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Abstract:

This research work is part of the framework of environmental assessment of brine discharges into the marine environment. Its main objective is to simulate the dispersion of a brine discharge in a marine setting using the CORMIX software, taking as a scenario study a coastal site in Corso (Algeria). Through this simulation, the aim is to achieve a better understanding of dispersion mechanisms, to identify sensitive areas, and to carry out a critical analysis of the obtained results in order to guide future technical and environmental decisions and to propose recommendations for a more sustainable management of desalination discharges.

Following the evaluation of the current configuration of the diffuser of the CORSO desalination plant, it was observed that the diffuser does not perform adequately under the three studied scenarios.

Based on the simulations carried out for the three scenarios, it can be concluded that the performance of the discharge system (diffuser) remains unsatisfactory and requires intervention and improvement in its design.

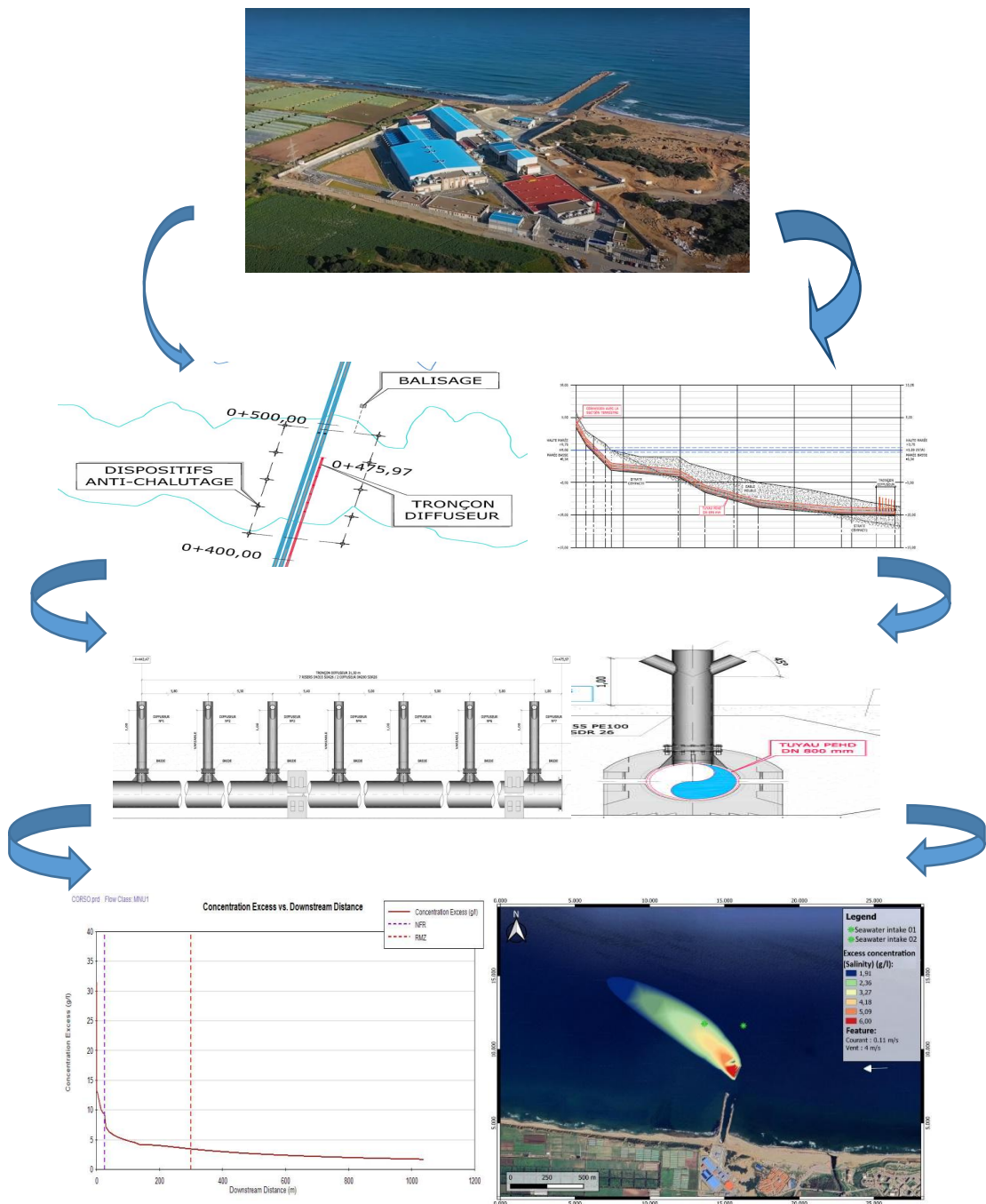
To address this situation, the following recommendations are proposed:

- In particular, increasing the discharge velocity, which is the driving parameter of the kinetic energy and initial jet momentum, responsible for the dispersion and dilution of the effluent.
- Repositioning the discharge point location relative to the intake point.

Furthermore, in order to further minimize the impact of brine discharge into the sea, it would be worthwhile, as a future perspective, to install a dilution system using seawater upstream of the outfall pipeline, either at the coastline or directly at the desalination plant itself.

Keywords : desalination, brine, dispersion, marine, CORMIX, Algeria.

Graphical Abstract



Introduction

Algeria has been experiencing increasing pressure on its water resources for several decades due to low precipitation, overexploitation of groundwater aquifers, and the gradual degradation of the quality of conventional water resources. In order to address this structural water deficit and ensure long-term water security, the country has launched an extensive program for the development of non-conventional water resources, primarily based on seawater desalination. This strategy aims to guarantee a minimum availability of drinking water for major coastal urban centers, where demand continues to rise. Today, several desalination plants are operational along the Algerian coastline and make a significant contribution to drinking water supply, particularly in regions characterized by insufficient natural water resources.

In this context, the Algerian government initiated, in the early 2000s, an ambitious national program for the development of large-scale seawater desalination facilities, which are currently operational, under construction, or at the planning stage. The program aims to secure potable water supply along a coastal strip of approximately 150 km and to substantially increase the coverage of drinking water demand (DWD), rising from 18% in 2023 to 42% by 2025. In the longer term, desalination is expected to meet more than 60% of national drinking water needs by 2030, corresponding to an estimated production capacity of 5.6 million m³/day (Maamar et al. 2026).

At the global scale, reverse osmosis (RO) desalination is widely acknowledged as a mature, reliable, and efficient technology. However, despite its widespread adoption, RO desalination remains highly energy-intensive and requires continuous optimization to enhance its technical and economic performance (Shokri and Sanavi Fard 2023; Anis et al. 2019).

However, despite its undeniable advantages, seawater desalination raises significant environmental concerns, particularly with regard to the discharge of brine into the marine environment. Brine is a hypersaline effluent that is generally denser than the surrounding seawater. When inadequately managed, such discharges can lead to substantial disturbances of marine ecosystems, notably through localized increases in salinity, alterations in water column stratification, and reductions in dissolved oxygen concentrations, with potentially long-lasting effects on marine flora and fauna (Missimer and Maliva 2018; Gupta et al. 2025).

Several studies have highlighted direct impacts on benthic organisms, particularly diatom communities, which are highly sensitive to salinity variations and play a crucial role in marine trophic chains (Grammatiki et al. 2025). In the Mediterranean basin, these impacts are of even greater concern due to the high density of desalination facilities and the limited renewal capacity of water masses (Bali and Ghanem 2024; Plan Bleu UNEP/MAP 2025).

In this context, assessing and controlling the environmental impacts of brine discharges is a critical issue for the sustainable development of desalination projects. Numerical modeling therefore constitutes a key tool for investigating brine dispersion processes and predicting potential impact zones. Among the available models, the CORMIX software (Cornell Mixing Zone Expert System) is widely employed to simulate discharge plumes in aquatic environments, as it accounts for the hydrodynamic, topographic, and physicochemical characteristics of the receiving water body. In particular, CORMIX enables a realistic representation of negatively buoyant jet behavior and facilitates the evaluation of diffuser system performance in the near-field region (Socolofsky and Jirka 2002; Amitouche et al. 2022; Bouthiba et al. 2024).

Overview of the Corso Desalination Plant

The Corso desalination plant was commissioned in September 2023, with a production capacity of 80,000 m³/day based on reverse osmosis (RO) technology. The facility requires an average energy consumption of approximately 3.375 kWh/m³ (around 4 kWh/m³). It was constructed by the National Company of Civil Engineering and Construction (GCB) in partnership with the Algerian Energy Company SPA (AEC), at an estimated cost of USD 200 million. The Corso seawater desalination plant (SDEM Corso) supplies potable water to several municipalities in the Boumerdès and Algiers wilayas (SDEM Corso 2022).

1.1 Geographic Location

Corso is a coastal municipality located in the Boumerdès Wilaya, northern Algeria, approximately 45 km east of the capital city, Algiers. The area lies along the Mediterranean coastline, which provides favorable conditions for seawater intake and desalination activities (SDEM Corso, 2022).



Fig. 1 Corso seawater desalination plant

1.1.1 Seawater Intake System

The seawater intake constitutes the offshore component of the desalination plant. Seawater abstraction is carried out by siphoning and is ensured by a system composed of three main elements: the intake tower, the intake pipeline, and the intake basin.

Intake Tower

To ensure efficient and reliable seawater abstraction, two circular reinforced concrete intake towers, each with an external diameter of 3.4 m, have been constructed at a bathymetric level of -14.6 m. Each tower is equipped with six (06) intake openings with dimensions of $1.38 \text{ m} \times 1.5 \text{ m}$, positioned 2.3 m above the seabed in order to limit sediment entrainment.

The intake openings are fitted with removable bar screens featuring a grid spacing of $10 \times 10 \text{ cm}$ and a bar thickness of 1 cm, providing effective protection against the ingress of large debris and marine organisms while facilitating maintenance operations. A manhole with a diameter of 2 m is installed on the tower cover to allow inspection and access for operational and maintenance purposes.

The intake system is located at a depth selected to ensure optimal seawater quality for treatment, thereby improving operational efficiency and contributing to the overall performance and reliability of the desalination plant.

Intake Pipelines

Two seawater intake pipelines are constructed of high-density polyethylene (HDPE) and are characterized by the following specifications: an internal diameter of 1,400 mm, an installation depth of -14.6 m, and a total length of 875 m, including 800 m offshore and 75 m onshore. Each pipeline conveys a flow rate of $8,186 \text{ m}^3/\text{h}$.

The hydraulic design of the intake pipelines accounts for tidal variations, with a maximum high tide level of $+0.7$ m and a minimum low tide level of -0.34 m [38].

Discharge System

Following the reverse osmosis process, a significant volume of brine is generated, corresponding to approximately 55% of the intake flow, with an estimated discharge of $97,778 \text{ m}^3/\text{day}$. The brine is conveyed by gravity to the marine environment through a submarine outfall.

The resulting diffuser system consists of seven vertical risers with a nominal diameter (DN) of 355 mm, each equipped with two discharge ports, for a total of fourteen outlets, each with a nominal diameter of 200 mm.

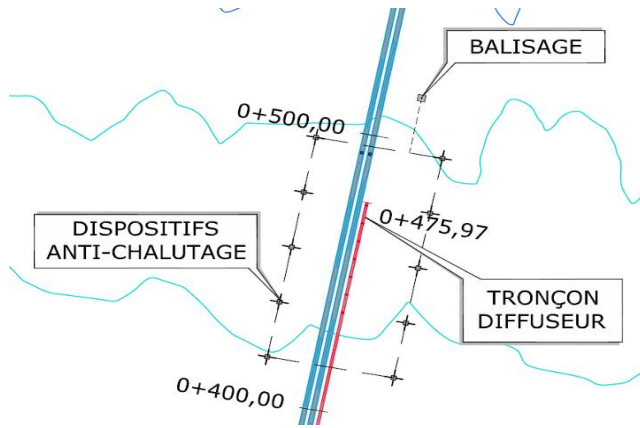


Fig. 2 Layout of the diffuser system at the Corso desalination plant (SDEM Corso, 2022)

Table 1. Brine discharge system.

Mode	Pipe	Diameter	Offshore length	Flow rate	Recovery	Salt concentration
Gravity-driven marine outfall	An HDPE pipe equipped with seven risers, each fitted with two discharge ports.	800 mm	Approximately 500 m	55% of the intake flow rate, approximately 97,778 m ³ /day	Part of the flow is diverted to the dual-media sand filter backwash tank. Each backwash cycle requires approximately 2,002 m ³ per filter every 48 hours.	Approximately 70 g/L

Simulation of Brine Dispersion in the Marine Environment

2. Introduction and Problem Statement

Desalination plants discharge the same mass of seawater constituents as those abstracted from the marine environment, but within a significantly reduced volume of water. In the scenario of a desalination plant such as the Corso facility, a defined volume of seawater is abstracted (exceeding 177,000 m³/day), approximately half of which is recovered as potable desalinated water (80,000 m³/day), while the remaining portion is discharged as brine with a salinity approximately twice that of the intake seawater.

As a result, the discharged effluent exhibits a salinity nearly double that of ambient seawater, leading to a significantly higher density. Upon discharge into the marine environment, this dense effluent sinks due to its negative buoyancy and forms a hyper-saline layer that spreads along the seabed following the local bathymetry. The highest dilution levels are achieved during the initial dilution process, when the turbulent discharge jet mixes with the receiving water body.

The initial dilution process primarily depends on discharge parameters such as diffuser type, number of discharge ports, outlet diameter, and exit velocity. These parameters represent key design variables that can be adjusted to enhance brine dilution and mitigate potential environmental impacts.

In this chapter, the current hyper-saline brine diffuser of the Corso desalination plant is first examined, and its behavior under varying climatic and hydrodynamic conditions is analyzed through multiple numerical simulations using the specialized model CORMIX. This analysis aims to assess the performance of the existing diffuser system.

In a second step, the effects of variations in discharge velocity and the number of diffuser ports are investigated in order to identify appropriate configurations that ensure effective brine dilution within the receiving marine environment.

2.1 Numerical Modeling Using CORMIX

To address the objectives of this study and investigate the identified research problem, version 12.0 GTD of the CORMIX software (License ID: 781438781) was used to analyze the near-field marine dispersion processes associated with the brine discharge from the Corso desalination plant. The CORMIX code (Cornell Mixing Zone Expert System) is a widely used modeling tool for the analysis, prediction, and design of discharges of toxic, saline, thermal, or buoyant effluents into water bodies.

In the vicinity of the diffuser, mixing processes driven by diffuser geometry, discharge exit velocity, and buoyancy-induced vertical motion dominate over advective transport caused by ambient marine currents. For this reason, CORMIX was selected, as it provides an appropriate representation of mixing processes within the so-called *near-field* region. CORMIX is a steady-state model belonging to the class of length-scale models, which evaluate the relative influence of effluent flow rate, momentum flux (flow rate $\times$ discharge velocity), buoyancy, and ambient current velocity on effluent dispersion within the receiving environment.

The CORMIX model offers an efficient three-dimensional representation of effluent mixing and transport processes across a wide range of receiving environments, with a high level of spatial detail. The governing equations are based on a geometric analysis of the effluent trajectory from the discharge point through the immediate downstream plume in both the near-field and far-field regions. These regions are traditionally modeled using integral equations. The model relies on self-similarity assumptions to reduce the three-dimensional governing equations to one-dimensional integral formulations, allowing the computation of the three-dimensional plume trajectory and the maximum centerline concentration.

To represent the mixing zone, CORMIX employs modular approaches based on the assumption of a lateral Gaussian distribution of concentrations. The model calculates the maximum concentration along the plume centerline, corresponding to the minimum dilution, commonly referred to as the hydrodynamic centerline dilution.

Brine discharge dispersion modeling has become an essential tool for the environmental assessment of desalination plants. Among the available models, CORMIX is widely used for analyzing mixing zones associated with saline discharges in marine environments, particularly for negatively buoyant plumes (Jirka et al. 1991; Socolofsky and Jirka 2002). The model is recommended by several environmental agencies for regulatory assessments of marine discharges (U.S. Environmental Protection Agency 2025).

2.2 Description of the Corso SDEM Discharge System

• Simulation Parameters

A set of parameters common to all simulated scenarios was defined to represent the operating conditions and technical characteristics of the Corso seawater desalination plant. This approach enables consistent comparison and discussion of the simulation results. The parameters include characteristics related to ambient seawater, discharged brine, and the submarine outfall system.

These parameters are summarized as follows:

Table 2. Characteristics of the Corso desalination plant

Effluent characteristics:	
Maximum discharge flow rate	1.13 m ³ /s
Salinity	70 (g/l)
Salinity tolerance limit	31.5 (g/l)
Density (20°C)	1051.200 (Kg/m ³)
Receiving environment characteristics:	
Salinity	38.5 (g/l)
Density (20°C)	1027.170 (Kg/m ³)
Wind speed	2 m/s
Current velocity	0.02_2 m /s
Diffuser characteristics:	
Distance from the shoreline	476 m
Water depth at the discharge point	8 m
Diffuser section length (m)	32.5 m
Number of ports	14 ports
Diffuser height	1 m
Port diameter	0.2 m
Exit velocity	2.86 m/s
Discharge angle	45°

• Diffuser Design

Using the CORMIX model, which incorporates all the previously described parameters, the baseline diffuser design was established by systematically varying the relevant design characteristics.

The key design factors associated with the submarine outfall that influence brine dilution include the discharge angle, diffuser elevation above the seabed, installation depth, discharge velocity, and the number of diffuser ports.

The series of numerical simulations conducted allow for the assessment of the individual influence of each parameter on effluent discharge behavior and brine dispersion, thereby providing insight into their role in mitigating potential impacts on the marine environment.

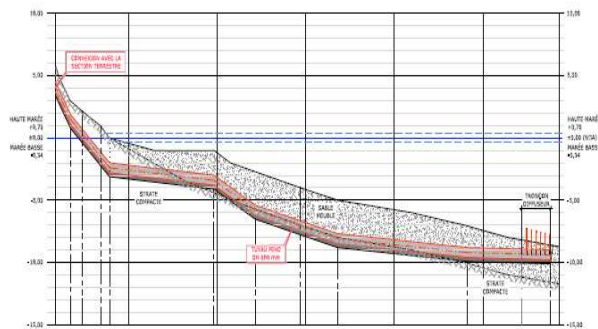


Fig. 3 Longitudinal profile of the diffuser (SDEM Corso, 2022)

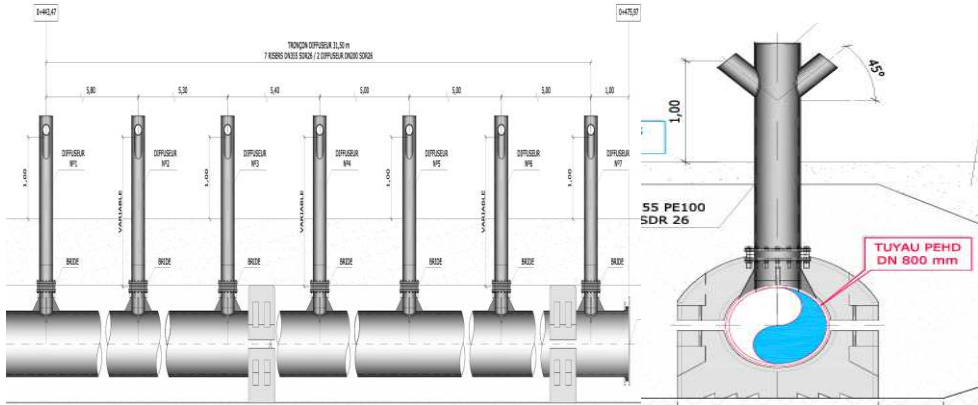


Fig. 4 Diffuser of the Corso desalination plant (SDEM Corso, 2022)

2.3 General Concepts

Prior to conducting the numerical simulations, it is essential to identify and recall several general principles that will subsequently assist in determining whether a given combination of parameters for diffuser design is appropriate.

Brine is typically discharged in the form of a turbulent jet whose density is significantly higher than that of the ambient seawater. Rapid mixing of the discharged brine is therefore desirable in order to ensure minimal environmental impact, which requires a thorough understanding of jet development and behavior.

In other words, the salinity tolerance of the receiving environment (40.5 g/L) must be reached within the near-field region, at the shortest possible distance from the discharge point. Furthermore, the extent of the near-field region should be minimized to reduce the energy required during discharge operations (Sánchez-Lizaso et al., 2020; Sánchez-Lizaso et al., 2021).

Given that the density of the jet exceeds that of the receiving water, the jet exhibits negative buoyancy and will eventually impinge on the seabed at a distance from the discharge point that depends on the initial momentum flux, buoyancy, discharge angle, and local bathymetric conditions.

Once the jet reaches the seabed, it propagates as a gravity current characterized by a very low mixing rate. Consequently, the discharge must achieve a sufficiently low salinity—when combined with ambient seawater salinity—well before reaching the seabed, in order to ensure minimal impact on the marine environment.

The required effluent dilution rate was calculated as $S = 14.75$. In other words, the discharge salinity, equal to 70 g/L, must be diluted by approximately 15 times so that the resulting plume does not exceed the tolerated salinity of 40.5 g/L once mixed with seawater. The required dilution rate is therefore calculated as follows:

$$S = \frac{\text{Effluent salinity} - \text{allowable salinity}}{\text{Allowable salinity} - \text{ambient salinity}} = \frac{70 - 40,5}{40,5 - 38,5} = 14,75$$

Diffuser design plays a decisive role in the efficiency of initial brine dilution. Recent numerical studies have shown that increasing discharge velocity, optimizing the number of discharge ports, and adjusting jet orientation can significantly enhance near-field dilution, particularly in shallow waters (Gil Trujillo and Sadhwani Alonso 2025; Alfaifi and Bonakdari 2024). These findings highlight the importance of diffuser designs adapted to local environmental conditions in order to minimize the environmental impacts of desalination discharges.

2.4 Analysis and Interpretation of Results

2.4.1 Assessment of Diffuser Behavior in the Receiving Environment

This section examines the behavior of the existing diffuser under varying climatic and hydrodynamic conditions that may occur within the receiving marine environment, as well as the resulting development of the brine plume under these different conditions.

Ambient velocities associated with both wind- and current-induced flows play a significant role in plume development and, consequently, in brine dilution processes (Sola et al. 2024).

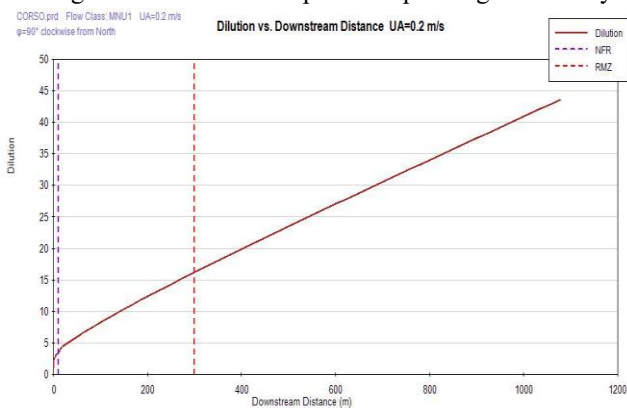
Accordingly, diffuser performance was analyzed for three representative velocity scenarios: a favorable scenario, an intermediate scenario, and an unfavorable scenario, following the approach adopted in previous studies (Amitouche et al. 2022; Bouthiba et al. 2022). These scenarios are summarized in the following table:

Table 3. Environmental velocity Scenarios considered

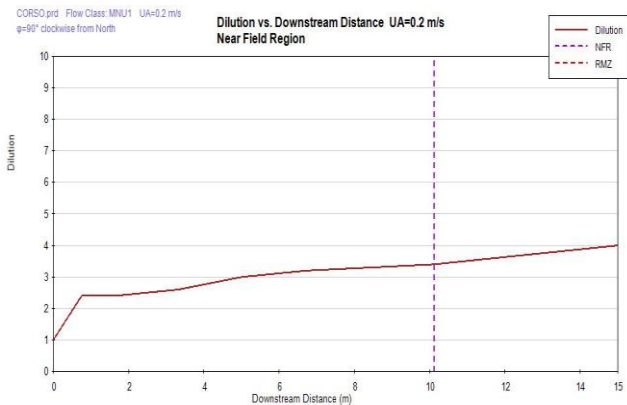
Scenario type	Current velocity, V (m/s)	Wind speed, U (m/s)
Scenario 1: Favorable	0.2	8
Scenario 2 : Intermediate	0.11	4
Scenario 3 : Unfavorable	0.02	2

• **For the first scenario:**

Fig. 7 illustrates the shape of the plume generated by the simulation results.



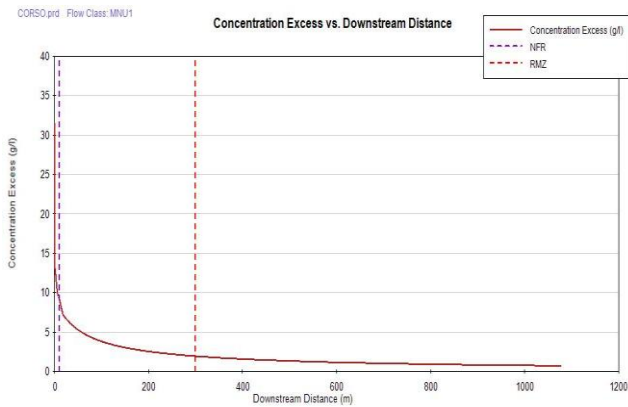
a) Near-field and far-field.



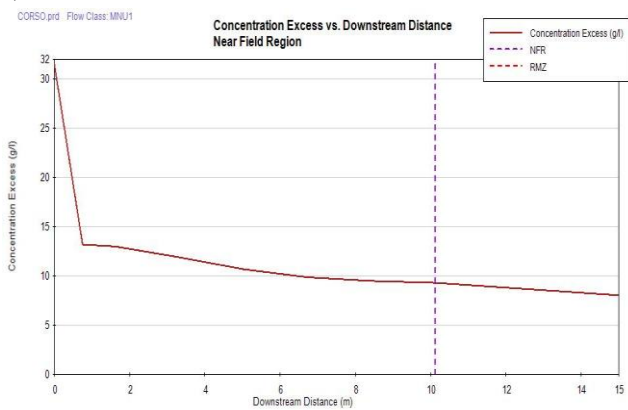
b) Near-field.

Fig. (a,b) 5 Variation of dilution as a function of distance X ($V = 8 \text{ m/s}$, $U = 0.2 \text{ m/s}$)

- At a distance of $X = 300 \text{ m}$ (RMZ), the dilution reaches $S = 16$, which is slightly higher than the recommended dilution value of $S = 15$. This level of dilution complies with environmental regulations for marine discharges, which recommend a mixing zone extent of 300 m (Figure 5a).
- After traveling a longer distance of $X = 1,100 \text{ m}$, the dilution reaches a significantly higher value of $S = 44$. Over a displacement distance of $X = 800 \text{ m}$, an increase in dilution from $S = 16$ to $S = 44$ is observed.
- The near-field region is located approximately 10 m from the discharge point and corresponds to a dilution of $S = 3.5$, which is below the recommended value (Figure 5b).
- The substantial increase in dilution is primarily driven by ambient environmental conditions, particularly wind-induced and marine current velocities, which enhance dilution from $S = 3.5$ to $S = 16$ at $X = 300 \text{ m}$.



a) The near field and the far field.



b) The near field.

Fig. (a,b) 6 Variation of the excess concentration as a function of distance X

- At a distance of $X = 300$ m (RMZ), the salinity excess ($\Delta C \approx 2$ g/L) at the boundary of the mixing zone is approximately equal to the tolerated limit, corresponding to 5% of the ambient seawater salinity.
- A very gradual decrease in salinity excess is observed, from $\Delta C \approx 9$ g/L at $X = 10$ m (end of the near-field region) to $\Delta C \approx 0.5$ g/L at $X = 1,000$ m.
- The admissible salinity excess is achieved at a distance greater than 250 m from the discharge point (Figure 6a).
- At the near-field boundary ($X = 10$ m), the salinity excess ($\Delta C \approx 9$ g/L) exceeds the tolerated threshold defined as 5% of the ambient salinity.



Fig. 7 Brine discharge plume from the Corso seawater desalination plant under favorable conditions ($V = 8$ m/s and $U = 0.2$ m/s)

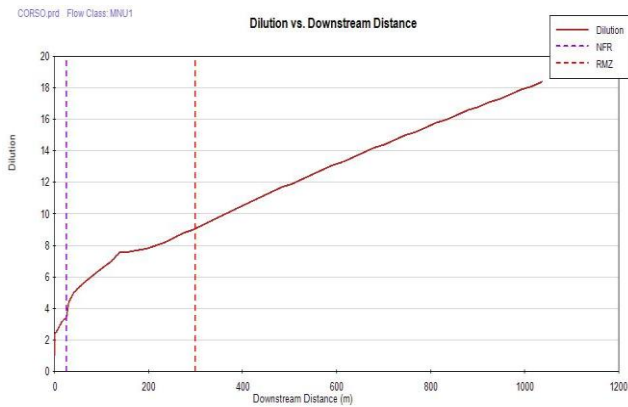
- Fig. 7 presents a GIS-based graphical representation of brine dispersion from the Corso desalination plant in the marine environment, showing the locations of both the discharge points and the seawater intake structures, under favorable conditions ($V = 8$ m/s and $U = 0.2$ m/s). The plume depicted in the figure is directed westward and moves offshore, away from the coastline.
- This simulation indicates that no interaction occurs between the discharge plume and the seawater intake waters (two intake towers). Consequently, the feedwater supply remains unaffected by the brine discharge and retains its natural characteristics, particularly its salinity.

In conclusion, for the favorable scenario ($V = 8$ m/s and $U = 0.2$ m/s), the kinetic energy of the discharge system associated with a jet exit velocity of 2.86 m/s results in a very short near-field region (approximately 10 m). However, the admissible dilution is not achieved within this distance.

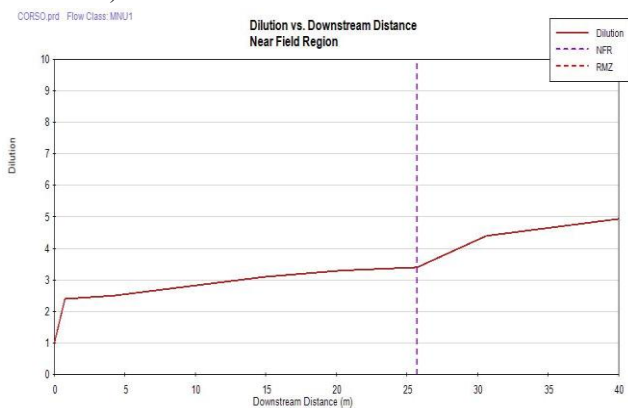
The required dilution is only attained beyond the recommended regulatory mixing zone (RMZ = 300 m), primarily due to the combined effects of wind- and current-induced advection. A significant portion of the observed dispersion is therefore driven by ambient environmental conditions rather than by the diffuser itself.

The discharge system contributes a dilution of approximately $S \approx 9$ out of the required $S = 15$, corresponding to about 60% of the total dilution within the near-field region. Consequently, it can be concluded that the existing discharge system does not exhibit satisfactory performance and fails to ensure adequate dilution in the near-field zone.

➤ For the second scenario:



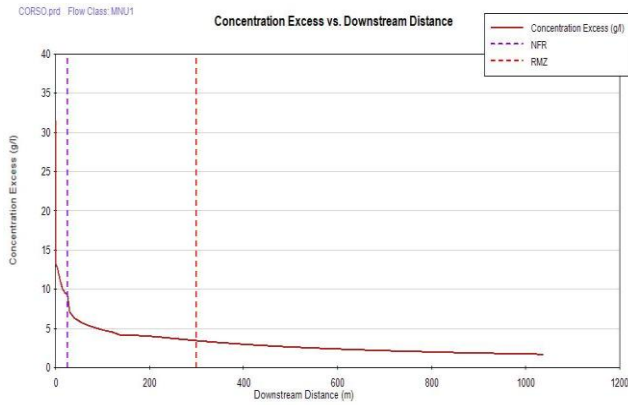
a) Near-field and far-field.



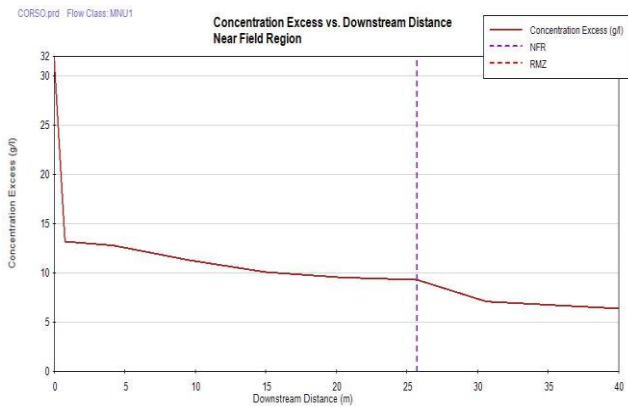
b) Near-field.

Fig. 8 Variation of dilution with distance X ($V = 4$ m/s, $U = 0.11$ m/s)

- At a distance of $X = 300$ m (RMZ), the dilution reaches $S \approx 9$, which is below the recommended dilution value of $S \approx 15$ (Figure 8a).
- After traveling a longer distance of $X = 1,200$ m, the dilution increases to $S \approx 18$. This indicates that an increase in dilution from $S = 15$ to $S = 18$ requires a displacement distance of approximately 900 m, reflecting a very slow dilution process (Figure 8a).
- The end of the near-field region is located approximately 26 m from the discharge point and corresponds to a dilution of $S \approx 3.5$, which remains below the recommended value (Figure 8b).



a) Near-field and far-field.



b) Near-field.

Fig. 9 Variation of excess concentration with distance X

- At a distance of $X = 300$ m (RMZ), the salinity excess ($\Delta C \approx 3.5$ g/L) at the boundary of the mixing zone exceeds the tolerated limit defined as 5% of the ambient seawater salinity.
- A very slow decrease in salinity excess is observed, from $\Delta C \approx 7$ g/L at $X = 26$ m (end of the near-field region) to $\Delta C \approx 2$ g/L at $X = 1,000$ m.
- The admissible salinity excess is only achieved at a distance greater than 1,000 m from the discharge point (Figure 9a).
- At the near-field boundary ($X = 26$ m), the salinity excess ($\Delta C \approx 9$ g/L) remains significantly higher than the tolerated threshold.

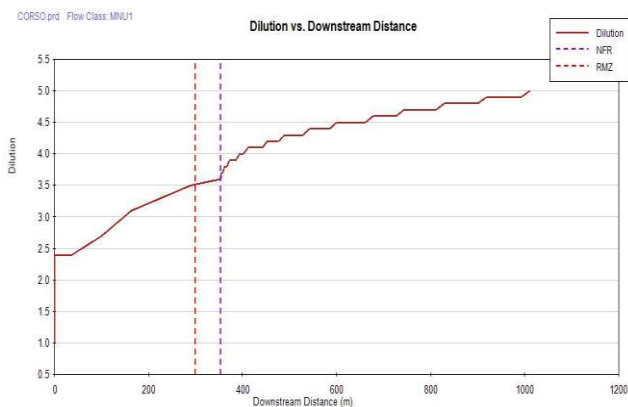


Fig. 10 Brine discharge plume of the Corso SDEM under intermediate velocity conditions ($V = 4$ m/s and $U = 0.11$ m/s)

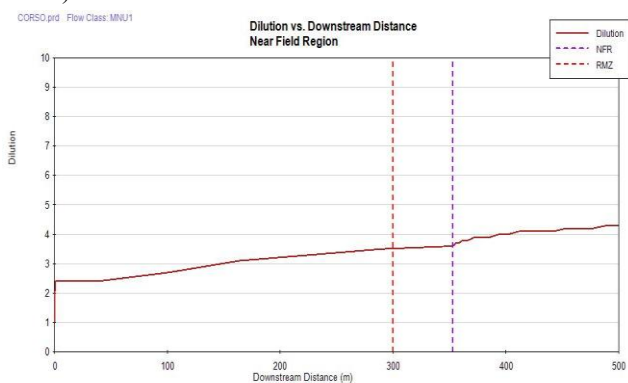
- The GIS-based graphical representation of plume dispersion and movement, showing the locations of the discharge and intake points under the intermediate scenario ($V = 4$ m/s and $U = 0.11$ m/s), is presented in Figure 10. The results indicate an interaction between the brine discharge plume and the intake waters, affecting one of the intake towers. This interaction may increase the salinity of the intake water by concentrations ranging from 2 to 4 g/L, which could potentially influence the operation of the reverse osmosis (RO) unit (Bouthiba et al., 2022).

In conclusion, for the intermediate scenario ($V = 4$ m/s and $U = 0.11$ m/s), the performance of the discharge system (diffuser) remains unsatisfactory and requires design intervention and improvement, particularly through increasing the discharge velocity and optimizing the location of the discharge point relative to the intake structures.

➤ For the third scenario :



a) Near-field and far-field.



b) Near-field.

Fig. 11 Variation of dilution with distance X ($V = 2$ m/s, $U = 0.02$ m/s)

- At the end of the near-field region, the dilution reaches a maximum value of $S \approx 3.5$ (Figure 11). A dilution level of $S = 5$ is only achieved at a considerable distance from the discharge point, approximately $X = 1,000$ m (Figure 11a).
- These results indicate that brine dispersion is very slow and inefficient under the prevailing natural conditions.
- The near-field extent of approximately $X \approx 300$ m (Figure 11b) appears relatively large, while dilution remains low at this distance. This behavior may be explained by plume recirculation, characterized by backward plume movement (negative X-values), as illustrated in Annex 1.

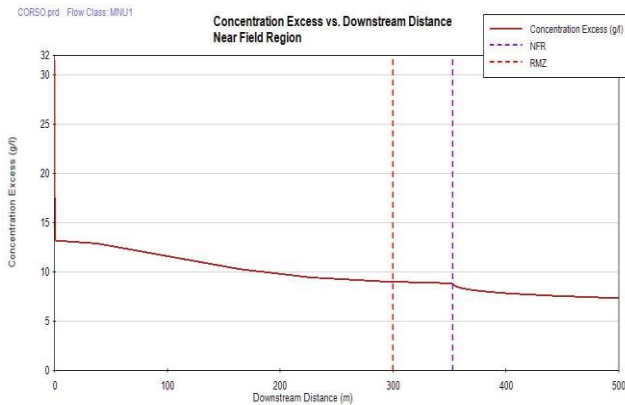


Fig. 12 Variation of excess concentration with distance X

- La valeur maximale de l'excès de concentration est situé au point de rejet ($X=0$) avec une valeur ($\Delta C = 31,5$ g/l = $70-38,5$).
- Une diminution rapide de 31,5 à 13 g/l se produit juste à la sortie de diffuseur. Cette diminution rapide est provoquée par l'énergie cinétique de rejet (vitesse de jet).
- Pour arriver à un excès $\Delta C \sim 7$ g/l, le rejet doit parcourir une distance $X = 500$ m de point de rejet (fig. 12).
- The maximum concentration excess is observed at the discharge point ($X = 0$), with a value of $\Delta C = 31.5$ g/L (calculated as $70 - 38.5$ g/L).
- A rapid decrease in concentration excess, from 31.5 g/L to 13 g/L, occurs immediately downstream of the diffuser. This sharp reduction is primarily induced by the kinetic energy of the discharge, associated with the jet exit velocity.
- To reach a concentration excess of approximately $\Delta C \approx 7$ g/L, the discharge plume must travel a distance of approximately $X = 500$ m from the discharge point (Fig 12).

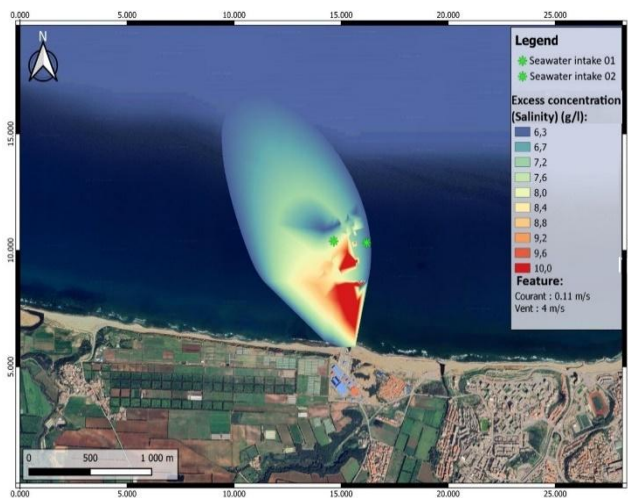


Fig. 13 Brine discharge plume of the Corso SDEM under unfavorable velocity conditions

- The GIS-based representation of brine plume dispersion and movement, showing the locations of the discharge and intake points (Fig. 13), reveals a pronounced interaction between the brine discharge plume and the intake waters at both intake towers. This interaction may lead to an increase in intake water salinity, with concentration increments ranging from 6.3 to 9 g/L (Bouthiba et al., 2022; Amitouche et al., 2022)
- In addition, a return of brine toward the coastline is observed (Fig. 13). This behavior can be attributed to insufficient initial discharge kinetic energy (jet exit velocity of 2.86 m/s) combined with unfavorable meteorological and hydrodynamic conditions.

Conclusion for the Unfavorable scenario.

In conclusion, for the unfavorable scenario ($V = 2$ m/s and $U = 0.02$ m/s), the performance of the discharge system (diffuser) is unsatisfactory. This finding highlights the need for design intervention and optimization, particularly through an increase in discharge velocity to enhance near-field mixing and reduce potential environmental impacts.

General Conclusion

In the context of the current global water scarcity, seawater desalination, regarded as a non-conventional method for potable water supply, has emerged as a relevant and indispensable solution. Consequently, the number of desalination facilities continues to increase worldwide, particularly along the Mediterranean coastline.

Indeed, numerous desalination plants have been commissioned, all of which discharge substantial volumes of brine effluents into the Mediterranean Sea. In addition to being two to three times more saline than ambient Mediterranean seawater, these discharges may also contain various heavy metals and chemical substances that could pose long-term risks to marine ecosystems.

Brine effluents are released into the marine environment through dedicated diffuser systems designed to promote dilution, with the degree of dilution being closely linked to diffuser configuration and design.

Therefore, proper design and optimization of brine diffusers are essential to ensure acceptable dilution levels and to minimize potential adverse impacts on marine fauna and flora. Based on the assessment of the current diffuser configuration of the Corso desalination plant, it was found to be ineffective under all three studied scenarios (favorable, intermediate, and unfavorable), with the following deficiencies observed:

- ✓ Under favorable environmental conditions ($V = 8$ m/s, $U = 0.2$ m/s), the near-field dilution reaches $S = 9$, corresponding to only 60% of the recommended dilution level ($S = 15$).
- ✓ Under intermediate conditions ($V = 4$ m/s, $U = 0.11$ m/s), partial interaction occurs between the brine discharge and the intake waters. In this scenario, the admissible salinity excess is only achieved at a distance greater than 1,000 m from the discharge point.
- ✓ Under the unfavorable scenario ($V = 2$ m/s, $U = 0.02$ m/s), the plume exhibited a backward movement toward the shoreline and significant interaction with the intake waters near the two intake towers. A dilution of $S = 5$ was reached only at a distance of approximately 1000 m from the discharge point. This indicates that brine dispersion is slow and ineffective under such natural conditions.

The results obtained in this study are consistent with those reported in the literature, which emphasize that undersized or poorly adapted discharge systems relative to local hydrodynamic conditions can lead to persistent high-salinity zones and interactions with seawater intake structures (Bouthiba et al., 2024; Omerspahic et al., 2022). In the Mediterranean context, characterized by a high concentration of desalination facilities, sustainable management of brine discharges appears essential, as also highlighted by the Blue Plan of the United Nations Environment Programme (Plan Bleu – UNEP/MAP, 2025).

Based on the simulations performed for the three investigated scenarios, it can be concluded that the performance of the discharge system (diffuser) remains unsatisfactory and requires intervention and improvement in its design. To address this issue, the following recommendations are proposed:

- In particular, increasing the discharge velocity, which is the primary parameter governing the kinetic energy and initial momentum flux of the jet, and is therefore responsible for enhancing effluent dispersion and dilution. (Maamar et al., 2026)
 - Repositioning the discharge point relative to the seawater intake location in order to reduce plume–intake interaction.
- Furthermore, to further minimize the environmental impact of brine discharge into the marine environment, it would be beneficial, as a future perspective, to implement a seawater dilution system upstream of the submarine outfall, either along the coastline or directly at the desalination plant.

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Conflict-of-Interest Statement

The authors declare that they have no conflicts of interest.

Author Contributions

B.H (Professor), Bo. A (PhD), and Ba. A (Professor) conceived and conducted the study, performed all numerical simulations, and revised the manuscript. A.M (Professor) and L.T (Professor) conceived and conducted the study, revised the manuscript, supervised the project, and reviewed and corrected the manuscript.

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