Larhyss Journal, ISSN 1112-3680, n°54, Jun 2023, pp. 239-267

IS SUSTAINABLE DESALINATION THE SAFE WAY FOR ACHIEVE WATER SECURITY?

REMINI B[1*]., AMITOUCHE M[2].

[1] Department of Water Sciences and Environmental, Faculty of Technology, Blida 1 University, Blida 9000, Algeria
[2] Laboratory of Food Technology Research, University M'Hamed Bougara –Boumerdes Boumerdes 35000, Algeria

(*) reminib@yahoo.fr

Research Article – Available at http://larhyss.net/ojs/index.php/larhyss/index
Received February 10, 2023, Received in revised form June 1, 2023, Accepted June 4, 2023

ABSTRACT

Two aspects must be taken care of to achieve sustainable desalination in Algeria. Obtain drinking water at a reasonable price and without damaging the environment. To this end, three projects are to be carried out to set up a desalination plant. The seawater intake tower, the desalination processes itself, and the brine discharge. The study has shown that the right choice of the location of the raw water intake tower (sea water) can greatly improve the performance of the station. Proper management of brine through well-designed discharge operations helps protect the marine environment. For the drinking water production plant, which consists of extracting salts from raw water, serious study is required to choose the right desalination process. Between reverse osmosis and distillation, the whole strategy of desalination in Algeria is the best choice for the process, which must adapt to our country. We want sustainable desalination, which must ensure our water security and our sovereignty.

Keywords: Seawater, Desalination, Distillation, Reverse Osmosis, Brine, Capture tower.

INTRODUCTION

In 2023, the world population has reached the threshold of 8 billion inhabitants and is likely to exceed 9 billion inhabitants by 2050 according to the United Nations. As a result, human-accessible freshwater capacity becomes unable to meet population demand. Added to this freshwater deficit, the acceleration of climate change has a direct impact on water resources, which are becoming increasingly scarce. This new "sick" climate has been taking hold for four decades in several areas of the planet. The particularity of this climate is that it is characterized by a long dry season marked by rising temperatures exceeding 40°C. The Mediterranean basin and, more particularly, Algeria are no exception to this disruption, and consequently, water is becoming increasingly scarce. This climate of extremes, which does not respect the pattern of the seasons, tends to impose its aridity, and consequently, the specter of thirst settles in our region. To this end, a sustainable hydraulic system must be established and adapted according to the means of each country. For example, the oases of Adrar (Algeria) invented a sustainable hydraulic system called foggara, which was accompanied by a hyperarid climate for 20 centuries. The miracle and who have never had water problems during their history, the foggara still continues to provide water to the oases. The foggara system exploits groundwater through a slightly inclined underground gallery consisting of capturing and transporting water from the subsoil to the ground surface (Remini, 2017; Remini et al, 2011). For 20 centuries, oasis dwellers have learned to live with foggara. Such a hydraulic system has ensured the water security and even the food security of the oasis (Remini, 2023a; Remini, 2023b). Another example demonstrates that for an extreme climate, it is necessary to invent a sustainable hydraulic means to supply water during long droughts, which is one of the characteristics of the new climate. This is the M'Zab valley, which is located 600 km southwest of Algiers. For more than 7 centuries, in addition to a hyperarid climate, the M'Zab valley has been a rocky region devoid of water sources apart from the sporadic and brutal floods that occur once or twice every two years on the M'Zab River. This is one of the characteristics of the arid climate. The Ksourian population carried out hydroagricultural development on the M’Zab River, which we have called the IRS system (Remini, 2020a; Remini, 2020b; Remini, 2020c; Remini, 2020d). It consists of recharging the water table during floods to extract water in periods of drought. Thanks to this ingenious hydroagricultural development, the population of M'zab ensured food security for more than 7 centuries.

Today, with the arid climate that has existed in the Mediterranean basin for a long time, Algeria must opt for a sustainable hydraulic system to ensure the country's food security and protect future generations. Can we rely on conventional waters? Or quite simply, we opt for the use of unconventional waters and more particularly the desalination of seawater. With conventional waters, water security in Algeria was threatened in the early 2000s by a severe drought, followed by the current drought that began in 2021. These dry periods have had a very negative impact on conventional water (surface and groundwater). This is how the dams had a double problem: strong evaporation, which has reduced the useful capacity of the dams, and an increasingly increasing deposit of mud cutting off a high volume of water from the dam. With regard to groundwater, the lack of precipitation has not favored the natural replenishment of the water tables, and consequently, the water tables have recorded a significant drawdown following the pressure that has been suffered from the demand for irrigation and food in drinking water. This has pushed the Algerian state to opt for the exploitation of unconventional waters and, more particularly, the desalination of seawater as a strategic choice. However, we should not stop at this stage since the national integration rate is very low in these high-tech desalination projects. Twenty years of seawater desalination, significant experience and the construction of approximately ten desalination plants were recorded during this period. However, to obtain blue gold from the sea, several processes for extracting salts from seawater have been invented over the years, of which reverse osmosis and distillation (MSF) are the most commonly used. given their appreciable production yield. Each of these two processes has these advantages and disadvantages, and only a study taking into account energy and national integration in the assembly of these plants can dictate the strategic choice between reverse osmosis and distillation (MSF) for Algeria. It is from this stage that Algeria must move toward sustainable desalination, which will accompany this new arid climate. Only, can we confirm that sustainable desalination is the surest way to ensure water security and protect future generations?

EVOLUTION OF SEAWATER DESALINATION IN ALGERIA

Oceans and seas occupy most of the planet. An inexhaustible salt water deposit that represents 97.2% of the total mass of water equal to 1380 million km^3. On the other hand, accessible fresh water represents only 0.07% of the total volume of the planet (Renaudin, 2003). Today, it turns out that this volume of drinking water cannot meet the water demand of the world's population, which has reached the bar of 8 billion inhabitants. In addition, the climate rebellion has pushed blue gold to become increasingly rare in Arab countries and the southern Mediterranean basin. The use of salt water has become the only way to meet the demand for drinking water. Only fetching sea water or ocean water is not a simple thing. Removing the salts to drink it or to irrigate is a rather delicate operation. It is the desalination of sea water, a state-of-the-art technology that consists of separating fresh water and salty concentrate (brine). Such an operation requires colossal funding that is not within the reach of all countries in the world that have a border with saltwater. Quite simply, a desalination operation does not take place at zero energy or zero brine. This means that drinking a liter of water from the sea requires energy and in return throws the equivalent of a liter of brine into the sea. Oceans and seas, only today are we at the development stage of the desalination process. At this stage, two problems arise: economic (price of a m^3 of fresh water) and environmental (carbon footprint). Seawater desalination produces fresh water when raw water is pumped from the sea to the desalination plant to turn into fresh water. The inevitable result is that a stream of water relatively concentrated in dissolved salts (brine) is discharged from the plant to the seabed. Today, there are two seawater desalination processes, and each process includes several techniques:

- Single-effect distillation process, multiple-effect distillation with horizontal sprayed tubes, flash distillation, and distillation by vapor compression. The distillation process (MSF) consists of heating salt water with the production of water vapor, which in turn condenses to form fresh water. The water is heated to a boil to produce the maximum amount of steam.
- Electro dialysis membrane process, reverse osmosis. The membranes are used commercially in two processes: RO reverse osmosis and ED electrodialysis.

Reverse osmosis involves separating dissolved substances from a pressurized salt solution by causing it to diffuse through a membrane. As some of the water diffuses through the membrane, the salt concentration of the remaining fraction increases. At the same time, part of the feed water is rejected without diffusing through the membrane. Electrodialysis is a process that uses the mobility of the ions of an electrolyte subjected to an electric field, and desalination is ensured by membranes that selectively eliminate salts, which makes it possible to obtain fresh water. The most commonly used techniques are flash distillation and reverse osmosis. Figure 1 illustrates the desalination processes available on the market.

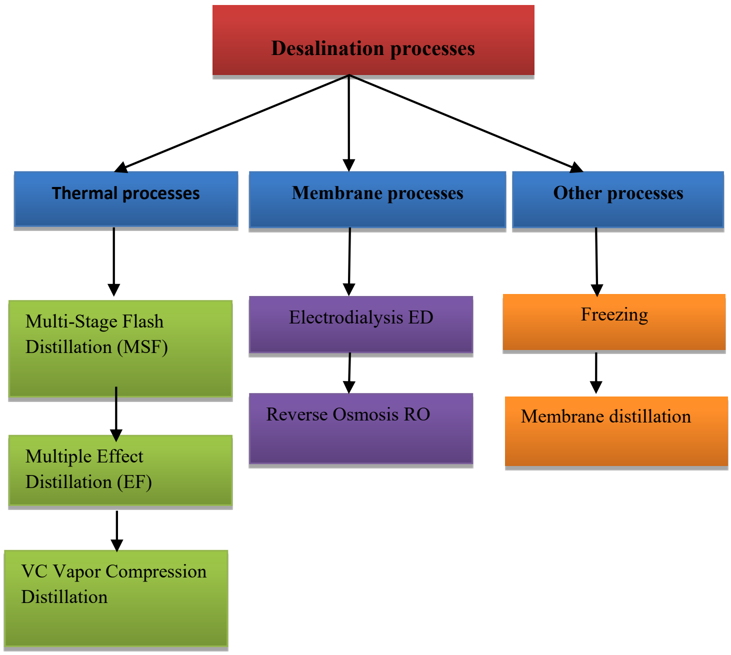

Figure 1: Types of seawater desalination processes

Algeria has to its credit a significant experience since the first quantities of desalinated water were started during the sixties, but with modest desalination stations. Seawater desalination and demineralization, the Algerian experience dates back to the sixties. There are currently 43 desalination units with a processing capacity of nearly 100,000 cubic meters per day. This flow is intended for a large part of the oil industry of Arzew and Skikda (Remini, 2010). Brackish water demineralization units were built in Abdala (1700 m^3/d), Ouenza (4000 m^3/d), Ouled Djellal (3000 m^3/d) and SONIC in Mostaganem (40000 m3/d) (Remini, 2010). Some actions have been undertaken within the High Commission for Research concerning development projects, such as the study and construction of a reverse osmosis desalination unit with a capacity of 200 m^3/d. It was only at the beginning of the 2000s following a severe drought that affected Algeria. It had a catastrophic impact on water resources. Several dams were dry like that of Keddara, which was supposed to supply the capital Algiers. Water bodies were close to exhaustion, especially that of Mitidja, which could no longer meet the demand of farmers and citizens. The underground coastal reservoirs have been contaminated by seawater, particularly those in the Tipaza region, following the drawdown of the water table. An ecological imbalance is caused by the change in the direction of the flow, which is oriented toward the south. A salty density current advances and contaminates the water and the soil. In view of these problems, the Algerian State has opted for the development of seawater desalination along the entire Algerian coast. Twelve large desalination stations have been built to produce fresh water at a flow rate of 2.2 million m^3/d, which has made it possible to slightly reduce the pressure on water from boreholes and dams (fig. 2). Five new seawater desalination stations with a capacity of 300,000 m^3/d each are currently under construction (fig. 3).

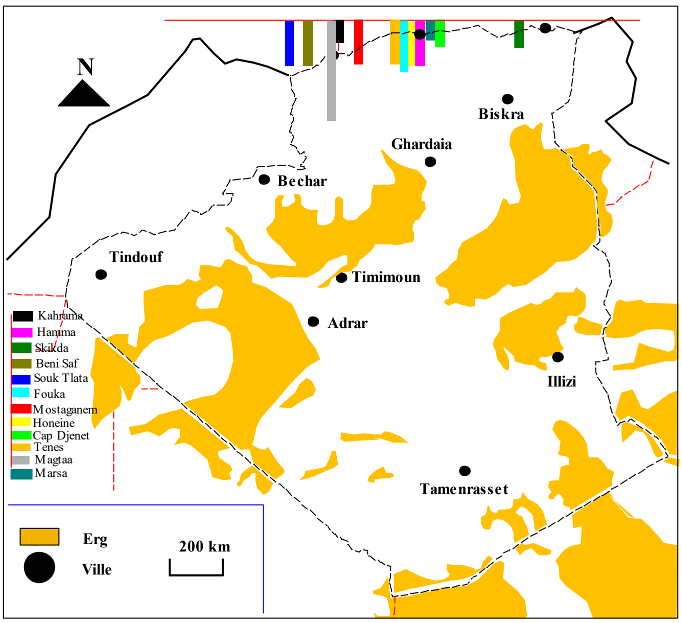

Figure 2: Desalination plants in operation in Algeria

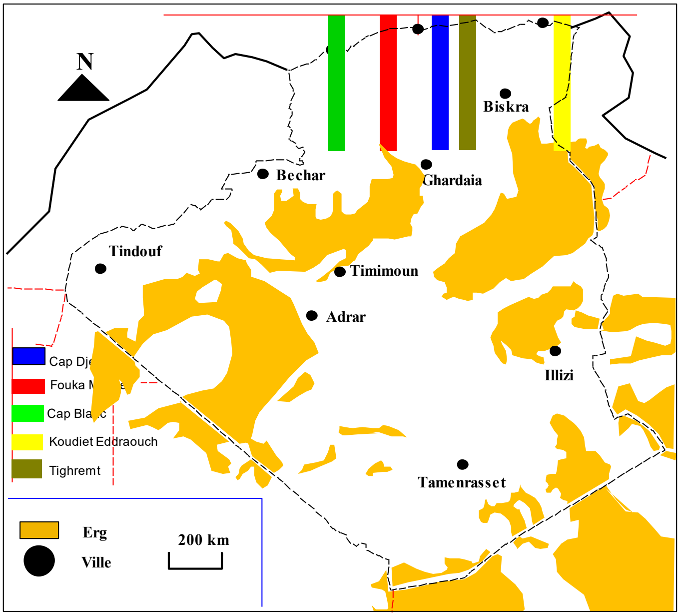

Figure 3: Desalination plants under construction in Algeria

Although these plants did not achieve the desired performance for various reasons, greater Algiers was supplied with drinking water 24 hours a day. Twenty years later, that is, at the beginning of 2021, other drought sets that started hard since the appearance of the indices in 2000 are today the same with the drying up of dams, such as those of Keddara and Boukourdane, the drawdown of water tables and the intrusion of marine waters into coastal aquifers. This forced the hydraulic services to establish a program of restriction of the flow of water to be consumed, especially during the summer seasons. In view of the water problems, the Algerian government has opted for the development of seawater desalination along the Algerian coast over a length of 1200 km. An ambitious program has been adopted by the highest authorities of the state given the importance of the water problem. To this end, from the end of 2024, the number of desalination stations will be increased to 22 stations to satisfy 42% of drinking water consumption and will exceed 60% in 2030. It is interesting to remember that all these stations are operating with the reverse osmosis process, except for the Kahrama station, which operates using the distillation process. Today, Algeria has extensive experience in the field of desalination, except with 2.2 million m^3 of desalinated water per day, or 800 million m^3/year of desalinated water. This is a very small quantity of desalinated water compared to the water stored in the 75 dams in operation. For example, the 12 desalination stations in service annually produce the equivalent regulated by the Beni Haroun dam. By 2030, the quantity of water that will be desalinated will not exceed the volume of water regulated by the two dams: Beni Haroun and Koudiet Acerdoune.

WHAT LESSONS CAN WE LEARN FROM THE ALGERIAN EXPERIENCE IN DESALINATION?

The desilting of sea water has become a reality in Algeria following the drought that hit this country at the end of the 1990s and the beginning of the 2000s. This period of low rainfall was marked by the drying up of dams and the drawdown of the sheets. Faced with water scarcity, Algeria is committed to developing seawater desalination. Twenty years later, in 2020, Algeria had 12 large desalination stations (over 50,000 m^3 operational sites spread over a coastline of 1200 km, with a total capacity of approximately 2.2 million m^3 of desalinated water (and more than 2.6 million m^3 of brine discharge per day), which represents approximately 17% of the drinking water consumption. However, Algeria has chosen reverse osmosis technology that has been used in 11 of the 12 stations, except for the Kahrama station in Oran with the MSF technique. From the end of 2024, the number of desalination stations will be 22 stations to satisfy 42% of drinking water consumption and will exceed 60% in 2030. From the end of 2022, Algeria launched the construction of 5 large seawater desalination projects for an implementation period not exceeding 25 months, with an estimated capacity of 300,000 m^3/d each. These stations will be built in the wilayas of Tipasa (Fouka 2), Oran (Ras El Abiad), Béjaia (Toudja), Boumerdès (Cap Djinet) and El Tarf (Koudiet Eddraouch). It is the Algerian company that took charge of these factories. This is the company "Algerian Energy Company" (AEC SPA). The objective is to increase the rate of national integration in this field of technology. All five stations will be equipped with reverse osmosis-type desalination processes. During this 20-year period of seawater desalination, Algeria provided water for the population of the capital and the peripheral regions; however, the performance of these stations did not have the expected results. There are even stations that have recorded production stoppages during the flood period due to the lack of large quantities of fine sediment that can easily reach the site of the raw water intake tower. In addition, the downstream part concerns the discharge of brine and its impact on the marine environment. This subject has been very little studied during this period and deserves to be pursued and examined in depth. As we mentioned at the beginning of this article, desalination consists of removing salt from raw water to obtain soft water. This delicate operation is carried out using a desalination process. Two desalination techniques have proven their effectiveness on the market: reverse osmosis and distillation. Algeria has adopted the reverse osmosis precedent and has been generalized to all major desalination stations (11 stations in operation and 5 stations in the pipeline). This strategic choice was dictated by an in-depth study or was based on the cost of energy, which favors reverse osmosis without taking into account the other parameters (membrane, pretreatment, brine discharged into the seabed, etc.). The rest of the article will clarify the choice of the process.

TRANSITION TO SUSTAINABLE DESALINATION

A new climate is beginning to take hold in the Mediterranean basin region. At the beginning of the 1980s, the thermometer recorded increasingly high values in the Mediterranean region and more particularly in the southern part. Flash floods occur in Mediterranean countries just at the end of drought periods. The pattern of the four seasons begins to fade, giving way to a new pattern of extremes. In recent years, we see and feel it, it is the arid climate par excellence. Such a climate must be accompanied by a sustainable hydraulic system that must ensure the water and food security of our country. Our ancestors established a sustainable hydraulic system in the oases of Touat, Gourara and Tidikelt located in southwestern Algeria. They were accompanied by a hyperarid climate for 20 centuries with a sustainable hydraulic system. It is the foggara system that exploits the waters of the Grand Erg Occidental and the Continental Intercalaire aquifer (Remini, 2017). The best part is that they ensured their water and food security without damaging the environment (Remini, 2023). Therefore, can Algeria of today adopt a sustainable hydraulic means that must accompany this new climate, which will last for centuries and save future generations? A hydraulic means that proves to be the safest is undoubtedly the desalination of sea water but is not with the current desalination. Algeria must prepare for its transition to sustainable desalination. Therefore, to achieve such an objective, three aspects must be mastered. It is about:

Energy aspect

For the desalination of seawater, the energy consumption is a function of the process used for the production of fresh water. On the market, there are two processes that are the most commonly used, namely, reverse osmosis and distillation. However, reverse osmosis is more energy efficient than distillation and is the most widely adopted process in the world despite these environmental drawbacks. However, the ideal would be to take into account the 2Es of the economy (Price) and the environment. In this case, we enter directly into sustainable desalination, and the energy consumption has a relationship with the process used. Therefore, for sustainable desalination, EE (economy and environment) must be controlled.

- On the economic side, it is necessary to manage to reduce the price of energy while protecting the environment (borrows Carbonne). Today, the distillation process consumes more energy than reverse osmosis. The energy consumption for reverse osmosis is 3 to 5 kw/h/m^3, while that for distillation (MSF) is 8 kw/h/m^3. The latter is equipped with a brine recovery system (XP) (pressure Xchange). If we want to decrease more energy, we must develop a recovery system.
- On the environmental side, the environmental impact of different energy sources is assessed by their carbon footprint. The use of clean energies (solar energy and hydrogen) is a sustainable solution for operating desalination plants.

Marine environment aspect

The marine environment represents an important step in sustainable desalination. Today, most seawater desalination plants in the world discharge brine directly into the marine environment. In the long term and with significant quantities of brine, these discharges can have harmful effects on the marine environment and, more particularly, on the Mediterranean Sea, which is considered to be the largest semienclosed sea in the world. The concentration of the discharges (brine) reaches 3 times that of the feed seawater, with the addition of the chemicals used during the pretreatment and posttreatment phases. The constituents present in the wastewater discharged from desalination plants depend on the quality of the fresh water produced and the desalination technique adopted. Figure 4 summarizes the adverse environmental effects induced by seawater desalination.

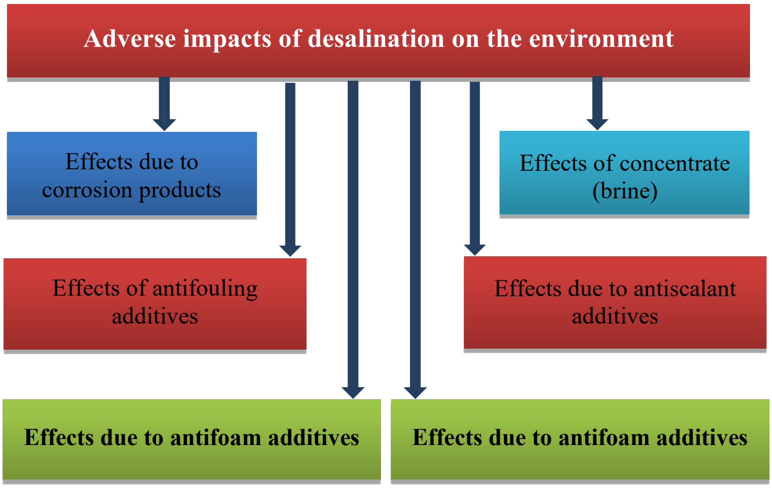

Figure 4: Effects of discharges from a reverse osmosis process desalination plant on the marine environment

HOW CAN WE HAVE AN EFFICIENT AND SUSTAINABLE DESALINATION PLANT?

The water security of a country is not on the agenda when it is very rich in water. However, water security will be threatened as soon as water begins to become scarce. With climate change having an impact on water scarcity, building a sustainable Algerian hydraulic system that can ensure the country's water security. Therefore, in this case, the use of seawater desalination becomes an essential option. The desalination of seawater consists of 3 major structures: the intake tower, the desalination process, and the brine discharge pipe (fig. 5).

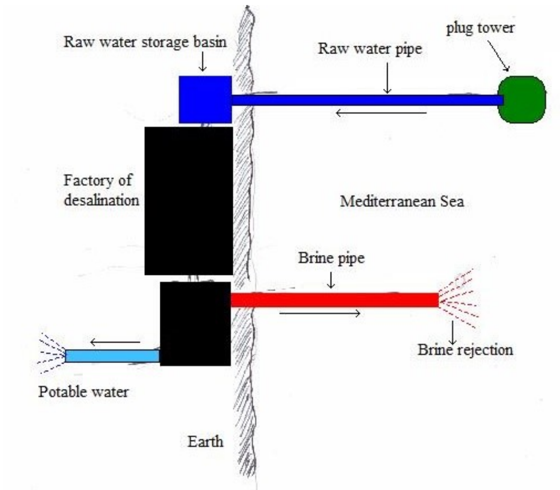

Figure 5: The three essential works of a desalination plant

Choice of site for the raw water intake tower (sea water)

River Sea: A balanced relationship of the marine ecosystem

The bridge between land and sea is represented by the watercourse. The fine particles torn from the slopes are transported by the rivers to flow into the sea. This mixture eroded by runoff in the high mountains and the undermining of the banks of the rivers is very rich in nutrients such as phosphorus and nitrogen. The magnitude of these amounts of mud reaching the saltwater varies from region to region. Thus, the mass of sediments emanating from Algerian rivers toward the sea is among the highest on the planet (Fig. 6). Obviously, it must be seen from the perspective of the volume of fresh water that transported these aggregates. More than 180 million tons of silt torn from the watersheds of northern Algeria are dumped annually into the sea (Demmak, 1982).

Figure 6: Discharges of fine particles in the Mediterranean Sea (Google Earth)

However, in periods of floods, the Algerian coast, similar to other Maghreb countries, is very active in terms of sedimentary dynamics. Several tons of sediment are discharged on the southern shore of the Mediterranean thanks to the solid flows drained by the rivers. At the exit of the wadi, the water loaded with fine particles is in contact with the sea water, and the difference in density causes two different phenomena depending on the sediment content. In the case where the concentration of fine particles is very high, a density current is formed and propagates on the sea bed and can reach several kilometers like a blade of well individualized mixture (Figs. 7 and 8).

The distance traveled depends on the pressure factor, and therefore, the density current vanishes as soon as the concentration of fine particles tends toward zero. In the case where the sediment content in the water drained by the river is low, the density current will not be able to form; therefore, it is the diffusion of fine particles in the sea that forms and will be carried away by sea currents (Fig. 9). The formation of a density current when aided by ocean currents can easily reach 20 km on the seabed. It can drain large amounts of dust.

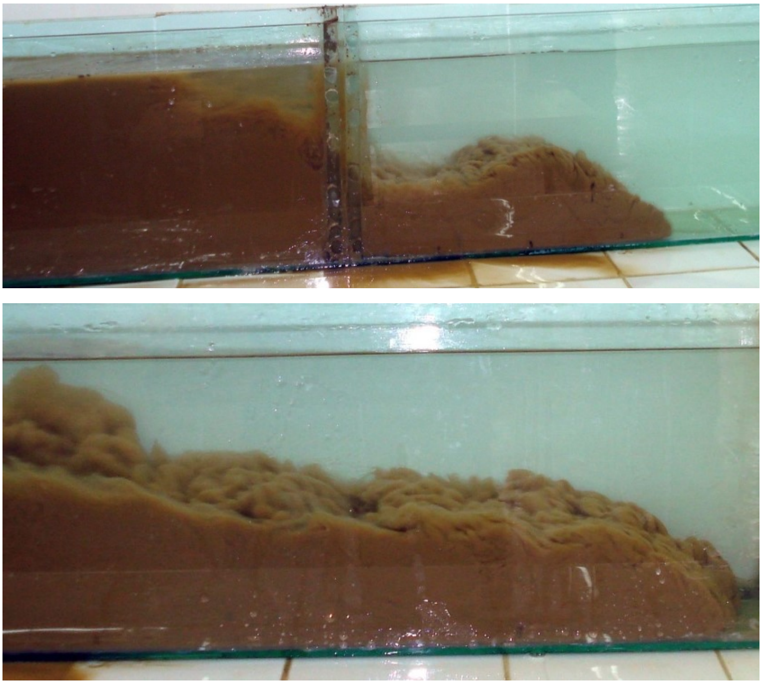

Figure 7: After 1 minute of formation, a density current propagates in a rectangular laboratory channel (Photo. Remini)

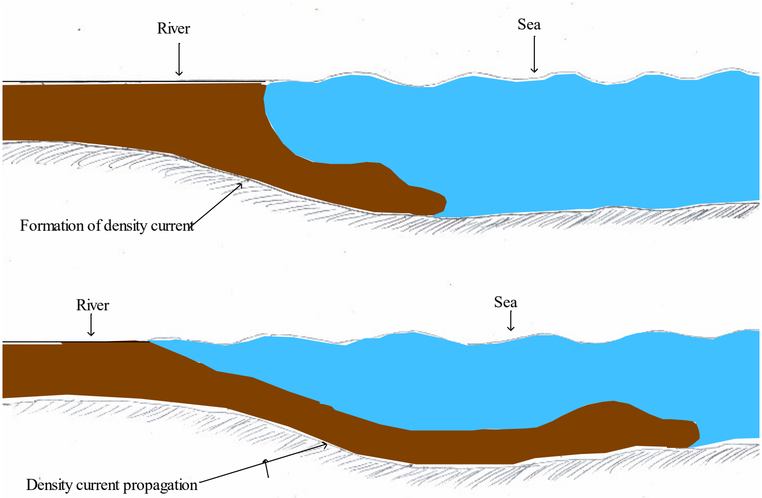

Figure 8: Propagation of the density current during floods in the seabed (Schema Remini, 2023)

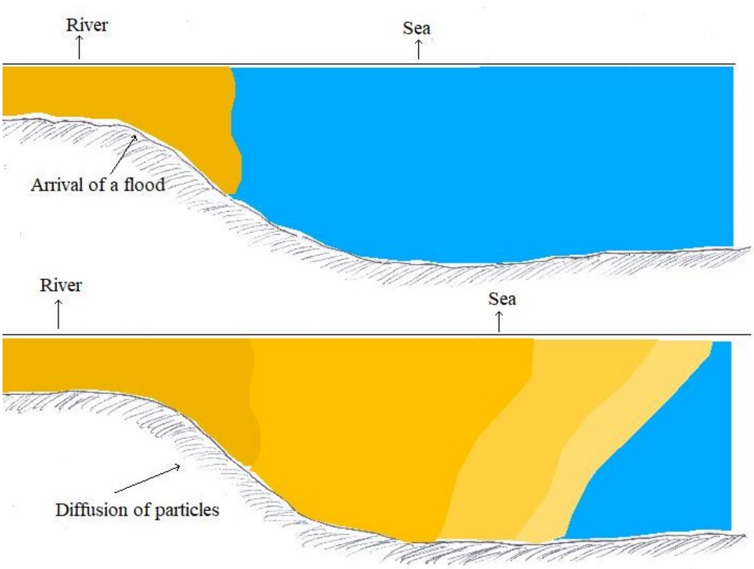

Figure 9: Simplified diagram of the diffusion of fine particles in the sea caused by the arrival of a low concentration flood

The ideal site for a raw water intake tower

The site of the catchment tower structure has a great influence on the pretreatment operations and even on the lifespan of the membranes used by the reverse osmosis process. These are plumes of fine particles diffused into the sea from solid inputs discharged by the wadis into the mouths. These inestimable quantities of mud rejected by the wadis come from the erosion of the watershed and the undermining of the banks. This wadi-sea relationship is part of the balance of the marine ecosystem.

To achieve a better production yield of fresh water (quality/price) of a desalination plant, we must choose the desalination process. Whether reverse osmosis or distillation (MSF), the choice of the raw water collection point is the most important operation in a project to build a seawater desalination plant. Therefore, to obtain a better price of a cubic meter of desalinated water, it is necessary to have a better quality of raw water in time and in space (sustainable quality). Therefore, the location of the capture tower must be well studied and thus take into account several parameters. For us, the choice of capture tower must depend on the geometric coordinates of the tower. Its position at the bottom of the ocean or the sea is essential. Its location must be far from the discharge points of water courses (wadis, rivers) and far from the free surface of the sea. In reality, even if we remove the intake tower as far as possible from the coast, the problem will not be solved, and the project will cost even more. Quite simply, the coast of the countries of North Africa (Algeria, Morocco and Tunisia) with a total length of 2000 km is among the coasts that receive the most sediment in the world. The plume of fine particles induced by the discharge of silt from the watercourse can go as far as possible under the effect of sea currents without being completely diluted in sea water.

- ***The depth of the capture tower***

The depth of the capture tower must be determined according to the height of the swell (H) and its position far from the bottom (h) to avoid the entry of floating objects and even particles carried under the effect of the swell (fig. 10).

- ***Coordinates (x,y)***

Spatially, the position of the catchment tower depends on the mouths of the rivers (Fig. 11).

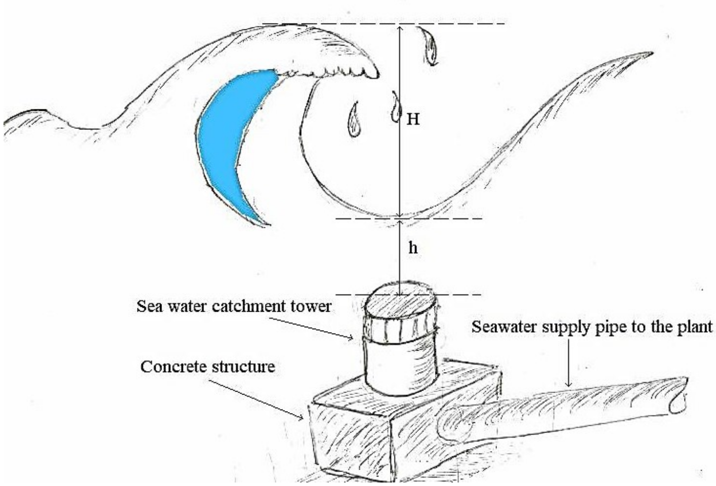

Figure 10: Simplified diagram of the position of the raw water intake tower of a desalination plant

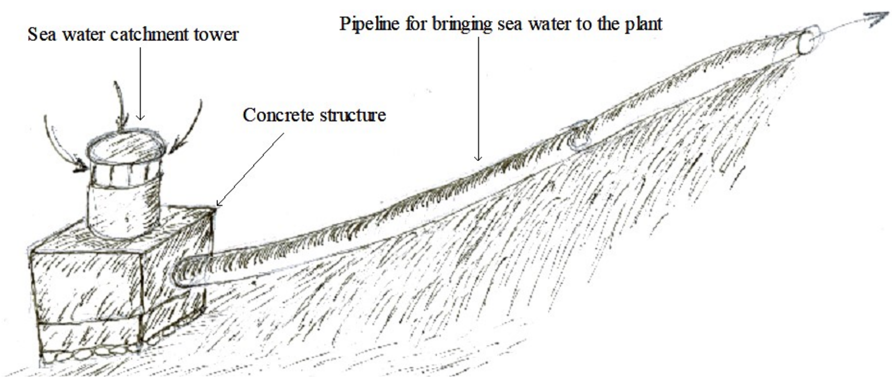

Figure 11: Simplified diagram of a desalination plant intake tower

Some examples of desalination plants in operation

Whether it is a density current that propagates in the seabed or a plume of fine particles that diffuses in the sea, the consequences are the same, i.e., the invasion of the intake tower. The propagation of fine particles on the seabed is much more complex than the sediments that propagate in the reservoirs of dams. We have raised 4 stations out of 12 that have solid transport problems, namely, the desalination station of Algiers (El Hamma), the desalination station of Mostaganem, the desalination station of Fouka and the desalination station of Ténès.

- ***Algiers seawater desalination plant (El Hamma)***

With a capacity of 200,000 m^3/d, the El Hamma desalination plant was put into operation in 2008 following the drought that affected Algeria in the early 2000s. The Hamma desalination plant is located 5 km from the mouth of the El Harrach River. The wadi of El Harrach is very active during periods of flooding. Several tons of fine particles are released at the mouth of the wadi, and then they spread in the form of a plume of dust to cover an area that can reach 20 km^2. The collection tower of the Hamma plant is easily invaded by these tons of solid particles (fig. 12).

Figure 12: El Harrach River releases tons of sediment during floods into the sea (Google Earth)

The El Harrach River, 35 km from Magta Lazrek, carries a large quantity of sediment. The rate of erosion of the watershed of the El Harrach wadi is 450 t/km^2.year, a significant value that will affect the concentration of fine particles in the waters of the El Harrach wadi. At the arrival of the mouth, the flood water is loaded with fine particles. With the contact of muddy water with sea water, a real density current is formed that flows on the seabed up to 20 km in the absence of sea currents. The latter can easily modify (increase or decrease) the speed of the density current, and it depends on the direction of the sea currents. These density currents can damage the collection tower and can even clog the pumps (Figs. 13 and 14)

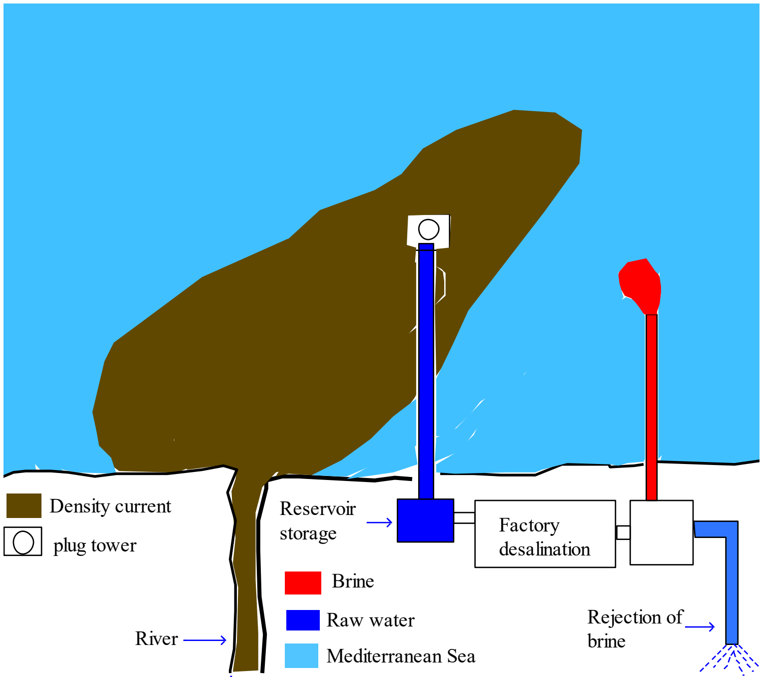

Figure 13: Approximate diagram of the propagation of a density current on the seabed that invaded the collection tower.

Figure 14: El Harrach River: A density current propagating toward the El Hamma station (Google Earth)

In the case where there is no formation of a density current due to a low concentration of fine particles, diffusion of the particles is formed (Fig. 15). A veritable chimney of dust spreads following the direction of the sea currents (fig. 16). These suspended particles can move slowly over several kilometers. In this case, no intake tower of a desalination plant with a radius of approximately 10 km will be safe from this cloud of dust under water. With this sedimentary dynamic created by the arrival of fine particles at the mouth of the wadi, the raw water collection tower, which is 5 km from the mouth of the wadi, has not been spared. by solid contributions. This will affect the pretreatment phase, and therefore, the age of the membrane will not exceed 2 years.

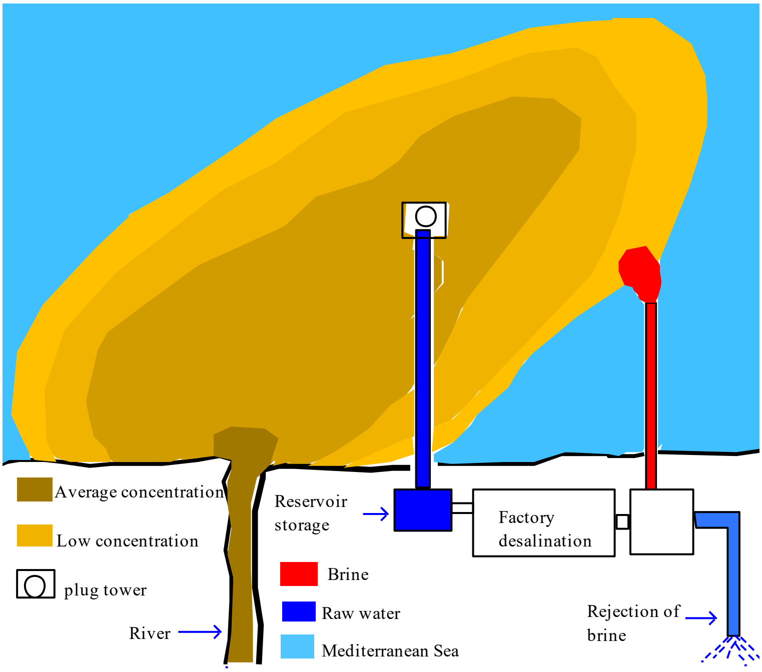

Figure 15: Approximate diagram of an underwater dust plume that diffuses according to the direction of the sea current that invades the raw water intake tower

Figure 16: A cloud of dust under water is carried by ocean currents (Google Earth)

- ***Mostagnem desalination station***

Commissioned in 2011, the Mostaganem seawater desalination plant has a production capacity of 200,000 m^3/d. Such a volume of drinking water was obtained thanks to the reverse osmosis process. However, the plant is located 2 km from the mouth of the Cheliff River. It is interesting to know that the watersheds of western Algeria are the most eroded, where erosion affects 47% of all the watersheds of northern Algeria, followed by the center (27%) and the east (26%) (Achite et al, 2006). The Cheliff River is well known for its solid transport. The floods of the Cheliff River carry an appreciable quantity following the significant erosion of its catchment area with an area equal to 56227 km^2. With this large quantity of fine particles, the density current is formed during periods of flooding. Given the location of the Cheliff River discharge point, which is 2 km away, the density current can easily reach the collection tower (Figs. 17 and 18). Expect rigorous pretreatment to purify the raw water before it reaches the process itself. These solid inputs influence the pretreatment process and even the life of the reverse osmosis membranes, which tends to decrease.

Figure 17: Formation of a density current during flood contact of the Chellif wadi with the sea (Google Earth)

Figure 18: Vanishing of a density current just after its formation due to sea currents that move in the opposite direction of propagation of the density current (Google Earth)

- ***Fouka desalination plant (Tipaza)***

With a length of 24 km, the Mazafran River originates at the crossings of the Chiffa River with the Djer River to flow into the Mediterranean Sea. With a specific erosion rate estimated at 824 t/km^2/year (Bellah, 2023), the watershed of Mazafran River is considered to be the most degraded watershed of the Algiers watersheds. With such an erosion rate, each time the flood transported by the Mazafran wadi comes into contact with the sea, a density current forms and spreads (Figs. 19 and 20). 4.5 km south of the wadi of Mazafran is the Fouka desalination station. With a capacity of 120,000 m^3/d, the Fouka desalination plant was built in 2011. Unfortunately, the Fouka station's catchment tower will not be spared by the solid particles thrown into the sea by the Mazafran wadi. This sedimentary dynamic generated by the Mazafran wadi at the level of the mouth has a direct influence on the pretreatment process and the desalination itself. It even has an impact on the life of the membranes and therefore has an effect on the price of m3 of desalinated water.

Figure 19: Density current propagates toward the site of the capture tower of the Fouka seawater desalination station (Google Earth)

Figure 20: Current of less dense density propagates toward the site of the capture tower of the Fouka seawater desalination station (Google Earth)

- ***Tenes desalination plant***

With a capacity of 200,000 m^3/d, the Ténès desalination plant is located approximately 700 m from the El Amri wadi. Despite the existence of a natural barrier of approximately 200 m located between the El Amri wadi and the Ténès seawater desalination station, the density current can circumvent the obstacle and invade the intake tower. the desalination station. El Amri River, a small stream, but these solid contributions are important and give rise to density currents at the contact between the water charged with the flood and the sea water. This very dense current arrives easily at the intake tower of the desalination plant (Fig. 21(a to e)).

a) Birth of the density current

b) Start of density current propagation

c) A low concentration current can circumvent the natural obstacle

d) High concentration density current

e) Concentrated and broad density current can cause damage to the socket tower.

Figure 21: Mechanism of density currents around the collection tower of the Ténès desalination plant (Google Earth)

Interaction between brine and water from the water intake tower

Another problem that must be taken into consideration in the design of desalination plants that work with the reverse osmosis process. This is the direct discharge of brine to the seabed. This is a case that resembles that of water charged with a flood with sea water. The contact between two liquids of different densities always generates the formation of a density current. By gravity, the brine in contact with seawater generates a density current that propagates on the seabed. Sea currents steer and push even the density current to flow faster. Directed by sea currents toward the direction of the intake tower, the brine in the form of a density current can easily reach the intake tower (Figs. 22 and 23). A simulation was made on the discharge into the seabed of brine from the Ténès desalination plant. The result obtained is very interesting, as shown in fig. 24, in which the brine plume completely covers the seawater intake tower.

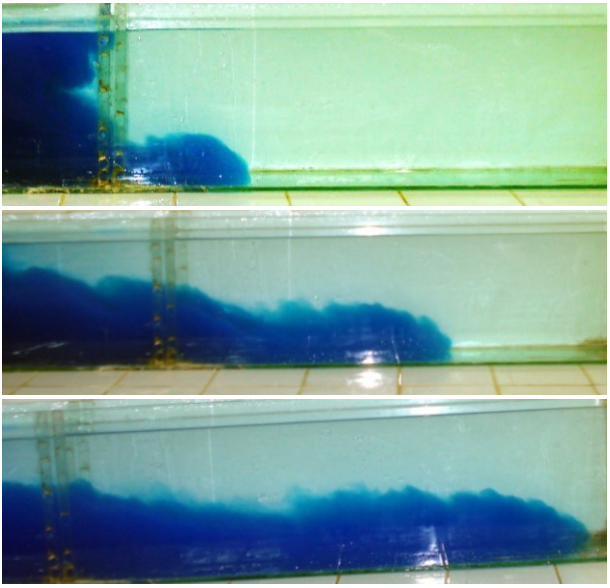

Figure 22: Density current in a laboratory channel (two liquids of different densities) (saltier green liquid).

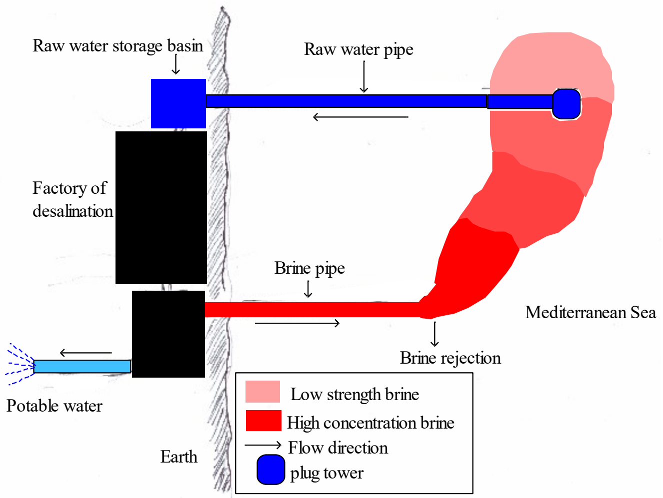

Figure 23: Simplified diagram of brine flow to the intake tower of a seawater desalination plant.

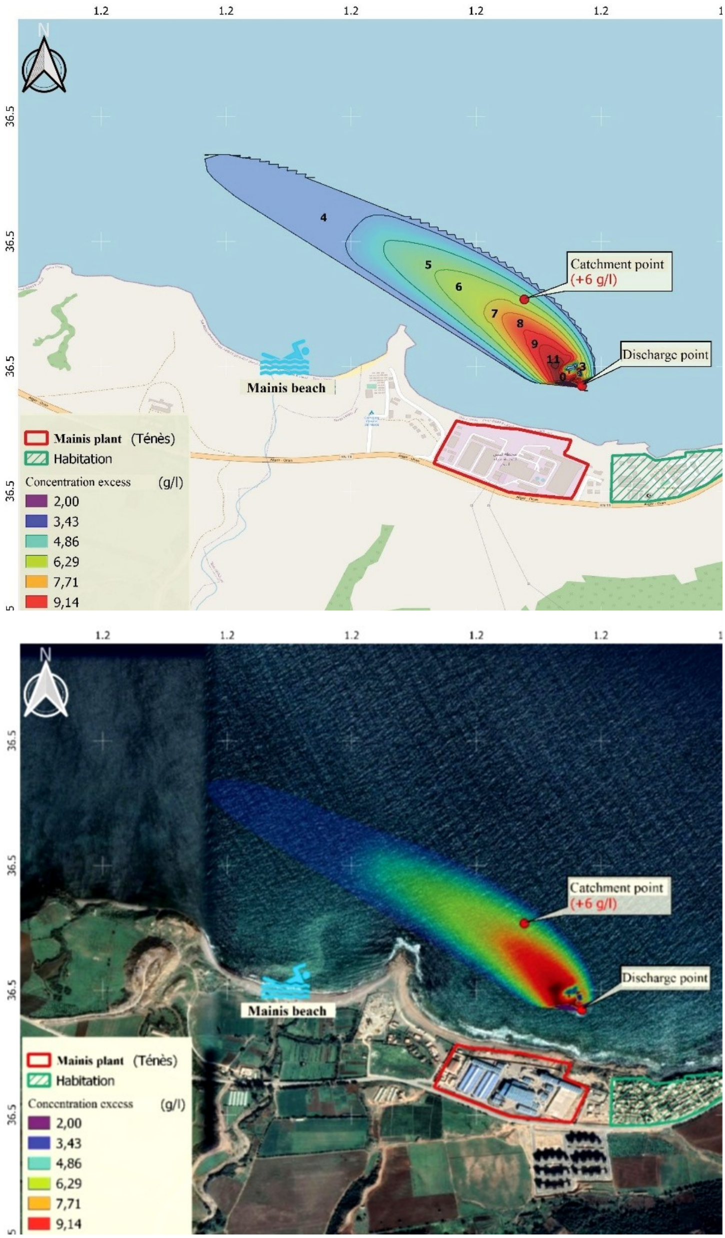

Figure 24: Interaction of brine discharges with water (point) from the Ténès desalination plant (Chlef-Algeria).

The choice of process to achieve sustainable desalination

Salts were removed from raw water (sea water) to obtain soft water. Such an operation requires a technique (a process) and energy, which we call seawater desalination. The process is not as simple as one imagines. Everything is based on the choice of the desalination process. Two criteria determine the best process: economy (which is related to energy) and the environment. We have summarized in Table 1 the main disadvantages and advantages of the two processes.

Table 1: Advantages and disadvantages of the two desalination processes: reverse osmosis and distillation (MSF)

	Desalination process	
Process element	**Reverse Osmosis**	**Distilling (MSF)**
collection tower	Reverse osmosis requires a good choice of the raw water withdrawal point.	For distillation the choice of the location of the capture tower is not a mandatory thing.
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
Diaphragms	Mandatory membranes	No membranes
High pressure pump	Equipment of the stations by high pressure (HP) pumps (over 60 bars	Distillation stations require pressure
Energy	Energy consumption 3 to 5 km/h	Energy consumption 8kw/h
Environment	Carbon footprint	Significant carbon footprint
Brine	The brine rejected by the reverse osmosis contains the concentrate and the ready-to-process chemicals.	The brine rejected by the distillation contains only the concentrate (salinity).

Based on Table 1, it turns out that the distillation (MSF) process consumes much energy compared to the reverse osmosis process. On the other hand, the distillation process has many advantages over RO. The distillation process can be the right choice for energy-producing countries rich in iron mines, such as Algeria. From a water and food security point of view, Algeria can opt for the distillation process. For Algeria, distillation can reach a much more affordable price per m3 of desalinated water than that of reverse osmosis since the rate of integration in the construction of a distillation station is very high compared to that of reverse osmosis in Algeria. LCA (life cycle analysis) is an essential decision-making tool to decide on the ideal choice of the two processes. The verdict on the sustainability of desalination should be made on the basis of a well-established environmental life cycle analysis (LCA). A simplified LCA flowchart of the desalination process is shown in Fig. 25.

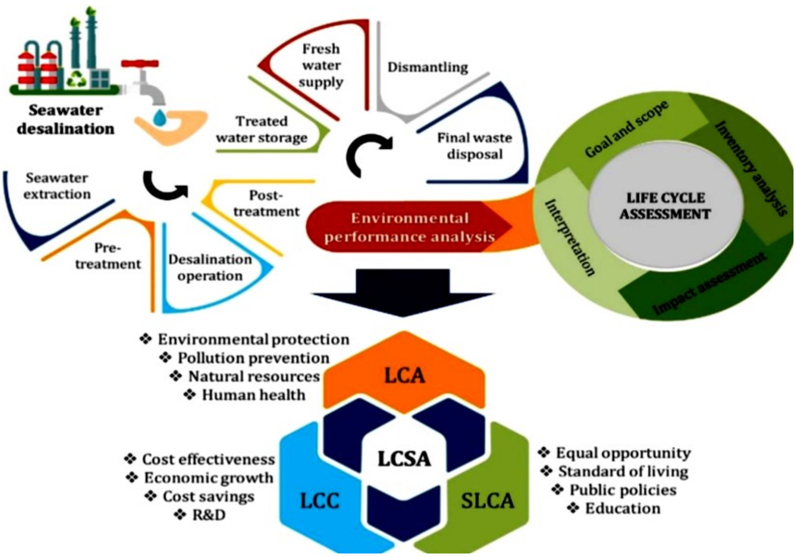

Figure 25: Simplified LCA flowchart of the desalination process (Aziz and Hanafia, 2020).

Brine management

We all agree on the following principle: the desalination of seawater is never carried out with zero energy or with zero brine. Therefore, in this case, we have to learn how to properly manage what we dump into the marine environment. There are four options for effective brine management:

Direct brine discharge

Several factories directly discharge the brine in a concentrated state into the sea. The management of such an operation is very delicate. Direct discharge in this case is not controllable and depends on random parameters such as sea currents and wind. Knowledge of the place of brine discharge must be well determined. A map of the seabed is needed to obtain an idea of where the brine is discharged. Today, the 12 stations discharge 2.6 million m^3 of brine per day (Fig. 26).

Figure 26: Direct discharge of brine to the seabed from a desalination plant in Algeria (Fouka Station)

Dilution by sea water

Diluting the raw water before discharging it into the sea remains the best solution for the moment. It is an assured and controlled dilution that does not require a large investment. A well-sized tank to initiate dilution before discharge into the sea without shocking the marine environment.

Dilution by purified water

From a strategic point of view, our country needs all water resources, whether conventional or unconventional. Therefore, this process is not possible at all.

Treatment and recovery of metals from brine

The recovery of brine is theoretically an effective solution; however, this technique requires advanced technologies. Very expensive, this technique is at the research stage. Developing this method to make it industrial scale remains a challenge for scientists to find a sustainable brine solution. Such a solution will sustainably preserve the marine environment and thus reduce the cost of desalination by recovering this brine.

Maximum use of local resource capacities

Today, we must work hard to achieve a reasonable rate of integration to ensure the security and sovereignty of this vital element, which is water.

CONCLUSION

As we mentioned at the beginning of this paper, the use of seawater desalination has now become a serious solution to water scarcity in several regions of the planet, including the Mediterranean basin and, more particularly, Algeria. In addition, with global warming, access to drinking water is becoming more complicated. Only a sustainable hydraulic system can change the data in the immediate future. For example, sustainable desalination could accompany this new arid climate. However, reducing energy and protecting the environment are two aspects to be mastered to achieve the sustainability of such a system in our country. For sustainable desalination, everything is based on the 2Es (Energy and Environment). Reduce energy (and therefore obtain drinking water at a reasonable price) and without damaging the environment. To this end, the choice of the desalination process that is suitable for Algeria between reverse osmosis and distillation becomes a national priority. Going toward sustainable desalination requires the choice of the site of the plant and, more particularly, the position of the capture tower, which must take into account the sedimentary dynamics imposed by the discharge of rivers into the sea. Brine is a mixture that pollutes the marine environment. Every time we drink a liter of desalinated water, a liter of brine is released to the bottom of the sea. Before achieving the recovery of brine, which is the dream of every scientist, we must control its discharge into the seabed. **Is reverse osmosis the right choice for seawater desalination in Algeria?**

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

ACHITE M., TOUAIBIA B., OUILLON S. (2006). Water erosion in Northern Algeria: Magnitude, Consequences and Prospects, 14th International Soil Conservation Organization Conference, Water Management and Soil Conservation in Semi-Arid Environments, Marrakech, Morocco.

AZIZ N., HANAFIA M.M. (2020). Application of life cycle assessment for desalination: Progress, challenges and future directions, Environmental Pollution, Vol. 268, Part B, Paper 115948.

BELLAH A. (2023). Study of water erosion and solid transport in suspension of the Algiers coastal watershed, north-central Algeria, Doctoral thesis in agronomic sciences, University Hassiba Benbouali – Chlef, Algeria, 133p.

BOUTHIBA A., AMITOUCHE M., MOUDJEBER D.E., MAHMOUDI H. (2022). MFA Goosen "Simulation study of the interaction between brine discharge and catchment water of a desalination plant in Tenes, Algeria under various hydrodynamic conditions", Desalination and water treatment, No 279, pp. 16-28.

REMINI B. (2010). The problem of water in northern Algeria. Larhyss Journal, N° 8, pp. 27-46.

REMINI B. (2017). The Tadmait foggara: Without energy, underground water on the surface of the ground, Larhyss Journal, No 32, pp. 301-325.

REMINI B., ACHOUR B., ALBERGEL J. (2011). Timimoun's foggara (Algeria): An heritage in danger, Arabian Journal of Geosciences, Vol. 4, No 3, pp. 495- 506.

REMINI B. (2023a). When the foggara ensures the water security of the oases, Larhyss Journal, No 53, pp. 219-257.

REMINI B. (2023b). The foggara: when the genius responds to a hostile environment, Study day on the foggaras. Adrar (Algeria), February 2.

REMINI B. (2020a). Oued M'zab's IRS Development - Population and Floods, life in harmony- Part 1: Hydraulic structures, Larhyss Journal, No 42, pp. 63-95.

REMINI B. (2020b). Oued M'zab's IRS Development - Population and Floods, life in harmony- Part 2: Design and operation, Larhyss Journal, No 42, pp. 145-166.

REMINI B. (2020c). Oued M'Zab IRS development population and flood, life in harmony part 3: the genius of floodwater sharing. Larhyss Journal, No 42, pp. 179-207.

REMINI B. (2020d). When the Oasian genius tamps the floods: ancestral IRS Development of Touzouz River (M'zab valley, Algeria), Larhyss Journal, No 41, pp.261-295.

REMINI B. (2010). The problem of water in northern Algeria. Larhyss Journal, No 8, pp. 27-46

RENAUDIN V. (2003). Desalination of seawater and brackish water, Culture Science Chimie, ENS, published on November 18.

https://culturesciences.chimie.ens.fr/thematiques/chimiephysique/thermodynamique-chimique/le-dessalement-de-l-eau-de-mer-et-des-eaux