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DESALINATION PLANTS SEARCH GOOD QUALITY RAW WATER

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ABSTRACT

Surprising, but it is reality that desalination stations shut down during periods of flooding. Despite a very demanding pretreatment phase, RO does not accept seawater laden with dust. What can we do to get our stations to agree to desalinate sea water and provide drinking water for the population? However, watercourses quite simply fulfill nature's mission, that of dumping tons of solid particles into the sea annually to preserve and protect the marine ecosystem. This study showed that more than 50 rivers and several Chaabat (ravines) discharge approximately 120 million tons of fine particles annually into the Mediterranean Sea along the 1200 km Algerian coast. However, these fine materials should not enter the desalination process. For us, the choice of the location of the water intake for a seawater desalination plant must follow a serious study to ensure good quality raw water. This will reduce the cost of the pretreatment phase and increase the lifespan of the membranes for the reverse osmosis process. Obviously, without forgetting, the price of m^3 of desalinated water will be less expensive. On the other hand, desalinating the brackish waters from the subsoil of the Sahara does not pose a problem with the quality of the raw water, but it does pose a problem with the temperature of the water in the deep water table, which exceeds 60°C. Only the cooling solution to reduce the temperature of the raw water to minus 30°C to be able to desalinate and obtain drinkable water, but at what cost?

Keywords: Desalination, Demineralization, Sea, Continental intercalary tablecloth, Brackish water, Water quality.

INTRODUCTION

Algeria quickly started to desalinate sea water in the 1970s. However, it was at the beginning of the 2000s that Algeria turned to the sea to quench its thirst, but after the extraction of salt. Desalination plants have been built on the Algerian coastline with a length of more than 1,200 km. Approximately ten desalination stations were built following a long drought that occurred at the end of the 1990s and caused harmful repercussions on water resources throughout Algeria. The scarcity of precipitation has increased the periods of filling artificial reservoirs and the recharge of natural reservoirs (underground aquifers). This is how several dam lakes evaporated and more particularly the dam waters of the Algiers hydrographic basin. For example, the Keddara dam with a capacity of 141 million m^3, built specifically to supply the capital Algiers, saw its reservoir without water following heavy evaporation. Even the “dead” volume of the dam was sucked up by a pumping system, an example that shows the seriousness of the water shortage problem at the time. Whether for irrigation or for the supply of drinking water, strong pressure has been exerted on the water hidden in the subsoil. The broken down reservoir dam (dry), the well and the drilling worked nonstop to have difficulty meeting an excessively high water demand. The flow leaving the aquifer is significantly higher than that entering. The water tables dry out and tighten, and the flushed water leaves the circulation corridors empty, thus causing subsidence of the ground in several places and more particularly in Mitidja (Remini, 2005; Remini, 2010). It should be noted that the Mitidja aquifer came close to exhaustion. Twenty years after the first drought, in 2021, another drought caused the same situation as that experienced at the beginning of 2000, which was water scarcity. The drying up of dam lakes and the drawdown of water tables are the two main consequences of this drought. The first is due to high temperatures, which induced strong evaporation from the dam lakes. Such a situation has caused a reduction in surface water and consequently a strong pressure on groundwater. For the second time, several tables came close to exhaustion. This time, the competent authorities launched a major project to build 5 desalination stations to produce 300,000 m^3 of drinking water per day each. This long-term drought is the result of the acceleration of climate disruption, which has manifested itself in Arab countries and the countries of the Mediterranean basin. In this case, blue gold is rare, and the solution for these countries can only come from the sea or the ocean, an inexhaustible deposit that represents 97% of the total water reserve on Earth. However, to drink this water, we have to remove the salt. It’s not such a simple task, but to achieve drinkable water, you need a whole desalination process. This is why there are currently more than 21,000 operational seawater desalination stations around the world, almost twice as many as ten years ago (Mazzega and Cassignol, 2022). Today, the desalination of seawater has become an essential option to minimize the effect of climate change, which aggravates the water stress situation in Arab countries and the countries of the Mediterranean basin, particularly Algeria. Therefore, we must expect that in the short and medium term, seawater desalination plants will increase even more to the detriment of reservoir dams. Only with the know-how and experience of more than half a century in the production of desalinated water has the design of desalination stations proven to be a complex project and requires more in-depth studies. In parallel with the desalination of sea water, Algeria launched a major project to build approximately fifteen stations for the demineralization of brackish water from the aquifer system. This paper discusses for the first time the study of the first phase of the desalination project (of sea water and brackish water), which concerns the capture of water. For the seawater desalination station, we are interested in the raw water collection tower. On the other hand, for the brackish water demineralization station, we use drilling to capture water from the continental intercalary aquifer.

DESALINATION STATIONS (SEA WATER AND BRACKY WATER) IN ALGERIA

Since the 1960s, Algeria has timidly begun to exploit the water resources of the Mediterranean Sea through the use of small desalination stations (fig. 1). It was only at the beginning of the 2000s that Algeria created these first stations of more than 200,000 m^3/d.

Today, 12 seawater desalination stations are in operation to produce 2.17 million m^3 of drinking water per year. Distributed along 1,200 km of the Algerian coast, 11 stations use the reverse osmosis process to desalinate seawater, and one station uses the distillation process (Remini and Amitouche, 2023) (Fig. 1).

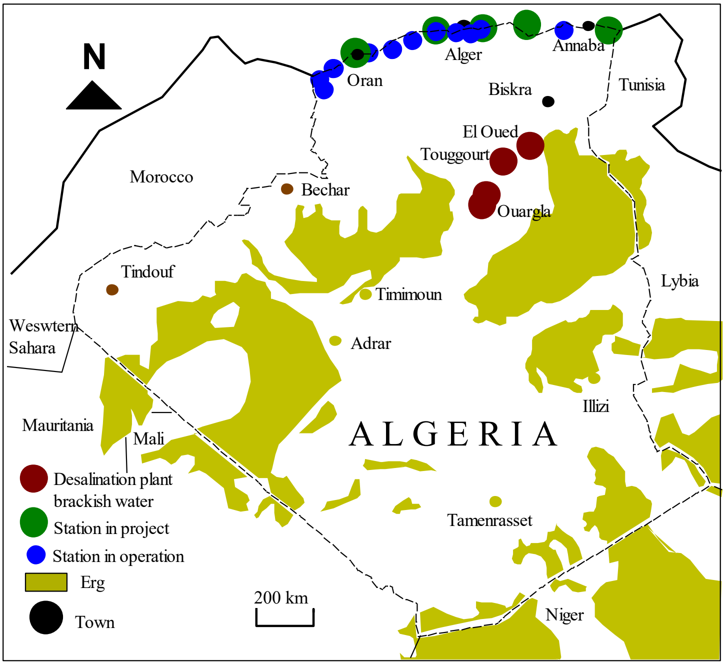

Figure 1: Geographical location of desalination stations in Algeria (Remini, 2023)

These 12 desalination plants were built during the period 2003-2020 following the severe drought that affected Algeria, which had harmful effects on water resources (Table 1). The persistence of drought following global warming has generated water stress in Arab countries and countries of the Mediterranean basin. There are even some countries that have water shortages in a seasonal to chronic state.

Table 1: Desalination stations in operation in Algeria

Number	Station	Wilaya	Capacity (m^3/day)	Put into operation
01	Kahrama Arzew	Oran	90.000	3rd quarter 2005
02	Hamma	Alger	200.000	3rd quarter 2007
03	Skikda	Skikda	100.000	3rd quarter 2007
04	Beni Saf	Ain Timouchent	200.000	4th quarter 2007
05	Mostaganem	Mostaganem	200.000	1st quarter 2008
06	Fouka(Douaouda)	Tipaza	120.000	1st quarter 2008
07	Souk Tléta (Sidna ouchaa)	Telemcen	200.000	2nd quarter 2008
08	Honaine	Telemcen	200.000	2nd quarter 2008
09	Cap Djinet	Boumerdes	100.000	1st quarter 2012
10	Magtaâ	Oran	500.000	4th quarter 2014
11	Ténès	Chlef	200.000	4th quarter 2015
12	Marsa	Alger	60000	4th quarter 2022
Total		**12 stations**	2 170 000	

Algeria has launched the construction of 5 desalination plants with a production capacity of 300,000 m3 of water each, bringing the annual production of drinking water to 3.6 million m^3 per year by the end of 2024 (Table 2).

Table 2: Desalination stations planned in Algeria

Number	Station	Wilaya	Capacity (m^3/s)	Put into operation
1	Cap Djenet	Boumerdes	300.000	2023
2	Fouka marine	Tipaza	300.000	2023
3	Cap Blanc	Oran	300.000	2023
4	Koudiat Eddraouch	El Taref	300.000	2023
5	Tghremt	Bejaia	300.000	2023

RESULTS AND DISCUSSIONS

Algeria has acquired 20 years of experience in the operation of 12 desalination stations and even the 5 factories that are under construction; they are supported by Algerian companies. Only the complexity of a desalination project requires the execution of 3 steps in a serious manner for the success of such a project. These are the collection tower system, the desalination process and the brine discharges (Fig. 2).

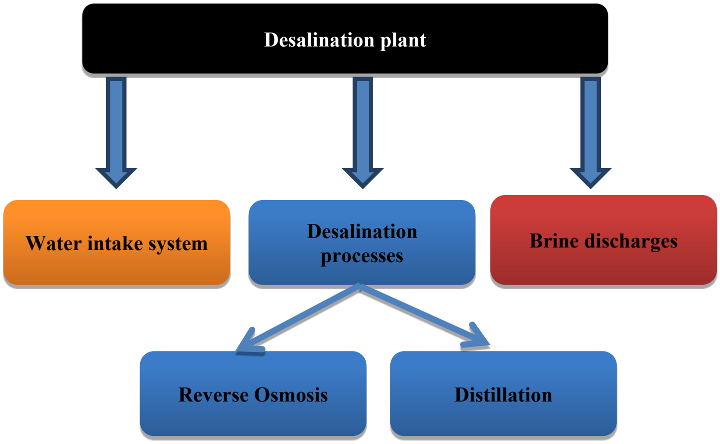

Figure 2: The essential parts of a seawater desalination project

In this study, we are only interested in the first stage, which concerns the capture of sea water. This is the most complicated stage of the desalination process since the performance of a desalination station depends on the quality of the raw water. Therefore, to build a seawater desalination plant, a serious study is required on the raw water collection system. It is a structure made up of 3 elements: the water intake tower, the raw water pipeline and the catchment basin with the screen (Fig. 3a, b, c and d).

a) El Marsa desalination plant water intake tower

b) Laying the raw water collection pipe from the Corso desalination plant

c) Screening of coarse and fine particles from the El Marsa station

d) El Marsa station pumping basin

Figure 3: The main elements of the collection system of a desalination plant (photo. Amitouche, 2022)

To bring raw water from the sea to the station's desalination process, a hydraulic system is created in the form of two communicating vessels (or the U-shaped tube). The water flows by difference in load from the water intake tower through the pipe to reach the catchment basin after passing through the coarse screen and the fine screen. By pumping, the water is pumped from the pumping basin toward the desalination plant.

The location of the water intake tower remains the most important point of the project. The correct choice of the collection tower site will reduce solid transport in the supply pipe, and therefore, the effects of fine particles on the pretreatment phase will be reduced. To this end, we insist on the correct choice of the location of the water intake tower of a desalination plant. This part has often remained neglected, which is why all desalination stations in Algeria today encounter solid transport problems during periods of flooding. Therefore, the success of such an operation will result in good quality seawater and consequently less expensive pretreatment and, above all, a long lifespan of the membranes for the reverse osmosis process. This means that with better quality sea water, we will have a high yield in the production of drinkable water and a lower price per m^3 of water.

Two types of water from neighboring lands can flow toward the sea. These are sanitation water (purified or unpurified) that is transported by rivers and discharged directly into the sea. In small quantities, this polluted water, once in contact with sea water, diffuses and flows slowly, but waves and sea currents can carry the plume of used water toward the location of the water intake. This phenomenon occurs throughout the year and removes to sea, but generally, it will have a high probability of reaching the location of the collection tower. These are large rivers that discharge a significant quantity of wastewater into the sea, which can pollute the raw water from desalination plants. The density current can go further out to sea and can cover a large surface area of the sea. For example, the El Hamma station (Algiers) is located 5 km from the El Harrach River. This watercourse is well known for its daily wastewater discharges. The wastewater plume can range from a length of 2 km to more than 9 km with the formation of a plume with an area of 10 km^2 (Fig. 4).

Figure 4: El Harrach River - Discharges of water into the sea during the low flow period (Google Earth).

The second type of water that can complicate the seawater pretreatment phase is water loaded with fine particles coming from catchment areas during periods of flooding (fig. 5). This is a thorny and unstudied case that can pose enormous problems to the desalination process, particularly during the pretreatment phase. Desalination plants equipped with reverse osmosis processes encounter problems with raw water loaded with fine particles. Reverse osmosis is a very demanding process in terms of raw water quality since it uses very delicate membranes in the treatment phase. Unfortunately, in arid countries, the fresh water discharged from rivers into the sea is too laden with fine particles. The watersheds are animated by a very active water dynamic during periods of flooding, which triggers soil erosion and the banks of the rivers. This is how impressive quantities of fine particles are removed from the slopes by water runoff. These fine particles are then taken up by waterways to transport them and then dumped into the sea.

The north of Algeria is characterized by a sedimentary dynamic that results in erosive activity whether at the level of the watersheds or at the level of the banks of the rivers. This is due to the degradation of watersheds and the absence of plant cover in several watersheds (Fig. 6).

This caused significant siltation in the 4 dams in operation, i.e., 1.2 billion m^3 of silt (Remini, 2017). This significant deposition of sediments at the bottom of the dams is a consequence of the phenomenon of water erosion, which records the highest values on the planet, exceeding 5000 $t/km^2/year$ in the watershed of the Agrioum River (Demmak, 1982). Obviously, this very active sedimentary dynamic has direct repercussions on the quantities of sediment transported by the rivers and discharged into the Mediterranean Sea. According to Demmak (1982), approximately 120 million tons of solid particles flow into the Mediterranean Sea. This is a significant quantity that only an intense hydrographic network can transport such a quantity of silt. From the hydrographic network of Algeria, we identified 51 rivers with a total length equal to 1500 km that discharge 120 million tons each year into the Mediterranean Sea (Table 3).

Figure 5: Beni Chougrane watershed - An example of intense erosion in northern Algeria (Photo Remini, 2014)

Table 3: Algerian rivers emptying into the Mediterranean Sea

N	Name of the wadi	Length (km)	N	Name of wadi	Lenght(km)
1	Tleta	12	27	El Harrach	15
2	Tafna	110	28	Hamiz	50
3	Meknassia	27	29	Corso	10
4	Halloufa	25	30	Merdja	5
5	Essenan	37	31	Isser	80
6	Guessiba	12	32	Larba	4
7	Tassmanit	4	33	Sebaou	80
8	El Kerma	6	34	Mleta	24
9	El Hammam	30	35	Youssef	27
10	Chellif	275	36	Ntaida	22
11	Guelta	12	37	Daas	21
12	Tarzoot	15	38	Saket	12
13	Allala	20	39	Soummam	60
14	Boucheghal	8	40	Agrioun	23
15	Goussine	412	41	El Kebir	42
16	Mentrach	12	42	Zhour	15
17	Ouattar	5	45	Tamanarat	9
18	Damous	36	44	Guebli	36
19	Kellal	6	45	Zeramna	15
20	Essebt	12	46	Kebir	36
21	Messelmoun	15	47	Seybouse	35
22	Hachem	22	48	Khelidj	15
23	Nador	8	49	Bounamoussa	20
24	Merzoug	4	50	MessidaZiama	10
25	Mazafran	17	51	Ziama	6
26	Beni Messous	10			

However, the problem that hinders and disrupts the desalination operation is during the rainy season. In this case, millions of tons of fine particles are released into the sea. The resulting plume takes on a yellowish color that can spread over several kilometers (Figs. 6 and 7). It is during this period of flooding that desalination stations are shut down until this plume of fine particles exceeds the raw water catchment area. This type of desalination plant shutdown is repeated with each flood. Unfortunately, this repeated problem prevents the smooth operation of the desalination station, and consequently, it would be difficult to achieve an appreciable operating yield of the station. Sometimes we even witness floods occurring at the same time on a series of rivers, one next to the other. In this state, a spectacular plume of particles is formed, which takes on a yellowish color that moves for several days and thus prevents desalination stations from purifying the seawater.

Figure 6: Sebaou River - Flood of March 2014 - Significant discharge of sediment into the sea and formation of vast plumes of dust (Google Earth)

Figure 7: Tafna River floods in February 2014. Significant release of sediment into the sea and formation of vast plumes of dust (Google Earth)

In this case, the only solution is to stop the desalination operation until the plume disappears. On the 51 rivers that lead to the Mediterranean Sea on a coast 1200 kilometers long. There are approximately ten rivers that are very active. These watercourses drain floods at least once or twice a year. These are the El Harrach, El Kebir, Soumam, Hamiz, Agrioum, Saf Saf, Mazafran, Sebaou, Chellif, Isser, Seybous, Tafna and El Hachem Rivers. In this case, the installation of desalination stations must be far from the mouths of the rivers to avoid invasion of solid particles on the water intake, and consequently, the pretreatment phase becomes more complicated. In such circumstances, the desalination of sea water, particularly that equipped with the reverse osmosis process, reduces the lifespan of the membranes, and consequently, the price of 1 m^3 of drinking water becomes more expensive. For example, the Mostaganem sea water desalination station, with a production capacity of 200,000 m^3/day, is located approximately 2.5 km from Wadi Chellif. It is a very active watercourse since it discharges several tonnes of fine particles into the sea each year. This causes a very concentrated density current, and consequently, its propagation speed becomes greater. Over time, the plume of brown dust takes on an increasingly large surface area, as in the cases of the flood of February 2019 (fig. 8) and that of March 2014 (fig. 9). We sometimes see discharges of polluted water from the Chellif wadi and the ravine (Chaabat), which is located 150 m from the desalination station. In such a situation, the dust plume becomes much larger.

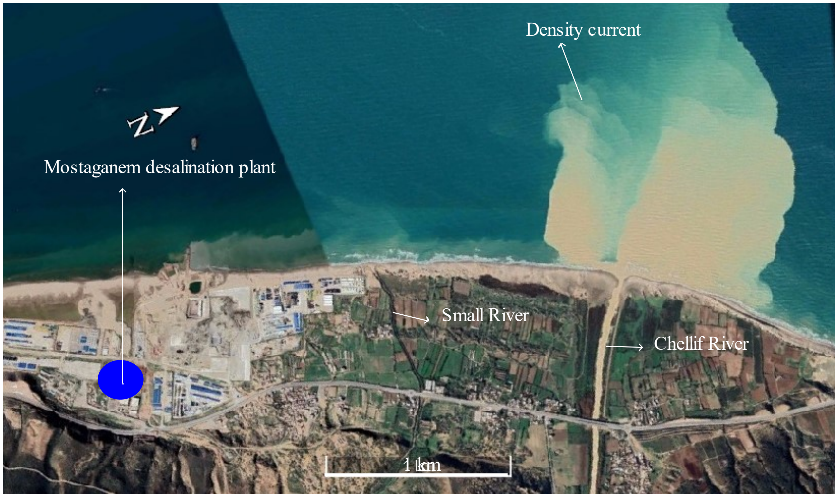

Figure 8: Flood in February 2019. Enormous plume of dust spreading in the vicinity of the Mostaganem desalination station. (Google Earth)

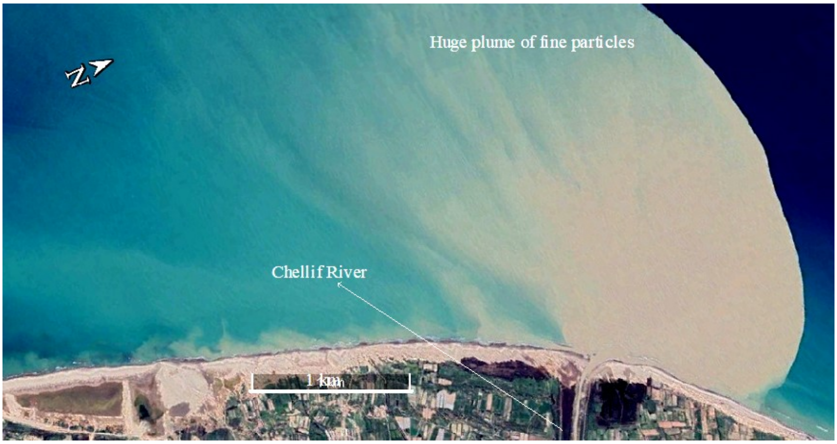

Figure 9: Chellif River March 2014. Enormous propagation of the fine particle plume out to sea (Google Earth)

The Cap Djenet seawater desalination plant with a production capacity of 100,000 m^3/d has been in service since 2012. Located in the wilaya of Boumerdes, this old factory was built approximately 2 km from the large Isser River. A new seawater desalination plant with a capacity of 300,000 m^3 is being built and is located right next to the old plant. It is reported that the quality of the raw water that is used by the current plant and that will be used by the new plant varies over time. The quality of raw water is poor during periods of flooding. Rivers transport large quantities of mud and discharge them into the Mediterranean Sea. The flood of May 2016 drained considerable masses through the Isser

River, which flowed into the mouth (fig. 10). The contact of flood water and sea water causes the formation of a yellowish density current that propagates toward the location of the raw water collection tower. During this period, the reverse osmosis desalination process is shut down.

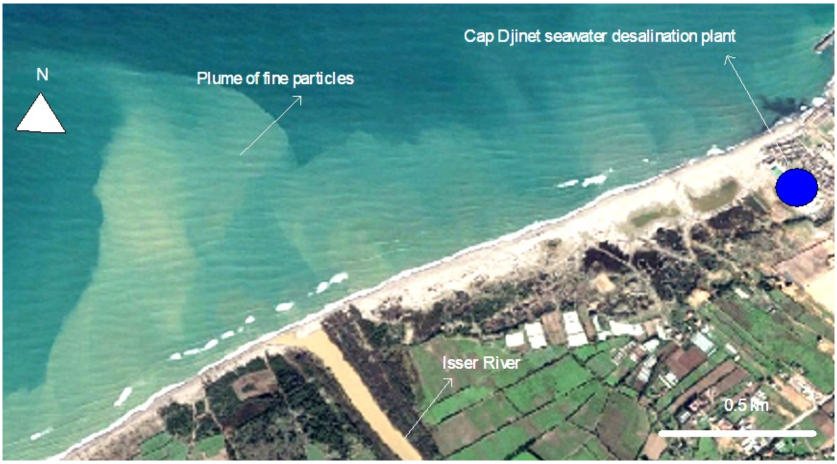

Figure 10: Isser River flood in May 2016. The area of the raw water collection tower of the Cap Djenet desalination station was invaded by a plume of fine particles (Google Earth)

The El Hamma seawater desalination plant (Algiers) with a capacity of 200,000 m^3/d was commissioned in 2007 to supply drinking water to the greater Algiers. The factory was installed 5 km from the mouth of the El Harrach River, a watercourse that has a very active sedimentary dynamic. In addition to water activity characterized by the discharge of domestic water, the El Harrach River discharges thousands of tons of fine particles into the Bay of Algiers (Fig. 11). With each flood drained by the El Harrach River, immense plumes of fine particles fill the Bay of Algiers, making the raw water of poor quality (fig. 12). In this case, the El Hamma station encounters raw water supply problems during periods of flooding. All these problems have repercussions on the pretreatment phase and even on the lifespan of the membranes used in the reverse osmosis process.

Figure 11: El Harrach River - Flood of May 2018. The charged water discharged from the El Harrach River into the sea causes an immense density current (Google Earth)

Figure 12: El Harrach River - Flood of May 2018. The Bay of Algiers is occupied by an immense plume of fine particles that even threatens the seawater collection tower of the El Hamma desalination station (Google Earth).

This problem does not stop at the level of the rivers, but even the ravines and the Chaabat contribute during periods of flooding to dumping tons of solid materials into the sea. With an undefined number of microstreams, the sediments participate in the formation of dust plumes of varying widths, which can pose problems for desalination stations. This is the case for the Ténès desalination station, which is located 1 km from a ravine. In the event of a flood, a brown density current propagates on the seabed and can even reach the area of the raw water collection tower of the Ténès desalination station (Fig. 13).

Figure 13: Flood of September 2016. Ténès seawater desalination station. A gully can trigger an immense plume of fine particles, and consequently, the raw water becomes of poor quality (Google Earth)

A special case that can generate plumes of mobile fine particles and that can also hamper the desalination operations of stations that are not far from the mouth. These are releases carried out periodically at the dams, which are located only a few kilometers from the mouth. We counted 9 dams located approximately twenty kilometers from the mouth (Table 4). Dam managers carry out periodic valve operations for 3 reasons:

- Withdrawal of density currents during periods of flooding; a solution to reduce siltation.
- Release quantities of suspension periodically to reduce siltation.
- Release quantities of water to recharge the alluvial tables.

Table 4: Operations of the drainage channels of the dams near the coast

Dam	River	Distance between the dam and the coast	Valve operations
Ighil Emda	Agrioum	23	Density current withdrawal
Keff Eddir	Damous	9	Release to reload the tablecloth
Hamiz	Haamiz	25	Releases during flood periods
Boukourdane	El Hachem	12	Release to reload the tablecloth
Beni Amrane	Isser	25	Releases during flood periods
Beni Zid	Guergoura	12	Releases during flood periods
Zardezas	Safsaf	35	Density current withdrawal
Oued Kissir	Kessir	0.7	Releases during flood periods
Beni Haroun	El Kebir	40	Releases during flood periods

During periods of flooding, the withdrawal of density currents takes place at some Algerian dams, such as Igjhil Emda, Oued Fodda, Ghrib, Sidi Mhamed Ben Aouda, Zardezas, Beni Haroun (Remini and Toumi, 2018), Foum El Gherza (Remini et al, 2015a), Boughezoul (Remini et al, 2015b) and Gragar (Remini and Benfetta, 2015). This technique was a success at the Ighil Emda dam since it increased its lifespan. The Ighil Emda dam uses a battery of 8 gates for the withdrawal of density currents to reduce the rate of siltation. The density current withdrawal efficiency reached 70% of the solid inputs (Remini, 1997; Remini et al, 1996; Remini et al, 1995). These quantities of silt, once arriving at the mouth located 23 km from the dam, will trigger a very concentrated density current, and consequently, immense plumes of dust will be produced in the sea, thus occupying a large area (Fig. 14). In this case, the future construction of a seawater desalination plant in the region must take this important parameter into account.

Figure 14: Agrioum River withdrawal for the month of November 2019. Very concentrated suspension evacuated through the dam gates into the sea (Google Earth)

Dam managers carry out valve operations to evacuate the silt deposited at the foot of the dam during the last flood. The aim of such an operation is to relieve the drainage channels by the deposits of silt drained by floods. Operating late or leaving the valves closed will cause the drain openings to clog. Generally, these flushed waters are too loaded with sediment since this type of operation serves to evacuate the mixture before it consolidates and blocks the valves. The discharged suspension of a high concentration of sediment discharges into the sea will cause plumes of sediment that can move toward the location of the water intake of the desalination plant. Therefore, in this case, decision-makers must take this important parameter into account before building a seawater desalination station in the vicinity of the mouth.

In certain dams, managers in contact with farmers carry out periodic maneuvers of the drainage channels to expel a quantity of water to recharge the alluvial table. The water level in the aquifer rises and allows farmers to irrigate their gardens without pressure. A quantity of water escapes and flows directly into the sea. The first releases of water carry a very high concentration of fine particles and will trigger immense plumes of fine particles that move out into the open sea. The case of the Keff Eddir dam is a good example since releases are carried out periodically to encourage the replenishment of the alluvial aquifer of the Damous River (fig. 15). In this case, decision-makers must take into account the parameter of releases from the bottom gates of the dams.

Figure 15: Releases from the Kef Eddir dam in January 2021 - Formation of an immense plume of fine particles (Google Earth)

The transfer of sediments and nutrients from continents to seas and oceans takes place during periods of rain to balance the marine environment. Only the contact zone between the water loaded with fine particles came from the watersheds and the sea water. In this case, we are talking about the mouth, an area that is characterized by a very active sedimentary dynamic considered as an area intermediate between charged water and salt water. The mouth is an area where very active sedimentary dynamics reign. It is at this mouth area that coarse particles (sand, gravel and pebbles) are deposited. Only fine particles can continue their journey out to sea. It is in this zone that, depending on the sediment concentration or the water temperature, during contact between charged water and sea water, two modes of transport occur: diffusion and density currents. In the case where flood water arrives at the mouth with a low concentration of fine particles, it would be difficult for a density current to form. Therefore, in this situation, the fine particles diffuse in the water and take the form of a mobile plume that will be carried by sea currents.

When the sediment content of the flood water is high, a density current is formed, sometimes called a gravity current, which is a phenomenon that is created naturally. It corresponds to the intrusions of fluids into others under very specific conditions. These stratified flows, the movement of two or more masses of miscible or immiscible fluids, have different densities due to the variation in temperature or the presence of suspended solids or even dissolved materials. They propagate while retaining their individuality or mixing as they go. These preferred flows can be above (overflow), through (interflow) and below (underflow) (Fig. 16a, b and c).

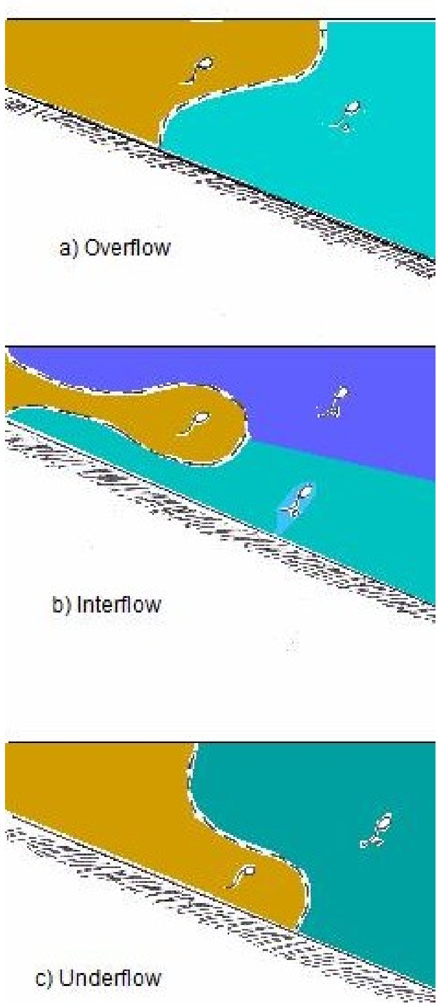

Figure 16: The types of flows that form during contact with charged water and sea water (Remini diagram, 2023)

Generally, the third case forms during floods, i.e. underflow followed by overflow. On the other hand, interflow rarely occurs given the difficulty of encountering 3 fluids of different densities. Upon arrival at the mouth of a river, the contact between the flood water loaded with particles and the sea water causes the formation of a density current (underflow), which propagates on the bottom marine in the form of a clearly individualized layer of brown water (Figs. 17a, b and c).

a) Contact between charged water and salt water

b) Start of formation of a density current

c) Propagation of a density current

Figure 17: Formation and propagation of a density current (Photo. Remini, 2012)

Once formed, the density current can go further out to sea as long as the density difference remains high, but as soon as it tends to zero, the density current fades and disappears. However, in our case, ocean currents can accelerate the underflow, especially when they are directed in the same direction. Even waves can influence the dynamics of density currents in the seafloor. The case of the propagation of a density current on the seabed remains an original case, and there is no serious study in this direction. On the other hand, we better control the density current formed during the contact of flood water (laden water) and dam water (fresh water). In this case, the underflow formed at the diving point flows along the bottom of the reservoir to reach the foot of the dam. For example, in the

Ighil Emda reservoir, the density currents travel approximately 7 kilometers from the diving zone to the foot of the dam (Remini, 1997; Remini, 2017; Remini, 2016). Density currents rise up with slight slopes, reflecting off obstacles, and are constantly propelled by a powerful driving force ($\Delta\rho/\rho$). Another particularity of these currents is their individuality in relation to the fluid where they propagate. On the other hand, density currents appear during periods of flooding during contact with water loaded with fine particles and sea water (salt water). In this case, the speed of propagation of the density current, which depends on the driving force ($\Delta\rho/\rho$), adds two parameters: waves and sea currents.

Regarding the desalination of brackish water in Algeria, the problem of capturing raw water does not arise since brackish water is housed in the depths of the subsoil of the Sahara and is protected from pollution and fine particles. This immense amount of groundwater is found in the basin of the Northern Sahara Aquifers System (NSAS). Made up of two superimposed aquifers, the Continental Intercalary and the Terminal Complex, the NSAS occupies an area of more than one million km^2 distributed between 3 countries (fig. 18 and 19): 700,000 km^2 in Algeria, 80,000 km^2 in Tunisia and 250,000 km^2 in Libya.

Current and future projects for brackish water demineralization stations will be carried out to exploit the Northern Sahara Aquifers system. Therefore, the raw water that will be captured by the demineralization stations is of good quality since it is groundwater.

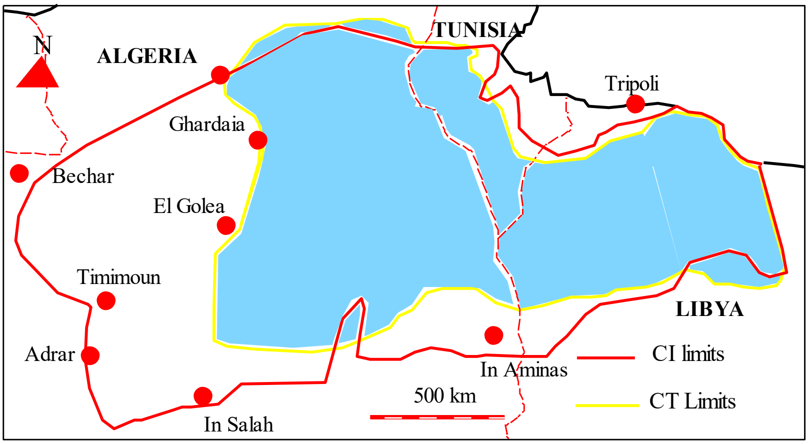

Figure 18: The limits of the Aquifer System of the Northern Sahara (NSAS) (Source OSS, 2017; Taithe et al, 2013).

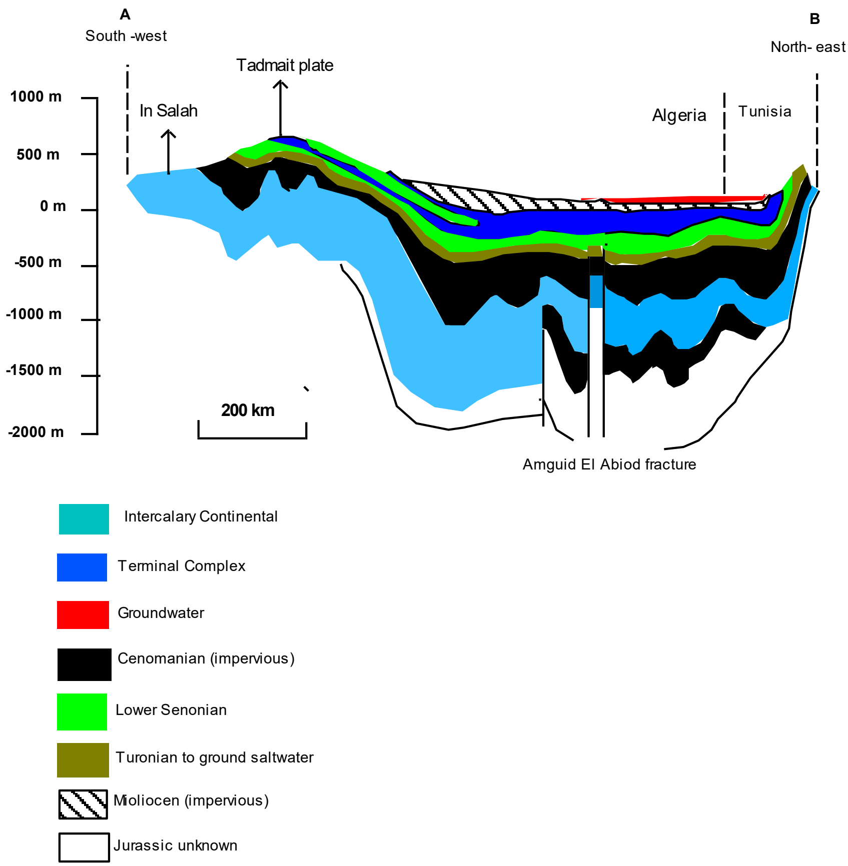

Figure 19: The aquifers of the Continental Intercalary and the Terminal Complex (Remini drawing, Source Unesco 1972 in Castany, 1982)

The volume of the Northern Sahara aquifer system is estimated at 60,000 billion m^3 of which 10,000 billion m^3 is exploitable (Taithe et al, 2013). Withdrawals reached 2.2 billion m3 in 2000. A value of 8 billion m^3 of withdrawals will be reached in 2030. In return, recharge was estimated at 1 billion m^3/year. Today, new research confirms that the rate of recharge of the aquifer is 1.4 billion m^3. In return, withdrawals reached the value of 2.75 billion m3 of water, or 40% of the total volume of withdrawals (OSS, 2017). In parallel with the desalination of sea water, Algeria has launched projects to desalinate brackish water from the Continental Intercalary aquifer.

Algeria has launched the construction of 15 brackish water demineralization stations in the south, 10 of which are in operation. The majority of these brackish water demineralization stations exploit water from the continental intercalary aquifer. Three large demineralization stations are located in the wilayas: Ouargla, Touggourt and El

Oued. Unlike seawater desalination plants, which encounter problems of turbidity and pollution of raw water, brackish water demineralization plants, the raw water is of good quality except that it is captured at 60°C. This requires the raw water to pass through a cooling system for temperatures from 60°C to 30°C (Figs. 20 a and b). After this cooling stage, the good quality raw water will be treated by the reverse osmosis process.

a) Ancient b) Recent

Figure 20: Cooling system for brackish waters of the Northern Sahara aquifer system (Photo. Remini, 2006).

Built in 2014, the Touggourt brackish water demineralization station called Ain Sahara is located in downtown Touggourt to treat a flow rate of 400 l/s. The brackish water desalination plant aims to meet the demand for drinking water for the entire population of Touggourt. The station is currently supplied by 3 boreholes with a depth of 1800 m with a flow rate of 400 l/s coming from the continental intercalary aquifer. The fourth (Sidi Mahdi 2) drilling with a flow rate of 150 l/s is nearing completion; it is at the connection stage to obtain a flow rate of 530 l/s (table 5).

Table 5: Drilling characteristics

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

Concerning the Touggourt desalination plant using the reverse osmosis process, the salinity of the raw water decreased from 2.5 g/l to 0.6 g/l after treatment. Indirectly, the Touggourt desalination plant also contributes to the protection of the drinking water supply network against scaling. It should be remembered that this scaling phenomenon constitutes the major concern of local authorities and mobilizes a large budget each year.

Although abundant, Touggourt water has a high limestone content. The evolution over time of limestone deposition in the water supply network is dramatic, leading to an annual decrease of approximately 35 mm in diameter or an average annual decrease of 10% in initial diameter (Remini and Sayah, 2008) (Fig. 21). The pipes, valves and elbows were completely closed after only seven years of service.

Figure 21: The condition of the drinking water supply network pipes in the town of Touggourt after 7 to 8 years of service (Photo Remini, 2016)

The wilaya of Ouargla benefited from a major program involving the construction of 9 brackish water desalination stations. These stations capture raw water in the subsoil of the Sahara from 26 boreholes, including 3 Albian boreholes giving rise to salinity levels of 3 to 6 g/l. The mission of these plants is to lower the salinity from 6 to 0.8 g/l and thus meet the physicochemical and bacteriological characteristics of drinking water according to the standards of the World Health Organization (WHO). Thanks to these 26 boreholes, these plants will make it possible to treat a volume of 70,000 m^3/d of raw water to provide a volume of 53,000 m^3/d. The largest Ouargla station has a capacity of 27,000 m^3/d and was commissioned in 2017. The station uses 3 boreholes to capture raw water from the Miopleocene (drilling 10 to 25 l/s) and the Senonian (drilling 10 to 25 l/s). Drilling 15 to 60 l/s) and Albien (drilling: 100 to 200 l/s). However, at the outlet of the borehole, the raw water is of good quality, but the temperature varies between 50°C and 70°C. This requires passing it through a cooler to lower the temperature to minus 30°C.

Oued Souf, the oasis with a thousand domes, sits on a sheet of Albian water with a capacity of 60,000 billion m^3, but unfortunately, it is brackish water, that is, moderately salty; it is not suitable for consumption. This situation has pushed the hydraulic services to the origin of the demineralization project and the purification of these brackish waters to meet the demand of the inhabitants of El Oued city. The El Oued brackish water desalination station, commissioned in 2018, has a production capacity of 30,000 m^3/d. The El Oued demineralization station captures raw water from the depths of the Continental Intercalary aquifer with salinity that varies from 4 to 6 g/l. The raw water is of good quality and without the presence of fine particles such as seawater, but its temperature is very high at 68°C. To avoid this critical situation, the temperature is reduced from 68°C to 25°C before entering the reverse osmosis process at the El Oued demineralization station.

CONCLUSION

Climate change, the earth is thirsty and turns to the oceans and seas. It is true that 97% of the globe is occupied by salt water. What to do in this case? Quite simply, you have to separate the salt from the sea water, but this is not an easy task. This is all cutting edge technology; a desalination station that must be set up. Such a project requires the execution of 3 parts: water intake, the type of reverse osmosis process and brine discharge. In Algeria, 12 desalination stations are in operation without forgetting the 5 desalination stations that are under construction. Unfortunately, some desalination stations encounter problems with seawater pollution. Two situations arise. The first concerns the discharge of wastewater from the river into the sea. This is the case for the El Harrach River, which discharges significant quantities of wastewater daily. This raw water tainted by wastewater can reach the water intake of the El Hamma desalination station. Given the small quantities of wastewater released by the El Harrach watercourse, this polluted water has a low chance of reaching the water intake of the El Hamma factory. The second situation concerns fine particles discharged from more than 50 rivers into the sea during periods of flooding. These fine particles come from intense water erosion that occurs in watersheds. Approximately 120 million tons of silt are released into the Mediterranean Sea annually.

By diffusion or by density current, these fine materials, which form plumes of dust, easily reach the water intake area. Along the Algerian coast over a distance of 1200 km, it would therefore be difficult to find a site far from a mouth. Therefore, the choice of the site for the design of the intake tower of a seawater desalination station must take into account several parameters, particularly the position of the mouth and the solid transport capacity evacuated by the river into the sea. To ensure good quality raw water, a detailed study on water intake and site selection must be an essential part of any water desalination plant construction project. Wed. Ensuring better quality raw water means less expensive pretreatment and a long life for the membranes and consequently a cheaper price for m^3 of desalinated water. On the other hand, in the case of Algeria, brackish water desalination stations are hidden in the subsoil of the Sahara. A gigantic mass of salt water is estimated at more than 60,000 billion m^3 of approximately 2.5 g/l and a temperature exceeding 60°C. For brackish water demineralization stations, the problem of raw water quality does not arise; however, when capturing raw water at 60°C, the reverse osmosis process does not accept such a temperature. In this case, cool the raw water below 30°C to obtain drinkable water, but at what cost?

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

CASTANY G. (1982). Principles and Practices of Hydrogeology, Dunod University.

DEMMAK A., 1982. Contribution to the study of erosion and solid transport in northern Algeria. Thesis of Dr. Ing. University of Pierre and Marie Curie, Paris XI.

MAZZEGA M.A., CASSIGNOL E. (2022). Geopolitics of seawater desalination Studies by Ifri, September.

OBSERVATOIRE DU SAHARA ET DU SAHEL (2017). Project for "integrated and concerted management of water resources in the aquifer systems of Iullemeden, Taoudéni Tanezrouft and the Niger river" (Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger, Nigeria) "GICRESAIT" hydrogeology and areas with high potential. OSS/Tunis report, May, 56 p.

REMINI B. (2005). The Problems of the Water in Algeria, University Publications Office, Algeria.

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

REMINI B., SAYAH L. (2013). Scaling of the potable water network of the Touggourt city (Algeria), Desalination and Water Treatment, pp. 1-4. DOI:10.1080/19443994.2013.810397

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

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

REMINI B. (1997). Siltation of dam reservoirs in Algeria. Importance, mechanisms and means of control using the racking technique. Doctoral thesis, National Polytechnic School of Algiers, March, 342p

REMINI B., TOUMI A. (2017). Is the Beni Haroun reservoir (Algeria) threatened by siltation? Larhyss Journal, No 29, pp. 249-263.

REMINI B., BENFETTA H. (2015). Is the Gargar reservoir dam threatened by siltation, Larhyss Journal, No 24, pp. 175- 192.

REMINI B., BENSAFIA D., MISSOUM M. (2015a). Silting of Foum el Gherza Reservoir. Geoscience Engineering Volume LXI , No1, pp. 1-9.

REMINI B., BENSAFIA D., NASROUN T. (2015b). Impact of sediment transport of the Chellif River on silting of the Boughezoul reservoir (Algeria). Journal of Water and Land Development. No 24 p. 35–40. DOI: 10.1515/jwld-2015-0005.

REMINI B., KETTAB A., AVENARD J.M. (1996). The Ighil Emda dam (Algeria): Withdrawal of sediments using density currents. “Vecteur Environnement”, Vol 29, No 4, pp.27-32.

REMINI B., KETTAB A., HIHAT H. (1995). Siltation of the IGHIL EMDA dam (Algeria). International Water Review: La Houille Blanche, No 2/3, pp.23-28.

TAITHE A., GALLAND F., TERTRAIS B. (2013). Transboundary aquifers: characterization of tensions and cooperation. Foundation for Strategic Research. Report N° 393/FRS/PSSI of September 2. 13 p.