *Membrane filtration*

Because it can get rid of inorganic contaminants like heavy metals as well as suspended particles and organic materials, membrane filtration has received a lot of attention for treating mineral wastewater. Depending on the particle size that can be maintained, several membrane filtering techniques, including ultrafiltration, nanofiltration, and reverse osmosis, may be employed to remove heavy metals.

- *Ion exchange*

An insoluble substance (resin) absorbs ions from an electrolyte solution and releases new ions of the same charge in a quantity that is chemically equivalent without affecting the resin's structure. This process is known as ion exchange, which is reversible.

strategies for electrochemical improvement.
Membrane electrolysis (ME),
electrodialysis (ED),
and electrochemical precipitation (EP)

- *Absorption*

A material is moved from a liquid phase to a solid/liquid surface (adsorbent) where it is chemically and physically bound. Adsorption is a mass transfer process (adsorbent). Physical and chemical adsorption, also known as physical adsorption and chemical adsorption, are the two categories into which adsorption may be divided depending on the kind of attraction between the adsorbent and the adsorbent.

- *Activated Carbon*

For a variety of contaminants, activated carbons (ACs) work well as adsorbents. One of its industrial uses is the absorptive removal of undesirable organic and mineral compounds from drinking water and wastewater.

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The effectiveness of activated carbon may be increased by having both a high surface area and a large pore size. Numerous research have employed activated carbon to remove heavy metals and other contaminants from wastewater. Due to a lack of commercial activated carbon, the price of activated carbon is rising (AC). Due to its large surface area, porosity, and flexibility, activated carbon offers a lot of promise for wastewater treatment.

IV. Objective and innovation

The goal of this thesis was to execute reverse electrodialysis in the area of energy or heat transfer, and it will be given greater consideration as a viable choice for advancement. The purpose of this study is to provide a reverse electrodialysis procedure that can aid in improved heat or energy transmission.

V. Related work

A voltage-based membrane process called electrodialysis employs electrical potential to move salt from seawater into the membrane, where it accumulates fresh water. In the 1960s, this technique was initially presented, roughly 10 years before reverse osmosis. This technique was first developed to desalinate seawater, but it is now being used to desalinate freshwater. Methods for electrodialysis often rely on four fundamental ideas: Positive and negative ions make up the majority of water-soluble salts. The ions travel in the direction of the asynchronous electrodes because similar poles attract and repel one another. A appropriate membrane enables one of the anions or cations to flow through. Depending on the kind of membrane, only one type of anion or cation is permitted to travel through the membrane when dissolved ions in salt solutions, such as sodium (+) and chloride (-), are moving in the direction of the opposing electrodes. An anionic membrane follows a cationic membrane in a regular pattern in the membranes. During the process, low-concentration salt water forms within the membranes while the salt water inside the channel is diluted and loses salt concentration. These gaps, which are referred to as being confined by two cell membranes, are where thick and diluted solutions are generated between spaces between alternating membranes. Several hundred cells coupled to electrodes, also known as supports, make up electrodialysis units. For a constant flow of desalination, the incoming water passes through all of the cells at once. Early in the 1970s, reverse electrodialysis was tried. The essential operating principles of reverse electrodialysis are the same as those of conventional electrodialysis, with the exception that the channels for desalinated water and salt water have the same design. Reverse electrodialysis involves moving the ions in the opposite direction of the electrodes multiple times each hour by flipping the electrode poles. The resultant water is immediately evacuated to achieve the necessary quality and empty the pipelines after switching the poles. The restarting of the purifying process just takes a few minutes. The fouling in the membranes is decreased by draining the tubes after each procedure. These treatment systems typically handle low-salt surface water rather than saltwater due to the peculiarities of the electrodialysis procedure. These devices are also utilized in various regions of the US to desalinate surface water

Modeling and design of a combined desalination-solar cooling water system based on the electrodialysis technology was the topic of a study presented by Salek et al. (2017). The usage of sweetening systems is seen to be a solution to these kinds of issues, given the poor quality of the drinking water that was accessible in most Iranian cities as well as the issues with a shortage of drinking water in certain underdeveloped sections of the nation. On the other hand, solar desalination facilities may be employed effectively in Iran owing to its great potential for receiving solar energy. One benefit of a combined desalination-water cooling system in the dispersed production of fresh water, particularly in hotter locations, is the simultaneous cooling of generated water. This study uses an electrodialysis device, an ammonia cooling absorption cycle, and solar heat absorbing surfaces to examine a combined method of producing fresh and cold solar water. The modeling of the system aims to chill the water generated by the ammonia absorption cycle and desalinate it on a modest scale for use in the electrodialysis department. The system receives all of the energy it needs from solar radiation. As a consequence, the solar absorber surface area is around 2,881 square meters, and the radiation diagram indicates that the electrodialysis machine requires at least 10 cells.

In these years, the lost energy in the cooling water of power plants is utilized to manufacture water from salt water, according to a study by Deh Navi and Shokrallahzadeh (2017). In this study, the impact of feeding a reverse osmosis vanguard unit with cooling water from a power plant along the Persian Gulf coast has been examined, along with the effects on the end product's quality and water recovery. Although the generated water flow almost doubled (from 7.5 to 14 L/m2/h) when the feed water temperature rose from 20 to 45 CO, there was a reduction in membrane retraction and salt separation by the membrane. The outcome was an increase in the electrical conductivity of the generated water to between 700 and 1200 S/cm. This shift results from the membrane's greater permeability to salt and water at a higher water temperature. Even if the generated water is still within WHO guidelines, increasing the water flow lowered the desire to consume it. This reduced energy usage for producing water.

The potential for obtaining electricity from the salinity differential between the Bahman Shir River and Khor Goban was the subject of a study presented by Farhani in 2016. The ability to extract energy from the difference in salinity between the Bahman Shir River and the Goban Estuary has been investigated in this study. The extractable capacity and an appropriate site for the power plant are given using the values obtained from measurements of the hydrological parameters of the river and the estuary and equations used in previous studies. The Bahman Shir River and Khor Goban have significantly different salinities, according to measurements taken in the fracturing and sinking circumstances. These observations indicate that the salinity difference of PSU 46, the flow of low-salt water in fractional mode, and the average water temperature at the end of March are all at least 169 cubic meters per second. In the worst case scenario, 166 megawatts of energy can be extracted with this salinity and flow rate difference. However, by implementing the suggested plan to build a channel with a flow rate of 279 cubic meters per second and a similar salinity difference, up to 200 megawatts of energy can be extracted using the reverse electrodialysis method.

A study titled "New advancements in the reverse electrodialysis procedure for energy generation utilizing water salinity difference" is presented by Abbasi et al. (2016). The desire to utilize renewable energy has risen recently due to factors such as global warming, the high price of oil, and the harmful environmental consequences of fossil fuels. Additionally, the mixing of aqueous solutions with various salinities releases a significant amount of energy. This energy is entirely renewable and sustainable. One of the most significant methods for using this salinity differential to generate electrical energy is reverse electrodialysis. By using ion exchange membranes, chemical potential difference driving force, and oxidation-reduction processes in the electrode component of the process, this method may generate electrical energy from a salinity difference. Reverse electrodialysis has been extensively studied so far in terms of process effectiveness, operational circumstances, and economic assessments. Reverse electrodialysis is not yet at the point of being industrialized and commercialized. This research focuses on recent developments that have helped this process become better overall. These studies on process improvement and the rapid advancement of ion exchange membranes demonstrate the possibility for commercialization of reverse electrodialysis in the near future.

A study titled "New advancements in the reverse electrodialysis procedure to create energy utilizing water salinity variations" was presented by Bargahi et al. in 2016. The usage of renewable energy has become more popular in recent years due to factors such as global warming, the high cost of oil, and the harmful environmental impacts of fossil fuels. A lot of energy is also released when aqueous solutions with various salinities are combined. This energy is entirely renewable and sustainable. One of the most significant methods for using this salinity differential to generate electrical energy is reverse electrodialysis. By using ion exchange membranes, chemical potential difference driving force, and oxidation-reduction processes in the electrode component of the process, this method may generate electrical energy from a salinity difference. Studies on the effectiveness of reverse electrodialysis in terms of process efficiency, operating circumstances, and economic assessments have been conducted so far. Reverse electrodialysis is still in the commercial and industrial development stages. The most recent developments in this method' all-encompassing enhancement are the subject of this research. According to studies on process optimization and the advancement of ion exchange membranes, reverse electrodialysis has the potential to become an industrial process in the not too distant future.

A study titled "Investigating the Electrodialysis Method for Water Purification" was given by Ahmadpari et al. in 2016. One of the most vital resources in everyday living, business, and agriculture is water. Water covers the majority of the surface of the world, but only a tiny portion of it can be utilized since sea and ocean water cannot be used because it contains a significant number of salts, particularly table salt. There are numerous desalination techniques available to turn salty water into drinkable water. Membrane technologies are one of these innovative water purification techniques that is often utilized to create useable water from salty water. Due to the use of low pressure pumps, great efficiency, cheaper production costs, and the capacity to remove all kinds of ions, this electrodialysis membrane technology is more appealing to researchers than the others. Ion exchange membranes are the foundation of the technique known as electrodialysis, which employs electric potential as its driving force. Ion exchange resins and polymer membranes are both employed in this system. In electrodialysis, ions are moved through a membrane using an intensity of current from an environment with a lower concentration to a solution with a greater concentration. Through a semi-permeable membrane, undesirable ions are selectively removed during electrodialysis water treatment. The electrodialysis system requires to offer a variety of conditions like water pressure management, membrane layer and direct current power supply. The technique of electrodialysis for water purification has been looked at in this research.

Exergy analysis of reverse osmosis desalination system using nanofiltration (NF) technology is the title of a study by Gadak et al. (2016). To enhance the functionality of the water desalination system, the exergy analysis of the reverse osmosis water desalination system using nanofiltration technology has been described in this study. There is a thorough explanation of the key elements of the water desalination cycle. Exergy and exergy destruction rate are calculated in all positions using the equations governing the problem, EES software, and the available salt concentration, pressure, and mass flow in each position of the desalination system. Due to the pressure drop, salt water is forced through the static mixer, filter, and pressure valves, degrading the system's efficiency. When energy passes through pressure relief valves, it is destroyed at a higher rate than when it enters the high pressure pump. In order to improve the system's efficiency, the pressure transducer is replaced rather than the choke valve.

The research "Comparison of Reverse Osmosis and Electrodialysis Methods in Water Purification" by Durbin and Shahidi (2015) was cited. Because freshwater is so scarce, brackish and saltwater may be treated using a variety of methods, including membrane processes like electrodialysis and reverse osmosis, to remove soluble salts. Reverse osmosis, in general, is a permeation membrane process with pressure acting as its driving force. The main objective of the reverse osmosis technology is to make the water sweeter, while it may also clean the water of dissolved sediments, bacteria, viruses, and other microbes. Although the sea is employed, electrodialysis's purifying agent, direct current, can only reduce the water ions in this procedure. In other words, this method only works with brackish water and its basic tenet is the separation of charged particles. This study, which takes into account the results of studies and researches carried out around the world to determine the best method of water

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purification system, makes technical comparisons between the reverse osmosis and electrodialysis desalination systems—the two most widely used desalination systems globally. have been completed, with the following results. The electrodialysis method is suggested for water purification because it is more effective at desalination than reverse osmosis, causes less membrane clogging, and needs less pre-treatment.

In a 2015 research, Thabit Ahed Jahormi and Mehrfar looked at how well nano-coated anionic membranes could harvest energy from salinity gradients. The salinity gradient force is the amount of entropy produced when two solutions of different salinities are combined. Since the estuary is where fresh and salt water from rivers and the ocean converge, this kind of renewable energy has a lot of potential there. By building a physical model based on the RED technique, the power density w/m2 and energy production efficiency were evaluated in this work. The desired physical model is a single-cell reverse electrodialysis battery with a nano-structured heterogeneous membrane. Utilizing 1 gNaCl/lit, the power density in this system was 0.58 w/m2. freshwater and saltwater concentrations vary. This amount was accomplished by dispersing silica nanoparticles on the battery cell membrane and meticulously arranging the design of the apparatus. The device's efficiency was increased by 11% when compared to non-nano membranes.

Reverse osmosis and electrodialysis are two methods of water filtration that Durbin and Shahidi evaluated in their 2015 study. Many methods, including membrane methods like reverse osmosis and electrodialysis, have been developed to remove soluble salts from brackish water and sea water due to the worldwide water scarcity. Reverse osmosis is essentially a pressure-driven permeable membrane process. However, only water ions may be reduced during electrodialysis since it employs direct electric current as a cleaning agent. In other words, this method only works with brackish water and its fundamental idea is the separation of charged particles. In order to choose the optimum technique of water purification system, technical comparisons between reverse osmosis and electrodialysis desalination systems—the two most used desalination processes worldwide—have been done. The findings demonstrate that, despite the better desalination effectiveness of the electrodialysis method, reverse osmosis is still the most widely used desalination technique globally.

A article written by Qadri and Hosseini in 2014 was titled "Investigation of membrane processes in desalination of salt water: a review of reverse osmosis and electrodialysis methods." Groundwater, lakes, rivers, the atmosphere, and polar glaciers make up less than 3% of the world's fresh water (precipitable water). This proportion is quite small. As a consequence, the bulk of the water on Earth is collected as salt water in the seas and oceans. Due to limits on fresh water supplies, much research is required to find creative ways to use saltwater sources. The Shai approach is one of the contemporary methods for removing salt from water that has recently grown in prominence in countries with a scarcity of fresh water supply. Due to its high efficiency and low operating cost, membrane separation has been employed for this purpose since the 1960s of the previous century and is now being investigated as a consequence. Membranes are used in the microfiltration, ultrafiltration, nanofiltration, and reverse osmosis processes to filter out suspended, colloidal, and other forms of microorganisms. One of the most used methods for large-scale water filtration in membrane systems is reverse smearing. This method is taken into account due to its easier implementation, lower cost, longer lifetime, less space need, minimal energy usage, and other advantages. After studying the general analysis of the water desalination process, the reverse smear and electrodialysis processes were each independently examined in this paper.

Energy generation from the difference in water salinity concentration utilizing the reverse electrodialysis technique on a laboratory scale is a study that Arashi and Ghali Kandi (2013) reported. The three essential necessities that all people have now are energy, environment, and water. In this regard, the variation in salt concentration of water resources is researched and taken into account as a source of clean energy. The goal of this study is to develop the functional framework of the desired system while examining the process of energy generation utilizing the salt concentration difference and the inverse electrodialysis technique. In this direction, using 10 productive cells in a lab setting, the fundamental operating parameters of the system—flow rate at four levels of 30, 20, 10, and 40 milliliters per minute, temperature at levels of 25, 15, and 35 degrees Celsius, and concentration difference at levels of 150, 90, and 210 g/liter—are examined. Likewise, Taguchi's approach is utilized to create experiments. Statistical analysis was used to estimate the impact value of each of these factors on the objective function, or the highest power of energy output per used membrane. According to the findings, discharge and temperature have the least impact on the objective function (15 and 3 percent, respectively), whereas concentration difference has the most impact (81 percent). In the best operating conditions of the system, where the concentration difference is equal to 210 grams per liter, the flow rate is equal to 40 milliliters per minute, and the temperature is equal to 35 degrees Celsius, the energy production power is equal to 0.6 watts per square meter, according to the results of the signal-to-noise (S/N) analysis. was acquired.

Evaluation and measurement of salinity gradient power in the Arvand River estuary based on reverse electrodialysis technology was the topic of a study presented by Lari et al. in 2012. The electrical energy produced by the salinity gradient is now regarded as another renewable energy source. By combining two kinds of water with various salt contents, this energy may be produced. Freshwater and seawater naturally and without hindrance combine in a river's estuary. The reverse electrodialysis technique is one of the feasible and acceptable ways to verify this mixing without inhibitors and extract energy from it. One of the freshwater rivers that finally flows into the Persian Gulf is the Arvand River, which runs along the border between Iran and Iraq. The water salinity of this river is explored in this study using the physical characteristics measured at three hydrometric stations. The electric energy that may be produced from it is then theoretically assessed and evaluated by comparing it to the water salinity of the Persian Gulf.

"Inspection of energy extraction systems from salinity gradient and selection of a suitable system for the southern coast of Iran" was the title of a study presented by Mursali et al. in 2016. We will introduce many ways to harvest energy from salinity gradient power (SGP) in this post and go into more depth about each one. Reverse electrodialysis (RED), pressure delayed osmosis (PRO), vapor pressure difference process (VPDU), mechanical-chemical turbine (MT), reverse capacitive deionization (RCD), and salt water solar pools are mentioned in the division of systems based on the method of using electrical energy from the power of the salinity gradient. Similar to that, in this study, we examined the salinity gradients throughout Iran's southern beaches, particularly at the mouths of the rivers that flow into it, utilizing measurements made of the physical characteristics of the water in the Persian Gulf by the ROPME group in 2001. The most suitable solution was selected based on its performance in order to maximize the potential of the salinity gradient in this area.

Enhancing the effectiveness of nanofilters pre-treatment of reverse osmosis water jet device with the assistance of sharp sand filter is the title of a 2009 study by Taghizadeh and Haider. A water jet cutting equipment is now being used in the industrial area of Tehran by a business that uses subterranean water to cut metals. Due to the high TDS of the subterranean water, the machine has encountered several issues after more than a few months of operation. A sharp sand filter was installed in the water inlet to the pump before the reverse osmosis device, which caused the cylindrical filters that we had to replace it every 4 days to be replaced every 30 days, which reduced costs and increased efficiency. Reverse osmosis was previously used with nanofilter pre-treatment, but with the passing of the costs due to the early replacement of nanofilters, the process was re-examined.

VI. Research Methodology

- *Type and method of research*

The current research is a type of applied research that is carried out by analytical-descriptive method.

- *Research hypothesis:*

1- It is assumed that heat transfer can be done with the reverse electrodialysis process.
2- It is assumed that energy transfer can be done with the reverse electrodialysis process.

- *Research variable:*

The parameters that have an effect on heat or energy transfer in the reverse electrodialysis process are the variables of this research, which will be investigated to determine the extent of the effect and its method.

- *Method and means of collecting information*

The method and means of collecting information in this research is the library method that is used in all scientific researches, and in some of them, the research topic relies on the findings of library research from the beginning to the end. In researches that do not have library content, researchers must use the library method in their research. In this research group, the researcher must study the literature and records of the problem and the subject of the research. As a result, he should use the library method and record and store the results of his studies in appropriate tools, including slips, tables and forms, and finally classify and exploit them. Considering the role of the library method in scientific research, it is necessary for researchers to be aware of this method. The first step in the library research skill is to get familiar with how to use the library, that is, researchers should be familiar with the library methods, the way of working from the spreadsheet and recording the specifications of the resources, the way of searching and ordering books. Library methods are used in all scientific researches, but in some of them, this method is used as a part of the research process, and in some of them, the research subject is library in nature from the beginning to the end. It relies on the findings of library research. In researches that do not have library content in appearance, researchers must use library methods in their research. In this research group consisting of descriptive, causal, correlational, experimental, etc., the researcher should study the literature and records of the problem and the subject. Read the research. As a result, he should use library methods and record and store the results of his studies in appropriate tools such as slips, tables, and forms, and at the end of the work, classify and exploit them. The researcher's information gathering tool in the library method, all printed documents such as books, encyclopedias, dictionaries, magazines, newspapers, weekly magazines, monthly magazines, dictionaries, yearbooks, printed interviews, research papers, scientific conference books, printed texts indexed in databases and Internet and intranet and any source that can be identified in printed form; and by mentioning the source to preserve the originality of the content and protect the rights of the researchers who have worked hard in that research.

Data processing

The method of this study is library. First, data and information are collected through the study of various articles, and then the work is continued using the laboratory method, and the results of the laboratory method are analyzed and evaluated.

- *Materials and methods*

In this research, the Taguchi test design method was used from the beginning of the research and the results were analyzed. By determining the main effects of the factors that have the greatest effect on the response, their optimal levels to achieve the desired response were determined. Analysis of variance is also used to determine the significance of effects in statistical analyses. The observed changes in response are due to changes in the levels of the desired agent or these changes are simply due to random measurement errors. In this research, the electricity production capacity can be checked

The reverse electrodialysis laboratory pilot including inlet flow tanks at a height of 1 meter from the cell (containing salt solution with different concentrations and a membrane tube containing 10 ion exchange membranes and 11 anionic membranes with an effective surface area of 100 cm per membrane) was used to perform the experiments. The distance between the membranes is directly correlated with the internal electrical resistance of the entire generator and is inversely proportional to the hydraulic drop of the system. The results of investigating the mathematical model of the desired system using spacers with different thicknesses showed that if spacers with a thickness of 100 micrometers are used, maximum thickness can be produced, although in the practice of making spacers with this thickness, the hydraulic drop is high. This study was finally used in a laboratory study of 3-layer spacers made of polystyrene and cellophane with a total thickness of 300 micrometers as shown in Figure. To prevent hydraulic shortcuts, the spacers were selected in a way It was found that the current flow in the pilot solutions required for the experiment with different concepts of compounds were prepared using sodium chloride salt. The function of the ions passing through the membrane is different based on their charge and molecular mass, and since this difference does not have a great effect on the test results, sodium chloride salt was used for the studied water. The amount of TDS was measured using a conductivity meter. The calibration curve of the conductivity of the water solution related to the salt concentration in it is shown in Figure 4.

VII. RESULTS

After determining the variables related to the system under investigation, including the distance between the membranes and their type, and determining the range of changes in factors such as flow in the preliminary tests, to investigate the effect of factors and determine the optimal operating conditions of the reverse electrodialysis system for generating electricity, from the experimental design method were used by Taguchi method. For this purpose, parameters of temperature, discharge, and concentration difference were considered in each of 4 levels. Then, the tests were performed with the specifications that can be seen in Table 1. It is worth mentioning that all the experiments were repeated 3 times and in the Taguchi analysis, the signal-to-noise (S/N) method was used. The following relationship was used to convert the laboratory results to the responses of the signal-to-noise method. And its results are presented in figures 4-7 to 4-9.

W = IV = I (E - IR)

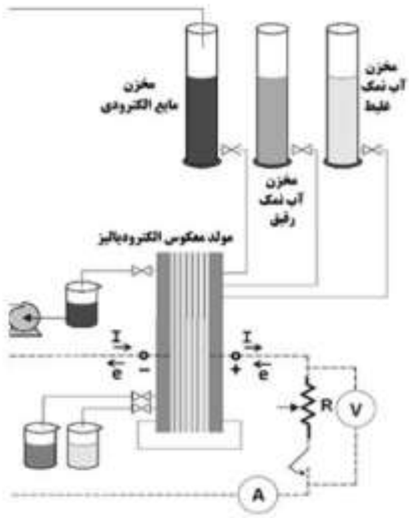

Figure 3. Research experiment design

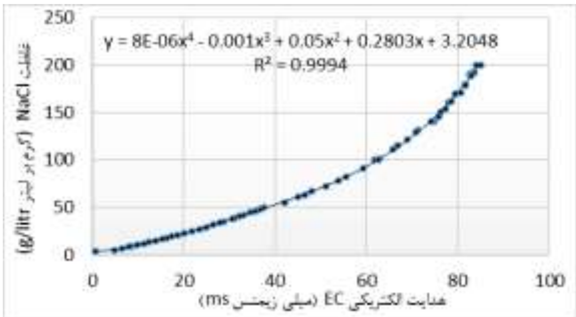

Figure 4. Calibration Curve To Convert EC to TDS For Sodium Chloride Salt At 25 Degrees Celsius

TABLE 1. the results of calculation of production power

Variables			Maximum power watt per square meter			Test number
concentration difference (gr/L)	(ml/min) mass flow rate	temperature (cº)	The first test	The second test	The third test	
50	40	5	0/0522	0/0533	0/0543	**1**
50	30	15	0/0523	0/0524	0/0530	**2**
50	20	25	0/0468	0/0472	0/0479	**3**
50	10	35	0/0345	0/0384	0/0352	**4**
100	40	15	0/242	0/2465	0/2450	**5**
100	30	5	0/1617	0/1623	0/1631	**6**
100	20	35	0/1980	0/1988	0/1995	**7**
100	10	25	0/1155	0/1168	0/1174	**8**
150	40	25	0/4605	0/4624	0/4609	**9**
150	30	35	0/409	0/4082	0/4089	**10**
150	20	5	0/2052	0/2050	0/2065	**11**
150	10	15	0/1486	0/1499	0/1503	**12**
200	40	35	0/6011	0/6020	0/5997	**13**
200	30	25	0/4725	0/4710	0/4699	**14**
200	20	15	0/3275	0/3270	0/3264	**15**
200	10	5	0/1483	0/1475	0/1461	**16**

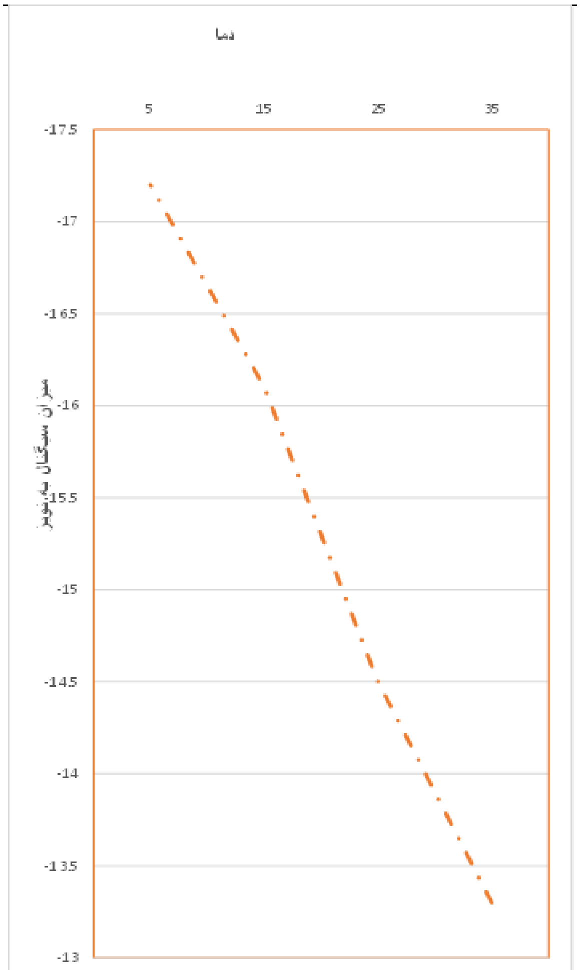

Fig. 5. The flow rate of changes in signal-to-noise in temperature (degrees Celsius)

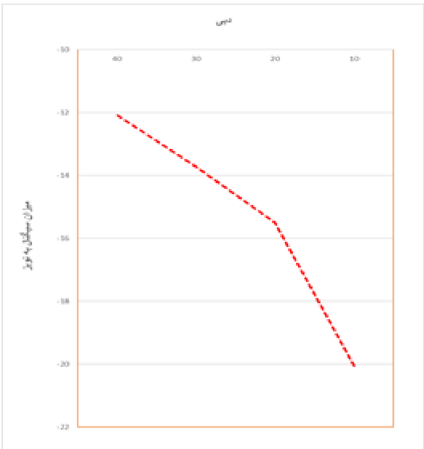

Fig. 6. Changes in the signal-to-noise ratio of the flow rate (ml/min)

The impact of temperature, flow, and concentration difference in the reverse electrodialysis system is shown in Figures 5 to 7. The horizontal axis in these graphs indicates the four levels that were taken into consideration for various values of each variable component, and the vertical axis, which was determined from the tests, displays the pace at which the signal-to-noise ratio varies. Figure makes it quite evident that as the concentration difference has grown, so too has the quantity of production power.

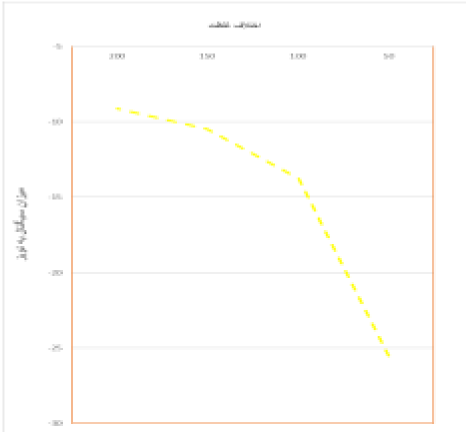

Fig. 7. Changes in signal-to-noise ratio of concentration difference (gram per liter)

At level 4, with a concentration difference of 200 grams per liter, the maximal production capacity has been attained. Figure shows that the ratio rises as flow increases, indicating that the system becomes more efficient as flow increases and that the maximum power is reached in four stages. Additionally, Figure shows that when temperature rises, the signal-to-noise ratio rises as well, with temperature level 4 having the maximum output power in terms of this ratio. The analyses' findings indicate that a concentration of 200 g/L, a flow rate of 40 mL/min, and a temperature of 35 degrees Celsius provide the most production power per square meter of membrane utilized. Despite the graph's increasing tendency, faster flow rates and smaller concentration differences are seen. The analysis was completed after the test data were entered into the QUALITECH-4 program, and the outcomes are shown in Table 2. The number of levels of each factor in it, less one, determines its degree of freedom, and the factor is the factor whose values are available in the standard tables related to the Taguchi test design method for various arrays, as well as the degree to which the desired factor is present or absent from the response. The algorithm decides. All chosen parameters impact the efficiency of electric power production with 95% confidence, according to the computed variable values in Table and its standard values in statistical references. Accordingly, it was found that the reverse electrodialysis method's most effective factor for producing electricity is concentration, which has an efficiency of 80.815 percent. The least effective component for producing electricity is temperature, which has a 3.310 percent impact.

TABLE 2. Variance analysis of electric power generation

Percentage	**Factor**	**Variance**	**Freedom of SS Squares**	**Degrees of freedom**	**Variables**
15.6	268.435	47.3	142.111	3	Dubai
80.815	1386.459	244.313	733.112	3	concentration difference
3.310	57.57	10.136	30.412	3	temperature
0.275	-	-	1.045	6	error
100	-	-	906.680	15	Total

VIII. CONCLUSION

Experts have long focused on the adoption of innovative and sustainable energy production methods. Utilizing the differential between the available electric power and the saline concentration is one of the potential solutions in this area. In this study, the ideal conditions for carrying out the reverse electrodialysis process to generate electrical energy were established according to the main effective parameters, including the difference in concentration, temperature, and flow rate of two solutions with different concentrations, using the results of the laboratory pilot test and the Taguchi method. The concentration parameter is the most effective factor in the system under study, and it was discovered that the variables chosen for the analysis had a 95% probability of affecting the output of electrical power. Additionally, when flow rate increases, the amount of electric power generated at various temperatures and concentrations changes as well, albeit this rise tends to diminish after reaching specific limitations. The findings demonstrate the system's capacity to generate electrical energy from the difference in the salinities of two solutions and suggest applications for it in water desalination facilities, among other systems.

Based on previous work, we will suggest the following
1-studies employing a pilot that is semi-industrial
2-Utilizing more recent data; 2; 3; and using a variety of applications to compare and evaluate the findings.
3- Adding additional variables to the investigation to get more ideal outcomes

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