Desalination of seawater as a means of ensuring water security

تحلية مياه البحر كوسيلة لضمان الأمن المائي

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Date of transmission: 06/09/2024 date of acceptance: 22/10/2024 date of publication: 01/12/2025

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Abstract: The problem of access to potable water is mainly evident in the cities of developing countries. The number of people who do not have access to good-quality water is currently estimated at 1.2 billion, and the number will reach about two billion in 2024 if governments do not invest heavily in this sector. In the face of water scarcity and deterioration, it is necessary to search for and move towards new and alternative water resources, represented by establishing an industry for desalinating salt water and converting it into potable water.

Desalinating seawater is another way to obtain water, but it is very expensive. However, Algeria was able to seize an eighth place in the global desalination market, which contributed significantly to reducing the country's water budget deficit and provided an additional resource that significantly impacted ensuring its drinking water needs

key words: Seawater desalination; Water security; Distillation; Reverse osmosis; Electrolysis

الملخص: تتجلى مشكلة الحصول على مياه صالحة للشرب بصورة أساسية في مدن البلدان النامية ويقدر عدد الأشخاص الذين لا يحصلون حاليا على مياه ذات نوعية جيدة بنحو 1,2 مليار شخص، وسيصل العدد إلى نحو مليارين في عام 2024 إذا لم تستثمر الحكومات بكثافة في هذا القطاع، وأمام ندرة المياه وتدهورها توجب البحث والاتجاه إلى موارد جديدة وبديلة للمياه والمتمثلة في إقامة صناعة تحلية المياه المالحة وتحويلها إلى مياه صالحة للشرب.

وتعتبر عملية تحلية مياه البحر طريقة أخرى للحصول على المياه إلا أنها طريقة مكلفة جدا غير أن الجزائر تمكنت من افتكاك المرتبة الثامنة في سوق التحلية العالمي وهذا ما أسهم بشكل كبير في تخفيف عجز الموازنة المائية للبلد ووفر موردا إضافيا كان له تأثيرا كبيرا في ضمان احتياجاته من مياه الشرب.

الكلمات المفتاحية : تحلية مياه البحر؛ الأمن المائي؛ التقطير؛ التناضح العكسي؛ التحليل الكهربائي.

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Introduction:

Man has transformed natural resources into economic resources that he uses to produce the goods and services he needs to satisfy his desires. With economic and technological development, pressures on natural resources have increased, and the scarcity of these resources has become a source of concern for man, who struggles with nature to satisfy his increasing multiple and renewable needs. Among these natural resources, we find water resources, which are considered the essential issue of his life. Its availability means life, while its shortage or misuse leads to poverty and extinction. Therefore, governments pay great attention to water and how to develop, control and provide it. Water represents 71% of the Earth's surface, while land, of course, occupies 29%. Statistics indicate that salty seawater constitutes 94% of the world's water, while freshwater represents 6%, glaciers represent 27% of fresh water, and 72% is groundwater. Less than 1% of freshwater remains in the atmosphere, waterways, or lakes. Providing fresh water for drinking and various uses in many countries of the world has become one of the ongoing challenges for development programs in coastal and desert areas that are located far from natural water sources such as rivers and fresh wells. By reviewing recent statistics on water sources, we find that the latter have become limited and defined by specific quotas of water. Through the above and the seriousness of the water situation, countries have paid increasing attention to their water resources and made many efforts to develop these resources to meet the increasing demand for various development needs, but their limitations on the one hand and the water policies that have been followed in the past decades on the other hand, especially in the field of securing the demand for water instead of managing it on scientific and economic bases to achieve the greatest return. Therefore, it has become imperative to look at ways to develop water resources in a way that achieves sustainable development and rationalizes the use of water resources, especially in agriculture.

The topic of this article is of great importance in the scientific field as one of the most important topics in the past, present and future, as it relates to the basic element of life, which is water.

Its importance from the practical side also lies in providing a natural resource that suffers from depletion due to many reasons and leads to wars known as water wars.

Hence, the study's problem is: How can water security be ensured by establishing a seawater desalination industry as an alternative source of fresh water?

To shed light on this study, we relied on the descriptive approach.

In order to answer the problem of this study, we divided the study into two parts. The first deals with seawater desalination methods by defining them, while the second part is devoted to studying seawater desalination in Algeria by shedding light on it and on desalination stations and their effects.

The first section: Seawater desalination methods:

Water desalination means separating fresh water from the salts dissolved in salt water, whether this water is seawater or well water. Therefore, it is called water sweetening or desalination[1].

Water sweetening or desalination is defined as a series of industrial processes that remove all or part of excess salts and minerals from water[2].

The seawater desalination program using renewable energy includes the selection of two different types of technologies; the first type is related to the use of advanced technology, which are technologies based on commercial quality systems and can reduce energy consumption to achieve the target values (reverse osmosis plants / thermal desalination plants). In contrast, the second type, which is represented by innovative desalination technologies, is based on new and innovative concepts for seawater desalination and can significantly reduce energy consumption to achieve the target values (membrane-based processes / thermal desalination processes[3].)

Water desalination is done through two methods: distillation and reverse osmosis[4] .

Algeria is a coastal country, which provides an opportunity to exploit seawater for desalination and obtain a new source of water [5].

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[1] Hassan Al-Banna, Saad Fath, Water Desalination Technology, Part One, Dar Al-Jamiah, Alexandria, Egypt, 2001, p. 8, quoted from Kamel Bouazem Amal Denon, Seawater Desalination in Saudi Arabia: Achieved Revenues and Potential Costs during the Period (2000-2014), Arab Economic Research, Issue 71, Summer 2015, Center for Arab Unity Studies, p. 23

[2] Wikipedia (the free encyclopedia), Water Desalination, viewed on 09/07/2022

[3] Masdar Program for Desalination of Seawater Using Renewable Energy, p. 9

[4] Loic Chervo, Natural Hazards in the World, Arab Journal of Riyadh, First Edition, 2015, p. 111

[5] Tayeb Qassas, The Problem of Water Resources Management in Algeria, PhD Thesis, Faculty of Economics, University of Setif, pp. 2015-2016.

First requirement: Distillation:

It is a very old idea dating back to ancient times. It was the only method used for desalination until before World War II. It is still used today on a large scale and is the most advanced and economical desalination method[1] .

The normal distillation process of salt water involves boiling salt water in a tank without pressure. The steam rises to the top of the tank and is condensed to turn into water droplets that are collected in the distilled water tank. This method is used in desalination plants with small production capacit.ies

This method is known as desalination by evaporation methods. This means that part of the salt water evaporates, leaving behind the salts, and the resulting steam condenses into pure water. This method includes five processes: flash evaporation, multiple-effect distillation, evaporation by steam pressure and solar energy, and finally, reheating.[2]

From the above, it is clear that the distillation process is similar to the natural[3] water cycle. This method has a number of advantages if the process is carried out at a lower temperature. This reduces the possibility of rust and scale formation and thus reduces the need for additional materials or maintenance and materials to resist rust. In addition, it requires fewer stages and equipment.[4]

Second requirement: Reverse osmosis:

This process is considered modern compared to distillation processes. Its application began in the 1970s. It is considered the most widely used process after rapid multi-stage distillation and the second largest technology used in the world.[5]

These properties are exploited in separating salts from water, and the most important of these methods are:

- Reverse osmosis.
- Electrolysis.[6]

Desalination is the process of separating water from a compressed saline solution through a membrane. This separation does not require heating or a

[1] Mustafa Mahmoud Suleiman, Water and the Natural Environment in the Arab World, Dar Al-Kitab Al-Hadith, Cairo, Egypt, 2009, p. 865

[2] M. Fouad Jawad Al-Sharabi - Dr. Abdullah Muhammad Al-Abbas, The Experience of Dual Production in the Kingdom of Saudi Arabia for Desalination of Salt Water and Production of Electricity in the Kingdom of Saudi Arabia for Desalination of Salt Water

[3] Fouad Jawad Al-Sharabi - Abdullah Majd Al-Abbas, the previous reference, p. 05

[4] Amal Dahman, The Problem of Desalination of Water in the Gulf Cooperation Council Countries between Environmental Protection and Achieving Water Security, North African Economics Journal, Volume 15, Issue 21, 2019, p. 61

[5] Amal Rahman, the previous reference, p. 61

[6] Essam El-Din Khalil Hassan, Water Purification, Academic Library 2000, p. 32

change in the liquid state, and most of the energy required for desalination is to pressurize the feed water.[1]

In practical terms, the feed water is pumped into a closed vessel where this water is pressurized against the membranes. Some types of the latter are membranes that allow fresh water to pass through and do not allow salt molecules to pass, and other types allow only positive or negative ions to pass through. When part of the feed water passes through these membranes, the remaining water salt content increases, and at the same time, part of the feed water is disposed of without passing through the membrane. This system is based on:

- Preliminary treatment.
- High-pressure pump.
- Membrane complex.
- Final treatment.[2]

Through this technology, many types of membranes are used, such as tubular membranes, hollow fibre membranes, capillary membranes, spiral membranes, and pillow-shaped membranes.[3]

The third requirement is the desalination of seawater by electrolysis:

Dialysis, also known as electrolysis,this method has been known since the [4] sixties, and this technology depends on

Most of the salts dissolved in water are positively or negatively charged, and these ions are attracted to the electrode according to the electrical charge they carry. Thus, membranes can be created that automatically allow the passage of ions according to their negative or positive electrical charge.[5]

Accordingly, desalination has become the most important sustainable source of water by addressing a number of challenges:

Imposing water tariffs to recover the total costs of water and wastewater, including the costs of distribution, transportation, treatment and environmental impacts.

And also relying on renewable energy sources such as solar energy for desalination, thus contributing effectively to achieving sustainability, reducing

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[1] Fouad Jawad Al-Sharabi, the previous reference, p. 06

[2] Fouad Jawad Al-Ribi, the previous reference, p. 06

[3] Rami Abdel Karim - Abbas Sandouk, Use of Renewable Energies in Desalination and Reverse Osmosis Technologies Fed by Photovoltaic Panels, Damascus University Journal of Engineering Sciences, Volume 30, Issue 01, 2014, p. 298

[4] Issam El-Din Khalil Hassan, previous reference, p. 38.

[5] Bayan Mohamed El-Kaid, previous reference, p. 175

the carbon footprint, integrating national economies into the knowledge-based production phase, and establishing a decentralized system consisting of mini-desalination plants in order to increase the efficiency of water control and also provide financial coverage and government assistance to improve desalination operations and mitigate their negative effects on the environment, and finally managing water demand, especially for the agricultural sector, which is the sector that uses the most water.[1]

The second topic: Desalination of seawater in Algeria

The water situation that Algeria experienced at the beginning of the third millennium contributed to the search for non-traditional alternatives to increase its water reserves. Desalination of seawater was the best alternative in light of the availability of supporting components such as energy sources and the coastal strip,and the desalination industry is not subject to climate fluctuations. [2] Desalination plants can also be built near consumption centres. Despite the high operating costs of desalination plants, their capital costs are less expensive than traditional facilities such as dams, and the desalination industry does not have political, social or legal caveats such as those related to natural water reservoirs or shared river basins. All of this and the drought waves that Algeria has witnessed over the past decades, the limited water resources in the north of the country, signs of climate change, which were characterized by significant fluctuations in the amount of rainfall, and the abundance of financial and energy resources necessary for the establishment of the desalination industry.[3]

Also, 11 dams, especially the old ones, are silting, causing the loss of about 100 million m3 of their storage capacity[4].

The first requirement: A brief about seawater desalination in Algeria:

The first beginnings of the desalination industry in Algeria date back to the sixties of the twentieth century, and we can summarize the most important stages that water desalination in Algeria went through as follows:

 1964: This year witnessed the establishment of the first station (small unit) for water desalination on the western coast of the city of Arzew Oran, with

[1] Ahmed Tartar - Braji Sabah, Water and the Problem of Sustainability, Mohamed Khider University, Biskra, Algeria, p. 21

[2] Kamal Bouazem - Amal Yinon, Desalination of Seawater in Algeria between Provision of Drinking Water and Environmental Protection during the Period (2005-2015), Al-Baheth Magazine, Issue 16, 2016, p. 324

[3] same reference, p. 324

[4] Adel Kadouda, Economics of Water Resources in the Agricultural Sector in the Arab World, PhD Thesis, Mohamed Khider University, Biskra, Algeria, 2018, p. 201

a production capacity of 573 m^3 per day. It was established by the French company VEOLIA SIDEM. The main purpose of its establishment was to meet the needs of the industrial zone, and it entered service in 1965 by adopting the multi-effect evaporation technology.

 1969: This year witnessed the establishment of the second seawater desalination unit, also hosted by the city of Arzew, Oran, with a daily production capacity of 3000 m3 per day, and was established by the company WEIR TCHNA

 1994: A desalination unit operating using reverse osmosis technology was established in the state of Mostaganem with the aim of meeting the water requirements of the paper industry.

- 1996: A desalination unit was established in the city of Annaba, operating using reverse osmosis technology to provide the water needs of the Asmidal company.

 2002: 21 reverse osmosis stations were established to desalinate seawater as part of the emergency plan.

 2005: The first major seawater desalination station was inaugurated by the Algerian President, which is the Krahma station in Arzew, Oran, with a production capacity equivalent to 88.6 x ^{3}10 m^3.[1]

- Currently, there are 23 desalination plants, and five stations are under construction to reach coverage of the need for potable water by approximately fifty per cent.

Second requirement: Seawater desalination plants in Algeria:

The desalination map in Algeria has developed with the adoption of the emergency plan for the year 2002, both in terms of the capacity of the stations and in terms of production capacity, which is as follows:

Algeria initially established small-sized desalination units of the mobile type, which were intended to supply housing with drinking water. Their production capacity ranged between (2,000-5,500) m3/day, and they were established by the German company LIMDE-KCA and the Algerian company HYDRO-TRAITEMENT.

Most of the small stations have stopped service, with the exception of 03 stations that were re-converted to other states to support the capacity to supply drinking water, especially in urban centers.

Algeria also has ten major desalination plants with a production capacity estimated at (88.6×^{3}10-500×^{3}10) These plants are in service. [1]

[1] Kamal Bouazem - Amal Yinon, previous reference, pp. 324-325

Algeria has relied on reverse osmosis technology in the seawater desalination industry, which is the technology it uses in most desalination plants, with the exception of one plant that uses multi-stage flash evaporation technology.[2]

Seawater desalination has contributed to providing drinking water and reducing pressure on traditional water resources (surface/groundwater). It has also contributed to the development of desalinated water production in Algeria. In addition, the weight of desalinated water in the water budget of some states, including major cities, is prominent due to its suitability for drinking according to internationally approved standards.

The third requirement: Effects of desalination of seawater: Seawater is available everywhere, which helps desalinate it and provides fresh water to the population. Desalination plants can be established near consumption sites along the coast. It is also a sure guarantee to avoid water shortages and the possibility of developing its economic efficiency because it consists of mechanical equipment / and it is free of political, social or legal obstacles, such as those faced by shared rivers, i.e. transboundary rivers, and the duration of its construction is shorter than the time it takes to extend water transmission lines from remote areas[3]. All of this is positive, but there are negative effects that are evident in air pollution due to the effects of oxides, pollution of seawater and marine life as a result of leakage of saline solutions, and increased local concentration due to liquid waste and residues of chemical treatment materials. Algeria produces huge quantities of saline solution, which are mainly confused by the number of quantities taken to produce desalinated water, which exceeds 1.5 million m^3 per day, which gives an estimate of the volume of saline solution resulting from these quantities that exceed millions of cubic meters by multiples.[4]

Pollution by greenhouse gases resulting from the use of electricity and steam to power desalination plants, estimating the gas emissions from seawater desalination plants in Algeria is not an easy matter, especially in light of the

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[1] Kamal Bouazem, previous reference, p. 325

[2] Khaled Bamardouf, Promising technologies in reducing the costs of desalination water, a research paper presented to the 26th Arab Conference on Water Resources in the Arab World, Reality and Challenges, 07-10, Kingdom of Saudi Arabia, 2012, p. 13

[3] Abbas Fadel Al-Saadi, Water Resources and Their Relationship to Population Growth in the Arab World, First Edition, 2018, Safaa Publishing and Distribution House, Amman, p. 136

[4] Kamal Bouazem, previous reference, p. 327

expansion of the sources responsible for emitting these gases, with the exception of the Kahrama thermal station, all stations operating in Algeria depend on electricity, which generates fossil sources (oil and natural gas) that pollute the environment.[1]

The mechanism of desalination of seawater kills microorganisms present in seawater. These dead organisms become part of the station's discharge, which produces a large amount of organic matter that causes problems for water quality and also forms a fertile base for the growth of bacteria, which is harmful to human health.

The decrease in dissolved oxygen is reflected in marine life.[2]

The analysis process in all methods depends on three main stages: the initial treatment, the desalination unit, and the final treatment. The initial treatment aims to prepare seawater for desalination, while the final treatment makes the desalinated water suitable for the desired uses.[3]

Conclusion:

With the lack of rainfall, the water crisis in the northern cities has become acute. Thus, the amount of traditional water resources need to be increased to secure the population and provide them with drinking water. Therefore, resorting to seawater desalination has become an urgent necessity and a strategic solution. Since 2001, Algeria has placed the provision of drinking water through seawater desalination within the national economic recovery plan, which has allocated a financial envelope estimated at 12 billion dollars, especially in Oran and neighbouring states. The national program includes the completion of 43 desalination plants by 2019, knowing that replacing or rehabilitating these plants and establishing new plants to keep pace with the increasing demand requires investing huge sums of money estimated at billions of dollars.

Studies on the effects of seawater desalination plants on the ecosystems in Algeria are still limited, and in an attempt to answer the problem, we have reached the following results:

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[1] Amal Yinon, Kamal Bouazem, Desalination of seawater in Algeria between providing drinking water and protecting the environment during the period (2005-2015), Al-Baheth Magazine, Issue 16, 2016, p. 326

[2] herine Adnan Qabrtay, Desalination as a means of sustainability and the implications of preliminary treatment on its environmental impact, King Abdulaziz Journal of Engineering Sciences, Volume 26, Issue 01, p. 105

[3] Obaid Farhat Ali, Economics of Integrated Management of Desalination of Highly Saline Well Water in Desert Lands, Volume 39, Part 3, September 2017, p. 444

- Desalination of brackish groundwater and seawater has enormous potential to bridge the water gap between the supply and demand sides in the region.

- Due to their proximity to industrial areas, desalination plants are a strategic option for achieving water security and economic growth.

- Departure from the concept of traditional water crises.

- Water technologies and dual-energy production.

- Restoring the environmental balance.

- Water purification plants were established randomly in addition to the lack of meters to measure the quantities of extracted water.

- Wastewater coming out of purification plants can be used to irrigate crops and other aspects.

- Poor water consumption threatens environmental disasters, including groundwater becoming salty.

- Seawater desalination technology is expensive.

Recommendations:

• There is a need to regulate the process of distributing seawater desalination plants geographically.

• Studies should be conducted on the process of environmental balance between the amount of water and the number of residents and predicting future risks of water depletion.

• Work on spreading the teachings of rationalizing water consumption.

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1. Amal Yenoni, Kamal Bouazem, Desalination of seawater in Algeria between providing drinking water and protecting the environment during the period (2005-2015), Al-Baheth Magazine, Issue 16, 2016.

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3. Obaid Farhat Ali, Economics of integrated management of desalination of highly saline well water in desert lands, Volume Thirty-Nine, Part Three, September 2017

4. Abbas Fadel Al-Saadi, Water resources and their relationship to population growth in the Arab world, First Edition, 2018, Safaa Publishing and Distribution House, Amman.

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Resources in the Arab World: Reality and Challenges, 7-10, Kingdom of Saudi Arabia, 2012.

6. Ahmed Tartar - Braji Sabah, Water and the Problem of Sustainability, University of Mohamed Khider Biskra, Algeria, p. 21. 7. Kamal Bouazem - Amal Yenoun, Desalination of seawater in Algeria between providing drinking water and protecting the environment during the period (2005-2015), Al-Baheth Magazine, Issue 16, 2016

8. Adel Kadouda, Economics of water resources in the agricultural sector in the Arab world, PhD thesis, University of Mohamed Khider Biskra, Algeria, 2018,

9. Issam El-Din Khalil Hassan, Water desalination, Academic Library 2000

10. Rami Abdel Karim - Abbas Sandouk, Use of renewable energies in desalination technologies and reverse osmosis fed by photovoltaic panels, Damascus University Journal for Engineering Sciences, Volume 30, Issue 01, 2014,

11. Fouad Jawad Al-Sharbi - Dr Abdullah Muhammad Al-Abbas, The experience of dual production in the Kingdom of Saudi Arabia for desalination of brackish water and electricity production in the Kingdom of Saudi Arabia for desalination of brackish water.

12. Amal Dahman, The Problem of Desalination in the Gulf Cooperation Council Countries between Environmental Protection and Achieving Water Security, North African Economics Journal, Volume 15, Issue 21, 2019

13. Masdar Program for Desalination of Seawater Using Renewable Energy.

14. Loic Chervou, Natural Hazards in the World, Arab Journal of Riyadh, First Edition, 2015.

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16. Mustafa Mahmoud Suleiman, Water and the Natural Environment in the Arab World, Dar Al-Kitab Al-Hadith, Cairo, Egypt, 2009

17. Hassan Al-Banna, Saad Fath, Water Desalination Technology, Part One, University House, Alexandria, Egypt, 2001, p. 8, quoted from Kamel Bouazem Amal Denoun, Seawater Desalination in Saudi Arabia, Achieved Returns and Potential Costs during the Period (2000-2014), Arab Economic Research, Issue 71, Summer 2015, Center for Arab Unity Studies

18. Wikipedia (the free encyclopedia), Water Desalination, viewed on 09/07/2022