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THE IMPORTANCE OF USING MEMBRANES IN SEAWATER DESALINATION AS A RESULT OF EXCESSIVE EXPLOITATION OF WATER SOURCES

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ABSTRACT

This paper is a detailed study of the need to find and implement new solutions for water filtration and the promotion of modern techniques that are more effective than traditional methods. As a result of extension waste water pollution as well as low efficiency through classical filtration means, more and more research is being discussed and researched worldwide, focusing on the use of hybrid membranes for seawater desalination. Hybrid membrane filtration processes present a number of advantages including superior water quality but also reduced energy consumption that was needed in previous purification processes. This review describes the water desalination process in detail by looking at the relationship between membrane module operating parameters and energy efficiency. The methodology and the experimental installation of the desalination process will be presented in part. The results of the study clearly showed that the combined use of membrane processes is efficient due to the flexibility of exploitation, the low acquisition costs and the high degree of water filtration through low energy consumption. A major advantage in the use of membranes is that the energy required to conduct filtering processes can be obtained from solar, wind energy, which means significant environmental benefits by promoting "green energy". The worldwide implementation of the use of membrane water desalination methods also involves increasing the percentage of fresh water, so this is a solution to be considered in present and future research.

KEYWORDS: desalination, reverse osmosis, hybrid membranes, salt wastewater

1. Introduction

The relationship between water and energy is the one that will always gravitate around human existence [1, 2]. Freshwater resources are limited and the oceans are the only ones that can provide water for all human needs [3]. However, ocean water is salty, which implies finding methods and techniques for removing salt. In this context, there is a need for energy consumption that involves both costs and emissions of pollutants into the environment [3-5].

A very effective solution to solving the water crisis but also to cushioning environmental pollution as a result of noxious emissions is desalination of water through membranes that can use both renewable energy and solar energy [6, 7].

Desalination is the process by which the salt contained in seawater is removed by means of a membrane under a certain pressure and at the same time the ratio of water without salt and feed salt water [8].

At 25 °C, filtering a cubic meter of salt water containing around 34,500 ppm requires an energy consumption of approximately 0.6 kW/h [8].

The combination of desalination technologies with solar energy capture systems, especially in arid regions, is a promising option for sustainable development, as drinking water needs can also be met, as well as reducing the negative impact on environmental factors due to harmful emissions [9].

This approach requires intensive research because it is essential that desalination technology is compatible with solar recovery, but it is still a solution that offers an alternative to the conservation of natural resources and also brings benefits to the environment and human health [10].

The membranes used in the desalination of water can be organic or inorganic of ceramic material, which involves high temperature thermal filtration processes [10], without the membrane being deteriorated and thus the supply water, irrespective of contamination with chemical agents, does not ease damaging the membranes used in filtering processes [11].

One of the most analyzed inorganic filtration membranes in the field of recent research is the mesoporous membrane of ɣ-alumina that serves in nano-filtration processes and the pore size is 3-5 nm and the molecular weight of the particles corresponding to this membrane is around 3,000-10,000 Da [12].

Some researchers tested a membrane of this kind but with a pore size of 1 nm and the permeate obtained was above the industrial expectations, being approximately of 5 L/m^2/h using a pressure of 1 bar, and other investigations tested a membrane of the same type but having a pore size of 1.61 nm, solvent-resistant, and the permeability was about 17 L/h/m^2 at a pressure of 1 bar [13].

Modern membrane desalination methods using renewable energies have advantages that increase future implementation confidence: desalinated water can be achieved on a large scale, operating temperatures are not very high, in some ways, the supply water does not require pre-treatment, maintenance and operating costs are reduced but, at the same time, with the operation of the installations specific to these modern methods, the staff does not require any higher qualification [14].

2. Methods of water desalination based on the use of solar energy

2.1. Desalination through ceramic membranes in several steps

Through this method, the solar energy is captured through a concentration system that has the power and capacity to make an entire desalination plant especially installed for this type of energy [15].

The desalination membranes allow only the passage of water vapor therethrough, since the distillation process produces pure water. Finally, salt is removed.

First, the solar thermal energy is collected and stored through the solar field, and then with the hot water coming into contact with cold salt water, the vaporization phenomenon occurs.

Parameters that follow this desalination method are: the concentration of energy obtained by the solar field because it influences the pressure, thus the entire process, the flow of the supply water according to the pressure, the quality of the filtered water as a result of the salinization concentration retained by the membrane module.

Current research predicts that in the near future, the cost of green energy technologies will decrease as they become more and more used [16].

Figure 1 shows the schematic diagram of the solar-based desalination plant:

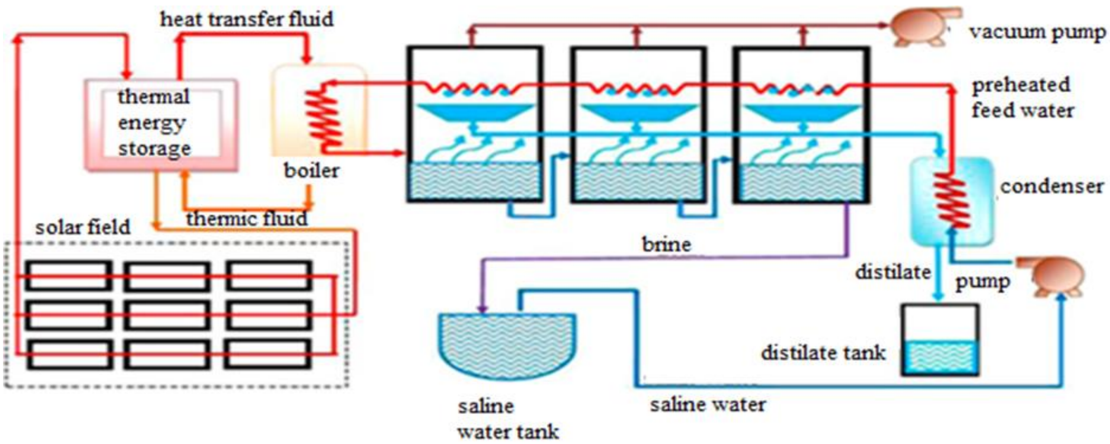

Fig. 1. *Experimental installation of desalination using solar energy* [14]

2.2. Multi-effect distillation

This desalination method raises its market share for being the most compatible with this solar energy system; studies have shown that over a year, such an installation with a working area of approximately 30,000-40,000 m^2 can produce around 1,000,000 m^3 of distilled water [14].

Some researchers compared the economy difference between the solar-based desalination technique and the water desalination method using fossil fuels, and found that for distilled water, the cost of desalination with solar energy is lower compared to a classic system works on diesel when the price reaches about $ 10/GJ [17].

In order for the desalination process to proceed in good conditions, the solar energy capture installation must be compatible with the desalination plant. The parameters to be monitored at such an installation refer to the captured solar power, the pump pressure, the steam generator pressure required by the desalination plant, the flow rate according to the feed temperature.

The performance of the desalination plant combined with a TC (thermal compression) solar energy capture unit is proven by doubling the salting water filtration efficiency, since the operation of this desalination plant can be done at a steam pressure of only 1 atm. [18].

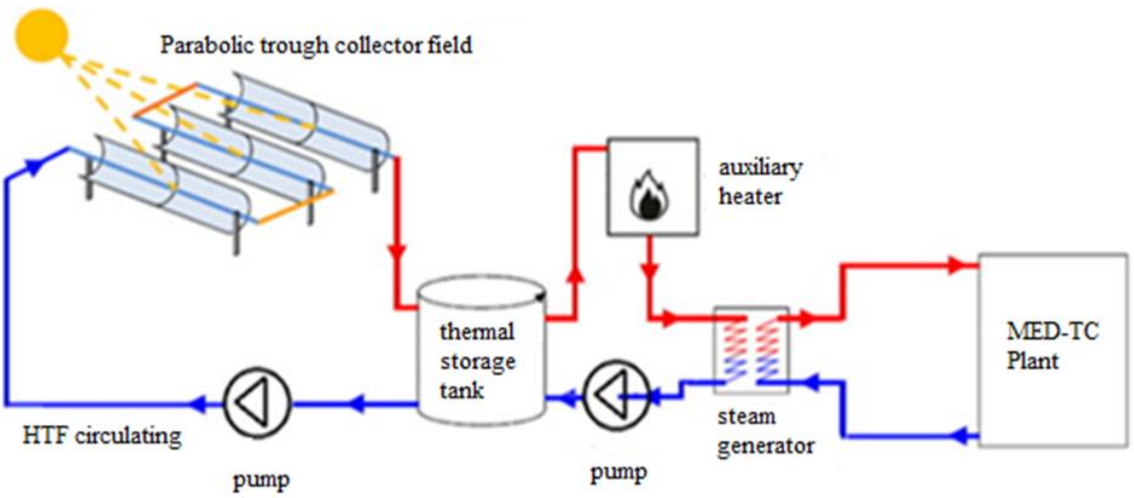

Fig. 2. *The energy capture plant compatible with desalination plant* [19]

The solar thermal capture installation (Fig. 2) is the part which ensures the operation of the desalination plant (Fig. 3). Steam with high pressure feeds a steam jet ejector at a pressure of 1 atm. [20].

The water vapor from the last effect of the desalination unit is sucked by the high-pressure vapor and thus avoids loss of energy in the condenser. The two pressures equalize and the steam becomes overheated.

The first effect dehydrates the steam mixture, producing saturated steam used as heat even for the desalination unit of the first effect.

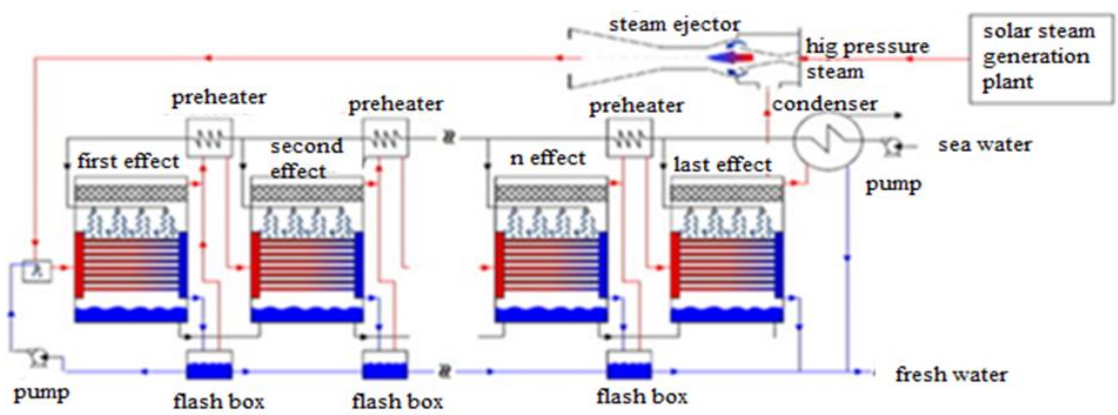

Fig. 3. *The energy capture plant compatible with desalination plant* [20]

The low compression ratio reduces the amount of steam in the desalination unit, which increases the filtration capacity [21]. The flow temperature does not adversely affect the distillation process, since the temperature difference between the effects and the temperature of the last effect are the ones that are observed during the process [22].

Studies on the feasibility of a desalination plant, such as Figure 2, show that the tap water temperature and the pressure in the ignition chamber influence the production of water, meaning lowering the evaporation pressure results in a higher amount of distilled water [23].

2.3. Reverse osmosis using solar thermal energy

With the help of a solar power concentrating plant, the heat can be generated which can then be used to obtain the electrical energy necessary for the operation of the desalination plant pumps by reverse osmosis (Fig. 4) [14].

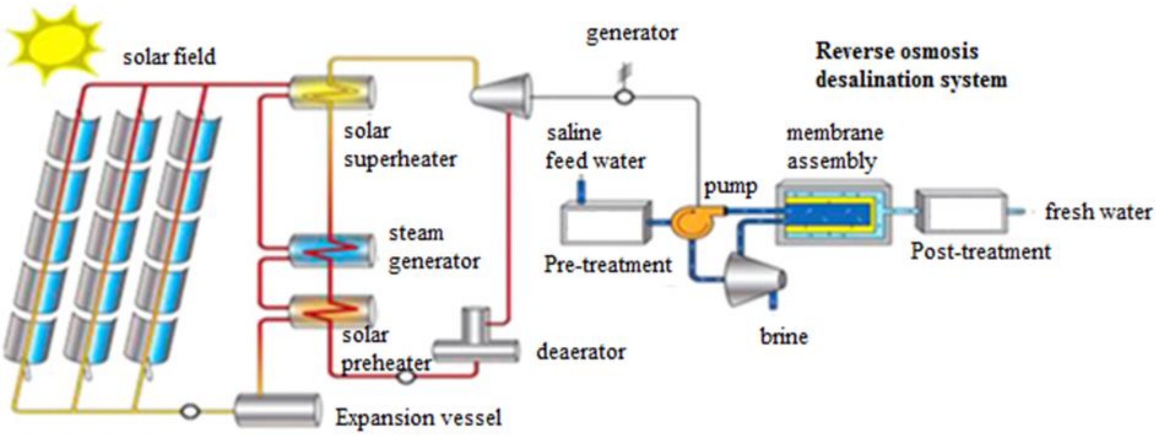

Fig. 4. *The energy capture plant compatible with desalination plant* [20]

The high-pressure pump is powered by the generator that converts the solar energy produced by the solar field into electricity.

Prior to the osmosis process, a pretreatment of salted water is required to retain coarse particles as much as possible. Then the pump feeds the membrane module and before fresh water is collected, another treatment is required.

During the process of osmosis through the membrane, the following are observed: the variation of the pump pressure depending on the turbine steam fluctuations due to the solar energy capture, membrane lifecycle during the process, water flow at the membrane inlet, membrane efficiency of the membrane filtering due to the quality of distilled water in the unit of time.

2.4. Reverse Osmosis based on energy obtained by photovoltaic panels

This modern seawater treatment technique is increasingly being promoted where water scarcity is increased and requirements are high. In other words, the areas concerned are arid and the predominant water sources are those with salt water.

Desalination of water through osmosis (Fig. 5) now exceeds 50% of the modern methods used in world-wide processes [24].

Always before the osmosis process, pre-purifying water is required. In this case, various chemical agents that do not endanger the type of membrane are introduced into the feed water, then by means of pre-treatment filters, larger particles or those that have increased their size due to applied chemical substances during the process remain on the filter surface.

Then the high-pressure pump feeds the membrane module to obtain the distilled water. The solar energy produced by the photovoltaic panels (Fig. 5) is the main source that puts the pumps into action [25].

Researches show that pre-filtering can successfully use nano-filtration to reduce turbidity, bacteria and reduce total dissolved solids [26].

During the salt water osmosis process, the parameters related to the energy produced for the operation of the filtration plant as well as the parameters of the desalination plant were followed, namely: the feed rate, the pressure applied to the module by the pump, the volume of the permeate in a time already established, the degree of purification of the distilled water.

Depending on these parameters, the efficiency of the use of the distillation membranes is determined by using the different pressures of the desalination plant.

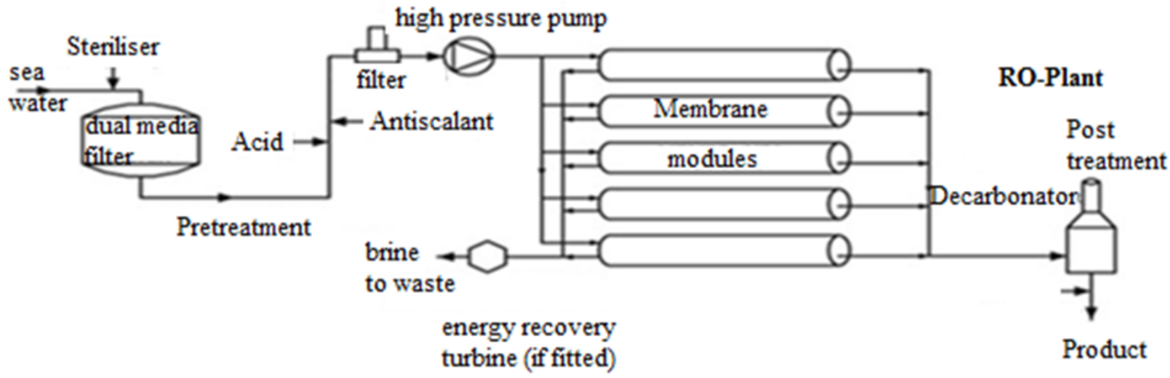

Fig. 5. *The energy capture plant compatible with desalination plant* [22]

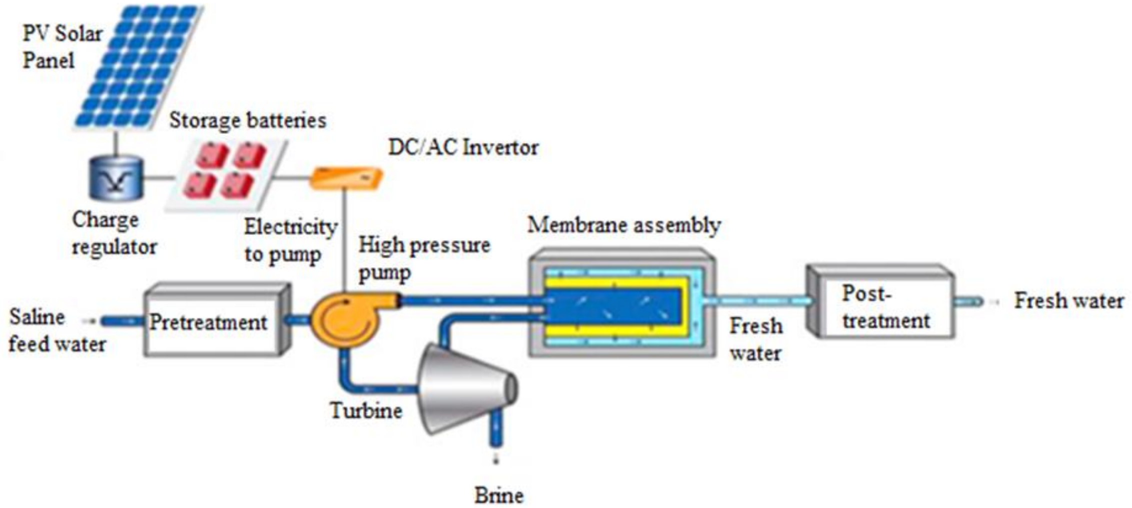

Fig. 6. *The energy capture plant compatible with desalination plant* [28]

The results of the research have shown that, per m^2 of membrane, the production of distilled water / day is up to 500-1500 L but this largely depends on the degree of loading of the membrane due to the salt concentration in the salt water (Fig. 6).

3. Results and discussions

3.1. Discussions on the tracked parameters

The purpose of this review was to test desalination membranes on the principle of exclusive use of renewable energies. Careful attention was paid to certain parameters, namely the feed flow, the pressure exerted by the feed pumps, the permeate concentration due to the salt rejection, the polarization of the concentration in a given unit of time. The focus was on membrane parameters, namely: water permeability, section area, hydraulic diameter, thickness of membrane feed space, density, salt diffusion coefficient, salinity and feed rate, permeate quality, etc.

Membrane testing has tracked the dependence of these parameters as a result of the solar power system being supplied by photovoltaic panels [19, 20].

Hydraulic resistance is the parameter that affects the membrane as a result of increasing pressure applied to it. In this case, flux sensitivity, permeate concentration, polarization of concentration and salt rejection [19] were analyzed.

The experimental data obtained from the experiments were compared with those of a ROSA (DOW) industrial software warehouse for the type of membrane tested, and the flow factor was 0.75.

This flow factor expresses the degree of performance of a system as a result of membrane weathering in relation to temperature and pressure applied over time during filtration processes [21].

3.1.1. Supply water pressure

As is known, feed pressure is one of the most important parameters in an installation that uses the membrane module in the case of osmosis. Therefore, it depends exclusively on the power supply of the pump, so of the energy captured by the photovoltaic panels.

The performance of the membrane is affected by these fluctuations as the authors say in their research. The pressure fluctuations of the supply water are shown in Fig. 7 as a result of the solar energy variation in time, i.e. from about 32 bars to 47 bars [19].

3.1.2. Feed flow

It is totally dependent on the pressure exerted by the pump. In other words, the varying of the pressure, change the flow of water. In correlation with Fig. 7, Fig. 8 shows the flow rate dependent on pressure fluctuations [19].

The same thing is observed in 810 minutes, although the pressure decreases, however, it is the same as that of the 905 minutes. Purple lines are the ones that show this and this fluctuation is due to the sudden increase in pressure, respectively from 32 to 47 bars [22].

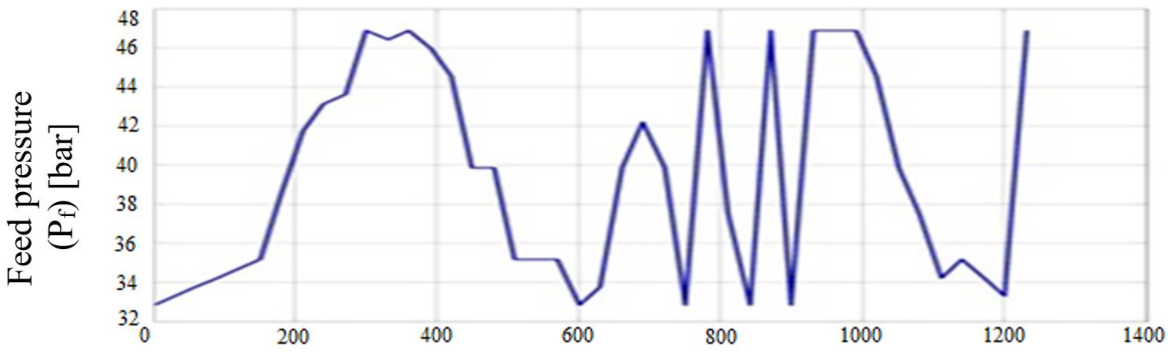

Fig. 7. *Time pressure fluctuations within the desalination plant* [19]

Fig. 8 shows the flow variation according to the pump supply pressure; in minutes 300 and 900 the flow is the same, so the same pressure if we take into account the hydraulic resistance of the membrane.

The membrane compaction phenomenon also causes the permeate flow to fall. Figure 8 shows that the results of the ROSA software are smaller than those of the theoretical model without taking into account the hydraulic resistance, which means that the 0.75 flow factor describes an old membrane that leads to the decrease of the flow of permeate by approximately 19 %, due to membrane compaction due to unstable operation [22].

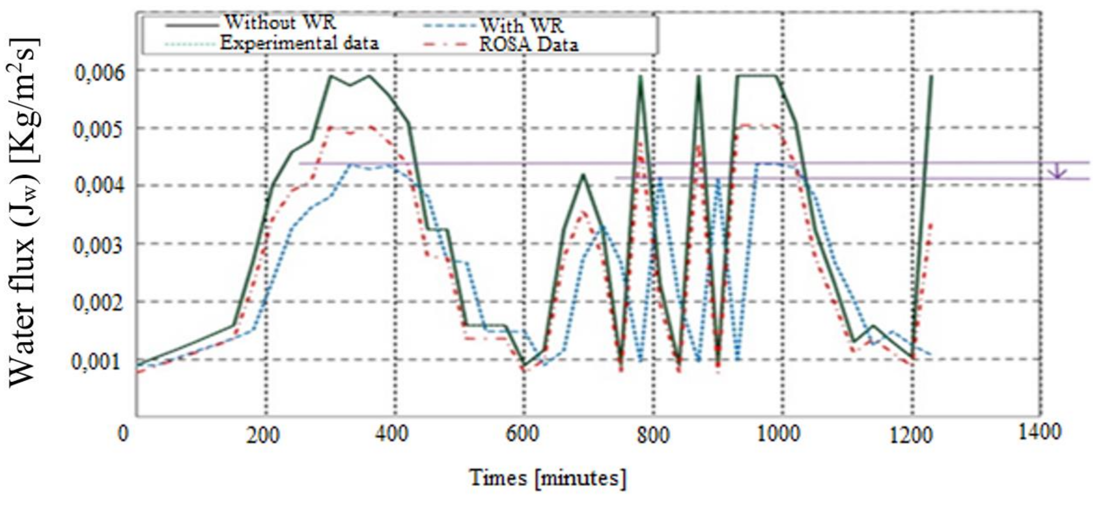

Fig. 8. *Variations of supply water flow over time, depending on pump pressure* [22]

3.2. Discussions on the efficiency of renewable energies used in desalination processes

Solar energy captured by photovoltaic panels is especially effective in arid areas. The only problem here is the cost of the panels. Instead, all desalination methods are compatible with solar energy capture methods.

The inorganic desalination membranes and ceramic ones that have been tested in the above experiments have shown increased filtration efficiency indifferently of the chemical agents used or the temperature. This is a major advantage.

Multi-effect desalination methods are being used more and more often and current research is increasingly focusing on this topic. The use of this method tends to be from the medium level to large and the cost of such an installation, per m^3, can be between 950-1900 euro compared to the solar panels at which the cost per one m^3 of the plant is between 1500-2500 euro [27].

For this reason, photovoltaic desalination technology occupies a lower place in the ranking of the use of solar desalination technologies and its use is low.

The use of osmosis through desalination technologies is increasingly successful, the scale of use being small to large and the cost per m^3 of plant is between 900-2500 euro but the membranes can be replaced at 4 or 5 years which means high lifetime efficiency of membranes used [27].

In conclusion, the desalination of water relative to the cost of acquisition and maintenance is most efficient by using the multi-effect desalination method, then osmosis through solar panels.

Modern desalination methods using renewable energies are reliable, operating costs are acceptable and the energy required for plant operation is reduced [28].

Osmosis begins to be in the top of current research due to the quality of the filtered water but a disadvantage is the need for high operating pressures and the fact that before water enters the membrane requires pre-treatment. Another disadvantage is the warping of the membrane, the greater the operating pressure means the higher the loading on the surface of the membrane [29].

4. Conclusions

Organic and inorganic desalination membranes are a key element for current research due in particular to efficiency in the quality of filtered water.

Osmosis is the process behind the desalination of water, and the pressure plays the essential role because the higher the permeate volume of the same quality in a lesser time.

Current research is increasingly focusing on the use of membranes used in desalination but also combines filtering processes with renewable energy installations.

Renewable energies can be successfully combined with desalination plants and bring benefits both in terms of environmental protection through emissions and reduced maintenance costs.

The experiments carried out in the research have also emphasized the safety of the installations due to the need for high pressures but the cases of danger were little confirmed by the tests carried out over a long period of time.

Although in the case of saltwater filtration, certain parts of the installations may be affected by corrosion, the present research focuses on finding the best substitutes for certain parts of the system where there is contact with salty water.

In modern saltwater filtration methods, the most efficient desalination solution remains osmosis, regardless of whether high pressure is required or that the volume of permeate is low.

The supply water concentration related to the type of load as well as the pressure of the feed pumps are essential parameters in the salting water desalination processes;

Research experiments have shown increased system reliability; in terms of electricity consumption, it is mainly used for the commissioning of pumps.

Modern desalination methods have particularly focused on compatibility with the capture of solar energies as renewable energy.

This review article emphasized the dependence between the parameters of the desalination plant and those of solar energy capture equipment as the main source of energy.

The results of the research have highlighted both the advantages and drawbacks of using sea water filtration membranes as a key element in increasing the percentage of fresh water to meet different consumption requirements.

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