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IS REVERSE OSMOSIS THE MOST SUITABLE SEAWATER DESALINATION PROCESS FOR ALGERIA?

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ABSTRACT

Algeria lies between two seas: the Mediterranean Sea to the north, an open sea, and the fossil sea to the south, an underground sea. These seas possess enormous water resources, but they are saline and undrinkable. To eliminate the salt, Algeria opted for reverse osmosis. Eighteen desalination plants and more than fifteen demineralization plants produce 1.35 billion m^3/y of fresh water. However, the plants' output has not reached the expected level. The reverse osmosis process is not well-suited to the raw water treated in Algeria. Reverse osmosis encounters difficulties during the rainy season. The polluted water discharged by the 50 Rivers (riverbeds) into the sea seeps into the plants' water intakes. To prevent turbidity in the raw water, the intakes must be located further from the treatment plants. For brackish water demineralization plants, reverse osmosis is not suitable for raw water at a temperature of 60°C. A cooling tower is necessary to lower the temperature to 30°C. The distillation process does not require a pretreatment step. It is better suited to warm and even turbid water. Distillation produces a green brine containing only salts and no chemical additives. In contrast, the brine discharged by reverse osmosis contains salts and chemical additives used during the pretreatment phase. Storing brine from a demineralization plant using distillation in evaporation ponds is not a viable solution, as it results in the loss of land and significant amounts of water through evaporation for just a few kilograms of salt. The most effective solution for brine from a demineralization plant is its direct discharge into the salt flats (chotts). However, for seawater desalination, brine in the sea without chemicals remains the only viable option at present. So, even though reverse osmosis consumes less energy, considering the parameters mentioned in the article, distillation is a much more favorable process than reverse osmosis.

Keywords: Seawater, fossil water, distillation, reverse osmosis, brackish water.

INTRODCUTION

Ensuring Algeria's water security is no easy task, especially with climate change complicating the replenishment of the country's freshwater reserves. This new climate is characterized by prolonged droughts marked by high temperatures, leading to significant evaporation. This dry season is followed by a short-wet period characterized by flash floods and deadly flooding (Remini, 2023; Remini, 2025a; Remini, 2025b). In such a situation, the dam is the primary victim of this climate disruption. The dam has suffered a double discount in its capacity: evaporation during prolonged droughts and siltation during flash floods (Remini, 2024b; Remini, 2023). Within a 20-year period, Algeria has experienced two droughts, one in the early 2000s and the other in the early 2020s. During both dry periods, water resources were severely impacted by this climate change. Rainwater, and particularly water stored in reservoirs, was not spared from the high evaporation rate, which exceeded 2 meters in several dams, notably Foum El Gherza (Biskra), Djorf Torba (Bechar), Ksob (Msila), Foum El Gueiss (Khenchela), and Brezina (Bayadh). The Keddara dam saw its water level drop to its dead volume during these two droughts (Remini, 2024a). In 2024, the Boukourdane dam completely dried up, forcing it to utilize its dead volume with a mobile pumping station. The same situation occurred at the Mefrouch dam, which also completely dried up during these two droughts. Similarly, the Bakhadda dam in the Tiaret province completely dried up following a severe drought. However, during February 2026, this same dam was drained and its water released through the spillway. During the short rainy season, torrential downpours cause flash floods that carry significant amounts of sediment (Remini, 2024b). The water laden with fine particles, in contact with the clear water in the dams, generates density currents that propagate along the wadi beds and settle at the bottom of the dams (Remini, 2017a). It is during periods of flooding that dams silt up. For example, the flash flood of November 2011 deposited 1.5 million m^3 of silt at the Foum El Gherza dam, built on the Labiod wadi. This water crisis, caused by the reduction in usable capacity due to evaporation and siltation, forced the population to turn to groundwater. While the water stored in aquifers escaped evaporation, it could not withstand the pressure of high demand from the agricultural and domestic sectors due to the lack of rainwater infiltration. Therefore, these hidden waters cannot meet the water demand from all socioeconomic sectors, leading to a drop in the water table. Along the coast, the phenomenon of marine intrusion into coastal aquifers is appearing in several places along the Algerian coast, which is 1600 km long.

Algeria's freshwater reserves, with an annual capacity of 13 billion m^3/y, are replenished by four water sources: rainwater, fossil water, wastewater, and seawater (Remini, 2025a). Only seawater and fossil water (brackish water) are readily available during periods of drought. However, these waters must be desalinated to become potable. This has led Algeria to consider seawater and brackish water desalination as a strategic option. Nevertheless, progress cannot stop there, given the very low level of national integration in these desalination projects, which require advanced technology. A quarter of a century of seawater and brackish water desalination has been a highly beneficial and significant experience, as Algeria has built 18 desalination plants and around 20 demineralization plants during this period. However, to obtain fresh water from both the Mediterranean and the fossil aquifer, several processes for extracting salts from seawater and fossil water have been invented in recent years. Two technologies have made the difference: reverse osmosis and microsulfur distillation (MSF). In fact, they are the most widely used in the world due to their significant yields in producing fresh water. Each of these two processes has its advantages and disadvantages; only a study taking into account energy and national integration in the construction of these plants can dictate the strategic choice between reverse osmosis and microsulfur distillation (MSF). In Algeria, the choice has been made, and all desalination and demineralization plants have been equipped with a reverse osmosis process. A total volume of 1.35 billion m³/y is produced by these plants, but this quantity of fresh water will increase with the construction of additional desalination plants (Remini, 2025a). Currently, the yield of some plants is not reaching the expected levels due to the problems encountered. In our opinion, the diversity of technologies in desalination plants is welcome. Today, several countries have opted for a proliferation of technologies.

In energy-producing countries, desalination by distillation is a key technology for freshwater production. Middle Eastern countries such as Saudi Arabia, Kuwait, and the United Arab Emirates have opted for hybrid desalination, using both reverse osmosis and distillation technologies. In Saudi Arabia, Ras Al-Khair is considered one of the world's largest desalination plants, utilizing both multistage thermal flash (MSF) and reverse osmosis (RO) technologies (Water TS, 2021). In the United Arab Emirates, the Qifda hybrid desalination plant, capable of producing 590,000 m³/day of freshwater, uses both distillation and reverse osmosis technologies. All these technologies have advantages and disadvantages. Only a thorough study, taking into account energy and national integration in the construction of these plants, can dictate the strategic choice between these desalination processes. It is from this stage that Algeria must move towards a strategic option that will ensure water security and, above all, the nation's water sovereignty. The best approach is to answer the question posed in the title of this paper: "Is reverse osmosis the most suitable seawater desalination process for Algeria?"

FRESHWATER STOCKS AND THE EVOLUTION OF SEAWATER DESALINATION IN ALGERIA

Algeria is among the few countries in the world with diverse water sources. Four water sources contribute to Algeria's freshwater stock: (Remini, 2025a; Remini, 2025b) (Fig. 1), namely Skay water, Wastewater, Seawater, and Fossil water.

As mentioned at the beginning of this article, Algeria lies between two seas. To the north, an open-surface sea, the Mediterranean Sea, and to the south, a subterranean sea, the fossil sea. Considered the largest semi-enclosed sea in the world, the Mediterranean Sea has a volume of 3.75 million km³ and covers an area of 2.5 million km² (Breuil, 1997). 5.5 million years ago, its volume was 12.5 million km³, a reduction of 70% of its initial volume. The Mediterranean Sea has a negative water balance; precipitation is less than evaporation, meaning that the amount of water returning to the sky is greater than the amount returning from the sky. This water deficit (precipitation < evaporation) is compensated by water entering the Atlantic Ocean through the Strait of Gibraltar. The

Mediterranean Sea connects to the Indian Ocean via the Suez Canal and to the Black Sea via the Sea of Marmara. The Mediterranean Sea is shared by 22 countries, including Algeria. Having access to the Mediterranean Sea and to the fossil sea hidden deep beneath the Sahara is a blessing and a gift from heaven. Regarding seawater, Algeria has a 1600 km border with the Mediterranean Sea; an infinite, inexhaustible, and free source of water, but it is saline with an average concentration of 38 g/l (Fig. 2).

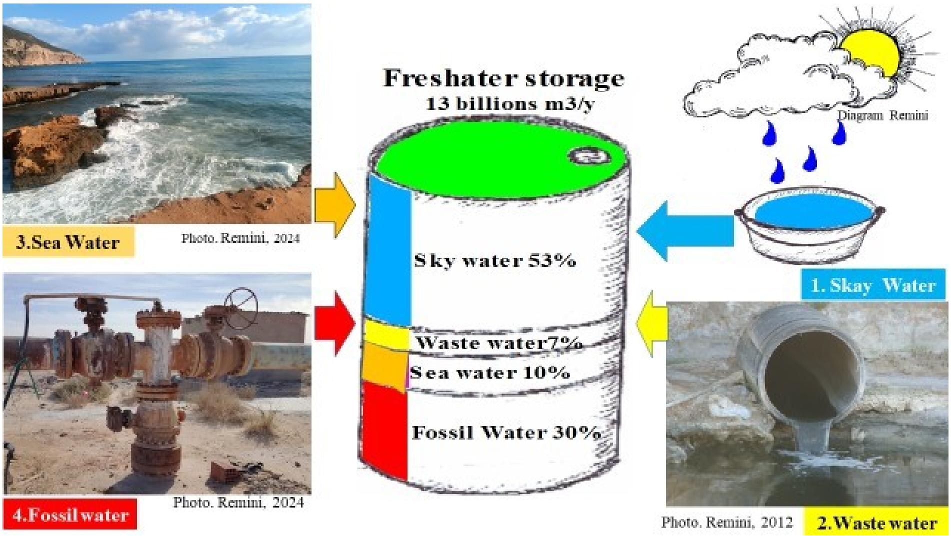

Figure 1: The main water sources that supply Algeria's freshwater reserves (Remini diagram, 2026)

Figure 2: A general view of the Mediterranean Sea. An inexhaustible water resource (Photo. Remini, 2024)

To make this water drinkable, the salts must be removed. Seawater desalination is the only way to render it potable. Several seawater desalination processes exist, but two technologies are most widely used worldwide: reverse osmosis and distillation. Algeria chose reverse osmosis based on a single criterion: energy savings compared to distillation. Eighteen seawater desalination plants have been built along a 1,600 km stretch of coastline. Only one plant operates using the distillation process (Table 1).

Table 1: Characteristics of desalination plants in operation

Wilaya	Station	Capacity (m^3/d)	Year of commissioning
Chleff	Ténès	200 000	2015
Bejaïa	Tighremt	300 000	2025
Tlemcen	Souk Tléta	200 000	2011
	Honaïne	200 000	2012
Alger	Hamma	200 000	2008
	El-Marsa	60 000	2022
Skikda	Skikda	100 000	2009
Mostaganem	Mostaganem	200 000	2011
Oran	Arzew	90 000	2005
	Mactaâ	500 000	2014
	Cap Blanc	300 000	2025
Boumerdès	Cap Djinet 1	100 000	2012
	Cap Djinet 2	300 000	2023
	Corso	80 000	2025
El Tarf	Berrihane	300 000	2025
Tipaza	Fouka 1	120 000	2012
	Fouka 2	300 000	2025
Aïn Témouchent	Béni Saf	200 000	2010

The same principle was adopted by Algeria to remove salt from the brackish waters of the Continental Intercalaire aquifer. Seawater desalination is not simply a project to construct a hydraulic structure, but rather a strategic choice by an entire country seeking to convert seawater into freshwater. It is a true revolution in seawater desalination that began in the early 2000s and will continue until the entire demand for drinking water is met. The entire 1,600 km Algerian coastline will be dotted with seawater desalination plants. A project for seven seawater desalination plants is under study to produce a volume of 0.68 billion m^3/y, by 2030, thus covering 60% of the drinking water demand (Table 2). In total, the seawater source will supply 2 billion m^3/y. These desalination plants will be built in the wilayas of Tlemcen (1 plant), Mostaganem (1 plant), Chlef (1 plant), Jijel (1 plant), Skikda (1 plant), and Tizi Ouzou (2 plants). Three of these seven plants are currently under construction: those in Tlemcen (300,000 m^3/day), Mostaganem (300,000 m^3/day), and Chlef (300,000 m^3/day). By 2030, the seawater source will supply Algeria's freshwater reserves with 2 billion m^3/y.

Table 2: Characteristics of the planned desalination plants

Wilaya	Station	Capacity (m^3/day)
Mostaganem	Mostaganem 2	300 000
Tlemcen	Tlemcen2	300 000
Chlef	Chlef 2	300 000
Tizi Ouzou	Tizi Ouzou 1	-
	Tizi Ouzou 2	-
Skikda	Skikda2	-
Jijel	Jijel 1	-

Far from the Mediterranean Sea lies southern Algeria; a desert region encompassing the Algerian Sahara, covering 85% of the national territory (2.382 million km²), or more than 2 million km². This vast region is driven by wind energy on the surface and hydraulic activity in the subsoil. This wind energy has led to the formation of the great ergs on the Saharan landscape, such as the Grand Erg Occidental, the Grand Erg Oriental, the Erg Erraoui, the Erg Iguidi, the Erg Chech, and the Erg Mourzouk (Fig. 3).

Figure 3: Wind dynamics on the ground and water dynamics in the subsoil (Photo. Remini, 2021)

Conversely, in the subsoil of the Algerian Sahara, water dynamics have led to the formation of six aquifer systems with a non-renewable or minimally renewable volume estimated at over 80 trillion m^3, covering an area of 4.3 million km^3. These are the Northern Sahara Aquifer System (NSAS), the Mourzouk Basin, the Iullemeden-Taoudéni-Tanezrouft Aquifer System (ITTAS), the Tindouf Basin, the Bechar-Errachidia Basin, and the Maghnia Aquifer. These underground reservoirs, whose boundaries extend beyond national borders, are called transboundary aquifers. Algeria shares these transboundary aquifers with eight countries (Tunisia, Nigeria, Niger, Burkina Faso, Mali, Mauritania, Benin, and Libya), three of which are classified as major aquifers (Table 3 and Fig. 4).

Table 3: Characteristics of Algeria's large aquifers (Remini, 2025c). Sources: French Scientific Committee on Desertification (FSCD), 2020; Seguin and Gutirrez, 2017; SSO, 2020)

N°	Aquifer system	Volume km^3	Area 10^3 km^2	Shared countries
1	Northern Sahara	60 000	1000	Algeria, Tunisia, Libya
2	Taoudéni/Tanezrouft/ Iulleden	15 000	2500	Algeria, Nigeria, Niger, Burkina Faso, Benin, Mali, Mauritania
5	Mourzouk	4 800	450	Algeria, Libya, Niger, Chad
4	Tindouf	800	221	Algeria, Western Sahara
5	Béchar-Errachidia	0,320	70	Algeria, Morocco
6	Meghnia	0,085	30	Algeria, Morocco

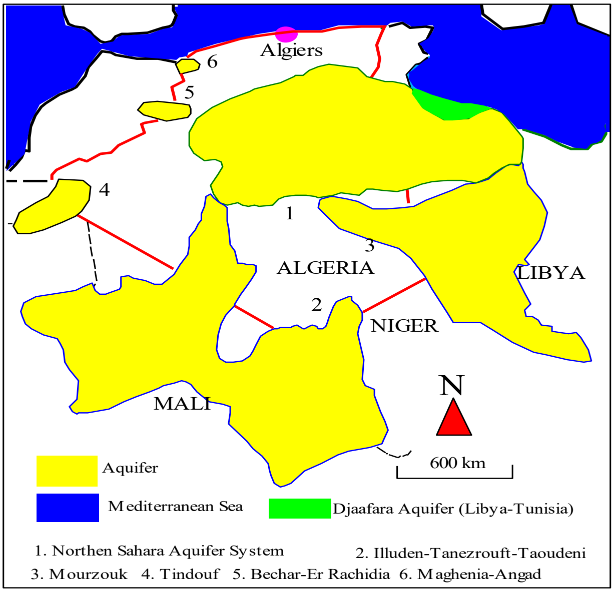

Figure 4: The 6 major transboundary aquifers with Algeria (Remini, 2025b; Remini 2025c)

Algeria, Tunisia, and Libya share the Northern Sahara Aquifer System (NSAS). The Murzuq Basin is shared between Algeria, Libya, and Niger. The Iullemeden-Taoudéni-Tanezrouft Aquifer System (ITTAS) is shared between Algeria, Niger, Mali, Nigeria, Burkina Faso, Mauritania, and Benin. Algeria alone sits atop a brackish water body covering an area of 1.2 million km², representing 50% of its territory. Through deep wells, Algeria extracts 3.75 billion m³/y from the Continental Intercalaire aquifer, which belongs to the Northern Sahara Aquifer System. The water reaches the surface with a brackish taste, a salinity of 2 to 2.5 g/l, and a temperature of 60°C to 70°C (Fig. 5). However, the Iullemeden-Taoudéni-Tanezrouft Aquifer System (ITTAS) and the Merzouk basin have not yet been exploited. No data or information is available on Algeria's share of water from these two aquifer systems.

Figure 5: Hot water at the inlet of the water in an open-air basin with a temperature of 60°C to 70°C (Remini, 2024)

Today, Algeria's freshwater reserves are estimated at 13 billion m³/y, but with accelerating socioeconomic development, these reserves must keep pace with the country's growth. It has been estimated that by 2060, freshwater reserves will reach 80 billion m³/y, at a rate of 2 billion m³/y. To achieve this goal, a water revolution is essential. This would require more than 20 billion m³/y of fossil water. Such a quantity necessitates enormous resources to significantly increase the number of deep wells. Furthermore, Algeria has launched an ambitious project over the past 25 years to convert brackish water from fossil seas into fresh water, reducing the salinity from 2.5 g/l to 0.3 g/l. This project aims to establish desalination plants in all the Saharan cities situated on this fossil, brackish sea. Currently, there are approximately twenty plants in operation. Called Ain Sahara (meaning the water source of the Sahara), the Touggourt desalination plant was built in 2014 to treat a raw water (brackish water) flow rate of 400 liters per second. This plant aims to meet the drinking water needs of the entire population of Touggourt. The plant is currently supplied by three boreholes, each 1,800 meters deep, with a total flow rate of 400 liters per second from the Continentale Intercalaire aquifer. The fourth borehole (Sidi Mahdi 2), with a flow rate of 150 liters per second, is nearing completion; its connection is underway to achieve a total flow rate of 530 liters per second from the four boreholes (Table 4). The Touggourt demineralization plant uses the reverse osmosis process to reduce the salinity of brackish water from 2.5 g/l to 0.6 g/l after treatment.

Table 4: Deep boreholes supplying the demineralization plant

Forage	Drilling (l/s)	Salinity (g/l)	Temperature °C	Depth (m)
Ain Sahara 1	142	2 à 2.5	50 à 60	1800
Ain Sahara 2	130	2 à 2.5	50 à 60	1860
Sidi Mahdi 2	150	2 à 2.5	50 à 60	1760
Sid Mahdi 3	110	2 à 2.5	50 à 60	1760

Nine brackish water desalination plants have been built in the Ouargla province. Twenty-six boreholes were drilled to tap into deep aquifers, including three Albian boreholes with a salinity of 3 to 6 g/l. Using reverse osmosis, the salinity of the raw water is reduced from 6 g/l to 0.8 g/l. The 26 boreholes supply the nine desalination plants with a flow rate of 70,000 m^3/day of raw water, producing 53,000 m^3/day of potable water. It should be noted that Ouargla's largest desalination plant has a capacity of 27,000 m^3/day and was commissioned in 2017. Three boreholes are used to extract raw water from the following aquifers:

- Miopleocene, with a flow rate of 10 to 25 l/s
- Senonian, with a flow rate of 15 to 60 l/s
- Albian, with a flow rate of 100 to 200 l/s.

The raw water is of good quality at the borehole outlet, but its temperature varies between 50°C and 70°C. It is therefore necessary to cool it by 30°C.

The El Oued brackish water demineralization plant, commissioned in 2018, has a production capacity of 30,000 m^3/day. This plant draws raw water from the depths of the Continental Intercalaire aquifer, with a salinity ranging from 4 to 6 g/l. The raw water is very hot, reaching a temperature of 68°C. Thanks to the cooling system, the water temperature is reduced from 68°C to 25°C before being introduced into the reverse osmosis process. Other plants are in operation, such as those in Ouargla, Tamanrasset, Ouled Djellal, In Salah, and Bechar. Others are planned, including one in Tindouf and a second plant in Tamanrasset. This is part of a larger project to build demineralization plants throughout the Algerian Sahara.

RESULTS

A country's water security is measured by its freshwater reserves. These reserves are primarily replenished by the following four sources:

- Rainwater: This is precipitation flowing into rivers and streams, and water that replenishes groundwater and alluvial aquifers. Only for drinking water supply does this water require treatment. Rainwater is stored in artificial reservoirs (dams and hillside reservoirs) and natural reservoirs such as lakes, groundwater, and alluvial aquifers.
- Wastewater: This includes drainage water, domestic wastewater, and industrial wastewater. Naturally, this water is used after passing through wastewater treatment plants.
- Seawater: This is water from seas and oceans. Obviously, this water is used after passing through desalination plants, as it has a high salinity.
- Fossil water: This is water that has been stored in deep aquifers for centuries. These large underground reservoirs are generally non-rechargeable or only partially recharged and can contain billions of cubic meters of brackish water. Very old, this water has a low salinity but is hot when it emerges from the ground; the temperature can reach 70°C. After cooling, this water can be used directly for irrigation. However, for domestic use, the water is treated at a desalination plant.

Virtually every country on the planet has at least two water sources at its disposal: rainwater and wastewater. Regarding rainwater, each country has its quota of precipitation from the sky. The amount of water each country receives depends on its climate and land area. Storing this water is not easy, as it depends on the country's financial situation. This involves drilling more wells to access groundwater and building dams to store surface water. However, the other two water sources are not available to all countries.

Countries located inland, far from oceans and seas, have not had the opportunity to desalinate these unconventional waters. Similarly, fossil waters, these ancient waters, are not available to everyone on Earth. Only countries fortunate enough to have a water reserve of several billion cubic meters in their subsoil can truly benefit. These mega-aquifers can have boundaries that extend beyond a country's borders; this is why they are called transboundary aquifers. Algeria is among the few countries that have four water sources to replenish its freshwater reserves. It is very interesting to see that a country like Algeria does not depend on a single water source but rather diversifies its water sources. This paper discusses the problems that prevent the "seawater" source from achieving a more or less significant yield. It is worth noting that the Algerian state has invested heavily in this water resource since the late 1990s.


a) Water intake tower b) the raw water pipeline


c) Coarse screening d) Pumping basin

Figure 6: Main components of the El Marsa desalination plant's intake system (Remini and Amitouche, 2023a)

The Algerian coastline, stretching 1600 km, has the highest concentration of fine particles in the Mediterranean basin. More than 50 wadis discharge an average of 120 million tons/y of solid particles into the sea during flood periods (Demmak, 1981) (Table 5 and Fig. 7). All this mud originates from the erosion of the watersheds.

Table 5: Rivers flowing into northern Algeria (Remini and Amitouche 2023a; Remini and Amitouche 2023b)

No	Name of the River	Length (km)	N	Name of the River	Length (km)
1	Tleta	12	27	El Harrach	15
2	Tafna	110	28	Hamiz	50
3	Meknassia	27	29	Corso	10
4	Halloufa	25	30	Merdja	5
5	Essenan	37	31	Isser	80

6	Guessiba	12	32	Larba	4
7	Tassmanit	4	33	Sebaou	80
8	El Kerma	6	34	Mleta	24
9	El Hammam	30	35	Youssef	27
10	Chellif	275	36	Ntaida	22
11	Guelta	12	37	Daas	21
12	Tarzoot	15	38	Saket	12
13	Allala	20	39	Soummam	60
14	Boucheghal	8	40	Agrioun	23
15	Goussine	412	41	El Kebir	42
16	Mentrach	12	42	Zhour	15
17	Ouattar	5	45	Tamanarat	9
18	Damous	36	44	Guebli	36
19	Kellal	6	45	Zeramna	15
20	Essebt	12	46	Kebir	36
21	Messelmoun	15	47	Seybouse	35
22	Hachem	22	48	Khelidj	15
23	Nador	8	49	Bounamoussa	20
24	Merzoug	4	50	MessidaZiama	10
25	Mazafran	17	51	Ziama	6
26	Beni Messous	10			

Figure 7: An example of the degradation of some watersheds in northern Algeria (Photo. Remini, 2012)

It is worth noting that today, climate change has a direct impact on watershed erosion. Indeed, after a prolonged drought marked by very high temperatures and sometimes forest fires (Remini, 2024b), the short rainy season following the drought creates soil conditions conducive to erosion. Flash floods trigger soil erosion, resulting in the removal of several tons of sediment into the wadis. Sediment concentrations exceeding 100 g/l have been recorded in several wadis, which discharge all this material into the sea (Fig. 8). Wind and ocean currents then disperse the fine particles over several kilometers, easily reaching the water intake tower.

Figure 8: Oued El Hammam carries excessively contaminated water, an example of sediment transport in the rivers of northern Algeria. (Photo. Remini, 2012)

The raw water intakes of all desalination plants are contaminated by dust during periods of flooding (Figs. 9a to 9f)). This situation necessitates a shutdown of the reverse osmosis process. The example of the Chlef province is worth mentioning. The Cheliff River, swollen during the torrential rains of January 2026, discharged several tons of sediment into the sea (Fig. 9 (a and b)). Formed by the confluence of the Nahr Ouassel and Touil Rivers, the Cheliff is the longest wadi in Algeria, exceeding 700 km in length. The Cheliff River basin covers an area of 1,480 km².

a) Oued Chellif. March 2014 b) Oued Chellif February 2019

c) Oued El Harrach, May 2018 d) Oued Sebaou March 2014

e) Oued Tafna. February 2014 f) Oued Agrioum 2019

Figure 9: Some examples of the extent of fine particle discharge from Algerian Rivers into the sea (Google Earth)

Furthermore, bad weather, waves, and currents carried sediment to the water intake of the desalination plant that supplies drinking water to the Chlef province, resulting in a shutdown for over three weeks. Another example concerns the Fouka desalination plant, which has also been affected by this problem. Indeed, each rainy season, characterized by flash floods, releases thousands of tons of fine particles into the sea, which then travel towards the water intake. This situation causes the desalination process to stop during floods, consequently disrupting the drinking water supply throughout the province. This problem of sediment transport was not taken seriously in the early 2000s. The water intake was located right next to the mouth of the river. Simply put, the water intake site must be considered in the feasibility study for a seawater desalination plant. As mentioned earlier, 50 Rivers (seasonal watercourses) discharge an average of 120 million tons of sediment into the sea annually. This creates significant sedimentary dynamics along the entire Algerian coastline. Therefore, the water intake must be located further offshore to prevent the influx of fine particles. However, this requires a longer pipeline distance, and consequently, the project will be more expensive. One option is to construct a settling basin upstream of the desalination plant, but for a large desalination plant (300,000 m^3/day), the basin's dimensions increase, making it more costly. For smaller desalination plants, drilling wells can be a solution. Finally, the discharge of solid particles into the sea caused by water erosion will increase in the coming years due to climate change. This means that the efficiency of desalination plants equipped with a reverse osmosis process decreases during periods of heavy rainfall, which increases seawater turbidity. In this case, why doesn't Algeria opt for desalination using the distillation process? Other drawbacks of the reverse osmosis process support and encourage the idea of switching to the distillation process. For example, the main equipment imported from abroad, such as membranes, high-pressure pumps, booster pumps, and PX energy recovery units, requires foreign currency.

It is also important to remember that raw seawater used for desalination by reverse osmosis plants requires very demanding pretreatment, and therefore significant chemical consumption. On the other hand, a desalination plant equipped with a distillation process does not require pretreatment and consequently does not need chemicals. Furthermore, the distillation process operates under all environmental conditions, even with very high seawater turbidity. This contrasts with the reverse osmosis process, which is very demanding and performs poorly during rainy periods. It should also be noted that the integration rate for the distillation process is higher than that of reverse osmosis. Several parts of the plant can be equipped and built in Algeria thanks to the availability of energy and iron ore deposits. Therefore, with the distillation process, we can even ensure Algeria's water sovereignty.

Regarding the "fossil water" source, Algeria is fortunate to have an underground sea composed of large aquifer systems:

- The Northern Sahara Aquifer System (NSAS)
- The Taoudéni/Tanezrouft/Iullemeden Aquifer System (ITTAS)
- The Merzouk Basin

These transboundary water bodies, with a total surface area of 4.5 million km^2, are shared among nine countries: Algeria, Tunisia, Libya, Niger, Mali, Mauritania, Benin, Nigeria, and Burkina Faso. Algeria alone sits atop a body of water representing 50% of its total land area. However, Algeria exploits the Northern Sahara Aquifer System with a flow rate of 3.75 billion m^3/year, representing 29% of its freshwater reserves. This aquifer system is composed of two superimposed aquifers; The Continental Intercalaire and the Terminal Complex. However, no information or data exists on the exploitation of the Taoudéni/Tanezrouft/Iullemeden Aquifer Systems or the Mourzouk Basin. It should be noted that the Continental Intercalaire aquifer has been exploited by approximately 1,000 foggaras for over 20 centuries (Remini, 2025c). Foggaras were invented to capture this water after the water sources from the Continental Intercalaire dried up (Fig. 10). It was the farmers of the Adrar, Timimoun, and In Salah oases who discovered the Continental Intercalaire aquifer (Remini, 2017b). The first deep well was drilled in the El Goléa oasis in 1891.

Figure 10: Kasria of a foggara in Timimoun. For more than 20 centuries, approximately 1000 foggaras have been exploiting the waters of the Continental Intercalaire aquifer (Photo. Remini, 2008).

The first well was drilled in 1956 at Sidi Khaled, and the second in 1974 at Ouled Djellal. The waters of the Western Sahara Aquifer System are brackish. From east to west, several deep wells have been installed to extract water from the Continental Intercalaire aquifer for agricultural irrigation and drinking water supply (Fig. 11).

Figure 11: Casings and accessories of boreholes intended for the exploitation of the Albian aquifers (Photo. Remini, 2021; Remini, 2025c)

Brackish water (2 g/l to 3 g/l) and a temperature of 70°C at the surface outlet. If the water is intended for irrigation, a water-cooling system becomes essential to lower the water temperature and allow for irrigation to be carried out under optimal conditions (Fig. 12 (a and b)). However, for supplying cities, the operation can be carried out directly with hot water. This is the case for the Touggourt province, which has been supplied for several years with hot water from the Continental Intercalaire aquifer.

a) New b) Old

Figure 12: Cooling tower for the brackish waters of the Continental Intercalaire in the Oued Righ valley (Photo. Remini, 2010)

Although abundant, the water from the Continental Intercalaire aquifer supplying Touggourt has a high lime content. The evolution of limescale deposits in the water supply network is dramatic, resulting in an annual decrease of approximately 35 mm in diameter, representing an average annual reduction of 10% of the initial diameter (Remini and Sayah, 2008). While it's true that the population has saved some energy since homes no longer use water heaters, the lifespan of the drinking water supply network has decreased due to scaling inside the pipes. In this case, the pipe cross-section is reduced, and sometimes the pipes even become clogged. The equipment and pipes in the drinking water supply network are replaced every 6 to 7 years (Fig. 13).

Figure 13: The condition of the drinking water supply network pipes in the town of Touggourt after 7 to 8 years of service (Remini and Amitouche, 2023a)

Since the installation of the Continental Intercalaire brackish water demineralization plant in the Touggourt province, the scaling problem has been resolved, and the water supplied to the population is of good quality. This brackish water demineralization plant was commissioned in April 2015 to produce a volume of 34,500 m³/day of demineralized water (Fig. 14). The raw water comes from six Albian boreholes with a total flow rate of 700 l/s to meet the needs of the municipalities of Touggourt, Nezla, Tébesbest, and Zaouia El-Abidia (Fig. 15). Thanks to the reverse osmosis process, which demineralizes and improves water quality, the salt content is reduced from 2.5 g/l to 0.3 g/l.

Figure 14: El Oued demineralization station for brackish waters from the Continental Intercalaire aquifer (Photo. Remini, 2023)

Figure 15: El Oued, Albian borehole over 1800 m deep (Photo. Remini, 2024).

Albian water is obviously very ancient, having been stored and sealed for centuries within an impermeable layer deep underground, reaching depths of up to 2500 m in some areas of the Algerian Sahara. It is very hot, with temperatures ranging from 60 to 70°C at the borehole outlet. The reverse osmosis process cannot handle such hot raw water, with temperatures exceeding 60°C, as found in the Touggourt region. Therefore, the Touggourt demineralization plant has been equipped with a cooling system to reduce the temperature of the Albian water from 60°C to 25°C. An entire tiered tower equipped with a system of radiators so that the water drawn from the Albian aquifer can cool down before passing through the reverse osmosis process (fig. 16).

The cooling tower and its equipment, an annex to the reverse osmosis demineralization plant, and its consumables such as membranes. The temperature drop in this cooling tower causes scaling in the pipes and radiator system, resulting in complete blockage (Fig. 17). Periodic replacement of the equipment in this cooling system is necessary, requiring additional funding that will be passed on to the price of a cubic meter of demineralized water.

Figure 16: A cooling tower for Albian aquifer water before it reaches the reverse osmosis process at the El Oued demineralization plant (Photo. Remini, 2024)

a) Initial state b) After operation

Figure 17: Fossil water cooling tower. Periodic replacement of consumable equipment. Example of radiators in a brackish water demineralization plant (Remini, 2024).

For each demineralization plant using the reverse osmosis process in the Sahara, the cooling tower is a hydraulic structure that complements the reverse osmosis process. All the groundwater beneath the Sahara is Albian and brackish, and therefore hot, with a temperature ranging from 62 to 70°C and a salinity ranging from 2 to 2.5 g/l. Furthermore, the raw water from the Continental Intercalaire aquifer contains iron, which poses problems for the membranes. The distillation process, however, can overcome these two problems (the presence of iron and the temperature of the raw water) (Fig. 18).

a) Water from El Oued b) Water from Biskra

Figure 18: Water from the Continental Intercalaire aquifer at some desalination plants (Photo. Remini, 2024).

As mentioned in this article, within the framework of a major strategic project launched by Algeria to make seawater and Albian aquifers potable, seawater desalination plants and brackish water demineralization units have been built, other plants are under construction, and more are planned. Given this experience acquired by Algeria in the field of desalination over the last 25 years, could Algeria turn to the distillation process?

It should be noted that the distillation process is based solely on the conversion of raw water from a liquid to a gaseous state. The advantage of the distillation process is that it produces raw water at 70°C. In this case, simply adding 10° to 20°C to the brackish water is enough to reach the evaporation threshold. It should also be noted that Algeria is an energy-producing country with iron ore deposits, thus ensuring a high level of domestic integration. Furthermore, this thermal process does not require pretreatment and therefore does not use pretreatment chemicals. On the other hand, the integration rate for the reverse osmosis process is too low, since consumables such as membranes, booster pumps, and PX heat exchangers are imported using foreign currency. Based on this initial assessment, it appears that the distillation process can compete with reverse osmosis for seawater desalination and brackish water demineralization in Algeria.

DISCUSSION

In Algeria, it all began with climate change, which altered the seasonal patterns. A long dry season characterized by high evaporation from lakes. A short-wet season marked by torrential rains that cause flash floods. A strategic choice was made by the Algerian state. The seawater desalination plant replaced the reservoir dam, a symbol of Algeria's water resources in the 1980s. As mentioned earlier, having a border with the Mediterranean Sea and an inexhaustible supply of water is a blessing. A water resource that is not dependent on climate is available year-round at our borders. However, the salt must be removed to make seawater potable. Several seawater desalination processes exist, two of which are the most widely used in the world: reverse osmosis and distillation. However, reverse osmosis is by far the most preferred. Algeria, with over 25 years of desalination experience, is no exception to this rule. Of the 18 large desalination plants in operation, 17 use reverse osmosis, while only one uses distillation. Similarly, the six demineralization plants all rely on reverse osmosis. After a quarter of a century of experience in seawater desalination, we ask the following question: "Is reverse osmosis the most suitable seawater desalination process for Algeria?" This is a question we already addressed in the article published in issue 58 of the Larhyss Journal (Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). So why this reliance on a single process, namely reverse osmosis? Even if we accept that reverse osmosis consumes less energy than distillation, we remain dependent on foreign suppliers for consumables such as membranes, pumps, and energy recovery systems. Furthermore, the local content rate for reverse osmosis plants in Algeria remains low. In addition, northern Algeria is a semi-arid region highly susceptible to erosion, and consequently, floods carry significant quantities of sediment to the sea. More than 50 wadis transport over 120 million tons of sediment annually to the sea (Demmak, 1982). The 1600 km long Algerian coastline is an area of very active sedimentation dynamics during the winter months. Therefore, seawater becomes heavily laden with fine particles. However, membrane processes designed for seawater desalination cannot handle such heavily laden raw water. In this scenario, the desalination plant is temporarily shut down until the seawater turbidity decreases. Such situations negatively impact the efficiency of reverse osmosis desalination plants. The water crisis that occurred in the Chlef province during January further underscores our question: "Is reverse osmosis the most suitable seawater desalination process for Algeria?" Indeed, the recent floods in January carried significant amounts of sediment to the sea, particularly the large volume of sediment discharged by the Chelif River. This caused a sharp increase in the raw water turbidity, necessitating the shutdown of the desalination plant. Other desalination plants have experienced the same problem in recent years and have led to the temporary shutdown of the desalination process, but the problem was less serious than that of the Chlef station. Therefore, we can confirm today that the reverse osmosis process, which requires good quality raw water, struggles to achieve acceptable efficiency during periods of high water. A new hydraulic problem has emerged: the raw water intake for desalination plants. Choosing the intake site, taking into account the river mouth, wind direction, and currents, is now a mandatory study for new projects to build reverse osmosis desalination plants. Obviously, other ancillary structures will be added to the desalination plants, such as a settling basin for fine particles (or the repositioning of intake points further offshore). While the distillation process is much simpler than reverse osmosis, since it does not take into account the turbidity of the raw water (the physicochemical characteristics of the raw water). (The availability of energy and metals for the construction of desalination plants in Algeria boasts a very high integration rate, with water production funded by the Algerian dinar in complete sovereignty and security).

The second part of this study concerns the second source of water resources that replenishes Algeria's freshwater reserves. This involves fossil waters hidden deep within the subsoil of the Algerian Sahara. Algeria is fortunate to possess a vast body of water comprised of the waters of the Northern Sahara aquifer system, the Marzouk basin, and the Iullemeden-Taoudéni-Tanezrouft aquifer system. These three basins together cover 54% of Algeria's total area. However, these ancient waters are brackish, necessitating demineralization processes. Around ten treatment plants have been built in the southern Algerian provinces, but they are all equipped with a reverse osmosis demineralization process, including the planned plants. So why use reverse osmosis to demineralize raw water ? This brackish water, which comes from the intercalated aquifer, reaches the surface at a temperature of 70°C. However, membrane processes like reverse osmosis cannot handle raw water at such a temperature. Therefore, a hydraulic structure is required upstream of the demineralization plant: a cooling tower to lower the temperature to a normal level. However, a demineralization plant equipped with a distillation process relies on recovering steam after raising the temperature of raw water to 100°C. This process is particularly well-suited to hot raw water like that from the Continental Intercalaire aquifer. It simply requires heating the brackish water (which is already at 70°C) further to reach its boiling point of 100°C. Moreover, the raw water from the Continental Intercalaire contains iron, which is harmful to the membranes used in reverse osmosis. Furthermore, the membrane process uses chemicals for pretreating the raw water, cleaning, and protecting the membranes. In contrast, the distillation process requires no pretreatment of its raw water. It needs neither membranes nor a cooling tower. Instead, the raw water arrives at the plant at 70°C; only 30°C is needed to reach the boiling point. Based on these observations, the distillation process is best suited to our brackish water desalination plants. The final point of this discussion concerns the environmental issue, specifically the discharge of brine from a seawater desalination plant or a brackish water desalination plant. After the raw water is separated into fresh water and the brine, which includes the concentrate (salts) and chemical additives, by reverse osmosis, the brine, representing more than 55% of the raw water, is discharged into the sea as the sole outcome. However, it is crucial to avoid discharging it as a highly concentrated jet (Remini and Amitouche, 2023) (Fig. 19).

Figure 19: Direct discharge of brine into the seabed from a desalination plant in Algeria (Fouka Station) (Remini and Amitouche, 2023a).

Two options stand out; in the first option, the brine is discharged into the sea after passing through a dilution basin. In the second option, the brine pipeline will be equipped with a Venturi diffuser; a more efficient technique for dispersing the brine in the marine environment, but it requires a high outlet velocity (> 5 m/s) to be fully effective (Maamar et al, 2025).

For a brackish water demineralization plant in the Sahara's fossil sea, the brine problem is far more complex than that of a seawater desalination plant. It's true that the salinity of the brine from a brackish water demineralization plant is much lower than that of the brine from a seawater desalination plant. The problem of where the brine is discharged from a demineralization plant is the major challenge in the brackish water demineralization process. All demineralization plants discharge their brine into the environment, and more specifically into the chotts (salt lakes). For example, the brine from the El Oued brackish water demineralization plant joins the treated water pipeline before being discharged into the Chott Halloufa. Regarding the brine discharged by the Touggourt brackish water demineralization plant, it flows into the Oued Righ canal to reach Chott Merouane. However, the advantage of a brackish water demineralization plant using distillation is that it does not use chemical additives in the pretreatment process. In this case, the resulting brine is a green brine containing only the concentrate (the salts). We can then recover these salts for reuse. It is simply a matter of constructing very large basins to receive the green brine, which will leave these salts as deposits through evaporation. It should be noted that the brine discharged by a demineralization plant is a significant quantity of water with a salinity of 5 to 8 g/l, which is stored in very large basins occupying a substantial area of land. Due to the high temperature, large quantities of water evaporate into the atmosphere, recovering a few kilograms of salt. In our opinion, this evaporation pond solution is not economical, as it wastes land and significant amounts of water. Therefore, discharging brine with a salinity of 5 to 8 g/l into the environment, specifically into the Merouane Salt Lake (for the Touggourt station) and the Halloufa salt lake (for the El Oued station), remains a much more viable solution. It should be noted that the salinity of this brine is lower than that of the salt lake water. However, the evaporation pond solution is very effective for brine from seawater desalination plants. Brine with a salinity of 70 g/l can be stored in evaporation ponds to recover large quantities of salt. In the case of distillation plants, the situation is even more interesting, since brine from a plant using the distillation process is a green brine without chemical additives. In this case, such brine from a demineralization plant using distillation, with a salinity of 5 to 8 g/l and without chemicals, can even be used for irrigation.

Based on Table 6, it appears that the distillation process consumes significantly more energy compared to the reverse osmosis process. However, the distillation process offers numerous advantages over reverse osmosis.

Table 6: Advantages and disadvantages of the two desalination processes: Reverse osmosis and distillation (Remini and Amitouche, 2023b)

	Process of	**Desalination**
Element of the process	Reverse Osmosis	Distillation (MSF)
Raw water intake	Reverse osmosis requires careful selection of the raw water intake point.	For distillation, the choice of location for the collection tower is not mandatory.
Pretreatment	Rigorous pretreatment is necessary. These operations require the use of chemicals.	Such a process does not require enough operations and therefore less chemicals for the Distillation technique (MSF).
Microfiltration	Microfiltration required	Absence of microfiltration
Membranes	Mandatory membranes	No membranes
High-pressure pump	Stations equipped with high-pressure (HP) pumps (greater than 60 bar)	Distillation stations (MSF) require pressure.
Energy	Consommation d’énergie 3 à 5 kw/h/m^3	Consommation d’énergie 8 kw/h/m^3
Brine	The brine rejected by reverse osmosis contains the concentrate and chemicals from the pretreatments.	A green brine. The brine rejected by distillation (MSF) contains only the concentrate (salinity).
Integration rate	Weak	Very high.

Table 7 summarizes the advantages and disadvantages of distillation and reverse osmosis processes for demineralization plants of brackish water from the Continental Intercalaire aquifer.

Table 7: Advantages and disadvantages of the two brackish water demineralization processes: Reverse osmosis and distillation

	Process of desalination	
Element of the process	Reverse Osmosis	Distillation (MSF)
Raw water intake	Deep drilling to draw water from the Continental Intercalaire aquifer.	Forages profonds pour puiser l'eau de la nappe du Continental Intercalaire.
Cooling tower	The presence of a cooling tower is mandatory.	Absence of a cooling tower
Pretretment	Rigorous pretreatment is necessary. These operations require the use of chemicals.	Such a process does not require enough operations and therefore less chemicals for the Distillation technique (MSF).
Microfiltration	Microfiltration required	Absence of microfiltration
Membranes	Mandatory membranes	No membranes
High-pressure pump	Stations equipped with high-pressure (HP) pumps (greater than 60 bar)	Distillation stations (MSF) require pressure.
Energy	Energy consumption 3 to 5 kWh/m^3	Energy consumption 8 kWh/m^3
Brine	The brine rejected by reverse osmosis contains the concentrate and chemicals from the pretreatment.	Green brine. The brine rejected by distillation (MSF) contains only the concentrate (salinity).

Initially, distillation appears to be a more advantageous process than reverse osmosis in Algeria. Whether for seawater desalination or brackish water demineralization, distillation proves to be the most beneficial method for Algeria. Even with the highest seawater turbidity levels, distillation can operate, thus avoiding temporary shutdowns of the reverse osmosis process during the rainy season. Furthermore, there is no longer any need to purchase membranes and other consumables using foreign currency. The desalination process for seawater and brackish water using distillation does not require pretreatment, and consequently, there is no need to purchase chemical additives. The brine discharged by a desalination plant using distillation is green brine, as it consists solely of the concentrate (various salts) without chemical additives. When green brine is discharged by a demineralization plant, its salinity, generally around 8 g/l, does not pose an environmental problem. Therefore, it can be discharged into the chotts (salt lakes) without causing environmental issues. The brine from the El Oued and Touggourt demineralization plants is discharged into the El Halloufa and Meouane chotts. The brine discharged into the sea by a seawater desalination plant using distillation, with a concentration of around 60 g/l, is green brine without chemical additives. For demineralization by distillation, the brackish water from the Albian aquifers reaches the surface at a temperature of 60°C to 70°C, which facilitates demineralization since the raw water is very hot (60°C to 70°C) and only 20°C more is needed to reach the boiling point. However, for reverse osmosis, the process is much more complex. The water temperature must be lowered from 70°C to 23°C for it to be suitable for the reverse osmosis process.

A cooling tower must be added to the design of a reverse osmosis demineralization plant, or this ancillary structure (cooling tower) is not present in a distillation demineralization plant.

The distillation process can prove to be a good choice for energy-producing countries rich in iron ore deposits, such as Algeria. From a water security and even water sovereignty perspective, Algeria can opt for the distillation process. For Algeria, distillation can achieve a much more affordable price per cubic meter of desalinated water than reverse osmosis, since the integration rate in the construction of a distillation plant is very high compared to that of reverse osmosis in Algeria. At the end of this discussion, we must answer the question posed in the title of this paper: "Is reverse osmosis the most suitable seawater desalination process for Algeria?" Therefore, to remove salt, whether from seawater or fossil water, the reverse osmosis process is competing with the distillation process. A very thorough strategic study of the two processes, taking into account all the remarks raised in this paper, will be able to definitively settle the matter.

CONCLUSION

As mentioned at the beginning of this article, Algeria's freshwater supply comes from four main sources: rainwater, seawater, wastewater, and fossil water. However, these waters are saline, and therefore a desalination process is necessary to remove the salts. A strategic choice, Algeria opted for desalination more than 25 years ago, and today produces 1.35 billion m^3/year with 18 seawater desalination plants and 5 brackish water demineralization plants currently in operation. In fact, seawater desalination in Algeria is not a recent phenomenon; during the 1960s, Algeria began to tentatively desalinate seawater. It was in the early 2000s that the desalination of large quantities of water began. Extensive experience has been gained over many years in seawater desalination and brackish water demineralization. While Algeria now boasts a variety of plants along its 1600 km coastline, the desalination process used remains the same: reverse osmosis. Despite market competition, distillation technology is better suited to Algeria. Whether for seawater desalination or brackish water demineralization, the integration rate for the dilution process is significantly higher than that of reverse osmosis. Therefore, even though reverse osmosis consumes less energy than distillation, the thermal process (distillation) eliminates the need for the pretreatment phase in desalination, along with the associated washing and cleaning of various process components. Furthermore, distillation is the most suitable process for North African countries. Indeed, during periods of high water, the turbidity of the Mediterranean Sea is very high, and it is in such conditions that distillation is best adapted to handle high turbidity. Turbidity, on the other hand, is a major obstacle for reverse osmosis. Today, with the recent severe weather, we have discovered that the raw water intake tower of a desalination plant with reverse osmosis has become a project of great importance that must be taken seriously. A good choice of the intake site increases the efficiency of a desalination plant. In addition, a hydraulic structure must be added to the plant: a settling basin for fine particles. The same observations can be made regarding brackish water demineralization plants. Indeed, the six demineralization plants are designed to treat the brackish water from the northern

Sahara aquifer system. This brackish water, at the wellhead temperature of 70°C, can only be treated by reverse osmosis if its temperature drops to around 23°C. In this case, a well water-cooling tower is necessary. However, the distillation process does not require these two ancillary structures (cooling tower and raw water intake). A definitive solution to this question will be found by comparing these two processes, taking into account all the points raised in this paper. There are two types of brine: one from a seawater desalination plant and the other from a brackish water demineralization plant. The first type of brine is discharged directly into the sea with a salinity of approximately 70%. This value is based on a 45% conversion rate. It's worth noting that the raw water used for desalination by reverse osmosis is none other than Mediterranean Sea water, with a salinity of around 38 g/L. The second type of brine comes from a demineralization plant that pumps brackish water from the Continental Intercalaire aquifer, with a salinity ranging from 2 to 3 g/L. This demineralization process uses two stages to produce potable water with a salinity of 0.3 g/L. Despite the brine being obtained with a salinity ranging from 5 to 8 g/l, its disposal remains a complex problem. While today the disposal of brine from seawater desalination is a simplified operation, as it is discharged directly into the sea, the disposal site for brine from brackish water demineralization poses enormous problems. For all demineralization plants in Algeria, brine is discharged into the environment, specifically into chotts (salt lakes). One proposed solution is the use of evaporation ponds, which require considerable space. Large quantities of brine from brackish water demineralization plants are poured into these ponds to recover a few kilograms of salt. This results in the loss of significant land and substantial amounts of water through evaporation for the sake of a few kilograms of salt. Such a solution is not economical, but it is interesting for brine from a seawater desalination plant. With brine having a salinity of 70 g/l, we recover a large volume of salts. However, it is difficult to find space to build evaporation ponds. Therefore, for brine from a brackish water demineralization plant using distillation, green brine (since it is free of chemical additives) can even be used for irrigation due to its low salinity. Even for green brine from a seawater desalination plant using distillation, storing it in evaporation ponds can be a good solution since we recover large quantities of salts.

In conclusion, even though reverse osmosis consumes less energy, considering the parameters mentioned above, distillation is a much more advantageous process. A more comprehensive study on this subject is necessary to reach a final decision.

REFERENCES

BREUIL, C. (1997). Fisheries in the Mediterranean: information on the fisheries context and the economic issues of their management, Food and Agriculture Organization (FAO), Fisheries Circular, No 927, Rome, FAO, 36p.

DEMMAK A. (1982). Contribution to the study of erosion and solid transport in northern Algeria. Doctoral thesis in Engineering. Pierre and Marie Curie University, Paris XI, France.

FSCD (French scientific committee on desertification). (2020). Deep water resources of the Sahara Desert and its arid and semi-arid borders, Thematic fact sheets, No 14, 3p.

MAAMAR S, AMITOUCHE M., REMINI B., ABDERAHMANE N. (2025). Dispersion of desalination brine discharges, a technique to protect the marine environment: Case of Fouka plant (Algeria), Environmental Engineering Research; Vol. 31, No 1.

REMINI B. (2017a). A new approach to managing dam siltation, Larhyss Journal, No 31, pp. 51-81.

REMINI B. (2017b). The Tadmait foggara: without energy from basement water to soil surface. Larhyss Journal, No 32, pp. 301-325.

REMINI B. (2023). Flash floods in Alegria, Larhyss Journal, No 56, pp. 267-307.

REMINI B. (2024a). Can we ensure water security in the era of climate change? Larhyss Journal, No 60, pp. 297-308.

REMINI B. (2025a). Climate change a threat to Algeria's water security, Larhyss Journal, No 64, pp. 517-561.

REMINI B. (2025b). Water capture techniques adapted to climate change, Larhyss Journal, No 63, pp. 233-283.

REMINI B. (2025c). Algeria’s groundwater an untapped strategic resource for water Security, Larhyss Journal, No 61, pp. 401-431

REMINI B., AMITOUCHE M. (2023a). Desalination plants search good quality raw water, Larhyss Journal, No 55, pp. 243-267.

REMINI B., AMITOUCHE M. (2023b). Is sustainable desalination the safe way for achieve water security? Larhyss Journal, No 54, pp. 239-267.

REMINI B., SAYAH L. (2013). Scaling of the potable water network of the Touggourt city (Algeria), Desalination and Water Treatment, Vol. 52, Issues 1-3, pp. 1-4.

REMINI B. (2024b). Dams in the face of climate change! Larhyss Journal, No 59, pp 229-241.

SEGUIN J.J., GUTIRREZ A. (2017). Water resources of the African continent: scarcity and abundance, Geosciences: The Bureau of Geological and Mining Research (BRGM), Journal for a Sustainable Earth, No 21, pp. 58-66

SSO (Sahara and Sahel Observatory). (2020). Water in our regions, Institutional monograph, Book-length report, SSO Publishing, Tunis, Tunisia, 120p.

WATER.TS. (2021). The ten largest desalination plants in the world. water-ts.com, published online on July 1, 2021.