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NATURAL DESALINATION OF SEA AND BRACKISH WATER

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ABSTRACT

This paper explores the idea of moving towards the natural desalination of seawater and brackish water. It simply requires replicating the vast natural seawater desalination plant that supplies the planet Earth. The natural water cycle, for example, can serve as a model for a thermal desalination plant. Three essential elements are all that is needed to provide drinking water for the entire planet: the oceans and seas, the sun to produce solar energy, and the earth, a site of mineralization that replenishes the distilled water with mineral salts. In addition to their role in regulating the climate by mitigating global warming, the oceans and seas represent the Earth's water tower. Compared to the Earth's natural desalination plant, we could install seawater desalination plants in northern Algeria and brackish water demineralization plants in southern Algeria. Create copies of Earth's seawater desalination plants. Consider the available space for solar panels and the construction of plants using the distillation process. The mineralization phase must be carried out outside the plant by replenishing groundwater with distilled water, while the post-treatment phase must be done on land. Brine from thermal desalination plants is free of chemicals due to their absence in the pre-treatment phase, such as reverse osmosis.

Keywords: Natural desalination, Brackish water, Seawater, Distillation, Brine.

INTRODUCTION

In the context of increasing pressure on water resources, the search for sustainable, resilient and locally adapted water supply solutions has become a central concern in hydraulic sciences. Several studies published in Larhyss Journal have shown that water security can no longer be considered only as a question of resource availability, but must be approached through an integrated vision combining climate variability, urban growth, groundwater protection, treatment technologies, hydraulic infrastructure, and risk management (Aroua, 2023; Sahu et al., 2024; Morsli and Habi, 2026). In arid and semi-arid regions, this issue is particularly important because drought, floods, sediment transport, water pollution, and aquifer vulnerability increasingly affect the reliability of conventional water resources (Derdour et al., 2017; Benali Khodja and Ferdjouni, 2024; Ben Said et al., 2024; Hafnaoui et al., 2023; Gassi and Saoudi, 2023; Remini, 2023c; Zegait et al., 2021; Do et al., 2025).

Recent research also emphasizes that climate change modifies hydrological regimes and increases uncertainty in water planning. Hydrological modelling, flow-duration analysis, flood-risk assessment and catchment-scale investigations have become essential tools for anticipating future water availability and protecting populations and infrastructure (Lalwani et al., 2026; Labed et al., 2026; Hachemi and Benkhaled, 2016; Patil et al., 2026; Ezz et al., 2025). These works confirm that water security must be based on diversified resources and robust systems capable of operating under extreme conditions. In this perspective, desalination, groundwater management, wastewater reuse, rainwater harvesting and improved water-treatment technologies appear as complementary options rather than competing solutions (Belkacem et al., 2017; Pandey et al., 2025; Tholibon et al., 2023).

For Algeria, the question is even more strategic because the country possesses both a long Mediterranean coastline and vast groundwater reserves in arid regions. The development of desalination must therefore be examined not only from the point of view of production capacity, but also in terms of environmental impact, brine management, energy demand, raw-water quality, and national technological sovereignty. The environmental evaluation of desalination discharges in Algeria has already shown the need to better control brine impacts on the marine environment (Belkacem et al., 2017). At the same time, studies dealing with urban water issues, water strategies in the Maghreb, and alternative supply systems demonstrate the importance of adapting technologies to local geographic, climatic and socio-economic conditions (Aroua, 2018; Aroua, 2022; Aroua, 2023; Maharaj et al., 2025).

The natural desalination approach proposed in this paper is therefore consistent with a broader scientific orientation that seeks to imitate, optimize or reinforce natural hydrological processes. Water harvesting, local water treatment, aquifer protection, urban water planning and hydraulic modelling all show that sustainable water management should rely on a combination of natural mechanisms and engineered systems (Bentalha, 2023; Patel and Mehta, 2022; Dendouga et al., 2026; Hountondji et al., 2026). By considering the ocean, the sun and the soil as the three fundamental components of a natural desalination chain, the present work contributes to this scientific debate and opens a pathway toward desalination strategies better adapted to Algeria's climatic, geographic and environmental realities.

Today, climate change threatens the water security of countries, and Algeria is not immune to this complex problem. Fortunately, Algeria's freshwater reserves are replenished by four main sources: rainwater, seawater, fossil water, and wastewater (Remini, 2025a; 2025b; Remini and Amitouche, 2026). Seawater contributes 10% of Algeria's freshwater reserves, or 1.35 billion m³/year (Remini, 2025a; Remini and

Amitouche, 2026). Eighteen seawater desalination plants are currently operating along the 1,600 km of coastline (Remini, 2025a). Only after more than a quarter of a century has Algeria acquired invaluable experience in seawater desalination. However, only one desalination plant is equipped with a distillation process; the other 17 operate using reverse osmosis. To minimize the salinity of brackish water in the southern Algerian provinces, demineralization plants for brackish water from the Continental Intercalaire aquifer have been installed. But all of these plants operate using reverse osmosis. Today, despite the expertise acquired in this complex field, which utilizes cutting-edge technology, the output of several seawater and brackish water desalination plants has not reached the expected results.

In recent years, disruptions in the distribution of drinking water from seawater desalination plants have been frequently reported in the northern Algerian provinces. Whether it's operational problems, issues with raw water intake, or brine discharges, these plants continue to supply water to the population. Significant progress has been made in this high-tech field. However, one problem that was never anticipated is the raw water intake point. Once the water passes the pretreatment stage, it undergoes the reverse osmosis process. However, floodwaters heavily laden with sediment are discharged from the wadis into the sea. In this case, the intake points become clogged with fine particles, rendering the membranes unable to function properly. In this case, the reverse osmosis process will be shut down while the particles settle (Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). So, should we diversify the processes to improve the efficiency of desalination plants? Furthermore, we haven't directly answered the question: "Is reverse osmosis the most suitable process in Algeria?" (Remini and Amitouche, 2026). We believe that now is the time to build new desalination plants that operate using distillation. We can even go further by harnessing solar energy. Natural desalination plants for brackish water in the Algerian Sahara. Energy, space, and brackish water to obtain drinking water. This is the main objective of this relevant article.

DESALINATION OF SEAWATER AND BRACKISH WATER IS AN ESSENTIAL OPTION TO ENSURE THE COUNTRY'S WATER SECURITY

Everyone is talking about water security, especially with the threat of climate change. So how does this relate to Algeria's growing population and the accelerating socioeconomic development of recent years? The government is launching megaprojects, mining, energy, industrial, and agricultural, that require impressive quantities of water. Algeria's freshwater reserves are estimated at 13 billion m^3/year, a volume below the water demands of a population reaching 47 million inhabitants and the economic sectors (Remini, 2025a). By 2060, freshwater reserves could reach 80 billion m^3/year. It is worth noting that Algeria's freshwater reserves are supplied by four water sources (Fig. 1). These are rainwater, fossil water, seawater, and wastewater (Remini, 2025a; Remini and Amitouche, 2026). Only the "Seawater" and "Fossil Water" sources are protected from climate change.

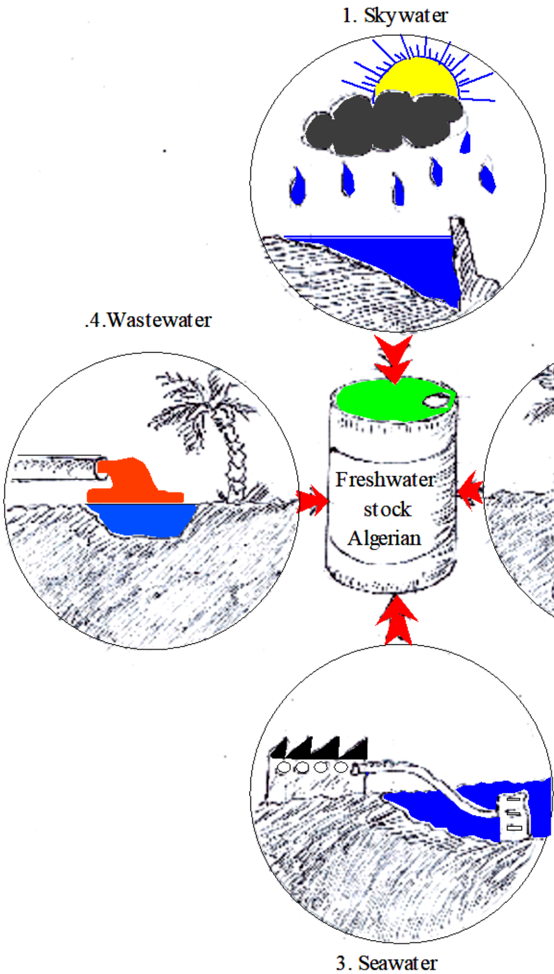


Figure 1: The 4 water sources that supply the Algerian freshwater stock (Remini diagram, 2026)

Therefore, to ensure a continuous supply of freshwater despite the threat of climate change, the exploitation of seawater and brackish water is becoming an essential option. These two water sources, which can withstand the climate threat, are not accessible to all 192 countries on the planet. Outside the natural water cycle, seawater and fossil water sources are available to Algeria to replenish its freshwater reserves. With an area of 2.38 million km^2, Algeria is located in North Africa and shares over 6,385 km of land borders with seven countries: Tunisia to the northeast, Libya to the east, Niger and Mali to the south, Mauritania and the Sahrawi Arab Democratic Republic (SADR) to the southwest, and Morocco to the west. To the north, Algeria opens onto the Mediterranean Sea along a 1600 km coastline. Algeria is among the few countries that possess two bodies of water.

To the north, an open sea, the Mediterranean Sea, and to the south, an underground sea, a sea of fossil water; brackish water par excellence.

A surface sea, The Mediterranean Sea

Considered the largest semi-enclosed sea in the world, the Mediterranean Sea has a volume of 3.75 million km^3 and covers an area of 2.5 million km^2 (Breuil, 1997). This vast quantity of free water is shared by 22 countries, including Algeria, but it is saline, with an average concentration of 38 g/l (Figs. 2 and 3).

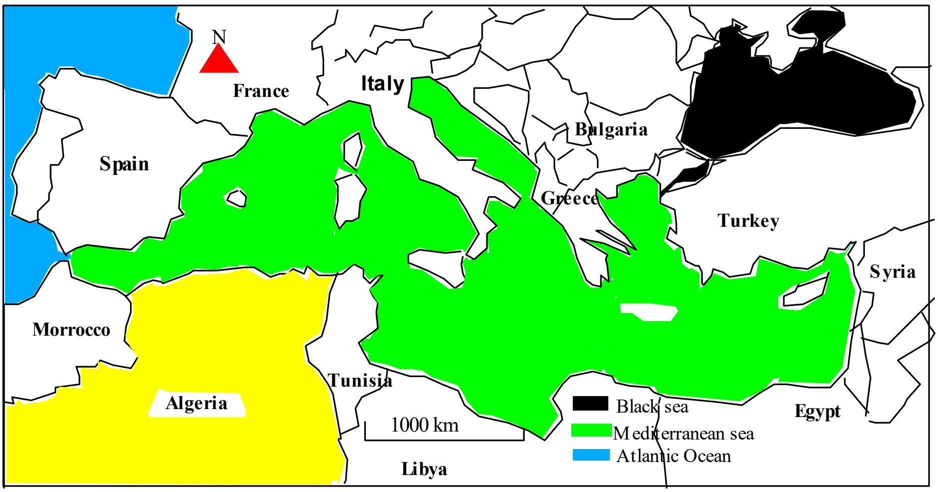


Figure 2: The Mediterranean Sea; the water tower of the countries of the Mediterranean basin (Remini, 2026)

The Mediterranean Sea has a negative water balance; precipitation is less than evaporation (precipitation < evaporation), meaning that the water returning to the sky is greater than the water returning from the sky. This water deficit is compensated by water coming from the Atlantic Ocean through the Strait of Gibraltar (Remini, 2026). Although the Mediterranean Sea connects to the Indian Ocean via the Suez Canal and to the Black Sea via the Sea of Marmara, the Strait of Gibraltar's connection to the Atlantic remains the most significant. Moreover, more than 5 million years ago, the Mediterranean Sea experienced an ecological crisis when it dried up following a tectonic event that led to the temporary closure of the Strait of Gibraltar (Gillard, 2024). Due to evaporation, the sea level plummeted, leaving behind a salt flat. The Mediterranean Sea is a semi-enclosed sea. The Strait of Gibraltar balance the salinity of the Mediterranean Sea. Thanks to the influx of fresh water from the rivers of the 22 countries in the Mediterranean basin and the influx of salt water from the Atlantic Ocean, with a salinity of 35 g/l, entering through the Strait of Gibraltar, the salinity of the Mediterranean Sea is reduced to maintain a concentration of 38 g/l to 39 g/l in the Mediterranean basin. High temperatures in the Mediterranean basin accelerate evaporation from the Mediterranean Sea, and consequently, the water becomes increasingly saline. Fortunately, the liquid input from the Atlantic, with a salinity of 35 g/l, passing through the Strait of Gibraltar, maintains the salinity of the Mediterranean Sea at 38 g/l. Therefore, we can say that thanks to the Strait of Gibraltar, the Mediterranean Sea maintains its water volume of 3.75 million km³ and its salinity of 38 g/l. Thus, there is no risk of an increase in seawater salinity from the discharges of the seawater desalination plants that will be installed by the 22 countries of the Mediterranean basin.

Discharging brine into the Mediterranean Sea risks causing local pollution. In what follows, we will discuss the reasons that favor distillation over reverse osmosis. Having a portion of water from the Mediterranean Sea and another portion from fossil seawater hidden deep beneath the Sahara is a blessing and a gift from heaven. Regarding seawater, Algeria has a 1,600 km border with the Mediterranean Sea; an infinite, inexhaustible, and free source of water. However, this water is salty and undrinkable. Therefore, to make it potable, the salts must be removed. Seawater desalination is the only way to make it drinkable. Several seawater desalination processes exist on the market, but two technologies are the most widely used worldwide: membrane desalination and thermal desalination. In the early 2000s, Algeria opted for reverse osmosis based on a single criterion: energy savings compared to distillation. Eighteen seawater desalination plants were built along a 1600 km stretch of coastline. Only one plant operates using the distillation process (Table 1).

Table 1: Characteristics of operating desalination plants (Remini and Amitouche, 2026)

Province	Station	Capacity (m^3/day)	Year of commissioning
Chlef	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

Seawater desalination is not simply a project to construct a hydraulic structure, but rather a strategic choice for 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 country's drinking water needs are fully met. The entire 1,600 km Algerian coastline will be dotted with seawater desalination plants. A project for seven desalination plants is currently under study, aiming to produce 1.86 million m^3/day, or 0.68 billion m^3/year, by 2030, thus covering 60% of the country's drinking water demand. In total, the seawater resource will reach 2 billion m^3/year. 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, seawater will supply Algeria's freshwater reserves with 1.35 billion m^3/year, representing 10% of the total freshwater volume (Remini and Amitouche, 2026).

An Underground Sea: Fossil Waters

The second, but less saline, sea lies beneath the Algerian Sahara, covering an area equal to 85% of the national territory (2.382 million km^2), or more than 2 million km^2. Algeria has adopted the same principle to remove salts from brackish water stored in large natural reservoirs located in the Saharan subsoil. It should be noted that the Sahara Desert has a dual dynamic: wind energy on the surface and water energy beneath the surface. Wind energy has led to the formation and shaping of the Great Ergs, such as the Grand Erg Occidental, the Grand Erg Oriental, the Erg Echech, the Erg Iguidi, the Erg de Bilma, and the Idehan Murzuk. Conversely, water energy has led to the formation of large reservoirs capable of storing billions of cubic meters of water. We can cite underground reservoirs such as the Northern Sahara Aquifer System, the Murzuq Aquifer, the Tindouf Aquifer, the Taoudéni-Tanezrouft Aquifer, the Iullemeden Aquifer, and the Chad Sedimentary Basin (Fig. 3). With the addition of this last aquifer, Algeria has a new water surface area of 80,000 km^2. This wetland area will be included in Algerian territory for the first time in 2025. Based on this new information, Algeria has a total wetland area of 1.25 million km^2, representing 52% of its total land area. These underground reservoirs, whose boundaries sometimes extend beyond national borders, are called transboundary aquifers. Algeria shares a volume of 87,000 billion m^3 of these 10 transboundary aquifers with 11 countries (Tunisia, Nigeria, Niger, Burkina Faso, Mali, Mauritania, Benin; Libya, Chad, Central Africa and Cameroon) of which 3 aquifers are classified as large aquifers (Fig. 3; Tables 2 and 3).

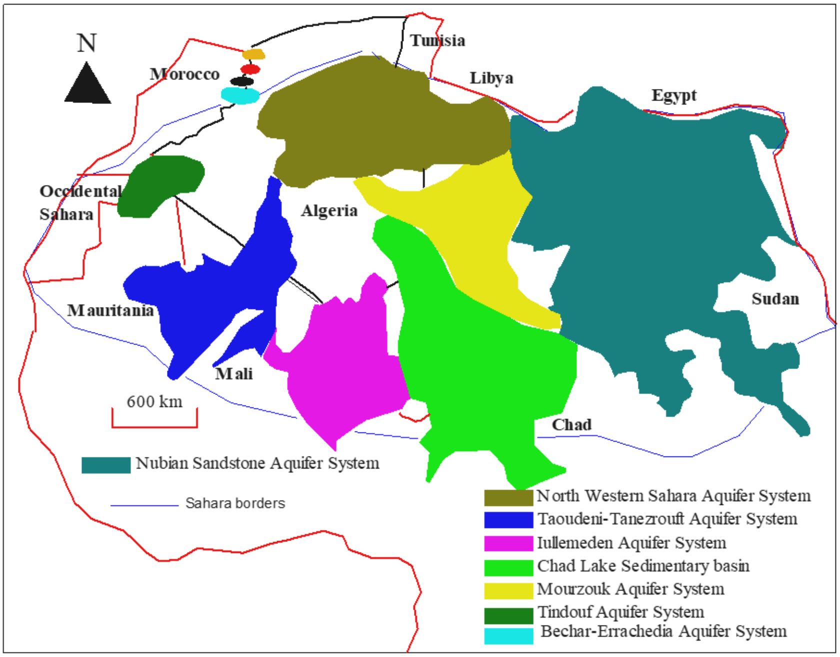


Figure 3: The two seas (Mediterranean Sea and Sea of Fossil Waters) which are available to Algeria. Taking into account the new map of transboundary aquifers, a slight modification has been made at the level of the sedimentary basin of Chad (Remini Diagram, 2026)

Table 2: Names of the aquifers shared with Algeria (Remini, 2025c)

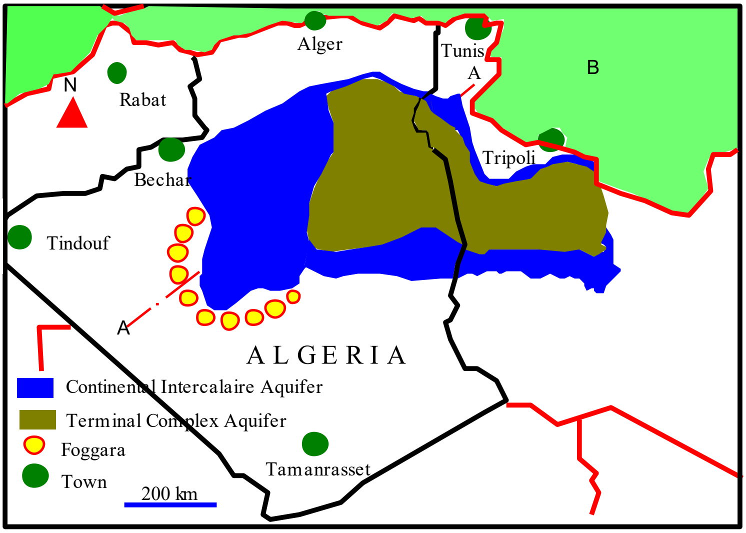
N°	Code	Name	Shared countries	Area (km^2)
1	AF069	North Western Sahara Aquifer System	Algeria, Tunisia, Libya	730,000
2	AF064	Taoudeni-Tanezrouft Aquifer System	Algeria, Burkina Faso, Mali, Mauritania	141,100
3	AF056	Iullemeden Aquifer System	Algeria, Benin, Mali, Niger, Nigeria	52,000
4	AF052	Lake Chad Sedimentary basin	Algeria, Cameroon, Central African Republic, Chad, Niger, Nigeria	80,000
5	AF070	Bechar Errachidia Aquifer System	Algeria, Morocco	8,400
6	AF068	Tindouf Aquifer System	Algeria, Mauritania, Morocco, Western Sahara	130,000
7	AF075	Ain Beni Mathar	Algeria, Morocco	100
8	AF078	Water table of the Meghnia plain and the Angad plain	Algeria, Morocco	745
9	AF067	Murzuk Aquifer System	Algeria, Niger, Libya, Chad	110,000
10	AF076	Chott Tigri-Lahouitta	Algeria, Morocco	111

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

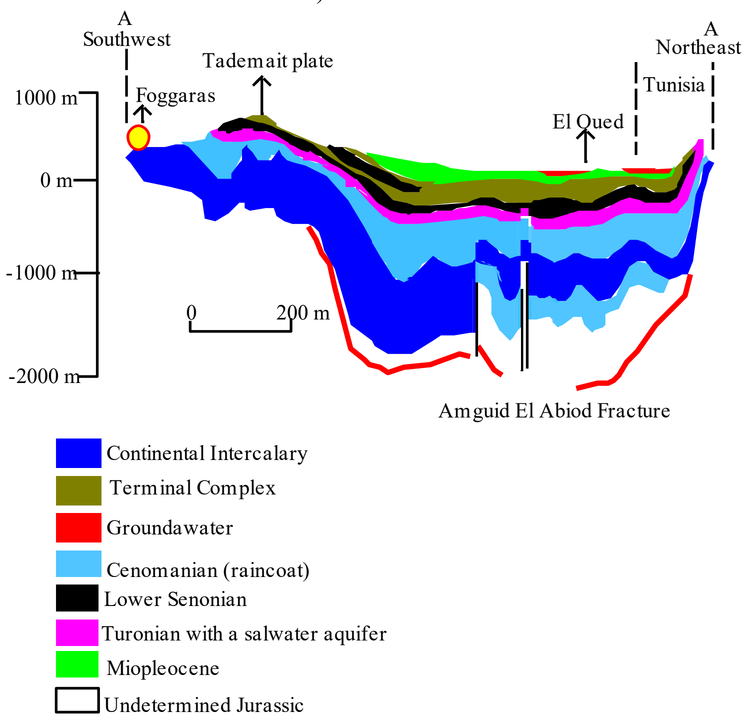
N°	Aquifer system	Volume km^3	Area 10^3 km^2	Shared countries
1	Northern Sahara	60,000	1000	Algeria, Tunisia, Libya
2	Taoudéni/Tanezrouft/	10,000	2000	Algeria, Burkina Faso, Benin, Mali, Mauritania
3	Iullemmeden	5,000	500	Algeria, Niger, Nigeria, Benin, Burkina Faso
4	Sedimentary basin of Lake Chad	5,800	1500	Algeria, Cameroon, Nigeria, Niger, Chad
5	Mourzouk	4,800	450	Algeria, Libya, Niger, Chad
6	Tindouf	800	221	Algeria, Western Sahara, Mauritania
7	Béchar-Errachidia	320	70	Algeria, Morocco
8	Meghnia	85	30	Algeria, Morocco

Algeria, Tunisia, and Libya share the Northern Sahara Aquifer System (SASS). The Murzuq Basin is shared between Algeria, Libya, and Niger. The Iullemeden-Taoudéni-Tanezrouft Aquifer System (SAITT) is shared between Algeria, Niger, Mali, Nigeria, Burkina Faso, Mauritania, and Benin. The Lake Chad Sedimentary Basin is shared between Algeria, Cameroon, Central African Republic, Chad, Niger, and Nigeria.

Algeria alone sits atop a brackish water body covering 1.25 million km^2, representing 52% of its territory. However, Algeria currently exploits only the Northern Sahara Aquifer System, which has a total capacity of 60 trillion m^3 (SSO, 2020). Thanks to deep drilling, Algeria draws 3.75 billion m^3/year from the Continental Intercalaire aquifer, which belongs to the Northern Sahara Aquifer System. The water reaches the ground with a brackish taste, a salinity of 2 to 2.5 g/l, and a temperature of 60°C to 70°C (Figs. 4a, 4b, and Fig. 5).



a) General view



b) Longitudinal section

Figure 4: The Continental Intercalaire and the Terminal Complex aquifers (Remini drawing, Source Unesco 1972 in Castany, 1982)

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)

It is worth recalling that the first Albian boreholes were drilled in the early 1940s in the Algerian Sahara. These initial boreholes revealed immense water reserves in the Saharan subsoil. However, the Continental Intercalaire aquifer has been exploited for over 20 centuries in the oases of Touat, Gourara, and Tidikelt by more than 1,000 foggaras (Remini et al., 2014) (Fig. 6). Even today, the foggara system is still in use, but with a significantly reduced numbe of users.

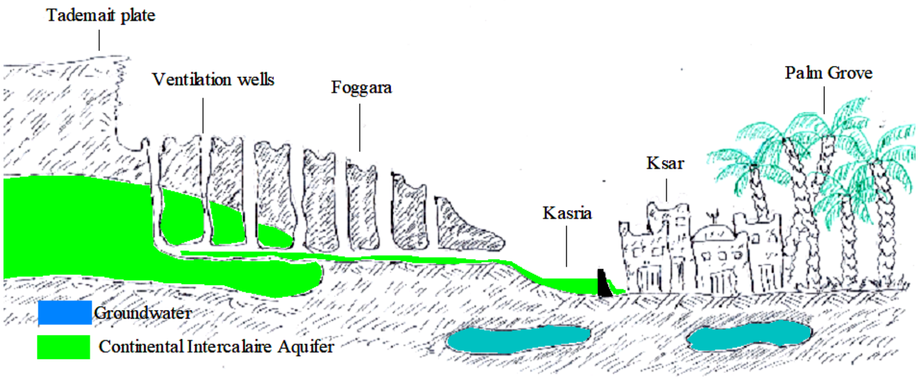
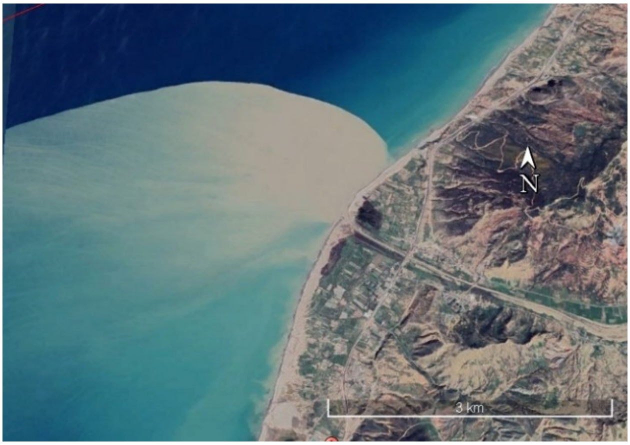


Figure 6: Diagram of a foggara in Touat that uses water from the Continental Intercalaire (Remini diagram, 2026)

However, the Iullemeden-Taoudéni-Tanezrouft Aquifer System (SAITT), the Lake Chad sedimentary basin, and the Merzouk basin have not yet been exploited (Remini, 2025b; Remini, 2021). No data or information is available on Algeria's share of water from these two aquifer systems. One study already indicates that the Merzouk basin is threatened with depletion due to a lack of recharge or persistent drought. A field study is essential to assess the feasibility of exploiting these water resources. As previously mentioned, Algeria needs 2 billion m³/year to reach a freshwater reserve of 80 billion m³/year by 2060 (Remini, 2025a). This vast quantity of water necessitates enormous resources to increase the number of deep wells. Furthermore, Algeria has launched an ambitious project over the past 25 years to convert the brackish water of the fossil sea into fresh water, reducing the salinity from 2.5 g/l to 0.3 g/l. The project aims to establish desalination plants in all the Saharan cities situated on this fossil, brackish sea. Currently, approximately twenty plants are operational. The Touggourt desalination plant was completed in 2014 to treat a raw water (brackish) flow rate of 400 l/s. This plant is designed to meet the drinking water needs of the entire population of Touggourt. The station is currently supplied by three boreholes with a depth of 1,800 m, with a total flow rate of 400 l/s from the Continental Intercalaire aquifer. The fourth borehole (Sidi Mahdi 2), with a flow rate of 150 l/s, is nearing completion; its connection is underway to achieve a total flow rate of 530 l/s from the four boreholes. The Touggourt demineralization plant uses reverse osmosis to reduce the salinity of brackish water from 2.5 g/l to 0.6 g/l after treatment. Nine brackish water demineralization plants have been built in the Ouargla province. Twenty-six boreholes were drilled to tap water from deep aquifers, including three Albian boreholes with a salinity of 3 to 6 g/l. Thanks to the reverse osmosis process, the salinity of the raw water drops from 6 g/l to 0.8 g/l. The 26 boreholes supply the 9 desalination plants with a flow rate of 70,000 m³/day of raw water to produce 53,000 m³/day of drinking water. It should be noted that the largest desalination plant in Ouargla has a capacity of 27,000 m³/day and was commissioned in 2017. The brackish water desalination plant in El Oued, commissioned in 2018, has a production capacity of 30,000 m³/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 was reduced from 68°C to 25°C before being introduced into the reverse osmosis process. Other plants are already operational, such as those in Ouargla, Tamanrasset, Oued Djellal, In Salah, and Bechar. More 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.

Distillation or Reverse Osmosis: The Reasons for Choosing!

Having a border with a sea or ocean is a blessing and a gift from heaven. The Mediterranean Sea's water volume is estimated at 3.75 million km³, but this immense quantity of water, in its current state, is undrinkable. The salts must be removed. Reverse osmosis and distillation are two of the most widely used processes in the world for separating water from its salts. So, in this case, which option should be adopted, taking into account all the parameters: financial, water sovereignty, energy, and environmental, to best adapt to a country like Algeria? As we mentioned earlier, Algeria has extensive experience in seawater desalination. Eighteen seawater desalination plants produce an estimated 1.3 billion m^3/year of drinking water (Remini, 2025a). Several brackish water demineralization plants are operating in the southern Algerian provinces. Almost all fossil water demineralization plants and 17 out of 18 seawater desalination plants use this technology. So, what criteria led Algeria to favor membrane systems over thermal systems? Could it be said that in the early 2000s, Algeria relied solely on financial considerations? Today, after a quarter of a century of operating seawater desalination plants using reverse osmosis, numerous problems have arisen, disrupting plant operations and resulting in decreased water production yields at several plants. Given this situation, should we continue to desalinate seawater and fossil water using reverse osmosis? This paper will discuss some problems that have slowed production in all seawater desalination and brackish water demineralization plants. Perhaps this will lead to a shift towards distillation rather than continuing to desalinate using reverse osmosis. Let's list some of the problems that have arisen in recent years at certain plants, resulting in frequent production stoppages, particularly at the desalination plant in the Chlef province. Indeed, during the month of April, the Chellif River, in flood, discharged several tons of fine particles into the sea following torrential rains that struck the entire Chlef region. A wave of dust invaded the raw water intake area of the seawater desalination plant (Figs. 7a, and 7b).



a) Flash flood of March 2014

b) Flash flood of December 2018

Figure 7: Flash flood in the Chellif wadi which discharged several tons of sediment into the Mediterranean Sea (Google Earth)

This situation caused the desalination plant to shut down until the water turbidity decreased, a process that took approximately three weeks. The reverse osmosis system, equipped with a membrane, is very demanding and only accepts high-quality raw water. Turbid raw water in the sea forces the plant to shut down. The plant must wait for the storm to pass and the fine particles to settle before it can resume operation. Today, we have a new problem that must be considered when planning a new plant equipped with a membrane system. It should be noted that we were the first to raise the alarm about the problem of the raw water intake point in the presence of fine particles (Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). This problem of raw water turbidity is new to desalination plants, as it has never been studied before. This turbidity issue is particularly evident along the coast of North African countries. On the 1,600 km long Algerian coast, 51 wadis discharge 120 million tons of sediment annually (Demmak, 1982; Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). With climate change, flash floods will carry significantly larger quantities of sediment. This will lead to increased turbidity in the sea, and consequently, the intake points will be inundated with tons of dust. In the coming years, this turbidity problem will become much more prevalent than it is today. Shutdowns at reverse osmosis desalination plants will become much more frequent. Only distillation desalination plants will be immune to this raw water intake problem. A new issue has recently emerged that is disrupting the operation of seawater desalination plants, particularly those using reverse osmosis. This issue is the turbidity of the raw water caused by dust carried by rivers during flood season. We are pleased to report this problem, which occurred in 2023, concerning the selection of raw water intake sites for seawater reverse osmosis desalination plants. This complex problem can affect the price per cubic meter of water. It is important to remember that Algeria's 1,600 km coastline is very rich in river sediments. More than 50 river mouths are located along the Algerian coast, with an average interval of 32 km between two watercourses

(Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). This limited space complicates the selection of raw water intake points for new reverse osmosis desalination plants. Moving further and further inland to avoid raw water turbidity and choosing the right location for the intake is crucial, but at what cost? Therefore, for reverse osmosis plant projects, the raw water intake problem must be taken very seriously. Moving the intake further inland would be an option to avoid drawing turbid raw water, but at what price? Moving from upstream to downstream to solve the problem of brine discharges into the sea. The discharge of brine in concentrated form must be permanently banned from our seawater desalination plants (Fig. 8).

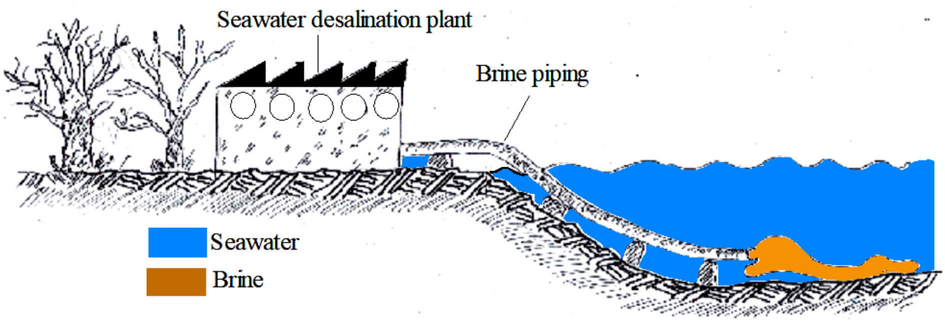


Figure 8: Approximate diagram of a direct discharge of brine into the sea (Remini diagram, 2026)

Our short-term goal is to protect the marine environment, and our long-term goal is to find uses for the brine. Currently, we want to find uses for the brine, but this process takes a long time to produce results. Therefore, in this case, the brine is diluted in a basin with seawater before being released into the sea. Such an operation remains, for the moment, the best solution for preventing large-scale pollution of the marine environment. However, these hydraulic structures must be properly sized (Fig. 9).

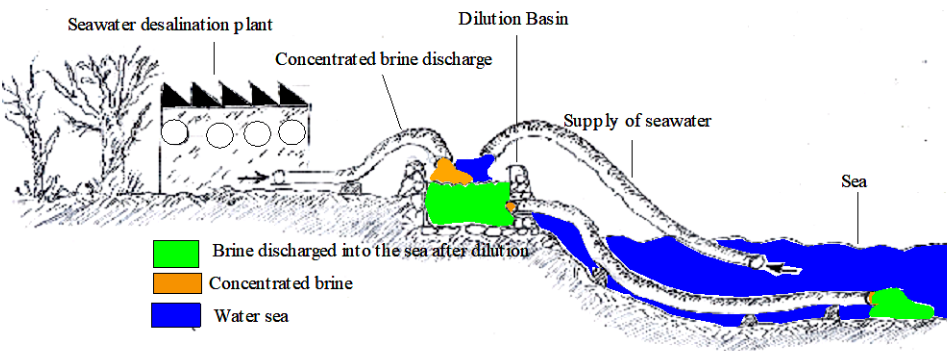


Figure 9: Approximate diagram of a seawater desalination plant equipped with a brine dilution basin before its discharge into the sea (Remini Diagram 2026).

Reverse osmosis requires significantly more chemicals in the pretreatment phase compared to distillation. This obviously has a major impact on the brine discharged into the sea. Brine from a desalination plant using distillation is much greener than that from a seawater desalination plant using reverse osmosis.

Regarding brackish water demineralization plants, distillation is the most suitable process for fossil waters. The temperature parameter is particularly favorable for the distillation of Albian waters that reach the surface at a temperature of 60° to 70°C. Adding 30°C to 40°C is sufficient to reach the boiling point. In this case, the water passes directly into the gaseous state (vapor), which is the principle of distillation (Fig. 10).

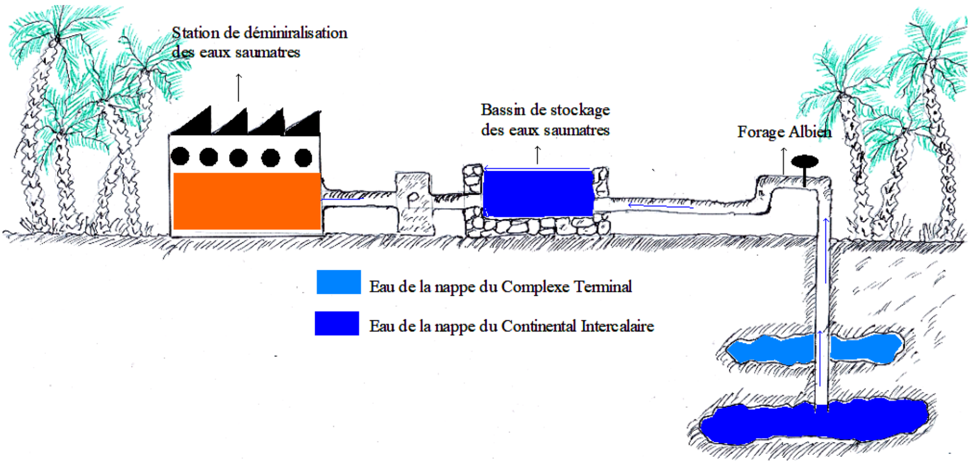


Figure 10: Approximate diagram of a brackish water demineralization station by distillation directly capturing raw water from the Albian borehole (Remini diagram, 2026)

However, in the reverse osmosis process, water with a temperature of 70°C causes damage to the membranes. Therefore, to overcome this problem, a hot water softening hydraulic system must be added to the plant. This involves a tower equipped with a fossil water cooling system to lower the temperature from 70°C to 23°C so that it can pass through the membrane system without difficulty (Fig. 11). This obviously requires more funding. In our opinion, the thermal process is still the best suited for the demineralization of fossil water.

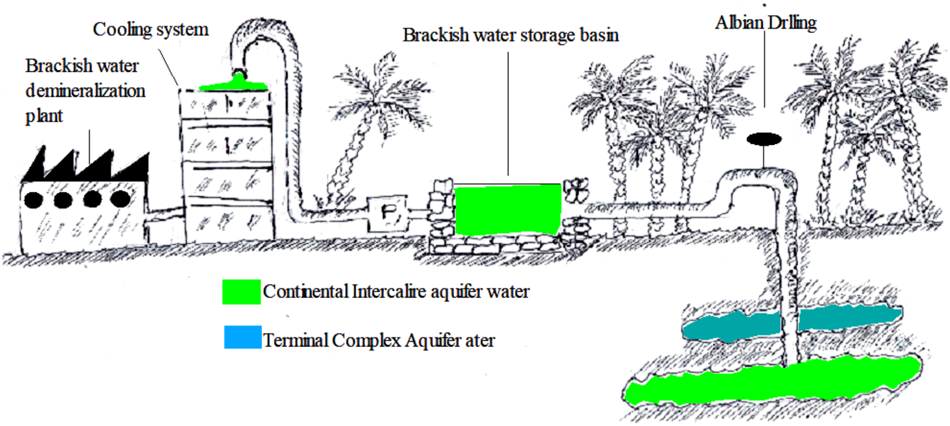


Figure 11: Approximate diagram of a brackish water demineralization plant using reverse osmosis, which captures raw water after it has passed through the cooling system (Remini diagram, 2026)

Furthermore, national integration in the construction of a seawater desalination plant equipped with a reverse osmosis process is too low compared to the construction of a seawater desalination plant using distillation.

TOWARDS NATURAL DESALINATION OF SEAWATER AND BRACKISH WATER

Nature Embraces Distillation

Now, if we carefully observe the natural water cycle, we can say that the Earth's water supply is achieved through the desalination of seawater and ocean water using a thermal process. Obviously, it is the sun that provides the energy for this massive desalination plant to remove salts and impurities. Therefore, three essential parameters are necessary to obtain potable water after natural desalination, as shown in Fig. 12:

- Raw water (seawater or brackish water)
- The sun to provide the energy to transform the water from a liquid to a gaseous state (vapor).
- The soil to ensure the remineralization of the pure water into potable water.

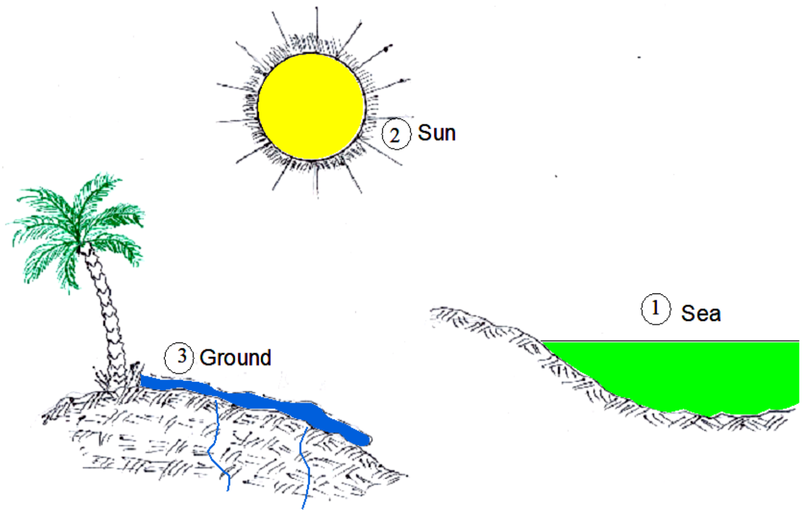


Figure 12: Diagram of the 3 parameters necessary to obtain natural desalination of seawater and brackish water by distillation (Remini diagram, 2026)

Comprising five oceans (Pacific, Atlantic, Indian, Southern, and Arctic) and several seas, this vast saltwater basin covers an area of 361 million km², representing 71% of the Earth's surface (Fieux et al., 2023). The total volume of water stored in this reservoir is estimated at 1.37 billion km^3, representing 97% of the Earth's water; the remaining 3% is freshwater. This immense quantity of saltwater constitutes the Earth's water tower. Removing the salts from this mega-volume using the energy provided by the sun and its rays, which shine across the entire surface of this vast reservoir of 361 million km^2, representing over 71% of the Earth's surface, is a powerful message demonstrating the value of this distribution of water on Earth, which contains 71% of the Earth's water and 29% of its land. It also demonstrates that evaporation is a function of the surface area of the body of water. Therefore, a vast quantity of fresh water obtained after evaporation will be more than sufficient to meet the drinking water needs of the world's population. Furthermore, the essential role played by oceans and seas is to ensure maximum evaporation to satisfy all water demands and consequently guarantee the planet's water security; this is their role as the Earth's water tower. They are the primary source of water that replenishes the Earth's freshwater reserves. Their volume is estimated at over 1.37 billion km^3 with an average depth of 3.8 km (Postel, 1969). The annual evaporation of seas and oceans has reached 425,000 km^3/year. After condensation, this quantity of water vapor transforms into clouds and then falls to the ground as precipitation, with a total volume estimated at 111,000 km^3/year. But this is distilled water par excellence. To make it drinkable, a mineralization process is necessary. Simply put, the flow of this pure water over the ground and its infiltration into the subsoil is nourished by mineral salts and will eventually become good quality water. Ultimately, the natural water cycle is nothing other than the natural desalination of seawater and ocean water through distillation. The energy provided by the sun allows water to change from a liquid to a gaseous state. Condensation and the merging of clouds thus promote the precipitation that falls to the ground. In the final stage of this process, the runoff of distilled rainwater captures mineral salts, making it potable (Fig. 13). It is clear that seas and oceans are the primary source of freshwater reserves, which amount to 1.37 billion km^3. Each year, a volume of 111,000 km^3 is desalinated by natural distillation and falls as precipitation on the five continents of the planet.

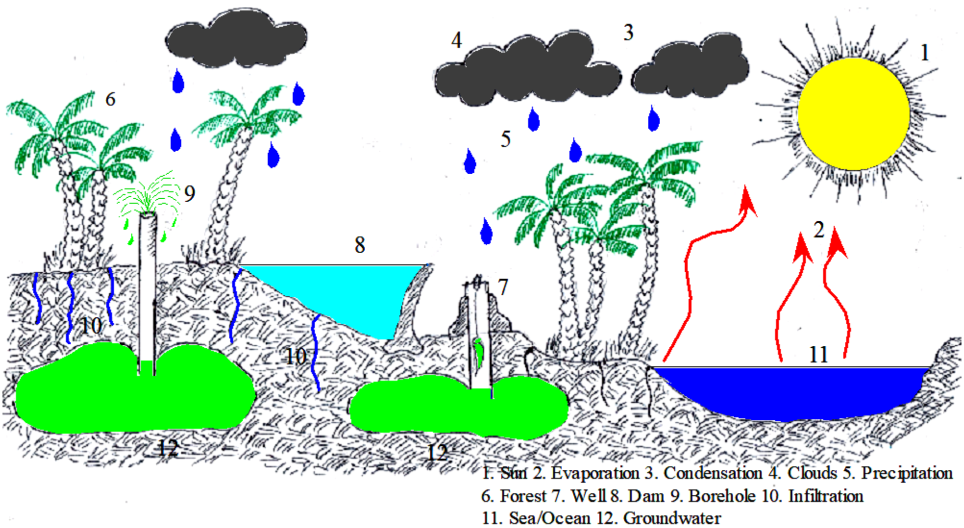


Figure 13: Approximate diagram of the natural water cycle. A mega-plant for the natural desalination of sea and ocean water by distillation (Remini diagram, 2026).

Planet Earth ensures its water security

So even planet Earth ensures its water security. Since we've discussed the Earth's water security, it follows that the Earth must have its own freshwater reserves. Indeed, the Earth holds the Earth's freshwater reserve (Earth's Freshwater Reserve). It has two water sources. The first source is "the waters of the seas and oceans." The second source is "fossil waters" (Fig. 14).

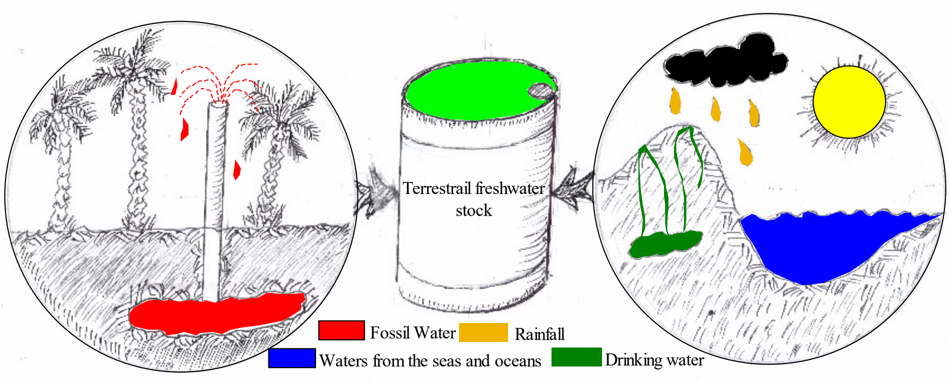


Figure 14: The two water sources that replenish Earth's freshwater supply (Remini diagram, 2026)

The water source: "Sea and ocean waters"

The water source, "Seas and Oceans," is the primary source that replenishes Earth's freshwater supply. However, to make these immense quantities of salt water drinkable, salts and impurities must be removed.

A review of the natural water cycle diagram clearly shows that planet Earth effectively ensures its own water security. The water tower of this blue planet is indeed the seas and oceans, with a total volume of 1.37 billion km^3, covering an area of 161 billion km^2 and representing 71% of the Earth's total surface area (Speich, 2015). This is precisely why it is called the Blue Planet. A powerful symbol highlighting the vastness of the water body compared to the surface area of the continents. This allows a large quantity of water to travel into the atmosphere, but in the form of vapor. The ascent to the sky is only possible for lighter water particles. Obviously, this entire long journey from bottom to top requires energy. And it is the sun that must provide this energy to transform water from a liquid to a gaseous state (vapor). Evaporation increases with temperature and the surface area of the seas and oceans (161 billion km^2). Of the 1.37 billion km^3 volume of water in the seas and oceans, 413,000 to 500,000 km^3 evaporate into the atmosphere annually. Precipitation falling on the five continents of the planet provides a volume of 111,000 km^3/year. Planet Earth has its own seawater desalination plant that operates using the distillation process. Once rain falls on Earth, some of it seeps into the subsoil to absorb minerals, and thus the distilled water is transformed back into drinking water. In the subsoil, reservoirs have formed to store surface water from rainfall. These reservoirs, with varying volumes, exist in different layers deep within the Earth. The upper aquifers are generally small in volume but are replenished during the rainy season and depleted during the dry season. This is done, of course, using wells and boreholes. For these types of aquifers, the problem of quantifying and extracting water does not arise. However, over the centuries, large aquifers have formed and continue to form deep underground, generally exceeding 2,000 meters in depth. These aquifers are large natural reservoirs that can store quantities of water exceeding billions of cubic meters. In fact, they are referred to as transboundary aquifers because they extend well beyond the area of a single country. Called fossil waters, these aquifers are rarely, if ever, replenished. These fossil waters have been hidden deep within the Earth for centuries. Today, with significant technological resources, these reservoirs can be accessed. For us, fossil waters are considered the second largest source of fresh water on Earth.

The source of water: "Fossil waters"

The second source that also feeds into the Earth's freshwater supply is fossil waters that have formed over centuries in the Earth's subsoil (Fig. 14). It should be noted that water stored in deep natural geological formations is intrinsically protected from the harmful effects of evaporation and siltation (Paulo Monteiro and Costa Manuel, 2004; Kheraz, 2012; Hountondji et al., 2020; Meroni et al., 2021; Merzougui et al., 2022; Later and Labadi, 2024). Today, these natural reservoirs are no longer recharged, or only minimally so, but their role is crucial as they can supply a significant portion of the world's population. This water source, "fossil water," is not mentioned in the natural water cycle. This fossil water is found in the Earth's subsoil. Extensive research has revealed the existence of several Albian aquifers on all five continents. However, this source has never been assessed, yet it is considered a guarantee for ensuring water security. Of a country or continent. The African continent is considered the most secure, able to guarantee its water security even under challenging climate change.

Everything invisible is complex. Groundwater is a complex issue. Originally, fossil water comes from rainfall that has fallen on the ground over centuries. Rainwater flows over the surface, with a large portion infiltrating the subsoil and another portion evaporating into the atmosphere. Water seeps into the subsoil and flows slowly through openings and conduits. While surface water flow is turbulent, underground water flow is very slow and therefore laminar. Generally, underground reservoirs located near the surface fill up in a few days or weeks, depending on the amount of rainfall. The water continues to move further and further from the surface, constantly seeking an opening or channel. The journey is very long to reach underground reservoirs with capacities of several billion cubic meters. These billions of cubic meters of water are stored in large reservoirs located far below the surface. This distance complicates the problem of aquifer recharge, especially when it is accessed through deep wells. In this case, the outflow rate will always be greater than the recharge rate. This is why transboundary aquifers are often described as non-renewable or only slightly renewable. However, they are actually renewable. The outflow rate (from the well) will always be much greater than the inflow rate, which is always difficult and complex. Therefore, we will always have the inequality: Inflow Rate < Outflow Rate (Fig. 15).

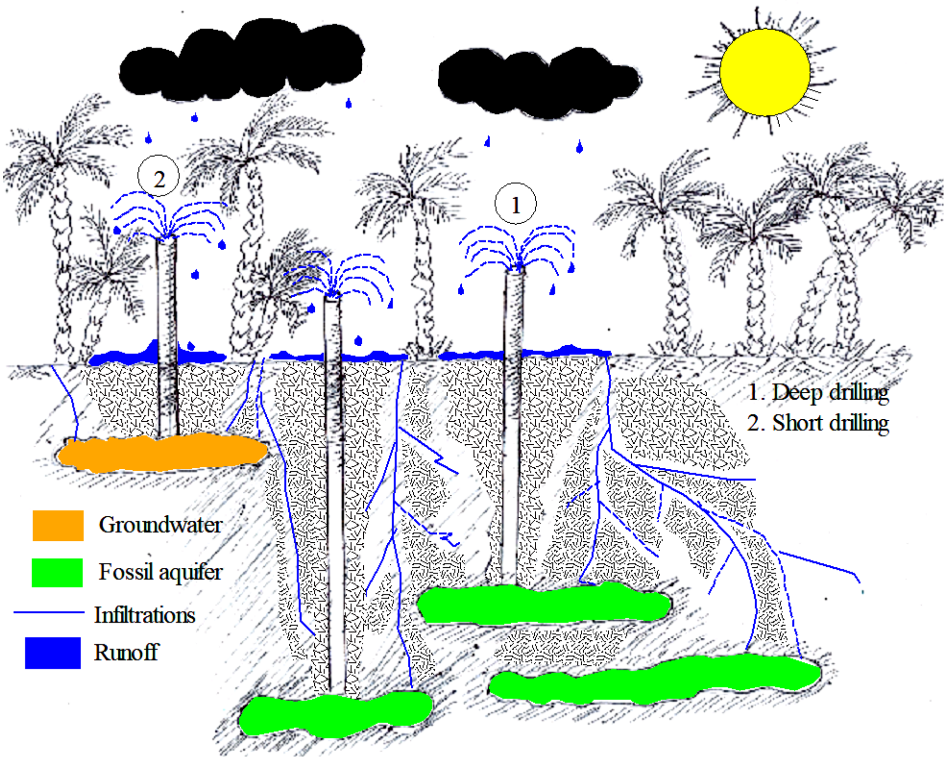


Figure 15: Approximate diagram of groundwater in the subsoil. The upper and deep aquifers that form in the subsoil (Remini diagram, 2026)

The recharge of upper aquifers is much greater and faster than that of deep aquifers due to the short distance between the water source (at the surface) and the aquifer. Let's return to the case of deep aquifers. These reservoirs have been forming for centuries, but due to the lack of technological means to obtain information and data on deep water, the exploitation of these water deposits did not occur. It was in the early 1940s that these water treasures began to be discovered, generally by chance. This is the case of the Northern Sahara Aquifer System in the Algerian Sahara, which was discovered during the 1940s. While drilling an oil well, they struck a hot, brackish water table, the discovery of "blue gold." However, the unique characteristic of the Northern Sahara Aquifer System is that it has been exploited by foggaras (traditional irrigation systems) for over 20 centuries by more than 1,000 foggaras. In fact, the oases of Touat, Gourara, and Tidikelt developed over the centuries thanks to the waters of the Northern Sahara Aquifer System. Today, with the increase in prospecting operations and the search for new aquifers worldwide, hundreds of fossil water deposits have been discovered. Transboundary aquifers are those that cross international borders. Their capacity is estimated at around billions of cubic meters of water, but it is currently difficult to assess the total water capacity of these transboundary aquifers. The latest inventory of transboundary aquifers, carried out in 2025 by IGRAC, identified 426 transboundary aquifers located deep within the Earth. Although these fossil waters, shared between several countries, are largely invisible, they are essential for ensuring water security and sustainable management.

Today, rainwater, the primary source of freshwater that replenishes the Earth's reserves, is known for its estimated quantity of 111 trillion cubic meters per year, which falls upon the continents. This quantity has, of course, been desalinated through natural distillation using water from the Earth's water tower, comprised of seas and oceans, as well as water from transboundary aquifers. However, the second source of water is fossil water. For this water resource, stored in transboundary aquifers, it is extremely difficult to assess its quantity. The number of these aquifers has never even been determined. Monitoring these water reservoirs, which generally extend beyond national borders, is essential to establishing a comprehensive list of aquifers capable of replenishing the Earth's freshwater reserves and contributing to ensuring water security for nations. It was in 2009 that a map of the Earth's transboundary aquifers was established by the International Groundwater Resources Assessment Centre (IGRAC) (IGRAC and UNESCO-IHP, 2025). Since this first map, rigorous monitoring of transboundary aquifers has been carried out. Five editions have been produced since 2009, 2012, 2015, 2021, and 2025. With each edition, new information and numerous design changes have been made, but the latest map of 2025 is the best. This edition presents substantial updates based on recent studies and revised assessments. In total, 426 transboundary aquifers have been mapped (Fig. 16).

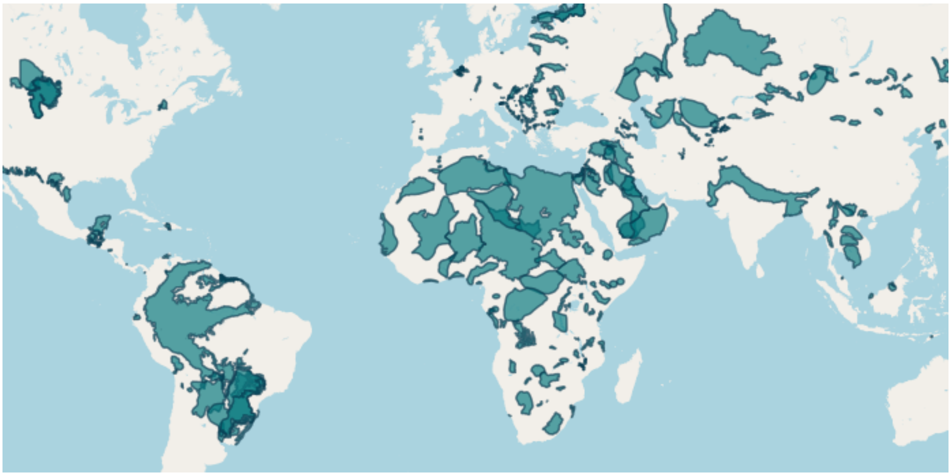


Figure 16: Map of transboundary aquifers of the world; 2025 Edition, the International Groundwater Resources Assessment Centre (IGRAC) and UNESCO-PHI (2025)

Planet Earth has 426 natural reservoirs in its subsoil. This figure depends on the availability and interpretation of hydrogeological data from several countries and frequent updates. For the 2025 edition, 49 new transboundary aquifers have been added, 41 existing aquifers have been revised, and 91 transboundary aquifers have been removed. This is good news for Algeria, as it is one of the countries that share the Lake Chad sedimentary basin. In total, Algeria is one of the countries that share six major aquifers in the world: the Northern Sahara Aquifer System (AF069), the Iullemmeden Aquifer System (AF056), the Tanezrouft-Taoudeni Aquifer System (AF064), the Mourzouk Aquifer System (AF067), and the Aquifer System... Tindouf (AF068) and the Lake Chad sedimentary basin (AF052). This water reservoir is shared between the countries of Algeria, Cameroon, the Central African Republic, Chad, Niger, and Nigeria. It should be noted that Algeria has been added to the group of countries sharing the Lake Chad sedimentary basin. The new 2025 map of transboundary aquifers worldwide confirms this. However, in-depth hydrogeological studies must be conducted to determine the dimensions and boundaries of the Lake Chad sedimentary basin within Algerian territory. The amount of water that can be extracted annually must be the subject of a thorough study.

Towards natural desalination of seawater and brackish water

Algeria's wealth lies in its sunshine, but we have not taken advantage of this inexhaustible resource. Let us use some of the sun's rays to remove salts from seawater and alleviate the thirst of both the population and the environment. Let us seize this opportunity to develop natural seawater desalination plants. Let us create models of the natural water cycle or simply design a mega desalination plant for seawater and ocean water.

As we mentioned at the beginning of this study, the goal of our work is to increase the freshwater supply to ensure national water security. Seawater is a reliable source for increasing the country's freshwater reserves. Algeria, with its 18 seawater desalination plants, produces 1.35 billion cubic meters per year. This quantity of water is currently insufficient to significantly increase the freshwater supply. Therefore, new seawater desalination plants must be built in the short term. However, the desalination of the future must be natural. In the first phase, we are starting with natural desalination plants for fossil water, which can be built in the southern Algerian provinces. These Saharan regions can easily adopt natural desalination of brackish water. Two important parameters facilitate the construction of brackish water desalination plants in the Algerian Sahara: the availability of space and solar energy. Thanks to deep drilling, brackish water is extracted from a depth of 2,000 meters at 70°C with a salinity of 2 to 3 g/l. Stored in a reservoir, after a brief pretreatment phase, the raw water goes directly into the distillation and condensation process to obtain distilled water.

The distillation process relies on two round trips. In the first phase, the water transforms from liquid to gaseous (vapor). The water evaporates, but it leaves behind impurities and salts. In the second phase, the water transforms from gaseous (water vapor) back into liquid; that is, the vapor condenses into precipitation, but the resulting water is distilled. This entire process is powered by solar energy. Space is needed to install solar panels to generate this energy. In the post-treatment phase, the distilled water is injected into infiltration basins to recharge groundwater aquifers or injected directly into the water table via boreholes or wells. In this case, we refer to it as the natural demineralization of brackish water (Fig. 17).

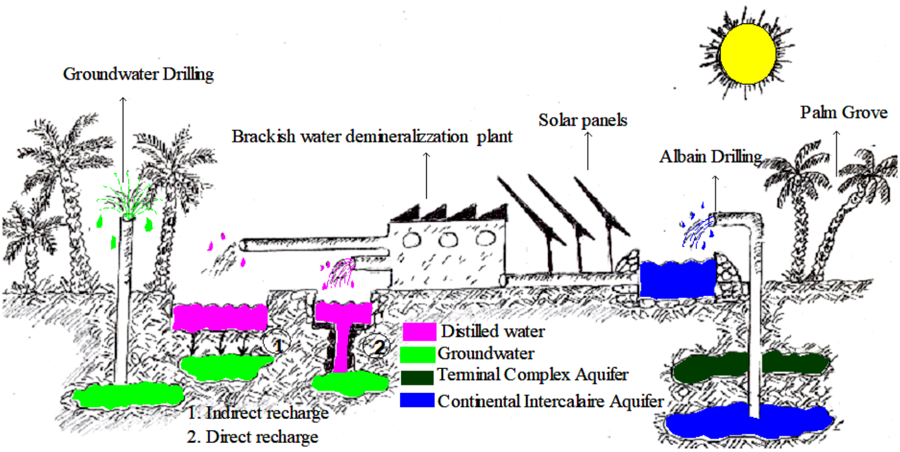


Figure 17: Simplified diagram of natural demineralization by distillation of brackish water in the Algerian Sahara (Remini diagram, 2026)

The brine discharged by a natural demineralization plant using distillation, composed of salts and impurities, can reach a salinity of 5 to 6 g/L. Two solutions can be recommended. The first is to construct evaporation ponds, given the available space in the Saharan regions. The second is to recover the salts after drying and evaporation of the water (Fig. 18). The second solution is to allow the brine to flow into the chotts (salt flats) along with the treated water (Fig. 19). It should be noted that brine from a demineralization plant using distillation is much greener than that from a reverse osmosis plant, which uses a significant amount of chemicals in the pretreatment phase.

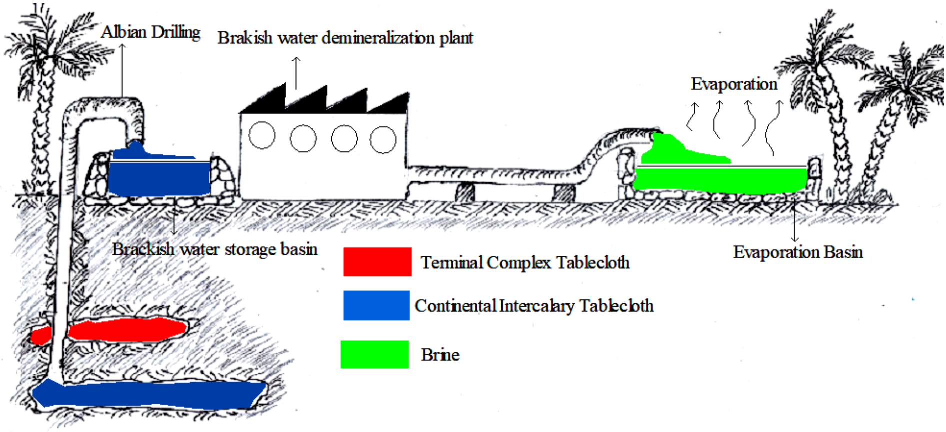


Figure 18: Approximate diagram of brine discharged from a demineralization plant by distillation into evaporation basins (Remini diagram, 2026).

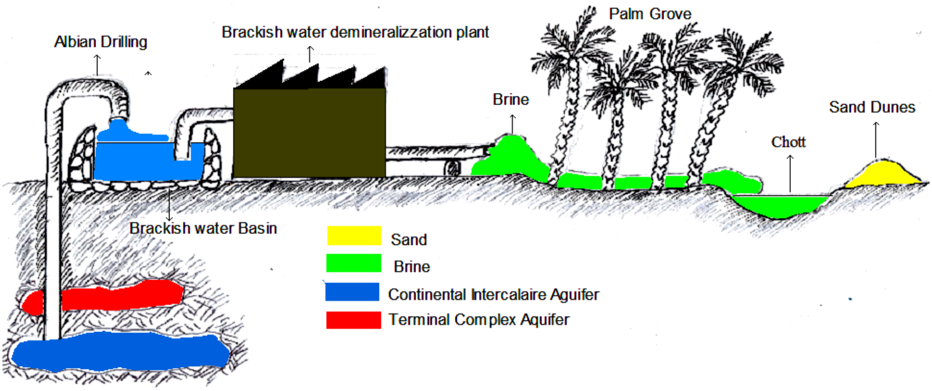


Figure 19: Approximate diagram of one of the brine discharges from a desalination plant using distillation in the Chotts (Remini diagram, 2026)

Regarding the natural desalination of seawater, distillation is a small-scale replica of nature. Seawater is drawn from the intake. The raw water is stored in a suitably sized basin. After passing through the pretreatment stage, the water goes directly into the distillation process. The liquid then passes into steam, and finally into distilled water. Pure water flows through a watercourse to be stored in natural reservoirs (upper aquifers) (Fig. 20). Good quality water is then extracted for the population through boreholes or wells.

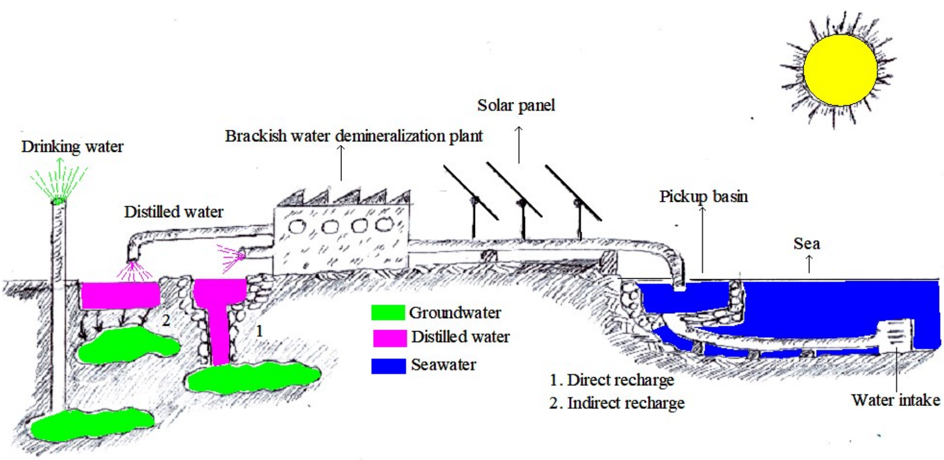


Figure 20: Approximate diagram of a natural seawater desalination plant (Remini diagram, 2026)

CONCLUSION

As we mentioned at the beginning of this article, seawater and ocean waters are indeed a reliable source of water, ensuring the water security of countries even in the face of the threat of climate change. However, it is necessary to remove the salts to make seawater and ocean waters potable. Reverse osmosis and distillation are two of the most widely used processes on the planet. However, a great deal of energy is required to purify seawater. On the other hand, on a synoptic scale, the oceans and seas constitute the water tower of planet Earth. Thanks to the energy provided by the Sun, billions of cubic meters of salt water are converted into fresh water each year. After condensation, this distilled water forms as precipitation, which falls to the ground to absorb mineral salts and thus become good quality, potable water. A natural process favors distillation over reverse osmosis for desalinating Mediterranean Sea waters and Saharan fossil waters. Similarly, the brine discharged by desalination plants is much cleaner than that discharged by reverse osmosis desalination plants. The rate of national integration in the construction of desalination or fossil water distillation plants is much higher than that of reverse osmosis plants. During floods, reverse osmosis plants encounter difficulties in capturing raw water that becomes too turbid due to sediment-laden water carried by wadis during flash floods, which eventually settles on the seabed. Only plants equipped with the distillation process can avoid this problem of fine particles, as they can capture raw water even with high turbidity. During the transition of water from a liquid to a gaseous state, impurities, solid particles, and salts are completely discarded; only the gaseous particles continue their journey, condensing and returning to the liquid state. Back to its initial state, that is, the liquid state, but this time, it is pure water without the solid particles and salts. This is an advantage not found in the reverse osmosis process. Furthermore, distillation is better suited to Algeria than reverse osmosis for desalination of the Saharan brackish water. Upon exiting the well, the brackish water has a temperature of approximately 70°C. In this case, it is only necessary to add 30° to 40°C to reach the boiling point and thus the vapor phase. After condensation, the water vapor returns to the liquid state: pure water. Conversely, hot water at 70°C must be cooled to 23°C to be accepted by reverse osmosis and successfully pass through the membranes. Therefore, a complete hydraulic system is required, attached to the demineralization plant; this system consists of a tower equipped with a cooling system. The raw water must first pass through the softening system before entering the reverse osmosis process. All these advantages make distillation the best process, particularly well-suited to a country like Algeria. Furthermore, Algeria offers vast open spaces, especially the Sahara Desert, and enjoys up to 97% sunshine. In fact, it is one of the sunniest regions on Earth. Temperatures exceed 50°C while the humidity level remains very low. Therefore, with all these characteristics, a scaled-down replica of nature can be applied in a first step to demineralize fossil waters in southern Algeria. In a second step, seawater can be naturally desalinated (distillation using solar energy) in the northern Algerian provinces. Natural desalination of seawater and brackish water involves desalination through distillation using solar energy.

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