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On the of seawater desalination environmental impacts and brine treatment based challenges and mitigation measures in Algeria

Sobre os impactos ambientais da dessalinização da água do mar e os desafios baseados no tratamento de salmoura e medidas de mitigação na Argélia

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ABSTRACT

In this paper the environmental impacts of seawater desalination is investigated and highlighted. Indeed despite the various benefits of desalination there is growing apprehension about the potential negative environmental effects it may bring and generate. Both during the plant construction and its operation service. There is the possibility of leading and causing adverse environmental impacts. A significant concern with desalination is the co-produced and generated waste known as 'brine' or 'reject,' which contains high salinity as well as chemical residuals which are released into the marine environment. Viable and cost-effective brine management systems are necessary to mitigate the negative impact of brine, also referred to as concentrate, which is a by-product of the desalination process. This high salinity substance poses a threat to the environment and must be managed effectively in order to reduce pollution. Aside from brine other difficulties include marine species entrainment and trapping, as well as high chemical use. This paper provides an extensive overview and evaluation of desalination technologies used in Algeria including thermal methods such as Multi-Stage Flash (MSF) and Multiple Effect Distillation (MED) as well as Membrane Reverse Osmosis (RO). Furthermore in order to assess the potential environmental implications of desalination and brine treatment on the Algerian coast, mitigation strategies are proposed to curb the environmental negative impact. To protect water resources for present and future generations, improved brine management techniques are needed to minimize adverse environmental effects and lower the financial burden of disposal. This will encourage further advancements in desalination plants. Ultimately, the paper emphasizes upcoming research opportunities in brine treatment technologies with a focus on improving the efficiency and sustainability of desalination.

Keywords: desalination, multiple effect distillation (MED), multi-stage flash (MSF), reverse osmosis (RO), brine, environmental impact.

RESUMO

Neste trabalho são investigados e destacados os impactos ambientais da dessalinização da água do mar. De fato, apesar dos vários benefícios da dessalinização, há uma crescente apreensão sobre os potenciais efeitos ambientais negativos que ela pode trazer e gerar. Tanto durante a construção da planta quanto seu serviço de operação. Existe a possibilidade de liderar e causar impactos ambientais adversos. Uma preocupação significativa com a dessalinização é o resíduo coproduzido e gerado conhecido como 'salmoura' ou 'rejeito', que contém alta salinidade, bem como resíduos químicos que são liberados no ambiente marinho. Sistemas viáveis e eficientes em termos de custos são necessários para mitigar o impacto negativo do chumbo, também conhecido como concentrado, que é um subproduto do processo de desalinização. Esta substância de elevada salinidade representa uma ameaça para o ambiente e deve ser gerenciada de forma eficaz para reduzir a poluição. Além da salmoura, outras dificuldades incluem o arrastamento e aprisionamento de espécies marinhas, bem como o alto uso de produtos químicos. Este artigo fornece uma extensa visão geral e avaliação das tecnologias de dessalinização usadas na Argélia, incluindo métodos térmicos, como Flash Multi-estágio (MSF) e destilação de múltiplos efeitos (MED), bem como Osmose Reversa por membrana (RO). Além disso, a fim de avaliar as potenciais implicações ambientais da dessalinização e tratamento de salmoura na costa argelina, estratégias de mitigação são propostas para conter o impacto negativo ambiental. Para proteger os recursos hídricos para as gerações presentes e futuras, são necessárias técnicas melhoradas de gestão de resíduos para minimizar os efeitos ambientais adversos e reduzir a carga financeira da eliminação. Isto incentivará novos avanços nas instalações de desalinização. Em última análise, o artigo enfatiza as oportunidades de investigação em curso em tecnologias de tratamento de moluscos com foco em melhorar a eficiência e a sustentabilidade da desalinização.

Palavras-chave: dessalinização, destilação de múltiplos efeitos (MED), flash multiestágio (MSF), reverso osmose (RO), salmoura, impacto ambiental.

1 INTRODUCTION

Water is a plentiful natural resource that inhabits more or less than three-fourths of the planet. However, only 3% of all water sources are potable. Approximately one quarter of people across the globe lack access to water of sufficient quality and/or quantity, while over 80 nations struggle with severe water issues [1]. According to the United Nations (UN), by 2050, approximately 7 billion people in 60 countries will experience severe water scarcity [2 ,3 ,4]. In the Middle East and North Africa (MENA) region, per capita renewable water resources are among the lowest globally. They continue to decline primarily due to population growth and climate change. The Food and Agriculture Organization (FAO) of the United Nations deems that water availability levels below 1,000 m^3 per person per year can significantly impede socio-economic growth and environmental sustainability [5]. The Mediterranean region is experiencing rapid social and environmental changes that adversely affect present and future sustainability [6].

Covering a total area of 2,381,740 km^2, Algeria is the second largest nation in Africa and consists of four main physical regions that stretch from east to west across the country in parallel zones. The population of Algeria is estimated to be 35.6 million with a yearly growth rate of 1.7% and an average density of 11 persons per square kilometer [7].

The Tell Zone situated in northern Algeria stretches from 80 to 190 km inland from the coast and typically experiences a Mediterranean climate with four distinct seasons. Approximately 80% of people reside in this area. It is the most humid area in Algeria with annual precipitation ranging from 400 to 1,000 mm [8]. The country is marked by a noticeable deficiency in rainfall these last years.

The northern region has reached its maximum groundwater usage resulting in increased pumping rates and subsequent depletion of the groundwater levels [8].

According to recent findings, Algeria is currently ranked 6th in terms of countries most severely affected by water shortage. By the year 2025, it is projected that Algeria will move up to 4th place without suitable measures being taken to combat this pressing issue [9].

In response to the water leakage issue of the existing network system, stakeholders in the water sector resolved to explore options for utilizing non-conventional water sources and conducted a comprehensive assessment into the dependability and costs of seawater desalination technologies [8]. This option is an asset for the country which has 1200 kilometers of coastline along the Mediterranean Sea. The history of desalination in Algeria began in 1964 with some small plants for the industry, particularly in the west of the country with a capacity of 576 m^3/day. However it was not widely used due to technological limitations, exorbitant capital expenditures, extremely high energy consumption and an unacceptably high unit cost for water relative to more traditional sources [10].

Currently, there are over 60 desalination plants in operation throughout the nation with an approximate capacity of 2 million cubic meters per day [11]. But the problem posed by specialists, environmentalists, politicians, engineers and other groups of the population on economic is the purpose of desalinating water. This concern questions about what the required amount to desalinate, the duration of the process, the location of the plant, and particularly the accompanying environmental mitigation measures. This paper outlines the growth of desalination capacity in Algeria and its associated environmental impacts on the sea as well as technological advancements that could reduce these impacts with a couple of examples. In addition, what relationship exists between the environmental effects of desalination technology and the methods Algeria uses for brine discharge?

2 DESALINATION TECHNOLOGIES

Approximately 61% of the world's desalination capacity is attributed to seawater desalination, with brackish water desalination making up to 30% [12]. Currently there are two important desalination technologies used in Algeria; thermal and/or membrane-based technologies. Reverse-osmosis (RO) is the primary method used in membrane desalination accounting for ¾ of global desalination capacity. The remaining capacity is largely attributed to thermal desalination techniques like multi-stage flash distillation (MSF) and multi-effect distillation (MED) [12]. As shown in the Table 1. Algeria has 11 mega desalination plants using SWRO technology with a total capacity of 2 110000 m^3/day.

Table 1. Main Mega – desalination plants in Algeria [12].

Plant / location	Capacity of production (m^3/day)	Year
Kahrama – Oran	86,880	2006
Hamma – Algiers	200,000	2008
Skikda	100,000	2009
Benisaf	200,000	2010
Mostaganem	200,000	2011
Souk Tleta – Tlemcen	200,000	2011
Fouka – Algiers	120,000	2011
Cap Djenet – Boumerdes	100,000	2012
Honaine- Tlemcen	200,000	2012
Tenes – Chlef	200,000	2015
Magtaa – Oran	500,000	2016

Source: Elsaid, K(2020)

3 IMPACT OF MEMBRANE DESALINATION PROCESS ON THE MARINE ENVIRONMENT

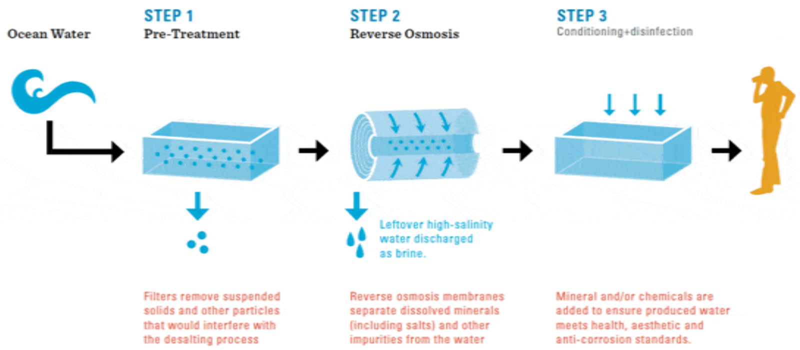
With rising energy costs and advances in membrane technology along with heigh awareness of the environmental consequences of fossil fuels, membrane desalination has become a more popular choice. Membrane desalination and RO technologies are often preferred due to their low energy consumption, adaptability to different capacities and suitability for a range of feed salinity levels [12,13].

Seawater contains various chemical compounds and ions with a Total Dissolved Solids (TDS) concentration of around 30,000-40,000 mg/L. In order to produce freshwater, it is required and necessary to remove the TDS.

In SWRO (Seawater Reverse-Osmosis) a semi-permeable membrane is used to separate water molecules and solids by permitting the permeation of water molecules while prohibiting the transmission of solids. Pre-treatment is done prior to this step to remove large-sized particles and solids (particulate, organic and biological material) as they could result in fouling or scaling on the membrane surface which causes operational problems [14].

Pre-treatment step requires use of chemical additives for antifouling and anticorrosive purposes. The typical operations of an SWRO desalination plant are depicted in Figure 1.

Figure 1. Scheme of a typical SWRO desalination process [14].



Source: Kim, J. (2019)

The seawater desalination process yields an extremely salty byproduct, the brine which is made up of a mixture of salt and other components once the desalination is finished. Because of the high concentration of salts but also the residue of chemicals used in pre-treatment that are listed in Table 2. It can also changes the terrain visual appearance and cause noise pollution, as well as the emission of greenhouse gases

Table 2. Chemicals used for processing at both desalination plants [15].

Product	Symbol	Utilization
Sodium hypochlorite	NaOCl	Desinfection
Ferric chloride	$FeCl_3$	Coagulant
Sodium sulphite	Na_2SO_3	Remove residual chlorine
Dispersant	-	Anti-scale
Sulphuric acid	H_2SO_4	pH correction

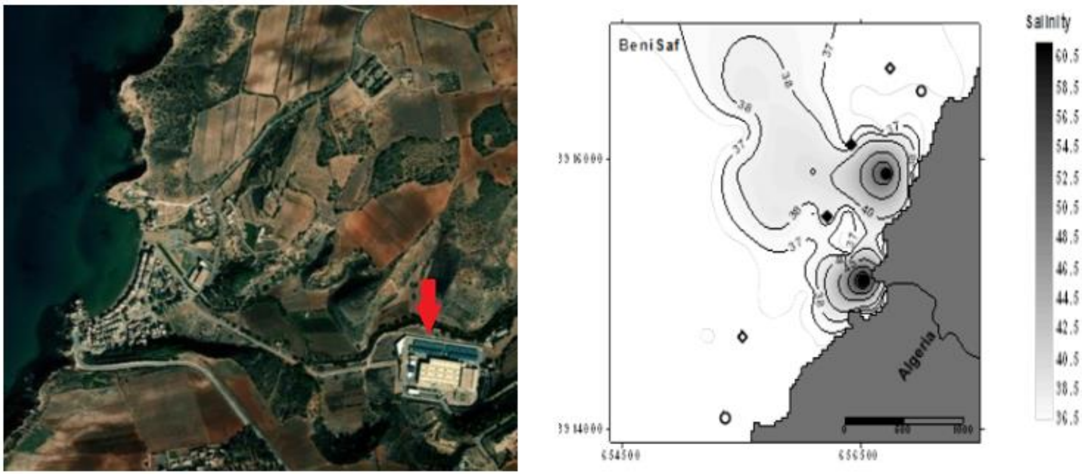
Source: Hamiche, A (2018)

On average the production of one liter of drinkable water creates 1.5 liters of brine with a salinity level between 68 and 90 g/l [15]. The concentration of RO waste effluent or brine salt is very high making it denser than saltwater and raising the likelihood of deleterious effects on stenohaline benthic habitats. These industrial discharges, are also characterized by a high salinity and a high load of chemical pollutants (Fe, Cu, Ni, Zn, Cr) have led researchers to the need to study their environmental impacts on coastal marine ecosystems. It is important to note that the osmotic pressure changes caused by this elevated salinity can be fatal to marine organisms which are not adapted to it [16].

Research has shown that SWRO desalination plants can have varying impacts on the salinity levels of receiving bodies of water. Observed effects can vary significantly from plumes with increased salt concentrations that extend for up to tens of meters to more extreme cases spanning multiple kilometers from the outfalls of desalination plants [17]. In Reverse Osmosis the concentration of brine is 1.3 to 1.7 times higher than that of the original seawater [18].

In Algeria, an important study conducted by Belatoui *et al*. [16] indicated that in coastal areas near the Beni Saf desalination plant (in the West of Algeria, with 200,000 m^3/day), the bottom salinity increased significantly to 62.8 g/l compared to 36.5 g/l in areas not affected by brine discharge. This increase is generally due to the length and direction of the Brine dispersion.

Figure 2. Position of Beni Saf plant and Spatial representation of salinity distribution on the sea-bottom [16].



Source: Belatoui, A. (2017)

Another investigation was conducted by Omar Rouane *et al*. [19] showed a significant difference in physico-chemical parameters analyses of seawater between site H near the discharge area of SWRO Bousfer Plant (Oran- West of Algeria with 5,000 m^3/day) and the other reference site located in Madragh considered as relatively clean. It was noted that at site H salinity and TDS levels were highest in comparison to any other site [19]. A normal value for temperature and pH is also mentioned. The results are presented in the Table 3.

Table 3. Sites comparison of Physico-chemical parameters [20,21].

Site	site H	reference site
Salinity (psu)	40.652	35.499
TDS (ppm)	32267.6	26813.6
T (°C)	16.060	15.66
pH	8.24	8.33

Source: Elimelech, M. (2011)

The previous study also includes an analysis of Patella rustica. The Lusitanian limpet or rustic limpet is a species of sea snail, a true limpet, a marine gastropod mollusk in the family Patellidae which is one of the families of true limpets. It is a rocky shore intertidal mollusc found throughout the Mediterranean and the north-east Atlantic from Mauritania to southern France [20]. A total of 200 specimens of P. rustica were collected from the bedrock of the medio-littoral zone. The results showed that the Limpets gathered from the "hotspot" site (H) exhibited the greatest levels of antioxidant defenses. The enzymatic activities of antioxidant defenses were notably higher than the reference site [19].

The same population of Patella rustica limpets native to the area has been employed as a sentinel species in order to evaluate potential negative consequences of brine discharges related to the plant. The impacts of brine are significant and demonstrate potential danger to the flora and fauna at this coastal location over the whole year.

It is probable that the limpets from the native population in the site of discharge which were consistently exposed to brine discharges throughout their life cycle experienced the most severe repercussions due to both the high salinity and presence of pollutants in this area. The salinity of SWRO brines being substantially higher (approximately two-fold) than that of seawater, coupled with the chemicals used in its pretreatment and membrane-cleaning protocols, can pose a risk to organisms when released into the marine environment [21,22,23]. Reverse osmosis plants typically discharge anti-scalants, coagulants and various cleaning chemicals such as surfactants, alkaline and acid solutions as well as metal-chelating agents [21,23,24].

to mitigate the potential effects of brines with a high salinity, the desalination plant brine can be blended with other streams of waste such as cooling water from power plants and treated wastewater effluent if the resources are available [21,22,23].

4 IMPACT OF THERMAL DESALINATION PROCESS ON THE MARINE ENVIRONMENT

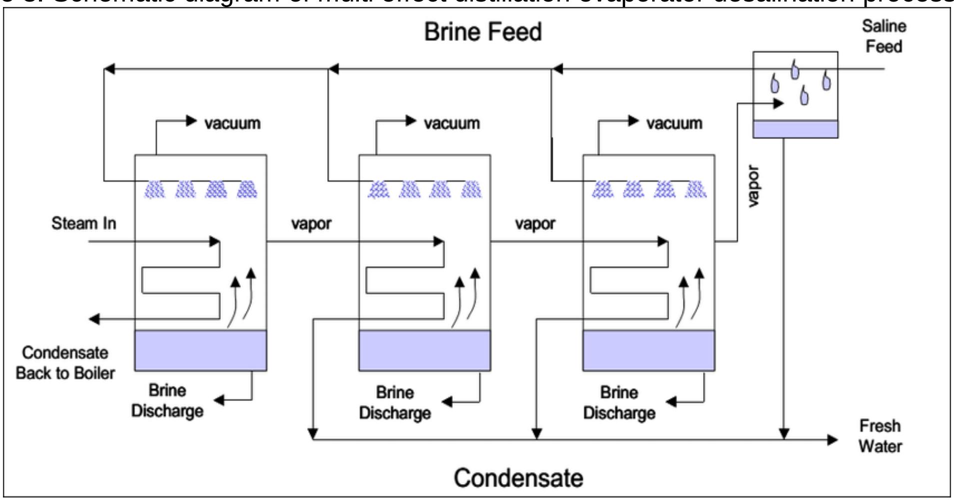
There are three major categories of thermal desalination namely the mechanical vapor compression (MVC), the multi-effect distillation (MED) and the multi-stage flash distillation (MSF). In Algeria there are only two types of desalination process technologies used are the MED and MSF. Thermal desalination operations account for 28% of the total capacity. The 21% of which is MSF process and 7% is MED process [25].

4.1 MULTI-EFFECT DISTILLATION (MED)

The MED (Multi-Effect Distillation) is a thermal desalination process that utilizes boiling at successive stages to desalt seawater. The latent heat of the heat source is utilized to boil a portion of the feed water in the primary stage. This produces freshwater vapor and brine at the applied pressure. A pump circulates the brine to the following effect where upon latent heat from the condensing vapor of the prior effect causes partial boiling and results in a production of additional distillate [26].

For the case of Algeria, as an example there is a MED plant in Arzew- Oran at the west coast of the country. The units were installed in the Algeria Oman Fertilizer plant since 2009. Distilled water will be used for process application using a Multiple Effect Distillation with Thermal Vapor Compression technology with Supervision of erection and commissioning of three skid mounted desalination units 3 x 3600 m3 water production per day. They are composed of two evaporation cells under the thermo compressor and another small units supply process water for an amonia and area complex in Arzew with volume of 3 x 2400 m3 production of water per day. The plant consists in three 2 stages TCD 2 2400 units, with skid mounted and delivered FOB [27]. Figure 3. show a schematic diagram of multi effect distillation evaporator desalination process.

Figure 3. Schematic diagram of multi effect distillation evaporator desalination process [14].



Source: Kim, J. (2019)

4.2 MULTI-STAGE FLASH DISTILLATION (MSF)

The milestone event in the evolution of desalination was the introduction of multi-stage flash desalination (MSF) in Kuwait in 1957 [13]. The MSF system consists of three primary components: Heat Input Section, intermediate Heat Recovery Stages, and Heat Rejection Stage(s) wherein waste heat is released into the environment [28].

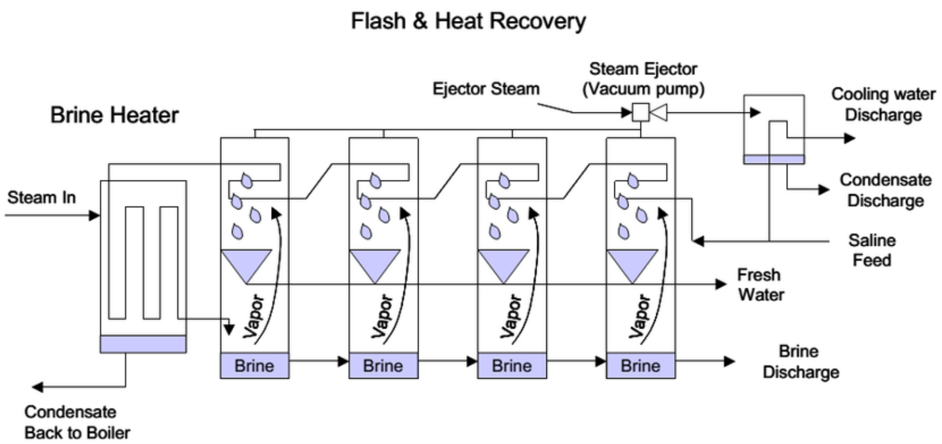
The MSF approach is analogous to multi-stage distillation, yet there is no transfer of material between the opposing streams. The multi-stage flash distillation method is an efficient flash evaporation process conducted in a vacuum environment wherein the level of vacuum is varied between stages and the evaporation temperature decreases from the initial stage to the final one [29].

The Cap Djinet Thermal Power Plant (Eastern of Algeria) utilizes a Multi-Stage Flash Distillation (MSF) process for its Desalination Unit. The desalinated water then undergoes demineralization in order to provide water with characteristics suited to a high pressure boiler feed. This power plant produces around 1,100 m3 of desalinated water daily. It is equipped with four individual desalination units [30].

There is also another important seawater desalination station in Karma located also in Oran built by Befesa agua SAU and operated by Geida Beni Saf SL (Cobra) ABENGUOA Spanish in association with the AEC (Algerian Energy Company) with a goal of producing 86 880 m^3 of water and generate 321Mwh of electricity per day [31].

The desalination plant relies on this principle to produce distilled water from seawater. In order to optimize this technique, the installation is equipped with several floors (17 floors) is used to increase production capacity. The pressure drop across the different stages is achieved through the use of ejectors that use steam from the boiler process as a motor fluid. The largest quantity of seawater is treated and made potable to serve the SEOR (water company of Oran) client. Figure 4 shows the Schematic diagram of Multi Stage Flash Distillation process.

Figure 4. The Schematic diagram of Multi Stage Flash Distillation process [14].



Source: Kim, J. (2019)

The hazards with thermal desalination process are the incompatibility with excessive warmness assets as scaling issues can arise for the duration of spray evaporation. Moreover it is difficult to reduce to smaller size because of its complexity with a wide variety of elements required. Given that, MED and MSF technologies has higher precise power consumption and greater greenhouse fuel (GHG) emissions are predicted. The brine discharge from a standard MSF plant is 7 to 15 °C heated than the feed water temperature [32]. In Multi Stage Flash (MSF) systems the brine concentration is increased from 1.1 to 1.5 times the original concentration of the seawater [18,33].

The release of brine into the marine environment produced by means of MSF may be as 15 to 20% extra saline than the feed water [32,34].

The kind and volume of effluent that desalination systems release into the environment depend on the procedure used. Following thermal desalination powered by auxiliary boilers the following compounds will be discharged into the environment [34]:

- CO_2, NO_x, and SO_x emissions
- brine concentrate
- Heat from the seawater drain and temperature of evaporation.

For the case of Algeria, a study about the impact of desalination in the west of the country showed that there is a considerable rise in salinity, conductivity, calcium, and organic matter in rejected water as well as an increase in the elements of chlorides, sodium, and potassium salts. But the most important observations concern the significant temperature increase of the brine discharge and consequently the considerable rise in temperature of discharge area. The turbidity increases significantly when compared to sea water which is influenced by the presence of suspended matter (MES). It has the potential to have an impact on wildlife and maritime flora [35].

In the study conducted by Einav [33] it is mentioned that the volume of discharge is nearly equal to one-half of the quantity of the feed seawater as illustrated in Table 4.

Table 4. Volume of discharged with respect to feed seawater volume [33].

	provide seawater	the discharge brine
Hourly flow (m^3)	13,000	6,750
Salts concentration (mg/l)	40,500	77,920
total salt content (t/h)	526	526

Source: Einav, R(2003)

For the most part the maritime environment may be harmed in the first instance by saline discharge, additives or their interactive conversion products as well as by corrosion products [36]. The wastewater effluent of MSF demonstrates slight hyper salinity in comparison to the receiving seawater body. This, however, presents a substantial thermal and chemical pollution potential that can drastically affect and diminish the water quality. Generally the MSF brine is less dense than seawater which causes it to rise to and float above the surface, reducing the probability of harm on benthic ecosystems but potentially increasing the risks for contamination of recreational or commercial fishing areas [37].

This substance also has an impact on fish fauna. Because of their mobility, these groups can swim far away from the turbidity and pollutants associated with brine and cleaning water releases. However, near MSF brine discharges the extinction of larvae and younger individuals has been observed [37,38].

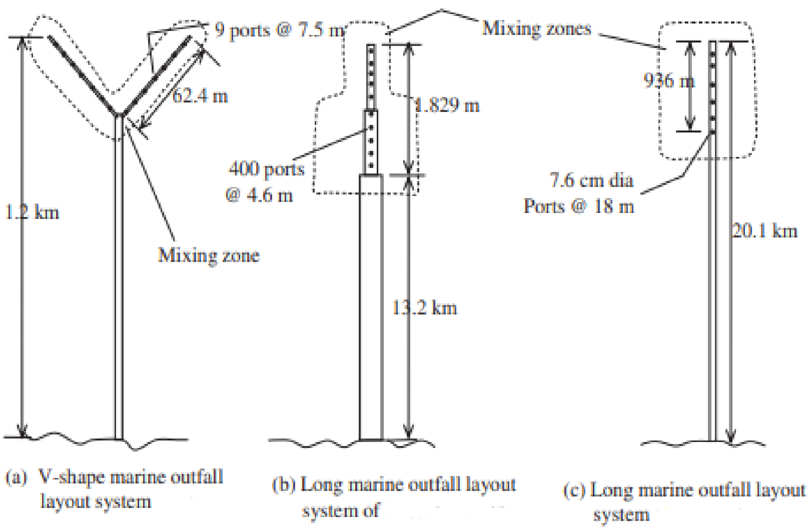
In the event of high-velocity jet discharges a considerable change in local hydrodynamics in the environment might impact sensitive fish species particularly smaller individuals causing disorientation and increasing their vulnerability to predators [37]. For example, it has been demonstrated that hypersaline discharges from reverse osmosis (RO) desalination plants have an impact on Posidonia oceanica meadows in the Mediterranean [39]. A more recent study found that seawater reverse osmosis (SWRO) discharges harmed Mediterranean benthic heterotrophic microorganisms [40]. A jet discharge velocity of 3 to 3.5 m/s should not be exceeded to reduce this influence [37].

5 TECHNIQUES FOR SPREADING BRINE DISCHARGE

The main goal of minimizing the impact of desalination implies a mastery of the Brine outfall. Brine outfall design in shallow receiving seas presents a significant challenge. There are only a few studies dedicated to the study of brine discharges in shallow coastal waters that we are aware of. Outfalls are categorized based on their location (surface discharge or submerged discharge), mixing feature (single port/multiport) and effluent properties (positive or negative buoyancy) [41]. The designs are created to ensure the highest level of initial dilution required by the environmental regulations established by regulatory agencies and within the "mixing zone" boundary.

In the literature there are two methods for Brine outfall systems namely the surface discharge method where the brine is discharged on the saltwater surface extremely close to the shore. In the surface discharge method results in high concentrated saline water accumulation on the shores [18,33]. Submerged discharge systems are required for current large capacity facilities to provide significant dilution to avoid adverse effects on marine life. This image depicts a disposal system in which a long pipe line is built from a desalination plant to release brine deep into the sea [18,41]. Finally, the brine spreads on the sea floor at the point of discharge forming a mixing zone where the concentration of brine exceeds an environmental water quality standard. The mixing zone strategy is now used to control and restrict brine pollution within a specified mixing zone surrounding the site of discharge [18]. Figure 5. depicts a typical layout of a marine outfalls with multiple ports at the end of a long pipe line. Around the multiport diffusers the mixing zones are defined. Figure 5(a) depicts a brine disposal system with a V-shaped diffuser. Figure 5(b) depicts a lengthy pipe line with progressively decreasing diameter and a diffuser system. Figure 5(c) depicts a nearly 20-kilometer long pipe line with a straight diffuser extending 936 meters [18].

Figure 5. Various deep sea marine outfall arrangement systems with multiport diffusers at the end [18].



Source: Ahmad, N. (2014)

At present Algeria has about 11 desalination plants with a collective capacity of approximately 2.1 million m^3/day [42,43]. The HWD (Hamma Water Desalination) and BWC (Benisaf Water Company) plants each produce 200,000 m^3/d of potable water using reverse osmosis processes, providing one fourth of the water requirements for both the city of Algiers and the west of the country respectively.

The HWD facility is located in the Hussein Dey city of Belouizdad town. It is adjacent to the port of Algiers and the Hamma Power Production Station. The plant site and process chosen were thought to be appropriate by its designers [42,44]. Table 5. displays more plant information.

Table 5. Specifications for the HWD plant [42]

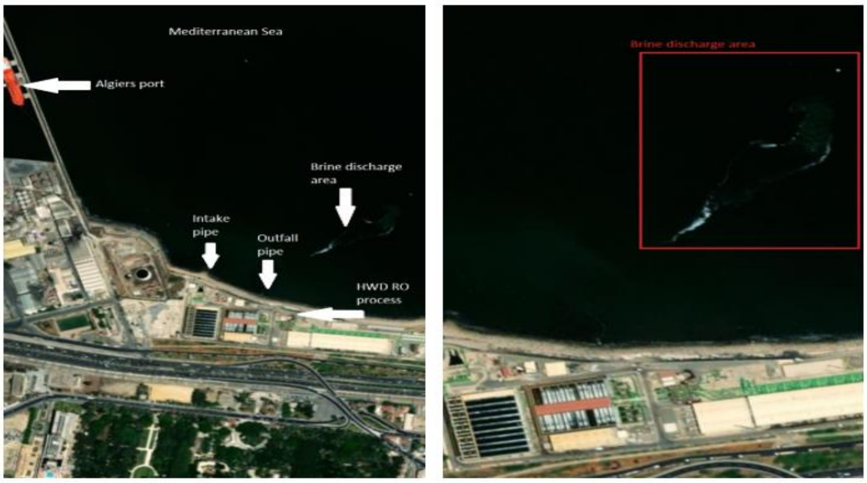
Constructor	construction Industries OCIA/Orascom
Operator	GE Infrastructure Water Process "GEIWPTA"
Components	9 modules of 25,100 m^3 /d per production unit, 8 in production and 1 in standby.
Start of the operation	April 2008
Sponsoring and Investment cost	Algerian Energy Company AEC \$257 Million

Source: Amokranea, M. (2021)

The HWD factory is positioned at the following GPS coordinates: 36° 45′ 6.26″ N, 3° 4′ 45.34″ E. The diagram shown in Fig.6 depicts an overview of the plant in service including its principal components such as the pre- and post-treatment facilities, the RO modules shed and the input and outfall pipelines [42].

The plant is provided with water sourced from the Mediterranean Sea with a salinity concentration of 34 to 37 g/L and a temperature range from 15°C to 27°C.

Figure 6. Placement of the HWD plant including its intake and outfall pipes [42].



Source: Amokranea, M. (2021)

The brine is released from the pressure exchanger units at a pressure of 0.7 bar and subsequently transported to the ocean through a submerged marine outfall. Gravity overflows approximately 300,000 m^3 /d of brine containing reject water and effluent from cleaning processes through a single reinforced concrete outfall conduit and discharges at a depth of 8 m through an exit nozzle (single port without the use of a diffuser) [42].

The jet of concentrate leaves the nozzle due to pressure and subsequently falls to the seafloor by gravity. Current designs have the nozzle angled at around 60° to the horizontal. The brine outfall pipeline is approximately 258 m long and 1.6 m in diameter [42,45,46]. The plant recovery rate, which in turn depends on the salinity of the original seawater and the process configuration, is largely responsible for the salinity of the brine [42, 23, 47].

There is significant movement around the end of the outfall pipe. This movement spreads for a long distance (Brine discharge area). A boiling structure can be seen on the water surface in the satellite view. The Centerline jet impacts the sea surface which the literature refers to this phenomena as centerline brine jet surface [42, 48].

There are numerous potential explanations behind the Centerline jet impacts such as disruption of concentrate flow and its chemical makeup as well as seasonal fluctuations in seawater properties (e.g. temperature and salinity).

The observations mentioned above can be largely attributed to the fact that project promoters did not employ Environmental Design Optimization. This approach is designed to create an optimal outfall system in terms of length, position and arrangement in order to minimize environmental impact and cut down on investment costs [42,44]. For comparison we choose another example from Algeria's west region, the Mostaganem plant is considered which is located in Mostaganem city near Oran town. This plant can be found at these GPS coordinates: (36°0′50.34″N, 0°7′40.25″E).

The designers deemed the selected plant site and process to be suitable. Table 6 provides additional plant information

Table 6. Specifications for Mostaganem plant [16]

Constructor	GS Inima Aqualia Spanish
Operator	GS Inima Aqualia Spanish
Components	9 modules of 25,100 m3 /d per production unit, including 8 in production and 1 on standby
Start of the operation	2011
Sponsoring and Investment cost	Algerian Energy Company AEC $300 Million

Source: Belatoui, A. (2017)

Mostaganem facility was likewise monitored using the same imaging approach. The graphic 7 below illustrates an overview of the plant in operation, including key components such as pre- and post-treatment facilities, the RO modules shed, and the input and outfall pipes.

Figure 7. Placement of Mostaganem plant including its intake and outfall pipes [42].

Source: Amokranea, M. (2021)

Brine is discharged into the sea using the same method as the HWD station a submerged marine outfall having the same volume and qualities of discharge. The observations revealed no surface interaction between the brine jet and the water surface. Mostaganem outfall discharge is equipped with a diffuser with 50 nozzles while the HWD one is fitted with a single pipe without a diffuser [16,42,49]. It is worth noting that the largest excess salinity reported at the Mostaganem plant is more than 9% (brine identified up to 200 meters from the outfall) [16,42]. It is also important to remember that the roughness of the seawater is likely to be greater than that created by the brine jet which greatly limits the surface interaction.

Such observations demonstrate the beneficial impact of rough seas in boosting dispersion and mixing [42,49].

6 CONCLUSION

Desalination is a solution to Algeria water scarcity because it improves the consistency of water delivery to all consumer sectors with a relatively low cost.

Typically the rejections from desalinated seawater are released either close to the shore or through an underwater outlet. These brines discharges have a detrimental, destructive and irreversible effects on the receiving system. This paper gives a study on Algeria current desalination capacity and its accompanying environmental implications on the sea. It proposes how to manage brine discharge to minimize these detrimental effects providing certain cases. The obtained data on the influence of brine desalination on the maritime environment are reliable and complementary to one another. The following conclusions can be derived from the study's findings:

- The brine discharge provides a significant thermal and chemical contamination risk that can significantly reduce seawater quality
- Increasing the possibility of infection of recreational or commercial fishing locations wich can cause extinction of larvae and younger individuals.
- The variations in osmotic pressure induced by this increased salinity can be lethal to marine organisms such as Patella rustica and the benthic ecosystem.

We affirm that the effects of desalination on the marine environment can be managed and regulated by implementing multiport diffusers which are suitable for plants as extensive as those in this study.

These diffusers (outfall brine pipe) speed up dilution which lead to minimizing the region affected by the hypersaline plume. The main result is the lowering of the influence of brine discharge on the benthic community such as seen at Mostaganem, where the benthic community was only mildly affected.

The installation of multiport diffusers can effectively mitigate and control the impact of desalination activity on the marine environment. By enhancing mixing and reducing the impact on benthic communities and surrounding areas, these systems provide a solution for addressing the potential effects of large-scale desalination facilities discussed in this paper.

The implementation of multiport diffusers technology can serve as a model for upcoming SWRO plants, efficiently producing freshwater while minimizing its impact on the marine ecosystem.

REFERENCES

[1] KARAGIANNIS, I. C.; SOLDATOS, P. G. Water desalination cost literature: review and assessment. **Desalination**, v. 223, n. 1-3, p. 448-456, 2008.

[2] DARRE, N. C.; TOOR, G. S. Desalination of water: a review. Current **Pollution Reports**, v. 4, p. 104-111, 2018.

[3] IHSANULLAH, I.; ATIEH, M. A.; SAJID, M.; NAZAL, M. K. Desalination and environment: A critical analysis of impacts, mitigation strategies, and greener desalination technologies. **Science of the Total Environment**, v. 780, p. 146585, 2021.

[4] TEOW, Y. H.; MOHAMMAD, A. W. New generation nanomaterials for water desalination: A review. **Desalination**, v. 451, p. 2-17, 2019.

[5] NEGEWO, B. D. (Ed.). Renewable energy desalination: an emerging solution to close the water gap in the Middle East and North Africa. **World Bank Publications**, 2012.

[6] IGLESIAS, A.; GARROTE, L.; FLORES, F.; MONEO, M. Challenges to manage the risk of water scarcity and climate change in the Mediterranean. **Water resources management**, v. 21, p. 775-788, 2007.

[7] MAHMOUDI, H.; ABDELLAH, O.; GHAFFOUR, N. Capacity building strategies and policy for desalination using renewable energies in Algeria. **Renewable and Sustainable Energy Reviews**, v. 13, n. 4, p. 921-926, 2009.

[8] DROUICHE, N.; GHAFFOUR, N.; NACEUR, M. W.; MAHMOUDI, H.; OUSLIMANE, T. Reasons for the fast growing seawater desalination capacity in Algeria. **Water resources management**, v. 25, p. 2743-2754, 2011.

[9] KEHAL, S. Retrospective et perspective du dessalement en Algérie. **Desalination**, v. 136, n. 1-3, p. 35-42, 2001.

[10] TSIOURTIS, N. Desalination and the environment. **Desalination**, v. 138, n. 1-3, p. 1, 2001.

[11] MITICHE, R.; METAICHE, M.; KETTAB, A.; AMMOUR, F.; OTMANI, S.; HOULI, S.; ... MAAZOUZI, A. Desalination in Algeria: Current situation and development programs. **Desalination and Water Treatment**, v. 14, n. 1-3, p. 259-264, 2010.

[12] ELSAID, K.; KAMIL, M.; SAYED, E. T.; ABDELKAREEM, M. A.; WILBERFORCE, T.; OLABI, A. Environmental impact of desalination technologies: A review. **Science of the total environment**, v. 748, p. 141528, 2020.

[13] QASIM, M.; BADRELZAMAN, M.; DARWISH, N. N.; DARWISH, N. A.; HILAL, N. Reverse osmosis desalination: A state-of-the-art review. **Desalination**, v. 459, p. 59-104, 2019.

[14] KIM, J.; PARK, K.; YANG, D. R.; HONG, S. A comprehensive review of energy consumption of seawater reverse osmosis desalination plants. **Applied Energy**, v. 254, p. 113652, 2019.

[15] HAMICHE, A.; STAMBOULI, A. B.; FLAZI, S.; TAHRI, A.; KOINUMA, H. Desalination in Algeria: Current State and Recommendations for Future Projects. **Thermo-Mechanics Applications and Engineering Technology**, p. 37-58, 2018.

[16] BELATOUI, A.; BOUABESSALAM, H.; HACENE, O. R.; DE-LA-OSSA-CARRETERO, J. A.; MARTINEZ-GARCIA, E.; SÁNCHEZ-LIZASO, J. L. Environmental effects of brine discharge from two desalination plants in Algeria (South Western Mediterranean). **Desalin. Water Treat**, v. 76, p. 311-318, 2017.

[17] ROBERTS, D. A.; JOHNSTON, E. L.; KNOTT, N. A. Impacts of desalination plant discharges on the marine environment: A critical review of published studies. **Water research**, v. 44, n. 18, p. 5117-5128, 2010.

[18] AHMAD, N.; BADDOUR, R. E. A review of sources, effects, disposal methods, and regulations of brine into marine environments. **Ocean coastal management**, v. 87, p. 1-7, 2014.

[19] BENAISSA, M.; ROUANE-HACENE, O.; BOUTIBA, Z.; HABIB, D.; GUIBBOLINI-SABATIER, M. E.; RISSO-DE FAVERNEY, C. Ecotoxicological effects assessment of brine discharge from desalination reverse osmosis plant in Algeria (South Western Mediterranean). **Regional Studies in Marine Science**, v. 39, p. 101407, 2020.

[20] Patella rustica – Wikipedia

[21] ELIMELECH, M.; PHILLIP, W. A. The future of seawater desalination: energy, technology, and the environment. **Science**, v. 333, n. 6043, p. 712-717, 2011.

[22] National Research Council. Committee on Advancing Desalination Technology and National Academies Press (US). **Desalination**: A National Perspective 2008. v. xiv.

[23] LATTEMANN, S.; HÖPNER, T. Environmental impact and impact assessment of seawater desalination. **Desalination**, v. 220, n. 1-3, p. 1-15, 2008.

[24] FRITZMANN, C.; LÖWENBERG, J.; WINTGENS, T.; MELIN, T. (2007). State-of-the-art of reverse osmosis desalination. **Desalination**, v. 216, n. 1-3, p. 1-76.

[25] TOTH, A. J. Modelling and optimisation of multi-stage flash distillation and reverse osmosis for desalination of saline process wastewater sources. **Membranes**, v. 10, n. 10, p. 265, 2020.

[26] ALHAJ, M.; HASSAN, A.; DARWISH, M.; AL-GHAMDI, S. G. A techno-economic review of solar-driven multi-effect distillation. **Desalination Water Treat**, v. 90, p. 86-98, 2017.

[27] Sea Water Desalination plant in Algeria – Sea water desalination plant in Algeria | Veolia (entropie.com).

[28] NAMBOODIRI, V.; RAJAGOPALAN, N. 2.6. Desalination. *In*: AHUJA, S. (Ed.). Comprehensive Water Quality and Purification. Elsevier: Waltham, MA, USA, 2014. v. 2, p. 98–119.

[29] TOTH, A. J. Modelling and optimisation of multi-stage flash distillation and reverse osmosis for desalination of saline process wastewater sources. **Membranes**, v. 10, n. 10, p. 265, 2020.

[30] AMITOUCHE, M.; REMINI, B. Operation of Cap Djinet desalination plant and dilution of brine with power station cooling water. **Desalination and Water Treatment**, v. 57, n. 8, p. 3514-3521, 2016.

[31] https://aec.dz/2023/05/25/kahrama/ Kahrama | AEC.

[32] MEZHER, T.; FATH, H.; ABBAS, Z.; KHALED, A. Techno-economic assessment and environmental impacts of desalination technologies. **Desalination**, v. 266, n. 1-3, p. 263-273, 2011.

[33] EINAV, R.; HARUSSI, K.; PERRY, D. The footprint of the desalination processes on the environment. **Desalination**, v. 152, n. 1-3, p. 141-154, 2003.

[34] SOMMARIVA, C.; HOGG, H.; CALLISTER, K. Environmental impact of seawater desalination: relations between improvement in efficiency and environmental impact. **Desalination**, v. 167, p. 439-444, 2004.

[35] MEHTOUGUI, M. S.; MEHTOUGUI, F.; KERFOUF, A. Impact of desalination of sea water on a coastal environment of Chatt El Hillal (Beni Saf–Western northern Algeria). **International Journal of Sciences**: Basic and Applied Research (IJSBAR-ISSN 2307-4531) (2015), v. 22, n. 1, p. 327-333, 2013.

[36] HÖPNER, T.; WINDELBERG, J. Elements of environmental impact studies on coastal desalination plants. **Desalination**, v. 108, n. 1-3, p. 11-18, 1997.

[37] PALOMAR, P.; LOSADA, I. J. Impacts of brine discharge on the marine environment. Modelling as a predictive tool. **Desalination**, trends and technologies, v. 234, 2011.

[38] EINAV, R.; LOKIEC, F. Environmental aspects of a desalination plant in Ashkelon. **Desalination**, v. 156, n. 1-3, p. 79-85, 2003.

[39] GACIA, E.; INVERS, O.; MANZANERA, M.; BALLESTEROS, E.; ROMERO, J. Impact of the brine from a desalination plant on a shallow seagrass (Posidonia oceanica) meadow. **Estuarine, Coastal and Shelf Science**, v. 72, n. 4, p. 579-590, 2007.

[40] FRANK, H.; RAHAV, E.; BAR-ZEEV, E. (2017). Short-term effects of SWRO desalination brine on benthic heterotrophic microbial communities. **Desalination**, v. 417, p. 52-59.

[41] JIRKA, G. H. Improved discharge configurations for brine effluents from desalination plants. **Journal of Hydraulic Engineering**, v. 134, n. 1, p. 116-120, 2008.

[42] Amokranea, M.; Salmic, A. Surface spreading of the brine discharge from the seawater reverse osmosis plants: Hamma Water Desalination plant in Algeria. **DESALINATION AND WATER TREATMENT**, v. 222, p. 81-91, 2021.

[43] ALGERIAN MINISTRY OF ENERGY. Available at: https://www.energy.gov.dz/?article=projet-de-dessalement-de-lreau-de-mer. Access in: 03 July 2020.

[44] MOOIJ, C. Hamma water desalination plant: planning and funding. **Desalination**, v. 203, n. 1-3, p. 107-118, 2007.

[45] BLENINGER, T.; JIRKA, G. H. Modelling and environmentally sound management of brine discharges from desalination plants. **Desalination**, v. 221, n. 1-3, p. 585-597, 2008.

[46] HAYATDAVOODI, M. (2017). Dhanak and Xiros (Eds.): Springer Handbook of Ocean Engineering: **Springer International Publishing** (), Springer Handbooks, 2016.

[47] JIANG, B.; LAW, A. W. K. Non-interfering multiport brine diffusers in shallow coastal waters. **Journal of Applied Water Engineering and Research**, 1, n. 2, p. 148-157, 2013.

[48] ABESSI, O.; ROBERTS, P. J. Dense jet discharges in shallow water. **Journal of Hydraulic Engineering**, v. 142, n. 1, p. 04015033, 2016.

[49] KRESS, N.; GERTNER, Y.; SHOHAM-FRIDER, E. Seawater quality at the brine discharge site from two mega size seawater reverse osmosis desalination plants in Israel (Eastern Mediterranean). **Water research**, v. 171, p. 115402, 2020.