Academic Journal of Research and Scientific Publishing | Vol 4 | Issue 43
Publication Date: 5-11-2022 ISSN: 2706-6495

A Review on Water Desalination Technology and Economics

Asst. Lect. Maha A. Faroon

Assistant lecturer, Civil Engineering Department, Engineering College, University of Basrah, Basrah, Iraq

Lect. Zainb A.A. AL Saad

Lecturer, Civil Engineering Department, Engineering College, University of Basrah, Basrah, Iraq

Prof. Dr. Ahmed Naseh Ahmed Hamdan*

Assistant Prof, Civil Engineering Department, Engineering College, University of Basrah, Basrah, Iraq

*Corresponding Author: ahmed.hamdan@uobasrah.edu.iq

Abstract

Water is essential for life on earth. There were civilizations everywhere there was water. The issue of severe freshwater shortage on Earth results from the planet's limited freshwater resources, quickly growing human population, and improving living standards (mainly due to industrial and agricultural advancement). Numerous studies and research programs have focused on the future of the water situation and the quest for non-traditional water sources, such as desalination. Desalination has been regularly employed since the 1960s. Major technologies have improved efficiency, dependability, and cost since then. MSF served as the standard thermal technique for many years. The most advanced thermal process is MEE. However, it is not commonly employed. Since reverse osmosis (RO) has surpassed MSF as the most popular desalination method, it needs to be used as a standard. Desalination technology costs have significantly decreased over the past 30 years due to research and development that has reduced energy usage and improved design. Table 1 lists desalination methods according to their anticipated prices. Most of the costs associated with desalination are related to capital expenditure and energy prices, whereas expenses like operation and maintenance are almost constant.

Keywords: Desalinating, Multi-stage flash, Multi effect desalination, Vapor compression.

1. Introduction

Desalinating water involves taking the dissolved salts out of salt water. Thermal and membrane desalination are the two main desalination methods used today.

Desalination methods may be used in municipal, industrial, or commercial settings. As technology progresses, desalination technologies are becoming economically competitive with other ways of providing potable water to meet our growing needs. While the latter technique boils or evaporates saltwater to create water vapor condensed to make salt-free liquid water, the former employs a specialized membrane filter to produce desalinated water.

Desalination technology was considered necessary during World War II to transform salt water into usable water in locations with few water supplies (Needham et al., 1980), (Hinkebein, 2021). Desalination methods have become more widely utilized in recent years to cleanse industrial and municipal wastewater before it is discharged or reused, as well as to create drinking water from groundwater and seawater.

In the 1950s, there were about 225 ground desalination units per day, producing 27 million gallons (mgd). There are currently approximately 3,500 units with a 3,000 mgd capacity globally. Desalination technology will be used more frequently as freshwater demand grows and the quality of the available supply deteriorates (Andelin, 1988).

Desalination has spread swiftly throughout the Middle East, Arabian Gulf, North Africa, and smaller islands. It is also being studied in other countries. FIGURE 1: Global desalination capacity.

Due to the limited available fresh water resources and the prohibitive cost of delivering fresh water from distant sources to water demand regions, there is a growing concern about water scarcity around the world.
Because of this circumstance, efforts to explore seawater and brackish water as potential sources of drinking water have been refocused. Studying the technology used in desalinating salt water and the factors affecting each method to choose the most appropriate method and Choice criteria for desalination technology and cost are the main objectives of this study.

2. The Process of Desalination

Distillation and membrane desalting are the principal methods. Distillation mimics nature by evaporating and condensing water. Multi-Stage Flash (MSF), Multi-Effect Distillation (MED), and Vapor Compression (VC) facilities desalinate salt water in stages. To lower energy use, membranes must create water without evaporation. To function, membranes need either electrical power or shaft power. Reverse osmosis for brackish and seawater and electrodialysis for brackish water exclusively are the two methods that have come into use. Figure 1 illustrates the principles of desalination and membranes.

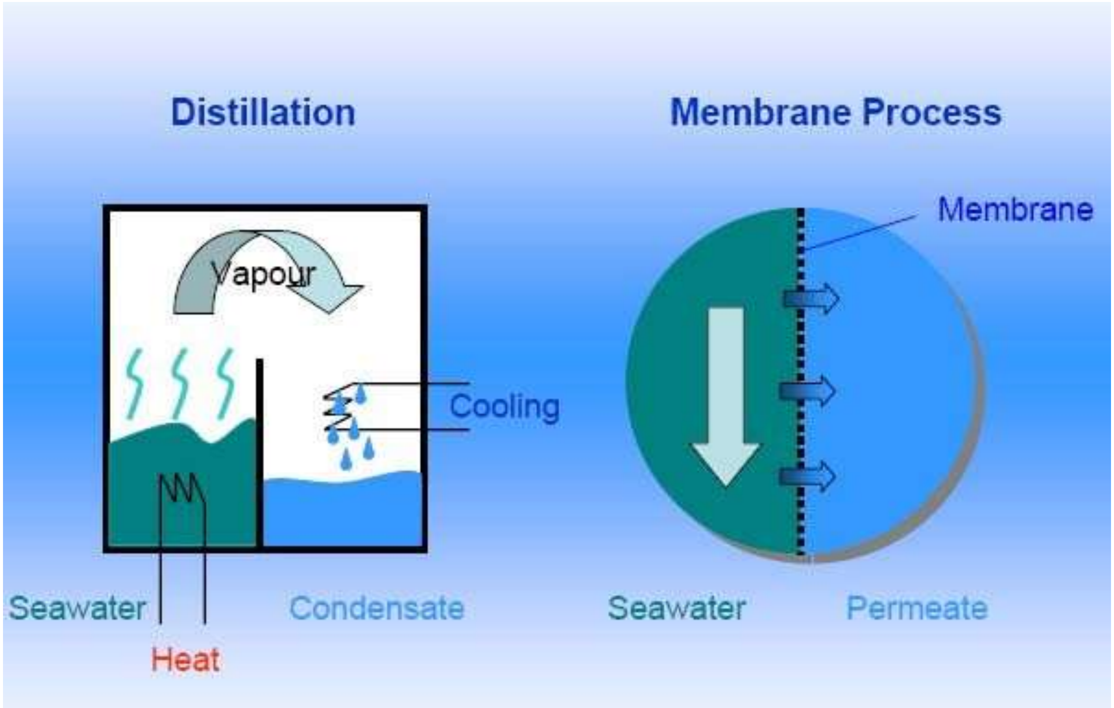


Fig 1 The Principles of desalination and membranes process.

2.1. Multistage flash distillation (MSF)

Msf is a thermal procedure that allows for the desalination of enormous volumes of seawater. This is accomplished in a sequence of closed tanks (stages), where the pressure is gradually reduced from one stage to the next. Water boils less when air pressure drops. In the initial desalination step, warmed seawater flash-boils condensed on heat-exchange tubes.

As demonstrated in Fig. 2, residual salt water is flashed, and freshwater is collected. Al-Jubayl, Saudi Arabia, is the world's largest desalination facility, producing 200 million gallons daily. MSF desalinates 85% of global water (Shoaiba, 2011).

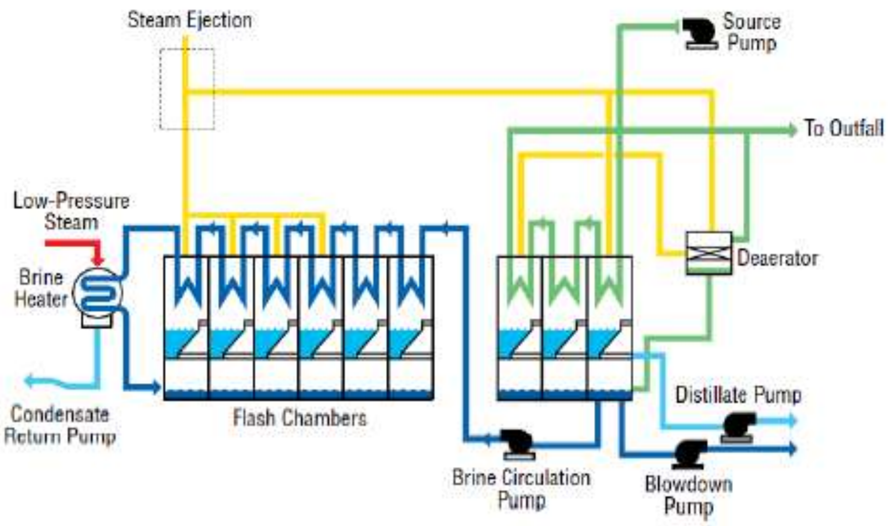


Fig 2: Multi-stage flash process (flowserve.com, 2013)

2.2 Multiple Effect Distillation

There are typically 5-10 phases in a MED desalination facility. The MED impact is seen in Fig. 3. From above the tangle, cold brine begins to rain down on the tubes. The condensation enthalpy of the vapor is sucked up by the brine coating on the pipe surface and evaporated. The demister removes undesired effects by filtering film evaporation vapor. Any leftover demister droplets and brine are gathered in the brine pool and carried out of the impact. In the event of flash evaporation, the pressure differential between the effect pressure and the brine pressure will cause more vapor to be generated. To achieve various effects, a condensate flash box of the same pressure as the effect can be mounted at the outlet of the bundle tubes. Evaporation of some of the condensate combines with the effect's vapor to boost thermal efficiency.

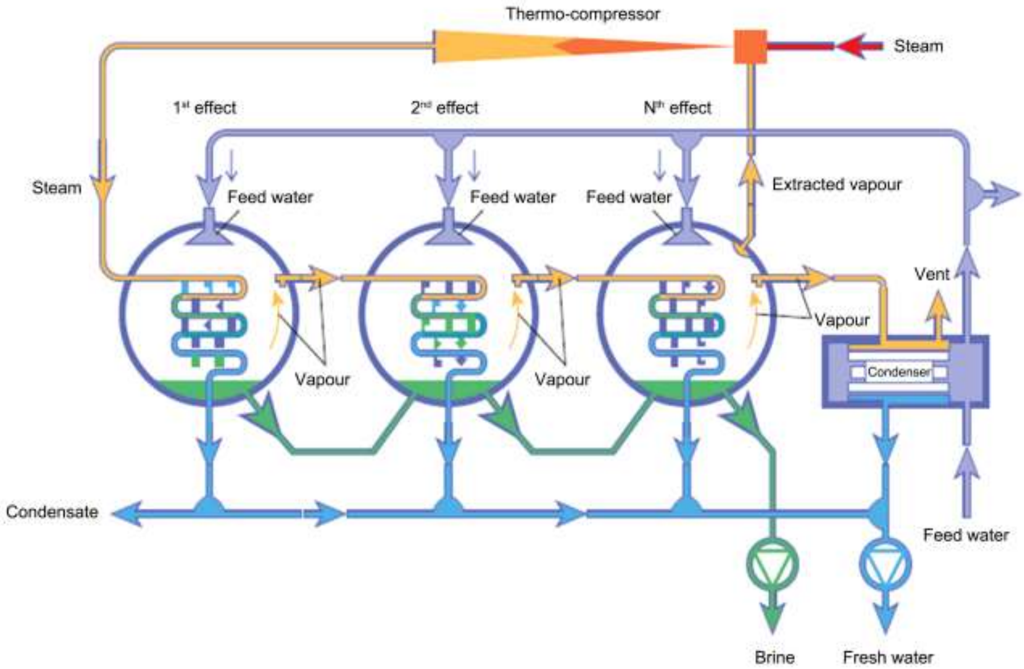


Fig. 3 Multiple Effect Distillation (MED) desalination (World Bank, 2019).

2.3 "Vapor Compression Distillation"

Sea or brackish water is evaporated using compressed vapor. Centrifugal compressors compress vapor. Under sub-atmospheric pressure, seawater is evaporated and condensed into fresh water. As a blowdown, the leftover concentrated salt water is removed at the double the initial concentration. As an electrical process, it's clean. Due to its high efficiency, it's ideal for single-purpose, small-capacity installations. The system includes a proven, optimized compressor with a high-efficiency centrifugal blower and a low compression ratio. Because the evaporator/condenser thermal differential is below 50 C, less compression work is necessary, reducing energy consumption. Figure 4 shows two forms of vapor compression desalination. First, a solar-powered mechanical compressor compresses vapor (MVC). The second kind uses thermal vapor compression (TVC) to extract water vapor and provide low evaporator pressure using high-velocity motive steam in the nozzle (Andelin, 1988).

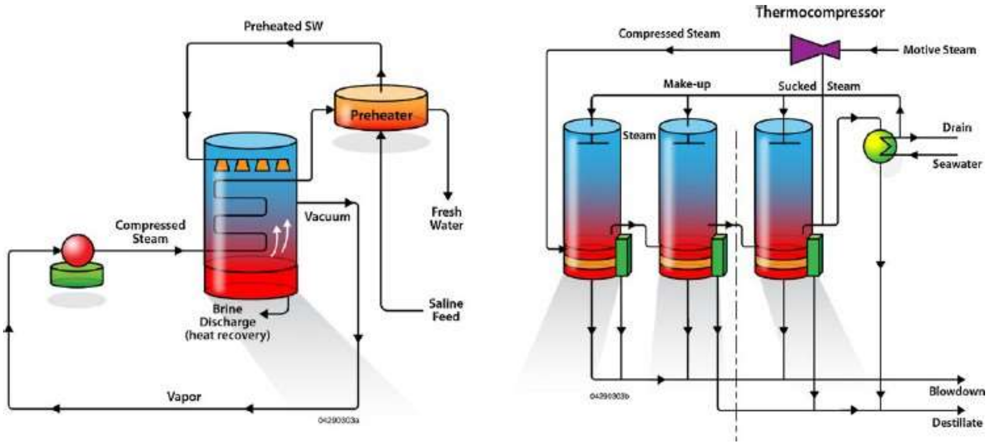


Fig 4 Vapor compression desalination (a) mechanical (b) thermal (Al-Karaghouli, 2009).

2.4 - Reverse osmosis

By forcing water through a semipermeable membrane, reverse osmosis (RO) may remove contaminants from water. There is no natural filtration happening with this membrane technology. By applying an external force, reverse osmosis may counteract the osmotic pressure exerted by the chemical potential, a thermodynamic parameter. Reverse osmosis, which employs a semi-permeable membrane, can be used to remove molecules and ions from a solvent. This technique is used in commercial and residential applications, creating clean water for human use (Fig. 5).

Ranging the salt side pressure and pushing water through the semi-permeable RO membrane, reverse osmosis discards almost all dissolved salts. Pressure is determined by feed water salt content—more osmotic pressure from feed water concentration. Desalinated, demineralized water permeates. The reject stream contains pollutants that didn't cross the RO membrane.

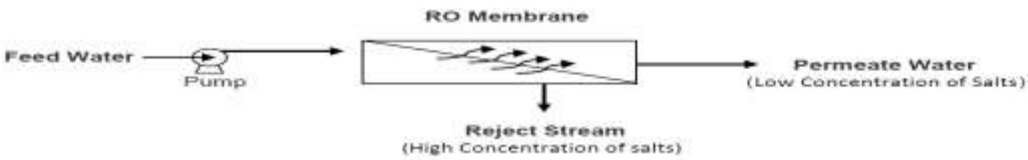


Fig 5. Vapor compression desalination is (a) mechanical and (b) thermal (Al-Karaghouli, 2009).

2.4.1 "Types of RO Membranes"

Commercial RO membranes are mostly cellulose acetate and aromatic polyamide. TFCM refers to aromatic polyamide membranes.

A membrane made from a paper byproduct and a synthetic layer is called a CTA membrane or a Cellulose Triacetate membrane. It is necessary to have a trace level of chlorine in the water supply to avoid bacterial growth on the membrane.

Chlorine is detrimental to the components of thin film membranes and must be removed before the water can pass through a thin film composite (TFC) membrane. Compared to cellulose acetate, which has a maximum operating temperature of 35 degrees Celsius, these membranes may be employed at 45 degrees Celsius.

2.5 Comparison of thermal and Membrane processes

To purify very salty fluids (most often saltwater) and produce vast volumes of product water, thermal methods are frequently employed (mostly seawater). Whenever there is an abundance of waste heat sources or a location with a cheap cost of energy,

When energy costs or flow rates are high, membrane technologies are better for treating brackish waters or salty wastes.

2.6 Choice criteria for desalination systems

- Problems with one's finances.
- Consumption of energy.
- Characteristics of the water that is used as a source.
- Constraints imposed by geography and location
- A product's water consumption.
- Concerns about pollution and waste disposal methods.
- Maintenance and operational issues
- Rates of use.

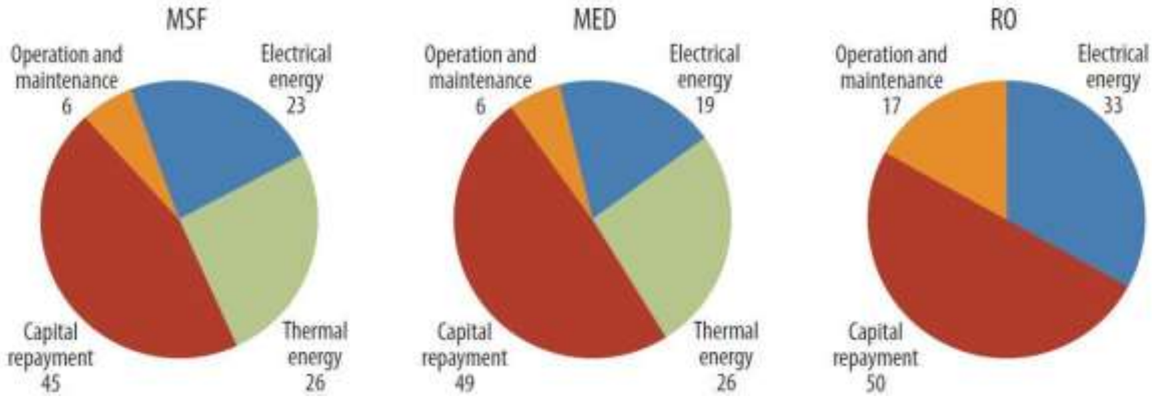
Publication Date: 5-11-2022 ISSN: 2706-6495

2.7 Costs of desalination

Desalination technology expenses have been drastically cut over the past 30 years due to efficiency and design advancements. Table 1 displays the expected prices of various desalination systems. Fees like operation and maintenance are relatively constant, but the primary expenses of desalination are the initial capital expenditure and the cost of electricity. Other factors that impact desalination prices include the salinity of the water supply, the accessibility of energy sources, the plant's scale, the land's cost, and the presence or absence of government subsidies. The entire yearly cost of each component using the most popular desalination technologies is shown in Fig. 6. The high expense of harvesting renewable energy sources and the need for advanced equipment and infrastructure make desalination systems that employ them less efficient than those that use fossil fuels. More research and development might lower renewable energy prices. In 20 years, renewable energy is expected to cost 0.05 USD/kWh, making it competitive with conventional power. Table 2 displays recent high pricing for REDS (Alkaisi, 2016).

	"MSF"	"MED"	"RO"
"Investment" "expenses"	"1,700 – "2,900"	1,700 – "2,700"	1,300 – 2,500
Spending on daily "operations."	0.65–1.25	0.67–0.96	0.58–0.88
Annualized price tag	0.84-1.6	1.21-1.59	1.06–1.36

"Table 1 shows the average cost of desalinating seawater using traditional methods (in US Dollars per cubic meter per day" (Alkaisi, 2016).



Below is a table showing the average price of desalination systems that use renewable energy.

"Methods of Desalination"	"MED"	"HDH"	"SD"	"ED"	"RO"	"MVC"	"RO"	RO
"Capacity (m^3/d)"	>5000	>100	>1	>100	>100	>100	>50	>1000
"Cost (USD/m^3)"	"2.5-3"	"2.8-7"	"1.4-12"	"11.2-12.6"	12.5-16.8	"5.6-8.4"	7-9.8	2.1-5.6

2.8 Desalination is growing around the World

Water supply is likely to become increasingly dependent on desalination in the years to come because of its rapid growth around the world. Desalination is becoming increasingly popular, especially in dry regions of the world. It appears that the annual desalination capacity is increasing rapidly over time. More desalination plants are being developed to meet demand. From 326 m3/d in 1945 to 5,000,000 m3/d in 1980 and 35,000,000 m3/d in 2004, this has expanded dramatically. In 2008, 14,000 plants produced 52,333,950 m3/d (Al-Karaghouli, 2009). 16,000 plants produced 67,000,000 m3/d in 2011, with 2012 predictions topping 79,000,000 m3/d.

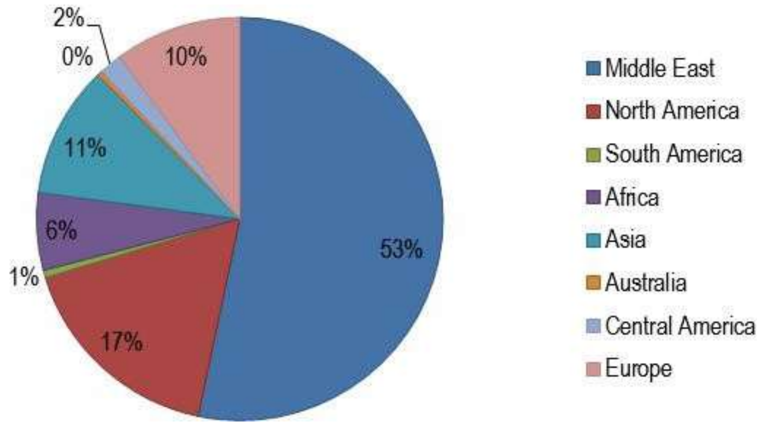
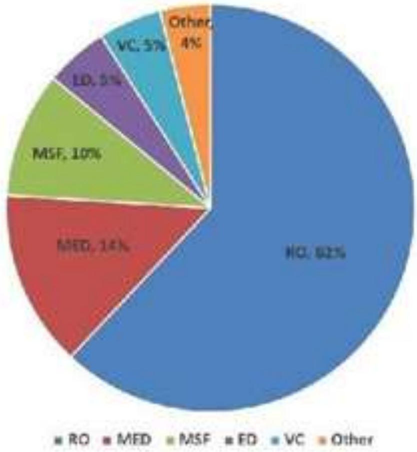


Fig. 7 Distribution of desalination facilities across the world (percent). (Zotalis et al., 2014).

The Middle East has most of the world's largest saltwater desalination plants. Ras Al-Khair, also called Ras Al-Zour or Ras Azzour SA, has generated over 1,000,000 m3/d since 2013. Incorporates membrane and thermal technology. Ras Al-Khair supplies Maaden's manufacturing plants with 1,350 MW of electricity and 25,000 m3 of desalinated water each day. Additionally, it allows water to Riyadh, the country's capital, and a few other central cities that require a combined 900,000 m3/d (constructionweekonline.com, 2013), (desalination.biz, 2013). Water for Jeddah, Makkah, and Taif is produced by the MSF Shuaiba 3 desalination facility on the east coast of SA, which has a capacity of 880,000 m^3/d. South Africa is also home to the Ras Al-Zour plant, producing 800,000 m^3 of water daily (Henthorne, 2009).

2.9 Distribution of installed plant capacity

Reverse osmosis (RO) systems are more popular than multi-stage flashing MSF and multi-effects distillation MED. Figure 8 shows each desalination method's worldwide contributions (Alkaisi, 2016).



Water output worldwide as a function of various desalination techniques is shown in Fig. 8 (Alkaisi, 2016).

3. Results

1- Water supply is likely to become increasingly dependent on desalination in the years to come because of its rapid growth around the world. Desalination is becoming increasingly .popular, especially in dry regions of the world.

2. The Middle East has most of the world's largest saltwater desalination plants.

3. RO systems are more popular than MSF MED.

4. Conclusions

Desalination is becoming increasingly popular, especially in dry regions of the world. It appears that the annual desalination capacity is increasing rapidly over time.

It is crucial to continue funding research into brine disposal since desalination can provide a sustainable water supply at a low cost.

5. Recommendations

1. The variety of technologies available on the market ensure products of different quality and distinguish themselves by efficiency.

2. Based on the earlier figures and the lower cost of water production, the RO unit is the best desalination technology now available. Additionally, by using commercially available technologies like solar panels and wind turbines, the prospect of using electrical energy as an input would make the coupling with renewable energy sources simpler.

3. Install tiny desalination units on uninhabited islands, powered ideally by renewable energy sources, to meet freshwater demand in a sustainable manner.

6. References

1- Needham, J.; Ping-Yu, H.; Gwei-Djen, L.; Sivin, N. (1980). Science and Civilisation in China: Volume 5, Chemistry and Chemical Technology; Cambridge University Press: Cambridge, UK; p. 60.32

2- Hinkebein, T. (2021). Desalination: Limitations and Challenges. National Academy of Sciences. Available online: https://www.ncbi.nlm. nih.gov/books/NBK83737/ (accessed on 3 May 2021).

3- John Andelin, Assistant Director, (1988). Using Desalination Technologies for Water Treatment, March.

4- A. Al-Alshaikh, IDA R&D Committee (2013). An Overview, in Desalination Research Centers, Achievement & Future Trends Workshop on 17–19 March, Hilton Hotel Jeddah Saudi Arabia. Available from: <http://idadesal. org/wp-content/uploads/2013/05/IDA_RD-Committee- Meeting-Combined-Overview-Presentations-Day-1.pdf>.

5- Shoaiba Desalination Plant. (2011). Water Technology. Retrieved on March 20.

6- Desalination, CalderTM – A Flowserve Company, HTTP:// www.flowserve.com/files/Files/Literature/FPD/fpd-10-ea4.pdf, February 2013.

7- World Bank. (2019). the Role of Desalination in an Increasingly Water-Scarce World. Washington, DC.

8- Al-Karaghouli A., D. Renne & L. Kazmerski., (2009). "Solar and wind opportunities for water desalination in the Arab regions," Renewable and Sustainable Energy Reviews, vol. 13, pp 2397-2407.

9- Ahmed Alkaisi, Ruth Mossad and Ahmad Sharifian-Barforoush, (2016). "A review of the water desalination systems integrated withrenewable energy," 1st International Conference on Energy and Power, ICEP2016, 14-16 December.

10 - Konstantinos Zotalis, Emmanuel G. Dialynas, Nikolaos Mamassis, and Andreas N. Angelakis, (2014). Desalination Technologies: Hellenic Experience.

11- Construction Week Online. (2013). Largest Desalination Plant in World 75% Complete. Availableonline:http://www.constructionweekonline.com/article-22824-largest-desalination-plant-in-world-75- complete/#.UgjrLtJM_7E (accessed on 14 July 2013).

12- The International Desalination & Water Reuse Quarterly Industry Website. Installed Desalination Growth Slowed in 2011–2012, 2013. Available online: http://www.desalination.biz/news/news_story.asp?id=6746&title=Installed+desalination+growth+slowed+in+2011%26%238209%3 B2012 (accessed on 30 September 2013).

13- Henthorne, L. (2009). The Current State of Desalination. In Proceedings of the International Desalination Association (IDA) World Congress, Dubai, United Arab Emirates, 7–12 November.

Doi: doi.org/10.52132/Ajrsp.e.2022.43.2